**UNITED NATIONS**
OFFICE FOR OUTER SPACE AFFAIRS

CONTRIBUTION TO THE "SPACE2030" AGENDA

# EU SPACE
# SUPPORTING A WORLD OF 8 BILLION PEOPLE

UNITED NATIONS

Right: Original cover image
Europe has just endured its second warmest winter on record. The image shows the impacts of the drought on the Loire River.
Photo credit: contains modified Copernicus Sentinel data (2021-23), processed by ESA, CC BY-SA 3.0 IGO



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A very special thank you to the United Nations Office for Outer Space Affairs (UNOOSA) for its invaluable work in promoting international cooperation in the peaceful uses and exploration of space and in the utilisation of space science and technology for sustainable development. In particular, we would like to thank Sharafat Gadimova of the ICG Executive Secretariat and Jorge Del Rio Vera of the Committee, Policy and Legal Affairs Section for their dedicated work and support.

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UNITED NATIONS OFFICE
FOR OUTER SPACE AFFAIRS

# CONTRIBUTION TO THE "SPACE2030" AGENDA

# EU SPACE SUPPORTING A WORLD OF 8 BILLION PEOPLE

UNITED NATIONS
Vienna, 2023

# FOREWORD BY THE ACTING DIRECTOR OF THE OFFICE FOR OUTER SPACE AFFAIRS

*Credit: UNIS*

In 2022, humanity crossed a symbolic milestone as the world's population reached 8 billion. Science has been among the main drivers of this growth, gradually increasing the human lifespan thanks to advances in public health, water, sanitation and hygiene, and nutrition, among many others. The increase in the population represents unique opportunities. There are 8 billion stories, minds, bright ideas and new perspectives, all waiting to leave their mark in improving life on our cosmic spaceship – planet Earth.

However, we are also dealing with challenges such as growing inequalities and division. The pressures on natural resources mount and urbanization poses the risk of intensifying emission and waste generation and pollution. Demographic trends affect all the Sustainable Development Goals (SDGs), and we collectively need to capitalize on the advantages to shape the future of humanity while mitigating the negative implications. As much as technological advances have proven transformative in enlarging the human population, they are crucial in maximizing our efforts towards building a better future that is sustainable and delivers equal opportunities to all.

In this context, space tools have undoubtedly become one of the drivers of sustainable development. For 60 years, the infrastructure in space has expanded and today it benefits industries, services and our daily activities. The reliance of modern society on these technologies is ever-growing.

To incentivize an even stronger utilization and development of space tools for a better future, the General Assembly adopted the "Space2030" Agenda in 2021. This forward-looking strategy reaffirms and strengthens the contribution of space activities and technologies to the achievement of global agendas. Awareness-raising plays an integral part. It is in fact the very first objective of the Agenda. Promoting the sector and its outstanding achievements not only in exploration but in making the Earth a better place to live is the means to harness support and generate greater interest from policy and decision makers, the public as well as the next generation.

The 2018 report we produced on the contributions of the European Global Navigation Satellite System (EGNSS) and Copernicus to the SDGs was very revealing and we are excited to offer our readers a new view on the contributions of space to tackling societal challenges, from climate to food security passing through water management and urbanization among others, through the lenses of the United Nations Agenda for Space, the "Space2030" Agenda.

**Niklas Hedman**
Acting Director,
United Nations Office
for Outer Space Affairs

# FOREWORD BY THE EXECUTIVE DIRECTOR OF THE EUROPEAN UNION AGENCY FOR THE SPACE PROGRAMME

*Credit: EUSPA*

The world reached a significant milestone as the global population hit 8 billion people. This remarkable achievement in human development is a result of gradual improvements in public health, nutrition, personal hygiene and medicine, which have led to an increase in the human lifespan. However, with the latest projections indicating that the population will reach 9 billion by 2037, we must prepare for the challenges and opportunities that lie ahead.

The increase in population presents both challenges and opportunities that must be addressed through relevant frameworks and initiatives, ensuring continued development while considering the sustainability of human activities. With these challenges in mind, the European Union Agency for the Space Programme (EUSPA) and the United Nations Office for Outer Space Affairs (UNOOSA) signed a memorandum of understanding in 2022 with the common goal of promoting the use of space technology, data and services for achieving sustainable development.

I am therefore pleased to present this joint study on the role of the European Union Space Programme components, namely Galileo, EGNOS, Copernicus and GOVSATCOM, and their synergies in addressing the sustainable challenges facing an 8 billion world today. This report also highlights how these components can pave the way towards a sustainable transition to a near-future world with a population of 9 billion people.

The report includes specific use cases that demonstrate how EU Space and its synergies can actively contribute to tackling several sustainability challenges, including food security, water management, environmental impact and climate change, disaster management and emergency response, migration, urbanization and energy. Those use cases support the implementation of the "Space2030" Agenda, and are underpinning the 2030 Agenda for Sustainable Development, the Sendai Framework for Disaster Risk Reduction, the Paris Agreement, the New Urban Agenda, and European Union frameworks such as the European Union Green Deal.

I would like to express my appreciation to the authors of this report for their dedicated efforts in putting together this valuable resource. I trust that it will serve as a useful reference for policymakers, stakeholders and anyone interested in leveraging space technology, data and services for sustainable development.

Together, we can work towards a sustainable future for all.

**Rodrigo da Costa**
Executive Director,
European Union Agency for the Space Programme

# LIST OF ABBREVIATIONS

| | |
|---|---|
| **AI** | Artificial Intelligence |
| **AIS** | Automatic Identification System |
| **AOP** | Agroecological and organic practices |
| **API** | Application Programming Interface |
| **ASECNA** | Agency for the Safety of Air Navigation in Africa and Madagascar |
| **B2B** | Business-to-business |
| **BIM** | Building Information Modelling |
| **CA** | Collision avoidance |
| **C3S** | Copernicus Climate Change Service |
| **CAMS** | Copernicus Atmosphere Monitoring Service |
| **CAP** | Common Agricultural Policy |
| **CEAP** | Circular Economy Action Plan |
| **CEMS** | Copernicus Emergency Management Service |
| **CHE** | CO2 Human Emissions |
| **CHIME** | Copernicus Hyperspectral Imaging Mission for the Environment |
| **CIMR** | Copernicus Imaging Microwave Radiometer |
| **CLMS** | Copernicus Land Monitoring Service |
| **CMS** | Copernicus Maritime Surveillance |
| **CMEMS** | Copernicus Marine Environment Monitoring Service |
| **CO2** | Carbon dioxide |
| **COPUOS** | Committee on the Peaceful Uses of Outer Space |
| **CORINE** | Coordination of information on the environment |
| **CSCDA** | Copernicus Space Component Data Access System |
| **CSS** | Copernicus Security Service |
| **DCN** | Digital Cellular Network |
| **DEM** | Digital Elevation Model |
| **DG** | Directorates-General |
| **DIAS** | Data and Information access services |
| **DO** | Drought Observatory |
| **DST** | Digital and space-based technologies |
| **EBPD** | Energy Performance of Buildings Directive |
| **EC** | European Commission |
| **ECMWF** | European Centre for Medium-Range Weather Forecasts |
| **EDAS** | EGNOS Data Access Service |
| **EEA** | European Environment Agency |
| **EEAS** | European External Action Service |
| **EFAS** | European Flood Awareness Systems |
| **EFFIS** | European Forest Fire Information System |
| **EFTA** | European Free Trade Association |
| **EGMS** | European Ground Motion Service |
| **EGNOS** | European Geostationary Navigation Overlay Service |
| **EGNSS** | European Global Navigation Satellite System |
| **EMSA** | European Maritime Safety Agency |
| **EO** | Earth observation |
| **EPBD** | Energy Performance for Buildings Directive |
| **ESA** | European Space Agency |
| **ESG** | Environmental, Social, Governance |
| **ETS** | Emissions Trading System |
| **EUMETSAT** | European Organization for the Exploitation of Meteorological Satellites |
| **EUSPA** | European Union Space Programme Agency |
| **EWS** | Emergency Warning Service |
| **FAO** | Food and Agriculture Organization of the United Nations |
| **FFO** | Full, Free and Open |

| | |
|---|---|
| **FRONTEX** | European Border and Coast Guard Agency |
| **GHG** | Greenhouse Gas |
| **GHSL** | Global Human Settlement Layer |
| **GIS** | Geographic Information System |
| **GMDAC** | Global Migration Data Analysis Centre |
| **GNSS** | Global Navigation Satellite System |
| **GOVSATCOM** | Governmental Satellite Communications |
| **GPS** | Global Positioning System |
| **GSMC** | Galileo Security Monitoring Centre |
| **HAS** | High Accuracy Service |
| **HPCM** | High Priority Candidate Missions |
| **IEA** | International Energy Agency |
| **ILO** | International Labour Organization |
| **IOM** | International Organization for Migration |
| **IoT** | Internet of things |
| **IPCC** | Intergovernmental Panel on Climate Change |
| **IRIS2** | Infrastructure for Resilience, Interconnectivity and Security by Satellite |
| **IUU** | Illegal, unreported and unregulated fishing |
| **JAXA** | Japan Aerospace Exploration Agency |
| **JRC** | Joint Research Centre |
| **LEO** | Low Earth Orbit |
| **LiDAR** | Light Detection and Ranging |
| **MEO** | Medium Earth Orbit |
| **ML** | Machine Learning |
| **NASA** | National Aeronautics and Space Administration |
| **NDVI** | Normalized difference vegetation index |
| **NEO** | Near-Earth Objects monitoring |
| **OS** | Open Service |
| **OSNMA** | Open Service Navigation Message Authentication |
| **PBN** | Performance-Based Navigation |
| **PM** | Particulate Matter |
| **PMU** | Phasor measurement unit |
| **PNT** | Position, navigation and timing |
| **PPP** | Precise point Positioning |
| **PRS** | Public Regulated Service |
| **PSTN** | Public Switched Telephone Network |
| **PVT** | Position, Velocity and Time |
| **RES** | Renewable energy sources |
| **RLM** | Return Link Messages |
| **RPAS** | Remotely Piloted Aircraft Systems |
| **RTK** | Real-Time Kinematic |
| **SAR** | Search and Rescue |
| **SatCom** | Satellite Communication |
| **SBAS** | Satellite-Based Augmentation System |
| **SCADA** | Supervisory Control and Data Acquisition |
| **SDG** | Sustainable Development Goal |
| **SoL** | EGNOS Safety of Life Service |
| **SOx** | Sulphur Oxides |
| **SME** | Small to Medium Enterprise |
| **SSA** | Space Situational Awareness |
| **SST** | Space Surveillance and Tracking |
| **STM** | Space Traffic Management |
| **UNFCCC** | United Nations Framework Convention on Climate Change |
| **UAV** | Unmanned Aerial Vehicle |
| **UNEP** | United Nations Environment Programme |
| **UNOOSA** | United Nations Office for Outer Space Affairs |
| **WHO** | World Health Organization |
| **WMO** | World Meteorological Organization |

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Melting sea ice in the Arctic.
Photo credit: Alfred-Wegener-Institute, E. Horvath

# EXECUTIVE SUMMARY

This report has been prepared following the *Day of 8 Billion*, designated by the United Nations as the day when the world population reached 8 billion people, to showcase how space technologies and its synergies can help to tackle the challenges of the world increasing population and complex societies while ensuring sustainable development and bolster resilience, leveraging the guidance of the "Space2030" Agenda and supporting the implementation of the global agendas.

On the one hand, such a milestone certainly constitutes a reason to celebrate the many human advancements in the fields of health and poverty reduction. Just to put it in perspective, the world population grew by 1 billion in just the last 11 years while it took hundreds of thousands of years to reach 1 billion: this clearly reflects the exceptional progress in human development in the last decades. On the other hand, this milestone also represents a motivation for asking ourselves how such population dynamics will impact the shape of our current and future communities. A world more crowded than ever, indeed, exacerbates the long-standing effects of phenomena such as climate change, urbanization, digitalization and globalization.

Several United Nations global agendas have been, in fact, designed and endorsed to guide future developments:

- *2030 Agenda for Sustainable Development*, a resolution providing a set of goals, the Sustainable Development Goals (SDGs), to be achieved until 2030 by all countries
- *Sendai Framework for Disaster Risk Reduction*, adopted in 2015, with the goal of preventing new and reducing existing disaster risks through the implementation of integrated and inclusive measures to prevent and reduce hazard exposure and vulnerability to disaster, increase preparedness for response and recovery, and thus strengthen resilience
- *Paris Agreement*, a legally binding international treaty on climate change adopted in 2015 in Paris and entered into force on 4 November 2016, aimed at limiting global warming well below 2, preferably to 1.5 degrees Celsius, compared to pre-industrial levels
- *New Urban Agenda (Habitat III)*, endorsed by the General Assembly in 2016 and reaffirming the global commitment to sustainable urban development as a critical step towards realizing sustainable development

To support these global agendas, the United Nations Committee on the Peaceful Uses of Outer Space (COPUOS), a unique intergovernmental platform that since the early stages of the space era has promoted international cooperation in the peaceful uses of outer space, in 2021 finalized the "Space2030" Agenda: space as a driver of sustainable development that Member States adopted in the General Assembly resolution 76/3. as a forward-looking strategy for reaffirming and strengthening the contribution of space activities and space tools to the achievement of global agendas, addressing the long-term sustainable development concerns of humankind.

Although these agendas have been developed at different times, they contain commitments aimed at ensuring sustainable development and leaving a better world to future generations. Within this context, solutions and services enabled by space can play a major role. In particular, this report considers the "Space2030" Agenda and its overarching objective 2: *Harness the potential of space to solve everyday challenges and leverage space-related innovation to improve the quality of life*. This report links the different areas of action mentioned under this objective with selected challenges that humankind is facing today where space can make a key contribution, either in monitoring or in contributing to the mitigation of some aspects of the challenge, with the objective of raising awareness and promoting the use of space applications to tackle them in the context of an 8 billion world.

The present report has been conceived within the cooperation agreement signed between UNOOSA and EUSPA with the goal of promoting how the use of space technology, data and services can contribute to achieving sustainable development in the context of an 8 billion world, and how the "Space2030" Agenda establishes the priorities of Member States for the space community.

Specifically, after analysing the objectives of the "Space2030" Agenda, 8 challenges related to overarching objective 2 have been distilled, namely:

- Food security
- Water management
- Environmental impact and climate change
- Disaster management and emergency response
- Migration
- Urbanization
- Energy
- Health

Since plenty of work has gone into challenge 8 (health) and numerous reports connecting space and health, including due to the pandemic, the contribution of EU Space to the health challenge is summarized in the Final remarks chapter while this report focuses on the other seven challenges above.

The goal of the report is to assess how the use of core space-based technologies, namely Earth observation, GNSS and satellite communications, can support the tackling of the challenges facing an ''8 billion world". In the context of this report the contribution of those technologies from the perspective of the EU Space components (Galileo, EGNOS, Copernicus, GOVSATCOM) and its synergies will be analysed, as already today, they deliver services in a coordinated manner and on a daily basis to an 8 billion world.

The methodology undertaken foresees a descriptive assessment, enriched by tangible use cases, aimed at evaluating how the EU Space components and their synergies, contribute to the fulfilment of the seven challenges introduced above. Specifically, the following two levels of analysis have been used:

- *EU Space component level:* Galileo and EGNOS, Copernicus and GOVSATCOM, also including a deep dive into their specific services
- *Application level:* For Copernicus, Galileo and EGNOS, leveraging the market taxonomy provided by the *EUSPA EO and GNSS Market Report*[1]

The main outcomes of the study, as provided in chapter 3, include:

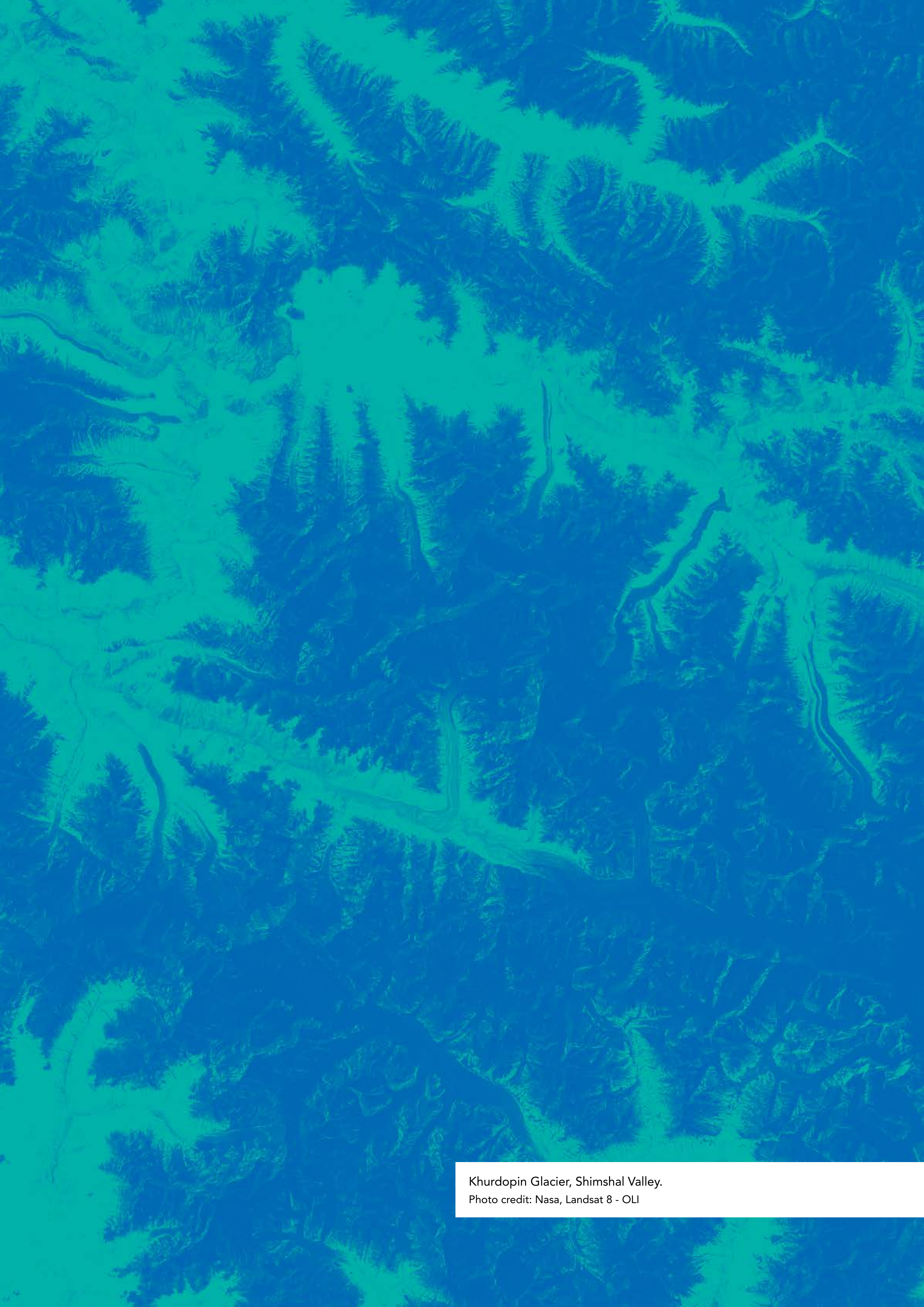
- At space component level:
    - EGNSS and Copernicus support all seven identified challenges, while GOVSATCOM contributes to six challenges.
    - Although each of the EU Space components can greatly contribute to the 8 billion world *challenges* separately, the full potential is unleashed due to its synergies and complementarity.
- At space components services level:
    - Four services (Galileo Open Service, Copernicus C3S, CEMS and Copernicus data) contribute to tackling all seven challenges.
    - 10 out of 17 EU Space services (>55 per cent) analysed support at least four challenges.
    - More importantly, the joint use of the four EU Space components services (synergies and complementarity) contributes to all the challenges.

[1] Application-level analyses only focus on EGNSS and Copernicus as only these two EU Space components were included in the *EUSPA EO and GNSS Market Report* (2022).

- At application level:
  - 118 out of the total 184 applications featured in 16 out of the 17 market domains included in the *EUSPA EO and GNSS Market Report* have been identified as fit to support the identified sustainable challenges.

The report shows that the EU Space components provide a unique set of data and services that complement each other or work in synergies, thus underpinning its overall contribution to 8 billion world challenges. In the context of new EU Space flagship initiatives under development, the EU Space contribution to the challenges will be boosted even further when adding the European Union Space Traffic Management with space situational awareness that ensures sustainable, safe and secure ''space", and the IRIS[2] constellation that will offer enhanced space-based secure communication capabilities to governmental and commercial users, while ensuring high-speed Internet broadband to cope with connectivity dead zones.

To fully unlock the potential of space technologies in continents and countries, the cooperation at different levels between the systems (Earth observation, GNSS, SATCOM, meteorology, etc.) and technologies (AI/ML, big data, HPC, etc.) stakeholders and between the organizations (private and public partnerships, networks of academia or entrepreneurs) is of paramount importance. To this end, EUSPA and UNOOSA will further strengthen their activities and ability to cooperate in order to accelerate the use of space technologies and their contribution to addressing sustainability challenges.



Khurdopin Glacier, Shimshal Valley.
Photo credit: Nasa, Landsat 8 - OLI

# INTRODUCTION

## BACKGROUND

The United Nations Committee on the Peaceful Uses of Outer Space (COPUOS), permanently established in 1959, has been at the centre of international cooperation in the peaceful uses of outer space and the global governance of outer space activities. Owing to its mandate, COPUOS plays a key role in the organization of the United Nations conferences on the exploration and peaceful uses of outer space and, in 2018, on the fiftieth anniversary of the first United Nations Conference on the Exploration and Peaceful Uses of Outer Space (UNISPACE+50), the international community gathered to reflect on more than 50 years of achievement in space exploration and use, and to strengthen global cooperation in outer space and the use of outer space for sustainable development.

Based on the results of the UNISPACE+50 process, the General Assembly invited the Committee to develop, a "Space2030" Agenda and implementation plan and to provide the General Assembly with the outcome of its work for consideration by the Assembly.

In October 2021, the General Assembly adopted the "Space2030" Agenda: space as driver of sustainable development,[2] reaffirming the crucial role of COPUOS and its subcommittees, supported by the United Nations Office for Outer Space Affairs, as unique platforms for international cooperation in the exploration and use of outer space for peaceful purposes, for the global governance of outer space activities, consistent with international law, for developing international space law, for fostering dialogue among spacefaring and emerging space nations, and for promoting the increased involvement of all countries in space activities, including through capacity-building initiatives.

The "Space2030" Agenda emphasizes the relevance of space tools for the attainment of global development agendas, in particular the 2030 Agenda for Sustainable Development and its goals and targets. These tools function either directly, as enablers and drivers of sustainable development, or indirectly, by providing essential data for the indicators used to monitor the progress towards achieving the 2030 Agenda and the Sendai Framework for Disaster Risk Reduction 2015–2030 and the commitments by States parties to the Paris Agreement. The fulfilment of these global agendas requires improved access to space-based data, applications and space infrastructure, considering the particular needs of developing countries. In particular, the "Space2030" Agenda contains four overarching objectives, underpinned by actions to be taken to realize the objectives.

On 15 November 2022, the world's population reached 8 billion people, a milestone in human development. This report examines the connections, opportunities and challenges for Earth observation, Global Navigation Satellite Systems (GNSS) and satellite communications from the perspective of the European Union systems:

[2] A/RES/76/3, resolution adopted by the General Assembly on 25 October 2021, the "Space2030" Agenda: space as a driver of sustainable development.

Copernicus, European GNSS (EGNSS) and GOVSATCOM. The report also establishes links between the different agendas referred to by the "Space2030" Agenda and, to complement this view through the lens of population increase, brings in the New Urban Agenda. It is not the intention of this report to provide an extensive view of the Copernicus, EGNSS and GOVSATCOM applications in support of the "Space2030" Agenda and the other global agendas, but to raise awareness about space capabilities and provide an overview of how space can contribute to the challenges of an 8 billion world. This report builds upon the "European Global Navigation Satellite System and Copernicus: Supporting the Sustainable Development Goals – Building blocks towards the 2030 Agenda"[3] published in 2018 by the United Nations Office for Outer Space Affairs and the European Agency for the Space Programme (formerly European Global Navigation Satellite Systems Agency (GSA)) but focuses on selected challenges rather than specific items of the agendas.

# THE UNITED NATIONS OFFICE FOR OUTER SPACE AFFAIRS

The United Nations Office for Outer Space Affairs (UNOOSA) manages and implements the Programme on the Peaceful Uses of Outer Space, which is aimed at strengthening international cooperation in space activities and in the use of space science and technology for achieving sustainable development. It represents the United Nations in promoting international cooperation in the exploration and peaceful uses of outer space for economic, social and scientific development, in particular for the benefit of developing countries.

The Office discharges these responsibilities by:

- Strengthening international cooperation in the conduct of space activities for peaceful purposes and the use of space science and technology and their applications towards the achievement of the Sustainable Development Goals
- Assisting the Committee on the Peaceful Uses of Outer Space and its Scientific and Technical Subcommittee and its Legal Subcommittee in their work and role as a unique platform at the global level for international cooperation in outer space activities
- Implementing General Assembly resolutions and decisions on matters relating to international cooperation in the peaceful use of outer space, including on transparency and confidence-building measures in outer space activities, and capacity-building work in this area
- Performing the functions, when required, of the executive secretariat for global conferences on matters relating to international cooperation in the exploration and peaceful uses of outer space
- Maintaining, on behalf of the Secretary-General, the Register of Objects Launched into Outer Space
- Implementing the United Nations Programme on Space Applications
- Implementing the programme of the United Nations Platform for Space-based Information for Disaster Management and Emergency Response (UN-SPIDER)
- Acting as the executive secretariat of the International Committee on Global Navigation Satellite Systems (ICG)
- Acting as the secretariat of the Space Mission Planning Advisory Group (SMPAG)
- Leading the Inter-Agency Meeting on Outer Space Activities (UN-Space) in its work on the examination of how space science and technology and their applications could contribute to the achievement of the Sustainable Development Goals
- Facilitating cooperation in matters relating to the peaceful exploration and use of outer space for the benefit of humanity, considering the interests and needs of developing countries, with and between governmental entities, including space agencies, intergovernmental and non-governmental organizations, and the private sector

[3] ST/SPACE/71, European Global Navigation Satellite System and Copernicus: Supporting the Sustainable Development Goals. Building Blocks towards the 2030 Agenda".

- Managing the resources of the trust fund in support of the United Nations Programme on the Peaceful Uses of Outer Space to implement the cooperation activities of the Office

UNOOSA serves as a conduit for promoting and facilitating the use of space-based solutions, including in the implementation of the "Space2030" Agenda, and should continue, within its mandate, functions and existing resources, to pursue partnerships with research institutions, academia, industry and the private sector, to provide broader opportunities to access space for the purposes of science, innovation, research and development, education and capacity-building. In that regard, the Office should implement activities to promote the use of space-based applications and technologies to support Member States in meeting the objectives of the global development agendas.

This report has been prepared following the declaration of the *Day of 8 Billion*, marked on 15 November 2022 and designated by the United Nations, to provide context for how space, in particular Earth observation, GNSS and satellite communications, can provide support to face some selected challenges of humankind. It was carried out under the mandate of UNOOSA to implement activities that promote the use of space-based applications and technologies, supporting Member States in meeting the objectives of the global development agendas. To that end, this report makes the link between the "Space2030" Agenda and four global agendas, namely the 2030 Agenda for Sustainable Development, the Sendai Framework for Disaster Risk Reduction 2015–2020, the Paris Agreement and the New Urban Agenda, the latter incorporating other dimensions such as issues of population and urbanization.

# THE EUROPEAN UNION AGENCY FOR THE SPACE PROGRAMME

As a European Union Agency, the mission of EUSPA is to implement the first integrated EU Space Programme and multiply the benefits generated by space data and services for citizens, businesses and governments.

As a body of the European Union, the Agency contributes to European Union priorities: green and digital transition, the safety and security of the Union and its citizens, while reinforcing its autonomy and resilience.

The main tasks of EUSPA encompass:

- Delivering safe, state-of-the-art, European satellite-based services to a growing group of users in Europe and around the world
- Promoting the use of space data and services from EU Space programme components including Galileo, EGNOS, Copernicus and GOVSATCOM
- Ensuring the safety and security of the EU Space Programme assets both in space and on the ground
- Supporting innovation along the whole value chain of business development for companies, start-ups, entrepreneurs, innovators and academia

Over the past 20 years, the European Union has been committed to creating an EU Space Programme and infrastructure that is competitive, innovative and that delivers real benefits to citizens and business alike. Building on these foundations, the EU Space Programme has made great leaps forward in recent years, delivering unique services in satellite navigation, Earth observation and telecommunications, and strengthening both the upstream and downstream sectors.

As a result, space technology, data and services are indispensable to the daily lives of Europeans. They also play an essential role in supporting the strategic interests of the Union. Space-based services are used seamlessly by mobile phone users, many of whom do not realize that their data is provided via satellite. Few people are aware that the weather forecasts, banking movements or directions that they receive via their smart phones are supported by space assets. In addition, a growing number of industries and entrepreneurs look to space data and services to develop solutions to the challenges we face in society. Nevertheless, the benefits that space can deliver are just starting to be unlocked and soon business and society will increasingly look to space technology as the resource of the future.

As the link between space and users, the ambition of EUSPA is to become the reference point for all space-related needs in the European Union. EUSPA brings all space stakeholders together, allowing them to leverage the synergies of the EU Space Programme's individual components to deliver the greatest possible benefits to European citizens and business. EUSPA plays a leading role in the implementation of the EU Space Programme. It promotes space-based scientific and technical progress and supports the competitiveness and innovative capacity of space sector industries within the Union, with a particular focus on small- and medium-sized enterprises (SMEs) and start-ups.

The EU Space Programme and the services and applications that it supports help to advance the European Union's objectives and to achieve its key policy goals and priorities.

To fully unlock the potential of EU Space beyond Europe, cooperation at different levels between space systems (e.g., Earth observation, GNSS, SATCOM, meteorology), cutting-edge technologies (e.g., AI, big data, etc.) and organizations (e.g., private and public partnerships, network of academia, network of entrepreneurs, etc.) is essential. In this respect, EUSPA plays an essential role in facilitating this international cooperation by supporting the development of a favourable ecosystem for space market uptake, collaborating with international agencies and entities and promoting industrial cooperation.

This report aims to assess from a descriptive viewpoint and by means of use cases how the use of EU Space (EGNSS, Copernicus, GOVSATCOM) can contribute to the challenges related to an 8 billion people world, paving the way to a sustainable future.

# OBJECTIVES AND METHODOLOGY

This report takes stock of the "Space2030" Agenda and dives into the implementation of its overarching objective 2: *Harness the potential of space to solve everyday challenges and leverage space-related innovation to improve the quality of life*, linking the different areas of action mentioned under this objective with selected challenges that humankind faces today where space can make a contribution, either in monitoring or in contributing to the mitigation of some aspects of the challenge, with the objective of raising awareness and promoting the use of space applications to tackle them in the context of an 8 billion world. It is worth noting that not all space technologies are considered here and the main focus of the report is on Earth observation, satellite navigation and satellite communication from the perspective of the European systems, Copernicus, EGNSS and GOVSATCOM.

To achieve this goal an analysis of the "Space2030" Agenda is undertaken to extract selected challenges, which are then validated by their appearance in the four global agendas considered in this report. It is worth noting that throughout the report, the "Space2030" Agenda is considered as the reference, as it provides a direct link between the challenges, space technologies and the global agendas. The work is complemented by a description of the challenges and how space can contribute to mitigating or monitoring them, providing specific use cases based on European systems. To this end, chapter 1 provides the population context and the analysis of the "Space2030" Agenda and the global agendas to determine the challenges, while the description and evolution of the EU Space component is included in chapter 2. Chapter 3 provides a more detailed description of the challenges and some of the areas where the use of space technology could be beneficial. It also provides use cases based on European projects. The final chapter (chapter 4) summarizes the main conclusions and take-aways of the report.

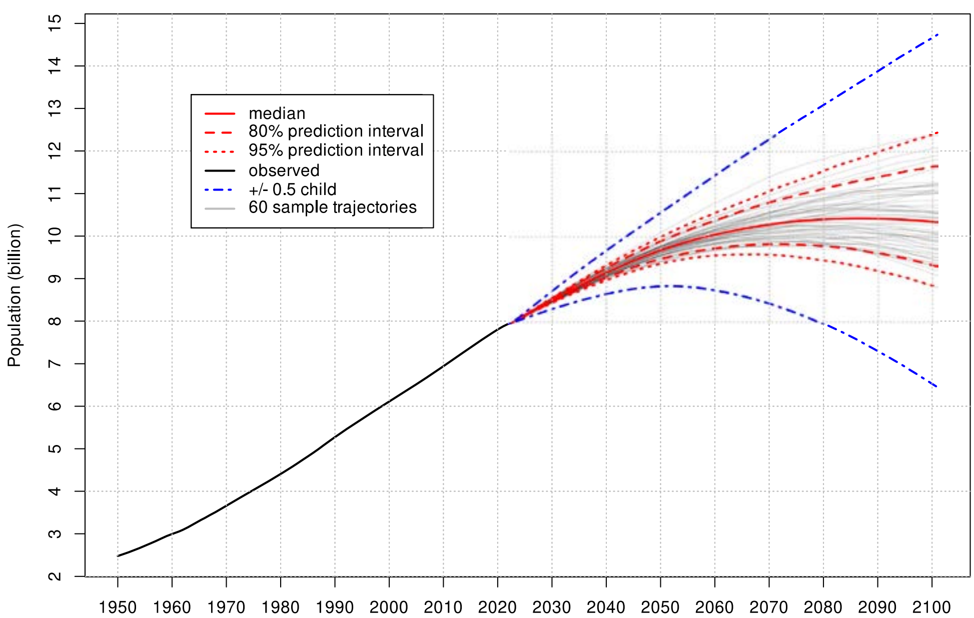
# 1. AN 8 BILLION WORLD AND THE GLOBAL AGENDAS

## 1.1 AN 8 BILLION WORLD

In 1960, the world population was estimated at more than 3 billion, and 24 years later the population had grown by another billion. However, according to the available estimates, it only took another 13 years, until 1987, to reach 5 billion, showing a pattern of accelerated growth. The growth rate stabilized for the following two milestones, and world population passed the 6 billion mark at the end of the twentieth century. The entire population of the world had doubled in less than 40 years.

On 31 October 2011, the United Nations Population Fund declared the Day of Seven Billion and, 11 years later, the 15 November 2022 was marked as the Day of 8 Billion. According to current scenarios, population will continue to grow until a point between 2050 and the end of the century, reaching a peak of between 9 billion and 11 billion. This increase in population creates challenges and opportunities to be addressed through the correct policies to ensure continued development, while considering the sustainability of the activities of humankind.

**EXHIBIT 1.** WORLD POPULATION AND WORLD POPULATION ESTIMATES WITH PREDICTION INTERVALS




*Source: 2012 United Nations, DESA. Population Division. Licensed under Creative Commons licence CC BY 3.0 IGO. United Nations, DESA. Population Division. World Population Prospects 2022.* http://population.un.org/wpp/

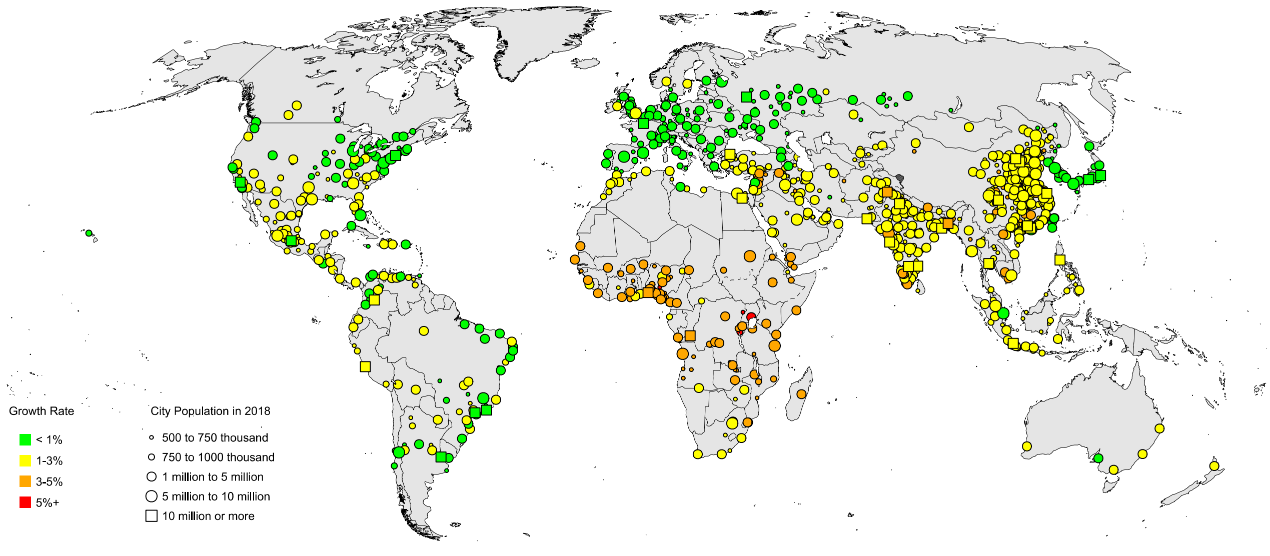
Growth rates and age structure of the population vary strongly from region to region. Moreover, there are differences in distribution. For example, between 2020 and 2050, globally, the proportion of people living in urban areas will increase from 55 per cent in 2018 to 66 per cent by 2050.[4] This trend is undisputed and irreversible. The world is becoming increasingly urbanized. Since 2007, over half the world's population has been living in cities, and that share is expected to rise to 60 per cent by 2030. Cities and metropolitan areas contribute to about 60 per cent of global gross domestic product (GDP) but they also account for about 70 per cent of global carbon emissions and over 60 per cent of resource use.[5]

Exhibit 2 shows the estimated growth rate of urban agglomerations by size class, and it is worth noting certain patterns in the figure. The continent where the growth rates are highest is Africa, followed by Asia. There are also areas of higher growth (higher than 1 per cent) in some urban agglomerations in Latin America, and in the United States and Canada. However, the majority of Europe, Japan and some urban agglomerations in the United States and Canada are experiencing growth rates that are below 1 per cent.

By 2050, the world's urban population is expected to nearly double, making urbanization one of the twenty-first century's most transformative trends. Populations, economic activities, social and cultural interactions, as well as environmental and humanitarian impacts, are increasingly concentrated in cities, and this poses massive sustainability challenges in terms of housing, infrastructure, basic services, food security, health, education, decent jobs, safety and natural resources, among others.

While an increase in population generates explicit benefits for societies and economies, and should not be stopped or obstructed, it must be managed to maximize positive impacts and minimize any adverse effects. To ensure sustainability and with a forward-looking vision, in 2015, all Member States adopted the 2030 Agenda for Sustainable Development, containing 17 Sustainable Development Goals to be reached by 2030, setting out a 15-year path for reaching the goals. Although progress has been made, action to meet the Goals is not advancing at the required pace and, in September 2019, world leaders called for a Decade of Action to mobilize resources, enhance national implementation and strengthen institutions to achieve the SDGs. Moreover, at

**EXHIBIT 2.** ESTIMATED AVERAGE ANNUAL GROWTH RATE OF URBAN AGGLOMERATIONS BY SIZE CLASS




Data source: World Urbanization Prospects: The 2018 Revision
The designations employed and the presentation of material on this map do not imply the expression of any opinion whatsoever on the part of the Secretariat of the United Nations concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries. Dotted line represents approximately the Line of Control in Jammu and Kashmir agreed upon by India and Pakistan. The final status of Jammu and Kashmir has not yet been agreed upon by the parties. Final boundary between the Republic of Sudan the Republic of South Sudan has not yet been determined. A dispute exists between the Governments of Argentina and the United Kingdom of Great Britain and Northern Ireland concerning sovereignty over the Falkland Islands (Malvinas).

*Source: 2018 United Nations, DESA, Population division. Licensed under CC licence CC BY 3.0 IGO.* https://population.un.org/wup/Maps/

[4] Demographic Trends and Urbanization, World Bank Group, 2020.
https://documents1.worldbank.org/curated/en/260581617988607640/pdf/Demographic-Trends-and-Urbanization.pdf (Accessed December 2022).

[5] United Nations, Sustainable Development Goal 11. https://unric.org/en/sdg-11/ (Accessed December 2022).

the time of writing this report, World Food Programme estimates show that the number of severely food insecure people doubled from 135 million pre-pandemic to 276 million over just two years and this number could increase to 345 million in 2022.[6]

In this report, some of the topics related to the population increase will be examined from the contribution of three core space-based technologies: remote sensing, satellite positioning and navigation and satellite communication, in particular, the contributions of Copernicus, European Global Navigation Satellite Systems (EGNSS) and GOVSATCOM, and how they can maximize positive impacts and monitor the variables enabling data-driven policymaking. The report uses the "Space2030" Agenda as a reference and shows the connections with other global agendas.

## 1.2 THE "SPACE2030" AGENDA AND SELECTED CHALLENGES

The "Space2030" Agenda contains the following four overarching objectives:

- Enhance space-derived economic benefits and strengthen the role of the space sector as a major driver of sustainable development
- Harness the potential of space to solve everyday challenges and leverage space-related innovation to improve the quality of life
- Improve access to space for all and ensure that all countries can benefit socioeconomically from space science and technology applications and space-based data, information and products, thereby supporting the achievement of the Sustainable Development Goals
- Build partnerships and strengthen international cooperation in the peaceful uses of outer space and in the global governance of outer space activities

Each objective is underpinned by actions to be taken by Member States to realize those objectives. This report focuses on overarching objective 2 and associated selected actions connected to the capabilities of Copernicus, EGNSS and GOVSATCOM. Those actions can be grouped into challenges connected to the global agendas. The grouping has been made to highlight the role of space in the context of an 8 billion world. Different grouping of actions may result in different challenges as the contribution of space to society and environment is quite broad, as demonstrated in ST/SPACE/71.[7] The list of challenges is not meant to be comprehensive but rather to provide examples, with the purpose of raising awareness of where the Earth observation, Global Navigation Satellite Systems and satellite communications can be of use in the context of an 8 billion world.

The selected challenges are the following:

- *Food security:* Just prior the global coronavirus disease (COVID-19) pandemic, some 2.4 billion people were suffering from food insecurity.[8] However, population continues to increase, and this increase combined with the environmental impact of human activity, in particular climate change, poses challenges for food security and agriculture. While some mid-and high-latitude areas will initially benefit from higher agricultural production, for many others at lower latitudes, especially in seasonally dry and tropical regions, the increases in temperature and the frequency of droughts and floods are likely to affect crop production negatively, which could increase the number of people at risk from hunger, as well as levels of displacement and migration.[9] Space contributes in multiple ways to improvements in food security, from precision farming to monitoring livestock, including fishing areas, and the provision of early warning for famine.

[6] Global Food Crisis, World Food Program, www.wfp.org/emergencies/global-food-crisis (Accessed December 2022).

[7] ST/SPACE/71, European Global Navigation Satellite System and Copernicus: Supporting the Sustainable Development Goals. Building Blocks towards the 2030 Agenda"

[8] Goal 2, Zero Hunger, United Nations. (Accessed on December 2022) www.un.org/sustainabledevelopment/hunger/#:~:text=Also%20in%202020%2C%20a%20staggering,people%20in%20just%20one%20year.

[9] Silvern, S., and Young, S. , (Eds.). (2013). Environmental Change and Sustainability. IntechOpen. https://doi.org/10.5772/46198

## Feedback loop

**This occurs when the current state of a system is part of the inputs which will determine the next state of a system. As a result, uncertainty builds up as time passes, making it very difficult to use simple models to make predictions.**

- *Water management:* Just as challenges to food security derive from population increase, there are also challenges to water management and aquatic ecosystems, not to mention issues related to sanitation and hygiene services. Despite recent progress, 2 billion people lacked safely managed drinking water in 2020, including 771 million who were without even basic drinking water.[10] At the start of the pandemic, 2.3 billion people worldwide (one in three) still lacked basic handwashing facilities (having soap and water at home), and 670 million had no handwashing facilities at all.[11] The challenges posed by issues related to water access and water management go beyond the household and affect schools, hospitals and other essential facilities. Space can contribute to water management in many ways, such as in supporting the mapping and management of water resources and in monitoring infrastructure.
- *Environmental impact and climate change:* The reason why these two items are covered under the same point is that they are tightly linked and affected by feedback loops.
  - Climate change is when the average weather starts to change, and its causes can be either natural or caused by human activities. There is overwhelming evidence that human activities have changed the climate.[12] Climate change goes beyond global warming and is also causing significant environmental changes. Human activities have caused biodiversity losses, global warming, disruptions in ecosystems, changes in land use and the declining quality of air, water and soil all of which have consequences for development and are interrelated as positive and negative feedback loops exist. The visibility and importance of climate change, caused by the human-induced warming of the atmosphere, has also raised awareness about the other consequences of environmental impact. Most of the world's carbon emissions come from developed nations, where population growth has slowed, and populations are more aged. During the COVID-19 pandemic, global carbon emissions went down by 7 per cent in 2020, and the median gross domestic product dropped by 3.95 per cent, meaning that for each 1 per cent decrease in carbon emissions, the GDP went down by more than 0.5 per cent. Space is key in monitoring the evolution of the Earth's climate and the environment, providing a global and integrated vision of the planet.
- *Disaster management and emergency response:* Concentrations of people and assets are growing in urban areas, often in high-risk areas such as storm-exposed coasts, flooding river deltas, earthquake-prone valleys and volcanic slopes.[13] Cities may not have proper drainage or flood protection infrastructure and may depend on vulnerable sources of essential water and energy supplies. To mitigate the devastation caused by these catastrophes, it is crucial to have accurate and complete information on population distribution which then can be used during the full disaster management cycle. Space supports the full disaster management cycle, from risk assessment, mitigation and adaptation to post-disaster needs assessment, passing through emergency response.
- *Migration*: Migration does not only occur between countries, but also from rural to urban areas. Migration has different drivers, such as climate change, demographic changes, conflict, urbanization

[10] Goal 6, Clean Water and Sanitation, United Nations Statistics Division, Department of Economic and Social Affairs. https://unstats.un.org/sdgs/report/2021/goal-06/ (Accessed December 2022).

[11] UNICEF, Factsheet: On Global Handwashing Day, UNICEF warns that 3 in 10 people do not have basic handwashing facilities at home to fight off infectious diseases, www.unicef.org/press-releases/fact-sheet-global-handwashing-day-unicef-warns-3-10-people-do-not-have-basic (Accessed, December 2022)

[12] International Panel on Climate Change, www.ipcc.ch/report/ar6/wg1/downloads/outreach/IPCC_AR6_WGI_SummaryForAll.pdf (Accessed December 2022)

[13] World Meteorological Organization, Disaster Risk Reduction, Climate Risk Management and Sustainable Development, Bulletin Vol 58 (3), 2009 https://public.wmo.int/en/bulletin/disaster-risk-reduction-climate-risk-management-and-sustainable-development (Accessed December 2022)

and overall economic development, all of which, in turn, are influenced by migration. Migration can create sudden surges in demand for services if the rate of change is fast. Space technologies can help track and monitor migration flows, supporting Sustainable Development Goal 10 "Reduce inequality within and among countries" with target 10.7 "facilitate orderly, safe, and responsible migration and mobility of people, including through implementation of planned and well-managed migration policies".

- *Urbanization:* Population and urbanization go hand in hand. Urbanization can be a catalyst for economic growth and social and cultural development. On the other hand, if not properly managed, it can lead to congested cities lacking green and open spaces, without proper provision of public transport, education centres or health-care facilities, and high levels of atmospheric pollution. According to data from 2019 for 610 cities in 95 countries and territories, about half the urban population has convenient access to public transport, defined as living within a walking distance of 500 metres to low-capacity transport systems, such as buses or trams, and 1,000 metres to high-capacity systems, such as trains and ferries.[14] The challenges and opportunities posed by urbanization are captured in SDG 11 which calls for making cities and human settlements inclusive, safe, resilient and sustainable and in the New Urban Agenda. Space can help to support urban planning and vehicle traffic management. It is key for smart grid management and provides key insights for data-driven decision-making.

- *Energy:* Global access to electricity increased from 83 per cent in 2010 to 91 per cent in 2020. Over this period, the number of people without electricity shrank from 1.2 billion to 733 million.[15] On the other hand, energy-linked emissions pollute and degrade the environment resulting in 3 million premature deaths per year.[16] Emissions will rise even after improvements in energy efficiency. For this reason, population growth could be a significant contributor to future carbon emissions, although it is important to recognize the uncertainty of future population growth and its impact on climate change. At the same time, climate change is also a driver of energy demand in items such as heating or air-conditioning. However, renewable flows of energy to Earth are more than the current energy demand. For example, the Sun beams to Earth more than 10,000 times the world's total energy use every second. Space can help in planning renewable energy plants, enabling smart grid management and help individual users to adjust their habits with renewable energy forecasts.

- *Health:* Several years have passed since the first cases of COVID-19 were reported. During that time, more than 500 million people have been infected worldwide and more than 15 million have died. The pandemic disrupted essential health services in 92 per cent of countries (figure until end 2021).[17] A lot of effort remains to be made, and the different targets under SDG 3 "Good Health and Well-Being" indicate the path to be followed, leading to stronger preparation in the event of another global pandemic. The COVID-19 pandemic affected all components of population change, including migration. Efforts must be made to consider demographic changes and their interconnection with other challenges such as population increase. Due to the pandemic, plenty of work has gone into numerous reports which make the connection between space and health. To avoid replicating this work here, some reports that can be consulted on the topic are listed below:
    - United Nations draft resolution on space and global health (A/AC.105/C.1/L.402)[18]
    - Draft report of the Working Group on Space and Global Health on the work conducted under its multi-year workplan (A/AC.105/C.1/L.403)[19]
    - Editor's Special: Innovative solutions for Health in *EUSPA EO and GNSS Market Report*, 2022/Issue 1

[14] Statistics Division, Department of Economic and Social Affairs, Sustainable Development Goal 11. https://unstats.un.org/sdgs/report/2020/goal-11/ (Accessed December 2022)

[15] United Nations, Sustainable Development Goal 7 "Affordable and Clean Energy". (Accessed December 2022) www.un.org/sustainabledevelopment/energy/

[16] United Nations Development Program, 2015, World Energy Assessment Key Messages (Accessed December 2022) www.undp.org/sites/g/files/zskgke326/files/publications/WEAKeyMessages.pdf

[17] United Nations, Sustainable Development Goal 3 "Good Health and Well-Being". (Accessed December 2022) https://sdgs.un.org/goals/goal3

[18] Draft resolution on space and global health, A/AC.105/C.1/L.402

[19] Ibid.

**EXHIBIT 3.** LIST OF CHALLENGES AND LINK TO THE "SPACE2030" AGENDA RELATED ACTIONS

| CHALLENGE | LINK TO THE SPACE2030 AGENDA |
|---|---|
| Food security | **Overarching objective 1**<br>**Action 1.7:** Strengthen the contribution of space technologies and their applications to sustainable fisheries management, agriculture, food safety and security, and nutrition. |
| Water management | **Overarching objective 2**<br>**Action 2.2:** Promote the use of space technologies and their applications to enhance scientific knowledge of the natural environment, including oceans and seas, mountainous regions, water cycles and resources, forestry, biodiversity, desertification and land degradation, as well as urbanization, with a view to contributing to the preservation of the natural environment, sustainable resource management and the protection of ecosystems. |
| Environmental and climate change | **Overarching objective 1**<br>**Action 1.1:** Promote the use of space-based solutions in global efforts to ensure sustainable forest and ocean economies.<br>**Overarching objective 2**<br>**Action 2.2:** Promote the use of space technologies and their applications to enhance scientific knowledge of the natural environment, including oceans and seas, mountainous regions, water cycles and resources, forestry, biodiversity, desertification and land degradation, as well as urbanization, with a view to contributing to the preservation of the natural environment, sustainable resource management and the protection of ecosystems<br>**Action 2.3:** Strengthen the use of integrated space applications to facilitate the observation of the climate and the assessment of disaster risks, improve early warning disaster systems and provide data for the indicators used to track progress in the implementation of the 2030 Agenda for Sustainable Development, the Sendai Framework and commitments by States parties to the Paris Agreement.<br>**Action 2.4:** Advance the role of space technologies in highlighting, analysing and addressing climate change and facilitating the transition to low-emission societies, and promote international collaboration in that regard, in line with existing and recognized international mechanisms and organizations. |
| Disaster management and emergency response | **Overarching objective 2**<br>**Action 2.5:** Promote the use of space-based technologies in all phases of the disaster management cycle, applicable to both natural and man-made disasters, including prevention, mitigation, preparedness, response, recovery, reconstruction and rehabilitation; monitor and assess elements such as exposure, hazards, disaster risk and damage in different regions of the world; and promote the sharing of disaster monitoring data. |
| Urbanization | **Overarching objective 2**<br>**Action 2.6:** Strengthen the use of space technologies and their applications to support the development of socially and environmentally sustainable human settlements and infrastructure, both urban and rural; improve livelihoods; study urbanization and migration patterns; and monitor cultural heritage sites and contribute to their preservation |
| Migration | **Overarching objective 2**<br>**Action 2.7:** Strengthen the use of space technologies and their applications to support the development of socially and environmentally sustainable human settlements and infrastructure, both urban and rural; improve livelihoods; study urbanization and migration patterns; and monitor cultural heritage sites and contribute to their preservation. |
| Energy | **Overarching objective 2**<br>**Action 2.4:** Advance the role of space technologies in highlighting, analysing and addressing climate change and facilitating the transition to low-emission societies, and promote international collaboration in that regard, in line with existing and recognized international mechanisms and organizations. |
| Health | **Overarching objective 2**<br>**Action 2.6:** Strengthen space-related cooperation in support of global health; improve the use and application of space medicine, science and technology, innovations in the global health domain, cooperation and the sharing of information and tools to improve the timeliness and effectiveness of public health and health-care interventions; and enhance capacity-building in space medicine, science and technology. |

Those challenges are directly connected to the "Space2030" Agenda as described in the table above. It is important to note that some actions cover a broader spectrum of activities than others and some of them may span over more than one challenge:

Action 2.1 "Support space science and research, as outer space provides a unique perspective for scientists to observe and study the Earth and the universe" is transversal and supports all the challenges encouraging the use of space for research and development.

As can be seen, the selected challenges span over all actions of overarching objective 2 and on the action under overarching objective 1. All actions are related to applications that can be served by Copernicus, EGNSS and GOVSATCOM. Introducing other space technologies such as satellite communications may produce further benefits.

## 1.3 SELECTED CHALLENGES AND CONNECTION WITH THE GLOBAL AGENDAS

The "Space2030" Agenda provides a bridge to other global agendas of the United Nations and refers to other agendas of the United Nations. This report presents a first analysis of the connections between the "Space2030" Agenda and four selected global agendas, namely:

- 2030 Agenda for Sustainable Development
- Paris Agreement
- New Urban Agenda (Habitat III)
- Sendai Framework for Disaster Risk Reduction

The 2030 Agenda for Sustainable Development is an overarching framework while the other three focus on specific areas.

The following sections will give an overview of each of the agendas considered, followed by a mapping of the challenges.

### 2030 Agenda for Sustainable Development[20]

In 2015, Member States adopted the General Assembly resolution entitled "Transforming our World: the 2030 Agenda for Sustainable Development". This resolution provides a set of goals, the Sustainable Development Goals (SDGs) to be achieved by 2030. The SDGs are for all countries, considering different national realities, capacities and levels of development, and respecting national policies and priorities.

Early in 2018, UNOOSA together with EUSPA carried out the first study on how Copernicus and EGNSS could contribute to the targets underpinning the SDGs.[21] The study showed that those two space systems contribute significantly to the targets, either by achieving them or by monitoring the progress towards their achievement. The study also classified the SDGs in two tiers: those which would benefit most from the use of Copernicus and EGNSS and those for which those technologies, although supportive, were not essential.

### Paris Agreement[22]

The Paris Agreement is a legally binding international treaty on climate change adopted by 196 Parties at COP 21 in 2015 in Paris and entered into force on 4 November 2016. The goal of the Paris Agreement is to limit global warming to well below 2° C, preferably to 1.5° C, compared to pre-industrial levels. In order to do so it is of paramount importance to lower greenhouse gas (GHG) emissions and achieve a climate-neutral world by 2050. Achieving this goal would significantly reduce the risks and impacts of climate change. However, on the other hand, the Paris Agreement recognizes the difficulty of the task, as the reduction of emissions must be done in a manner that takes into account the needs of society. For example, according to a recent analysis carried out by the Food and Agriculture Organization (FAO), around 31 per cent of human-caused GHG emissions originate from the world's agrifood systems,[23] so achieving the global

[20] A/RES/70/1.Transforming our world: the 2030 Agenda for Sustainable Development. https://undocs.org/A/RES/70/1

[21] ST/SPACE/71, European Global Navigation Satellite System and Copernicus: Supporting the Sustainable Development Goals. Building Blocks towards the 2030 Agenda"

[22] Paris Agreement 2015, https://unfccc.int/files/meetings/paris_nov_2015/application/pdf/paris_agreement_english_.pdf

[23] Food and Agriculture Organization, FAOSTAT portal. www.fao.org/faostat/en/#data/EM/visualize

warming limit of 1.5° C, should be done without threatening food production.

The Paris Agreement itself calls for equity and considers different national circumstances. In that regard, "the Paris Agreement will be implemented to reflect equity and the principle of common but differentiated responsibilities and respective capabilities." In the spirit of leaving no one behind and noting the importance of technology for the implementation of mitigation and adaptation measures, the Paris Agreement also establishes a Technology Mechanism to promote and facilitate enhanced action on technology development and transfer to support its implementation.

## New Urban Agenda[24]

The New Urban Agenda was endorsed by the General Assembly in 2016 and reaffirms the global commitment to sustainable urban development as a critical step for realizing sustainable development. It is also related to the 2030 Agenda for Sustainable Development in a very integrated manner, and to the achievement of the SDGs. In particular, SDG 11 focuses on making cities and human settlements inclusive, safe, resilient and sustainable, a topic of great importance in an 8 billion world, where over half the population live in cities, a figure that will continue to rise. Furthermore, cities and metropolitan areas contribute to more than half of the world GDP and over two thirds of global carbon emissions.

The New Urban Agenda is guided by the following principles which have been adapted to highlight the elements where Copernicus and EGNSS could contribute most:

- Leave no one behind
- Ensure sustainable and inclusive urban economies
- Ensure environmental sustainability

These elements are related to the challenges in many ways, and directly linked with the urbanization challenge, to manage the urban growth in a sustainable and equitable manner. It also connects with the energy challenge by promoting the use of clean energy to reduce the environmental footprint of the energy consumed (climate change and environmental impact challenge), or by building urban resilience, reducing disasters risks (disaster management and emergency response challenge) adopting mitigation and adaptation strategies for climate change, or by enhancing liveability, by reducing air pollution (health challenge) and increasing food security and improving the management of water resources (food security and water management challenges) and as well as providing access to social infrastructure and basic services such as health care (health challenge).

## Sendai Framework for Disaster Risk Reduction 2015–2030[25]

The Sendai Framework for Disaster Risk Reduction 2015–2030 was adopted in 2015, with the goal of preventing new and reducing existing disaster risk through the implementation of integrated and inclusive economic, structural, legal, social, health, cultural, educational, environmental, technological, political and institutional measures that prevent and reduce hazard exposure and vulnerability to disaster, increase preparedness for response and recovery, and thus strengthen resilience. It applies to risks of a large- or small-scale nature, frequent and infrequent, sudden and slow-onset disasters caused by natural or human-made hazards, as well as related environmental, technological and biological hazards and risks. It aims to guide the multi-hazard management of disaster risk in development at all levels as well as within and across all sectors.

To achieve its goal, the Sendai Framework defines the following priorities:

- Priority 1: Understanding disaster risk
- Priority 2: Strengthening disaster risk governance to manage disaster risk
- Priority 3: Investing in disaster risk reduction for resilience
- Priority 4: Enhancing disaster preparedness for effective response and to "build back better" in recovery, rehabilitation and reconstruction

Each priority provides a list of actions to be undertaken at both global and regional level and at national and local level.

[24] A/RES/71/256, New Urban Agenda, https://undocs.org/A/RES/71/256
[25] A/RES/69/283, Sendai Framework for Disaster Risk Reduction 2015-2030. https://undocs.org/A/RES/69/283

## Opportunities in the "Space2030" Agenda

**The "Space2030" Agenda is an opportunity and a call for action for the entire space sector to take action to enhance space-derived economic benefits and strengthen the role of the space sector as a major driver of sustainable development, solve challenges and improve the quality of life, harness the potential of space to solve everyday challenges, leverage space-related innovation to improve the quality of life as well as an opportunity to build partnerships and strengthen international cooperation in the peaceful uses of outer space and in the global governance of outer space activities.**

The Sendai Framework for Disaster Risk Reduction 2015–2030 is directly linked to the challenge of disaster management and emergency response. As seen in the other agendas, it is linked to the other challenges at different levels as managing the risk of disasters is aimed at protecting people and their property, health, livelihoods and productive assets, as well as cultural and environmental assets, while promoting and protecting all human rights, including the right to development.

## Mapping between the challenges and the selected global agendas

The "Space2030" Agenda provides a forward-looking strategy for reaffirming and strengthening the contribution of space activities and space tools to the achievement of global agendas, addressing long-term sustainable development concerns of humankind, putting forward the priorities of Member States on the areas where space could make a contribution to the fulfilment of the global agendas and how, making it the reference agenda for space actors.

As the challenges have been extracted from different actions reflected in the "Space2030" Agenda, it is worth comparing how they are reflected in the global agendas. Exhibit 4 provides the mapping of the agendas and the challenges, identifying which parts of the agenda can be related to a specific challenge, however, the relevance of space for the fulfilment of the specific part of the agenda was not considered in the creation of the mapping. A space actor should make the additional step of identifying the areas to which space can contribute for each global agenda. However, the "Space2030" Agenda simplifies that task, providing already the list of what Member States require from space technologies, data and applications.

**EXHIBIT 4.** MAPPING OF THE CHALLENGES AND THE GLOBAL AGENDAS CONSIDERED FOR THIS REPORT

*Note: the paragraphs and sections referenced do not make a specific reference to space technology, data or applications, that additional step shall be done to connect with space activities. See the previous work of UNOOSA and EUSPA on Earth observation and Global Navigation Satellite Systems and the 2030 Agenda for Sustainable Development.*[a]

| SUSTAINABILITY CHALLENGE | 2030 AGENDA FOR SUSTAINABLE DEVELOPMENT | PARIS AGREEMENT 2015 | SENDAI FRAMEWORK FOR DISASTER RISK REDUCTION 2015–2030 | NEW URBAN AGENDA |
|---|---|---|---|---|
| **Food security** | SDG 2: Zero Hunger | Preamble<br>Article 2, paragraph 1 (b) | Guiding principles, paragraph 19 (h)<br>Priority 2, Paragraph 28 (b)<br>Priority 3, Paragraph 30(j)<br>Priority 4, Paragraph 33 (h) | |
| **Water management** | SDG 6: Clean Water and Sanitation | No mention | Priority 4, paragraphs 33 (c) and (h) | Paragraphs 13 (a), 13 (h), 34, 64, 70, 71, 72, 73, 74, 88, 119, 120, 123 |
| **Environmental and climate change** | SDG 1: No Poverty<br>Target 1.5<br>SDG 2: Zero Hunger<br>Target 2.3<br>Target 2.4<br>SDG 3: Good Health and Well-Being:<br>Target: 3.9<br>SDG 8: Decent Work and Economic Growth<br>Target 8.4<br>SDG 9: Industry, Innovation and Infrastructure<br>Target 9.4<br>SDG 11: Sustainable Cities and Communities<br>Target 11.6<br>Target 11.a<br>SDG 12: Responsible Consumption and Production<br>Target 12.4<br>Target 12.c<br>SDG 13: Climate Action<br>SDG 14: Life Below Water<br>SDG 15: Life on Land | The topic of the agreement is to strengthen the global response to the threat of climate change. | Preamble<br>Expected Outcome, 16<br>Guiding Principles, 19 (h)<br>Priority 1, paragraphs 25 (b) (c)<br>Priority 2, paragraphs 28 (b) (c)<br>Priority 4, paragraph, 33 (a)<br>Priority 4, paragraph 34 (c)<br>Means of implementation, paragraph 47 (d) | Paragraphs 2, 3, 5, 10, 13 (h), (g). 14 (c), 15 (c) iii, 24, 35, 44, 50, 51, 54, 55, 58, 88, 94, 101, 106, 109, 111, 114 (d), 115, 119, 143, 144, 151, 165<br>A whole section on Environmentally sustain-able and resilient urban development. |
| **Disaster management and emergency response** | SDG 1: No Poverty<br>Target 1.5<br>SDG 2: Zero Hunger<br>Target 2.4<br>SDG 11: Sustainable Cities and Communities<br>Target 11.5<br>Target 11.b<br>SDG 13: Climate Action<br>Target 13.1<br>Target 13.3 | Article 7, paragraph 9 (b) (c) (d)<br>Article 8, paragraph 4<br>Article 10, paragraph 2 | The topic of the framework is disaster risk reduction | Paragraphs 14 (c), 19, 29, 63, 65, 67, 77, 78, 101, 119, 144, 165 |

[a] ST/SPACE/71, European Global Navigation Satellite System and Copernicus: Supporting the Sustainable Development Goals. Building Blocks towards the 2030 Agenda"

| SUSTAINABILITY CHALLENGE | 2030 AGENDA FOR SUSTAINABLE DEVELOPMENT | PARIS AGREEMENT 2015 | SENDAI FRAMEWORK FOR DISASTER RISK REDUCTION 2015–2030 | NEW URBAN AGENDA |
|---|---|---|---|---|
| **Migration** | SDG 10: Reduced Inequalities Target 10.7 | Preamble | Preamble<br>Priority 2, paragraph 27 (h)<br>Role of stakeholders, paragraphs 36 (a) (vi) | Paragraph 20, 28.34, 42, 57, 59, 104, 157, 159 |
| **Urbanization** | SDG 11: Sustainable Cities and Communities | Article 8, paragraph 4 | Preamble<br>Priority 2, paragraph 27 (d)<br>Priority 3, paragraph 30 (b) (f)<br>Means of implementation paragraph 47 (d) | The topic of the agenda is around urbanization |
| **Energy** | SDG 7: Affordable and Clean Energy<br>SDG 12: Responsible Consumption and Production Target 12.c | Indirect link to Emissions | No mention | Paragraphs 13 (a), 14 (c), 34, 44, 54, 66, 70, 71, 74, 75, 88, 111, 121 |
| **Health** | SDG 3: Good Health and Well-Being<br>SDG 5: Gender Equality Target 5.6 | Preamble | Preamble<br>Expected outcome and goal, 16, 17, 18 (d)<br>Guiding Principles 19 (c) (h)<br>Priority 1, Global and regional levels, paragraphs 24 (d), 25 (b) (d)<br>Priority 2, Global and regional levels, paragraphs 27 (b) (d), 28 (b)<br>Priority 3. Paragraphs 29, 30 (i) (j), 31 (e),<br>Priority 4, paragraphs 33 (c)<br>Means of implementation, 43, 44 | Paragraphs 2, 5, 11, 13 (a), 14 (a) (c), 32, 34, 36, 37, 39, 43, 54, 55, 67, 75, 88, 100, 108, 111, 113, 115, 118, 119, 123 |

As exhibit 4 shows, the selected agendas are interlinked and connected to all challenges, which speaks in favour of the validity of selecting those challenges. The selected global agendas set out the path for humankind concerning sustainability, disaster management, urbanization and climate change, all these aspects are captured in the "Space2030" Agenda, which provides a more direct link for space actors to the aforementioned challenges and other aspects concerning space sustainability, diplomacy and economy.

For the past decades, space activities have enhanced the knowledge of our home, the Earth, improving our understanding of the delicate connections between environment, biodiversity and human societal developments. Space technology, data and applications play an integral role in sustainability today and will continue to do so in the coming decades. The "Space2030" Agenda reinforces this notion and calls for action from all space actors.

Melting sea ice in the Arctic.
Photo credit: Alfred-Wegener-Institute, E. Horvath

# 2. DESCRIPTION AND EVOLUTION OF THE EU SPACE COMPONENTS

The following flagship components deliver European space-based services on a daily basis:

- *Galileo* is Europe's Global Navigation Satellite System (GNSS), on which numerous economic sectors rely, from transport and agriculture to border management and search and rescue. Its free and global 20cm high-accuracy service makes Galileo a game changer for autonomous driving and commercial drones. Already more than 3.7 billion smartphones are Galileo-enabled worldwide and all new smartphones in the European Union are required by law to use Galileo.
- *EGNOS* (European Geostationary Navigation Overlay Service) is Europe's regional satellite-based augmentation system (SBAS). It is used to improve GNSSs such as GPS, and Galileo in the future. EGNOS was deployed to provide safety-of-life navigation services to aviation. However, due to improved positioning performance, it is also intended to support applications in a wide range of other domains such as maritime, rail, agriculture and road. EGNOS is already operational in more than 400 airports and helipads.
- *Copernicus* is the European Earth observation system. It offers a vast amount of data from satellites and in situ (non-space) data, complemented by information services. It supports environmental management, helps mitigate the effects of climate change, and ensures safety and civil security across Europe. Copernicus is the largest provider of global Earth observation data. The vast majority of data/information delivered by Copernicus is made available and accessible to any citizen, and any organization around the world on a free, full and open basis.
- *GOVSATCOM* has the objective to ensure the long-term availability of reliable, secured and cost-effective satellite communication (SatCom) services to governmental users, contributing to the security and safety of all European Union citizens.

In addition, there are new EU Space flagship initiatives under development to boost satellite-based secure connectivity and ensure sustainable and secure space:

- *IRIS*[2] (Europe's new Infrastructure for Resilience, Interconnection and Security by Satellites) will be a ''new space" and multi-orbit constellation providing connectivity to the whole of Europe, including areas that do not currently benefit from broadband Internet, as well as to the whole of Africa. The system will ensure access to secure and cost-effective satellite communications services, for governmental communications and commercial use. It aims to protect critical infrastructures, support surveillance and crisis management, as well as enable high-speed broadband to best anticipate future challenges.
- *EU Space Traffic Management (STM):* STM encompasses the means and rules to access, conduct activities in, and return from outer space safely, sustainably and securely. STM aims at securing the long-term viability of space activities by ensuring that space remains a safe and secure environment as the European economy, society and citizens rely on space-based applications such as communications, navigation and Earth observation. It encompasses

various elements such as space situational awareness (SSA) activities, including space surveillance and tracking (SST).

In terms of governance, the European Commission has the overall responsibility for the implementation of the Programme in close cooperation with the European Union Member States, the European Union Agency for the Space Programme (EUSPA), the European Space Agency (ESA) and other stakeholders. Specifically, the EUSPA tasks include:[26]

- Managing EGNOS and Galileo service provision and ensuring the Space Surveillance and Tracking Front Desk
- Promoting downstream market and integrated applications based on Galileo, EGNOS and Copernicus
- Engaging the GOVSATCOM user community in shaping the service
- Improving GNSS services and infrastructure exploitation

Concerning IRIS², specific tasks still have to be allocated. However, EUSPA is already actively involved in building secure satellite communication infrastructure for Europe through the coordination of the first phase of GOVSATCOM on which IRIS² will be based.

## 2.1 EUROPEAN GNSS (EGNSS)

### 2.1.1 Galileo

Galileo is the European Global Navigation Satellite System (GNSS), providing stand-alone navigation, positioning and timing information (PNT) to users worldwide. Unlike other systems, it is under civilian control and has been designed to meet the diverse needs of different user communities.

Galileo provides Europe and European citizens with independent PNT services. The Galileo system offers several high-performance services worldwide, featuring various levels of accuracy, robustness, authentication and security:

- *Open Service:* Galileo is a free-of-charge global ranging, positioning and timing service. It also provides Navigation Message Authentication (OSNMA), allowing the computation of the user position using authenticated data extracted from the navigation message.
- *High Accuracy Service (HAS):* A free-of-charge high-accuracy corrections service disseminated through the Galileo signal (E6-B) and by terrestrial means (Internet). Galileo HAS offers real-time improved user positioning performances with an accuracy of less than 20 cm globally and for everyone. Galileo HAS has been operational since 24 January 2023.[27]
- *Commercial Authentication Service (CAS):* A service will provide users with the capability to obtain an authenticated Galileo PVT solution.
- *Public Regulated Service (PRS):* An encrypted navigation service for authorized governmental users and sensitive applications that require high continuity.
- *Search and Rescue Service (SAR):* Europe's contribution to COSPAS-SARSAT, an international satellite-based search and rescue distress alert detection system. Galileo not only quickly locates people in distress and makes their position known to the relevant authorities, but the SAR/Galileo RLS also provides an automatic acknowledgement message back to the user informing them that their request for help has been received.

Galileo entered its Initial Operational Capability phase in 2016. Since then, anyone with a Galileo-enabled device is able to use its signals for positioning, navigation and timing.

[26] https://european-union.europa.eu/institutions-law-budget/institutions-and-bodies/institutions-and-bodies-profiles/euspa_en
[27] www.euspa.europa.eu/newsroom/news/galileo-high-accuracy-service-now-operational

### 2.1.2 EGNOS

The European Geostationary Navigation Overlay Service (EGNOS) is Europe's regional satellite-based augmentation system (SBAS) that is used to improve the performance of global navigation satellite systems (GNSSs), such as GPS, and Galileo in the near future. EGNOS improves the accuracy and reliability of GNSS positioning information, while also providing a crucial integrity message regarding the continuity and availability of a signal. In addition, EGNOS also transmits an extremely accurate universal time signal. EGNOS delivers three core services:

- *Open Service:* free and open to the public, the Open Service is used by mass-market receivers and common user applications.
- *Safety of Life Service (SoL):* primarily geared towards civil aviation, the SoL service has potential applicability to a range of safety-critical transport applications which require enhanced and guaranteed performance and an integrity warning system, including maritime, rail and road.
- *EGNOS Data Access Service (EDAS):* offered on a controlled access basis, EDAS provides ground-based access to EGNOS data through the Internet to customers requiring enhanced performance for professional use.

EGNOS has been declared fully operational since 2009 for OS, and 2011 for SoL, continuously delivering high-quality services to all users with enabled receivers.

In a future perspective, as Galileo and EGNOS are user-driven programmes striving to meet the evolving needs and the increasingly challenging expectations of users in multiple domains, future evolutions of EGNSS services or the creation of new ones are already under study or development:

- On the upstream side, Galileo continues its deployment and launched its first so-called "Batch 3" satellites in 2021 to complete and replenish its nominal Galileo first generation constellation by 2025. In parallel, evolution studies are ongoing to prepare the first batch of the Galileo second-generation satellites. In addition, a new generation of EGNOS is currently under development. This new EGNOS V3 will introduce new services based on multiple frequencies of multiple constellations (GPS, Galileo).
- On the service level, many activities are ongoing to develop additional services for Galileo, including an Emergency Warning Service (EWS) and an extension of the SAR Return Link Service capabilities.

## 2.2 COPERNICUS

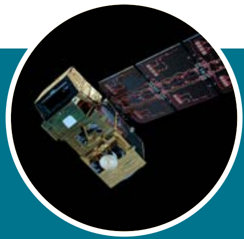
Copernicus is the Earth observation component of the European Union's Programme. It is a leading provider of Earth observation data, which delivers accurate, timely and reliable information in the field of environment and security, and supports a wide range of Union policies in domains such as climate action, agriculture, environment, energy, health, civil protection, humanitarian aid and transport. Copernicus also serves research, academic, commercial and other private users. The Earth observation data delivered by the Copernicus satellites through various data access platforms and the data and information delivered by the six Copernicus services are available to users on a free, full and open basis.

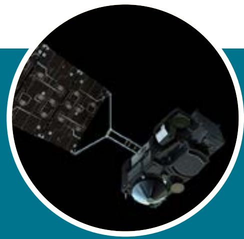
The system consists of three main components:

- The space component, which delivers data from a fleet of dedicated observation satellites (the "Sentinel satellites") and from Contributing Missions[28]
- The in situ component which collects data acquired by a multitude of sensors at air-, sea- and ground-level
- The service component, which transforms the wealth of satellite and in situ data into timely and actionable information products, in six thematic areas

[28] Contributing Missions are missions from ESA, their Member States, Eumetsat and other European and international third-party mission operators that make some of their data available for Copernicus. These satellites help cover the needs of Copernicus Service Providers, particularly for very high resolution optical and radar data. Contributing Missions play a crucial role in delivering complementary data.


Sentinel-1


Sentinel-2


Sentinel-3


Sentinel-4

Seven Sentinel satellites are currently operational and two (i.e., Sentinel-4 and 5) to be launched by 2024:[a]

**Sentinel-1** is a polar-orbiting, all-weather, day-and-night radar imaging mission for land and ocean services. Sentinel-1A was launched on 3 April 2014 and Sentinel-1B on 25 April 2016. Both were taken into orbit from Europe's Spaceport in French Guiana. The mission ended for Sentinel-1B in 2022 and plans are in force to launch Sentinel-1C as soon as possible.

**Sentinel-2** is a polar-orbiting, multispectral high-resolution imaging mission for land monitoring to provide, for example, imagery of vegetation, soil and water cover, inland waterways and coastal areas. Sentinel-2 also delivers information used for emergency management. Sentinel-2A was launched on 23 June 2015 and Sentinel-2B followed on 7 March 2017.

**Sentinel-3** is a multi-instrument mission to measure sea-surface topography, sea- and land-surface temperature, ocean colour and land colour with high-end accuracy and reliability. The mission supports ocean forecasting systems, as well as environmental and climate monitoring. Sentinel-3A was launched on 16 February 2016 and Sentinel-3B joined its twin in orbit on 25 April 2018.

[a] Source: ESA - The Sentinel missions

The programme is managed by the European Commission and implemented in partnership with Member States, the European Space Agency (ESA), the European Organization for the Exploitation of Meteorological Satellites (EUMETSAT), the European Centre for Medium-Range Weather Forecasts (ECMWF), European Union agencies and Mercator Ocean International. Within this context, EUSPA is in charge of communicating, promoting and developing the market for data, information and services offered by Copernicus, while contributing to maximize its socioeconomic benefits by fostering the development of a competitive and innovative downstream industry.

The Sentinel satellites are the Earth observation satellites of Copernicus and are designed to meet the needs of the Copernicus services and their users. There are currently six different models of Sentinel satellites, which ensure an independent and autonomous Earth observation capacity for Europe with global coverage. They deliver observations (including day and night, all-weather observations) that serve a wide range of user needs related to land and ocean surfaces, atmospheric measurements, air quality, emergency situations, and so on.

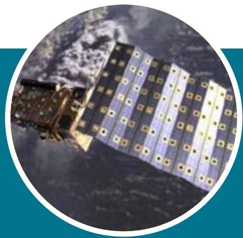
Future evolutions of Copernicus infrastructure include six Sentinel Expansion missions that will be deployed to address European Union policy and gaps vis-à-vis Copernicus user needs and to expand the current capabilities of the Copernicus Space Component.[29]

The development and construction of those new missions, also known as "High Priority Candidate Missions" (HPCM), were awarded to major European satellite manufacturers in 2020. Those missions will contribute to better respond to the needs of global institutional, scientific and commercial users by providing additional information regarding anthropogenic $CO_2$, the physical characteristics of the Earth and will also enable improved monitoring of polar regions, as detailed in exhibit 6 on page 22.[30]

[29] www.esa.int/Applications/Observing_the_Earth/Copernicus/Copernicus_Sentinel_Expansion_missionshttps://www.esa.int/Applications/Observing_the_Earth/Copernicus/Copernicus_Sentinel_Expansion_missions

[30] https://sentinels.copernicus.eu/web/sentinel/missions/copernicus-expansion-missions


Sentinel-5P


Sentinel-5


Sentinel-6

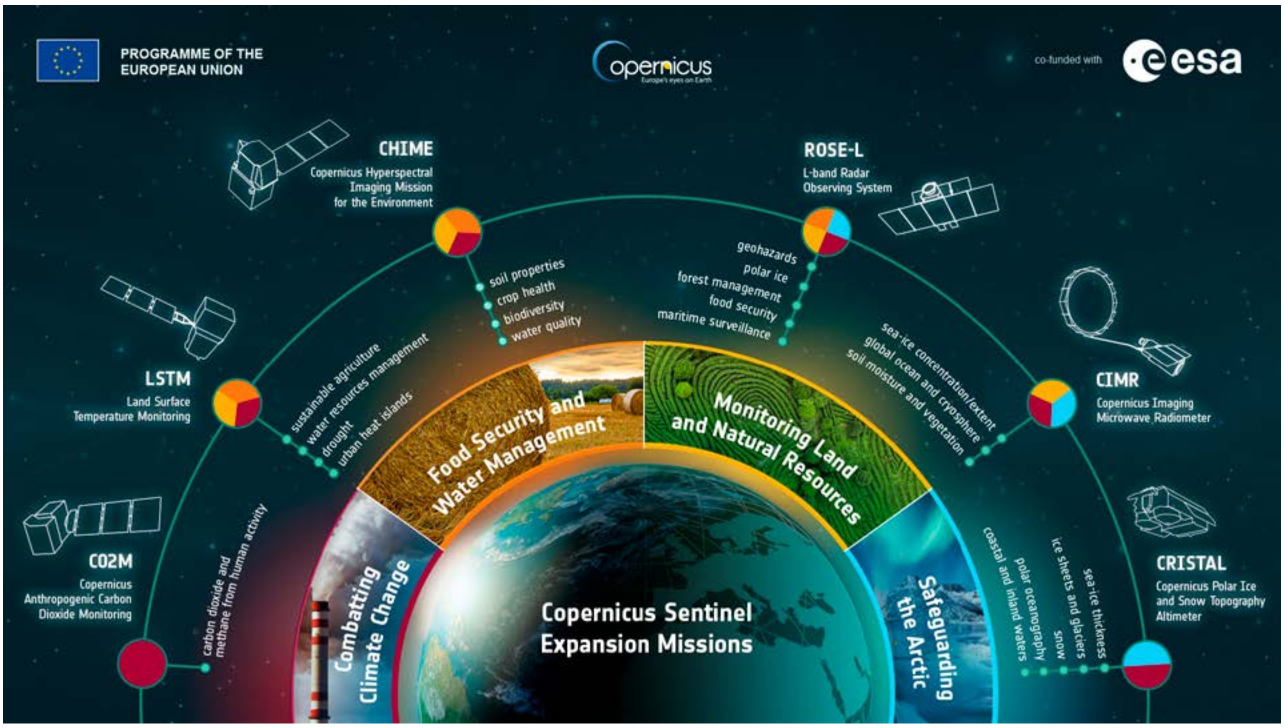
**Sentinel-4** is a payload devoted to atmospheric monitoring that will be embarked upon a Meteosat Third Generation-Sounder (MTG-S) satellite in geostationary orbit to monitor air quality and key trace gases and aerosols over Europe in support of the Copernicus Atmosphere Monitoring Service (CAMS) at high spatial resolution and with a short revisit time.

**Sentinel-5 Precursor** – also known as Sentinel-5P – is the forerunner of Sentinel-5 to provide timely data on a multitude of trace gases and aerosols affecting air quality and climate. It has been developed to reduce data gaps between the Envisat satellite – particularly the Sciamachy instrument – and the launch of Sentinel-5. Sentinel-5P was taken into orbit on 13 October 2017.

**Sentinel-5** will be a payload on board a MetOp Second Generation satellite that will perform atmospheric measurements, with high spatio-temporal resolution, relating to air quality, climate forcing, ozone and UV radiation and providing a daily global coverage.

**Sentinel-6** carries a radar altimeter to measure global sea-surface height, primarily for operational oceanography and climate studies. The first satellite was launched into orbit on 21 November 2020 on a SpaceX Falcon nine rocket from the Vandenberg Air Force Base in California, United States.

**EXHIBIT 5.** OVERVIEW OF THE COPERNICUS EXPANSION MISSIONS.




*Credit: ESA*

**EXHIBIT 6.** EXPLANATION OF THE SIX FUTURE COPERNICUS HIGH PRIORITY CANDIDATE MISSIONS AND MAIN APPLICATIONS.

| MISSION | DESCRIPTION |
|---|---|
| **CHIME: Copernicus Hyperspectral Imaging Mission** | Complementing Copernicus Sentinel-2 for applications such as land-cover mapping, it will carry a unique visible to shortwave infrared spectrometer, providing routine hyper-spectral observations to support new and enhanced services for sustainable agricultural and biodiversity management, as well as soil property characterization. |
| **CIMR: Copernicus Imaging Microwave Radiometer** | Responding to high-priority requirements from key Arctic user communities, the mission will carry a wide-swath conical-scan multi-frequency microwave radiometer to provide observations of sea-surface temperature, sea-ice concentration and sea-surface salinity while also providing unique observation capabilities for a wide range of other sea-ice parameters. |
| **CO2M: Copernicus Anthropogenic Carbon Dioxide Monitoring** | This mission will carry a near-infrared and shortwave-infrared spectrometer to measure atmospheric carbon dioxide produced by human activity, providing the European Union with a unique and independent source of information, to assess the effectiveness of policy measures, and track their impact towards decarbonization and allowing the verification of compliance with emission reduction targets of the Paris Agreement. The measurements from the mission would reduce current uncertainties in estimates of emissions of carbon dioxide from the combustion of fossil fuel at national and regional scales. |
| **CRISTAL: Copernicus Polar Ice and Snow Topography Altimeter** | The CRISTAL satellite mission will contribute to a better understanding of climate processes, with its dual-frequency radar altimeter and microwave radiometer to measure and monitor sea-ice thickness and overlying snow depth. It will also measure and monitor changes in the thickness of ice sheets and glaciers worldwide, while measurements of sea-ice thickness would support maritime operations in polar oceans and, in the longer term, would help in the planning of activities in the polar regions. |
| **LSTM: Copernicus Land Surface Temperature Monitoring** | The satellite mission will respond to the priority requirements of the agricultural user community, for improving sustainable agricultural productivity at field-scale in a world of increasing water scarcity and variability. It will carry a high spatial-and temporal resolution thermal infrared sensor to provide observations of land-surface temperature. Such measurements and derived evapotranspiration indicators are key to understand and respond to climate variability, manage water resources for agricultural production, predict and monitor droughts and also to address land degradation, hazards such as fires and volcanoes, coastal and inland water management as well as urban heat island phenomena. |
| **ROSE-L: L-band Synthetic Aperture Radar** | The satellite mission will provide additional information that cannot be gathered by the Copernicus Sentinel-1 C-band radar mission, since it would carry an L-band SAR, whose lower frequency L-band signal can penetrate through many natural structures such as vegetation, dry snow and ice. It will be used in support of forest management, to monitor subsidence and soil moisture and to discriminate crop types for precision farming and food security. |

*Credits: ESA*

The Copernicus services deliver value-added information products in six thematic areas:

| | |
|---|---|
| **ATMOSPHERE** | The **Copernicus Atmosphere Monitoring Service (CAMS)** continuously monitors the composition of the Earth's atmosphere at global and regional scales and delivers accurate and reliable information and forecasts related to air pollution and health, ozone hole monitoring, solar energy, greenhouse gases and climate forcing. ECMWF implements CAMS Under a Contribution Agreement from the European Commission. |
| **MARINE** | The **Copernicus Marine Environment Monitoring Service (CMEMS)** provides regular and systematic reference information and forecasts on the physical and biogeochemical state, variability and dynamics of the ocean and marine ecosystems for the global ocean and the European regional seas. Mercator Ocean International implements CMEMS on behalf of the European Commission to implement CMEMS. |
| **LAND** | The **Copernicus Land Monitoring Service (CLMS)** delivers geographical and environmental information on the land cover, which includes land cover characteristics and changes, land use, vegetation state, water cycle, snow and ice, phenology and earth surface energy variables. Since 2022, it also operates the European Ground Motion Service. The CLMS is jointly implemented by the European Commission's Joint Research Centre and the European Environment Agency. |
| **CLIMATE CHANGE** | The **Copernicus Climate Change Service (C3S)** provides authoritative information about the past, present and future climate, as well as tools to enable climate change mitigation and adaptation strategies by policymakers and businesses. C3S is implemented by the European Centre for Medium-range Weather Forecasts (ECMWF) on behalf of the European Commission. |
| **EMERGENCY** | The **Copernicus Emergency Management Service (CEMS)** delivers on-demand geospatial information for emergency situations and humanitarian crises that arise from natural or man-made disasters anywhere in the world and provides early warning and monitoring information for floods, wildfires and droughts. The CEMS is implemented by the European Commission's Joint Research Centre. |
| **SECURITY** | The **Copernicus Security Service (CSS)** is a dedicated service to deliver information that helps the European Union improve crisis prevention, preparedness and response and to face security-related challenges in the areas of maritime surveillance, border surveillance and support to European Union external action. The European Commission has entrusted the European Maritime Safety Agency (EMSA), the European Border and Coast Guard Agency (FRONTEX) and EU SatCen with the operation of the different components of the CSS. CSS services are only accessible to authorized users. |

The massive amount of data and information produced in the context of Copernicus – representing tens of terabytes every day – are freely available and accessible to any citizen or any organization around the world thanks to a full, free and open data policy.

Considering the amount of data to be exploited, traditional processing chains have today reached their limits. Copernicus data are delivered to their users through a variety of online data access platforms,[31] such as the ESA-managed Copernicus Data Space Ecosystem, which was inaugurated in January 2023, and the EUMETSAT-managed EUMETCast platform. In addition to the above platforms, several Copernicus services have developed their own online platform, which provides users with access to information and forecasting products, associated documentation and support services for their use. 1,000+ Copernicus products are available to users in total.

To fully tap the potential of Copernicus data, in 2017, the European Commission launched the development of five cloud-based platforms: the Copernicus Data and

[31] Refer to www.copernicus.eu/en/access-data for further information on data access.

Information Access Services (DIAS). Each DIAS provided access in a virtual environment to all Copernicus data and information, as well as tools and utilities to process them in the cloud without having to download massive amounts of data. Building on the experience gained with the launch of the DIASes, a new Copernicus data access service, referred to as the Copernicus Data Space Ecosystem,[32] was launched in January 2023. This service is part of the Copernicus activities delegated by the European Commission to the European Space Agency and aims at harmonizing and streamlining the Copernicus Data Access framework through a single platform to better access and exploit the Copernicus Data. The new service will be fully operational in July 2023 after a progressive phase-in period corresponding to the phasing out of the current data distribution service, leaving time for users to migrate and familiarize themselves with the new service interfaces.[33] In parallel, EUMETSAT, ECMWF, Mercator Ocean International and EEA operate the WEkEO cloud-based platform, which provides access to a variety of Sentinel data and to products and information from the Copernicus Atmosphere, Ocean and Land Monitoring and Climate Change Services.

## 2.3 GOVSATCOM

*"GOVSATCOM is a crucial pillar of the EU Space Programme. While Copernicus and EGNSS provide the necessary data, services and products, growing security threats require means of communication that is robustly protected against interference, interception, intrusion, and other risks. With GOVSATCOM the European Union will make another step into securing its strategic autonomy in space."*

Rodrigo da Costa
EUSPA Executive Director

In a highly fragmented landscape, with telecommunications services being offered by both nationally owned and commercial satellite infrastructures, a gap currently exists between governmental satellite communications (SatCom) needs and available solutions. As a result, key missions, operations and infrastructures are exposed to security risks. Access to secure SatCom services is key in case of network interruptions (e.g., in case of natural or human-made disasters), unavailability (e.g., in maritime areas or in the Arctic region), humanitarian missions and operations of critical infrastructure. This is where the European Union GOVSATCOM (The European Union Governmental Satellite Communications) programme component comes into play.

Secure satellite communications that can be timely and efficiently deployed are critical for governmental security actors such as police, border guards, firefighters, civilian and military crisis forces. SatCom services can assist in securely operating response missions, which may not be able to rely on the terrestrial networks or may be subject to cyberthreats.

The GOVSATCOM programme component, which has been launched by the European Commission as the fourth component of the EU Space Programme (currently in pre-operational phase and the initial service is foreseen in 2024), ensures the long-term availability of reliable, secure and cost-effective governmental satellite

[32] https://dataspace.copernicus.eu
[33] https://ec.europa.eu/commission/presscorner/detail/en/ip_22_7374

communications services for the European Union and national public authorities managing security critical missions and infrastructures.

In this context, GOVSATCOM complements the capabilities offered by Copernicus, Galileo and EGNOS and will provide assured and secured communications.

GOVSATCOM is intended to be a user-centred programme with a strong security dimension across national and civil-military boundaries and is one of the elements of the Global Strategy for the European Union's Foreign and Security Policy of June 2016. The Programme will contribute to the European Union response to hybrid threats and provide support to both the European Union Maritime Strategy and its Arctic Policy.

Three main use cases have been identified:

- *Crisis management*, which may include civilian and military by common security and defence missions and operations, natural and human-made disasters, humanitarian crisis, and maritime emergencies
- *Surveillance*, such as border and maritime surveillance or surveillance of illegal trafficking
- *Key infrastructures*, including diplomatic work, police communications and digital, energy and space infrastructures, such as Galileo and EGNOS

For what concerns the specific use cases related to space infrastructure, the following are mainly envisaged:

- GOVSATCOM for the interconnection of remote sites of the ground infrastructure (e.g., Galileo Sensor Stations).
- GOVSATCOM contributing to a better dissemination of space data (e.g., EGNOS data, contribution to a better dissemination of Galileo navigation data, Copernicus data, etc.)

GOVSATCOM may also serve specific use cases, such as providing connectivity to the Arctic region, for machine to machine (M2M) and Internet of things (IoT) communications, as well as for remotely piloted aircraft systems (RPAS) command and control.

Although the primary focus is on continental Europe and its neighbouring regions (Africa, Mediterranean, Middle East Asia, Arctic, Atlantic), GOVSATCOM services are planned to support crisis management missions in areas according to specific needs from authorized users. They will cover the crisis area with connectivity and will be made available in less than 48 hours.

Implemented in close collaboration with EUSPA, the European Union Member States, the European External Action Service (EEAS), and with a large number of other European Union agencies and actors, GOVSATCOM will provide an appropriate level of European independence in terms of technologies, assets, operations and services. GOVSATCOM will also provide support to several European Union policies, but above all, it will strengthen European Union capacity to protect its citizens.

EUSPA is responsible for coordinating the GOVSATCOM user network and analysing user needs and requirements to build a user perspective and assess market trends. EUSPA also generates market and user technology intelligence focusing on space services for governmental users and synergies between the secure services offered by the space programme components. Finally, EUSPA supports the definition of the security baseline and manages the development of the architecture for the secure ground infrastructure, also known as Hub, which will be in charge of aggregating the supply and making it available to the users.

During the first implementation phase running until 2025, EU GOVSATCOM will use the capacities and services provided by existing national SatCom systems and accredited service providers. Access to these existing infrastructures will be provided through one or several operational hubs interconnecting the users and the operations centres of the different SatCom suppliers in a smart and secure manner.

Should the first phase be insufficient to cover the evolving demand, a second phase might see additional bespoke space infrastructure or capabilities being developed through one or several public-private partnerships beyond 2025.[34]

[34] https://defence-industry-space.ec.europa.eu/govsatcom_en and https://www.euspa.europa.eu/european-space/govsatcom

## 2.4 IRIS²

Acknowledging the changing nature of the space ecosystem and to better address current and future challenges, European Union co-legislators reached a provisional agreement on a regulation establishing the European Union secure connectivity programme for the period 2023–2027[35] on 17 November 2022. The co-legislators then adopted the Regulation (EU) 2023/588 on 15 March 2023, establishing a Union Secure Connectivity Programme (IRIS²/IRSS) for the period from 2023 until 2027.[36]

The programme sets goals for the European Union to deploy a European Union satellite constellation called "IRIS²" (Infrastructure for Resilience, Interconnectivity and Security by Satellite), which will enable secure communication services by 2027.

IRIS² will be based on a multi-orbital constellation, combining the benefits offered by low earth (LEO), geostationary (GEO), and medium earth orbit (MEO) satellites. It will comprise a space, ground and user segment, designed, built and operated to address a diverse range of services. It is set to provide secure communication services to the European Union and its Member States as well as broadband connectivity for European citizens, private companies and governmental authorities. This new component of the EU Space Programme will put an end to dead zones in Europe as well as the whole of Africa using the constellation's North-South orbits through a resilient and ultra-secure space and ground-based system. It may include the development and launch of up to 170 LEO satellites between 2025 and 2027.

Relying on quantum cryptography through the European Quantum Communication Infrastructure (EuroQCI),[37] and enhanced cybersecurity through a secure-by-design approach for the infrastructure, the system will bring an unprecedented security to its users, divided in three security levels, among accredited commercial services, to robust governmental services and to enhanced (high degree of confidentiality) services.

The system will support a large variety of governmental applications, mainly in the domains of surveillance (e.g., border, maritime), crisis management (e.g., humanitarian aid, maritime emergency, civil protection) and connection and protection of key infrastructures (e.g., secure communications for European Union embassies, transport and space infrastructure). The system will also allow mass-market applications, including mobile and fixed broadband satellite access, satellite trunking for B2B services, satellite access for transportation, reinforced networks by satellite and satellite broadband and cloud-based services.

Complementing Copernicus, Galileo and EGNOS, the system will also open more opportunities for synergies between already existing components of the EU Space Programme. For instance, the synergies between Earth observation, SatNav and SatCom can be useful, among others, for addressing maritime emergencies and supporting disaster management. Synergies have been demonstrated to play an important role when addressing the SDGs, where EGNSS and Copernicus synergies have been highlighted already in the previous report of this series. Synergies with satellite communications are deemed even more important.[38]

EUSPA is already actively involved in building secure satellite communication infrastructure for Europe through the coordination of the first phase of GOVSATCOM on which IRIS² will be based.[39]

[35] https://ec.europa.eu/commission/presscorner/detail/en/STATEMENT_22_6999

[36] https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32023R0588&from=EN

[37] https://digital-strategy.ec.europa.eu/en/policies/european-quantum-communication-infrastructure-euroqci

[38] Baumgart, André and Vlachopoulou, Eirini Ioanna and Del Rio Vera, Jorge and Di Pippo, Simonetta. (2021). "Space for the Sustainable Development Goals: mapping the contributions of space-based projects and technologies to the achievement of the 2030 Agenda for Sustainable Development." Sustainable Earth. 4. 10.1186/s42055-021-00045-6.

[39] https://defence-industry-space.ec.europa.eu/eu-space-policy/eu-space-programme/iriss_en

# 2.5 SPACE TRAFFIC MANAGEMENT

## The European Union approach to space traffic management (STM)

To ensure a safe, secure and sustainable use of space, the EU Space Programme has defined the European Union approach for space traffic management (STM).

There are various challenges in today's space:[40]

- More than 1 million debris items larger than 1cm are orbiting the Earth, an ever-increasing number.
- Currently, more than 1.7 million satellites have been registered with ITU to be launched in the next decade. This rapid growth of satellite deployments could further exacerbate the issues of space debris and increase collision risks.
- Increasing congestion in space is threatening the viability and security of space infrastructure and operations.

Such an environment is likely to increase the risk to space activities, where collisions could create hundreds of new debris particles and could severely damage or destroy active satellites, resulting in significant disruptions to services.

European Union Space Traffic Management (STM)[41] encompasses the means and the rules to access, conduct activities in, and return from outer space safely, sustainably and securely. STM relates to the following elements:[42]

- Space situational awareness (SSA) activities, including space surveillance and tracking (SST)
- Orbital debris mitigation and remediation
- Management of space orbits and radio spectrum
- The entire life cycle of space operations, including launch phase, in-orbit operations of spacecraft, and end-of-life de-orbit operations
- Re-entry phase of spacecraft (both controlled and uncontrolled)

**EXHIBIT 7.** ILLUSTRATION OF SPACE DEBRIS

*Credit: SST Corporation (2022)*

## Space situational awareness

To mitigate the risk of a collision between European space assets – such as Galileo, EGNOS, Copernicus and GOVSATCOM satellites – and other spacecraft and debris, the European Union established a set of capabilities through the space situational awareness (SSA) component of the EU Space Programme.

SSA is an essential component of the EU Space Programme. By providing comprehensive knowledge and understanding about space hazards, SSA plays a key role in ensuring the safety and security of the European economies, societies and citizens who rely on space-based capabilities and applications such as communication, navigation and observation applications.

SSA covers three areas:

- Space surveillance and tracking (SST) of human-made objects
- Space weather monitoring and forecast of solar activity, and other phenomena
- Near-Earth objects (NEO) monitoring (only natural space objects)

[40] https://defence-industry-space.ec.europa.eu/system/files/2022-02/Factsheet%20-%20Space%20Traffic%20Management.pdf
[41] https://defence-industry-space.ec.europa.eu/eu-space-policy/eu-space-programme/eu-approach-space-traffic-management_en
[42] https://ec.europa.eu/commission/presscorner/detail/en/QANDA_22_923

EU SST is the operational pillar of the European Union approach to space traffic management. It is essential for protecting space-based infrastructure, facilities and services. EU SST uses a network of ground- and space-based sensors and other infrastructure to survey, track and protect artificial space objects orbiting Earth. It is composed of three service functions:

- Collision avoidance to mitigate the risk of collision between satellites and space objects. Over 135 public and private organizations from 23 European Union Member States currently benefit from this service
- Monitoring atmospheric re-entries of de-orbited objects, controlled or non-controlled
- Fragmentations in orbit to monitor the creation of space debris caused by fragmentations of satellites (generally after the end-of-life)

Following the European Commission's decision of 3 June 2022,[43] EUSPA has taken responsibility for the Programme's SST Front Desk operations service. Specifically, this service is being implemented by the EUSPA Galileo Security Monitoring Centre (GSMC) in Madrid.

The operational information is built by the SST Partnership made of European Union Member States, from the SSA assets and national operations centres that are owned by the Member States.

The Front Desk is the main interface to deliver SST information and services between the SST Partnership and the users' community, including activities related to user coordination, service performance, engagement and promotion.

In addition to its SST Front Desk responsibilities, EUSPA contributes to the system's security monitoring, particularly establishing the security requirements needed to shape the SST network in support of the European Commission and the EU SST Partnership.[44]

## Fact

Over **268 satellites** were monitored, **+/- 300,000 measurements per day** performed, and **435 collision avoidance events and high interest events** (more than 1 per day) recorded by EU SST in 2021

[43] www.euspa.europa.eu/newsroom/news/euspa-takes-space-surveillance-and-tracking-helpdesk-2023
[44] www.euspa.europa.eu/european-space/space-situational-awareness

# 3. HOW EU SPACE ADDRESSES THE IDENTIFIED SUSTAINABILITY CHALLENGES

## 3.1 INTRODUCTION AND METHODOLOGY

Space-based data and services have the potential to provide support for addressing all the sustainability challenges previously identified and thus contribute to the achievement of the objectives, guidelines and recommendations featured in the "Space2030" Agenda, including regional strategies, such as the European Union's Green Deal.

Earth observation is becoming more and more used as a key source of information, as it has undisputed advantages for data-driven decision-making. Data acquired through satellites are systematic and consistent, providing a source of reproduceable information from a very limited set of sensors under the scrutiny of the scientific community. Additionally, using Earth observation is cost-effective as opposed to time-intensive or sometimes even inaccurate manual reporting or reporting based on a plethora of sensors, each of which being a possible source of inaccuracies. Furthermore, satellites can assess phenomena remotely, even in regions where the physical access of people is difficult, for example, for geographical or political reasons.

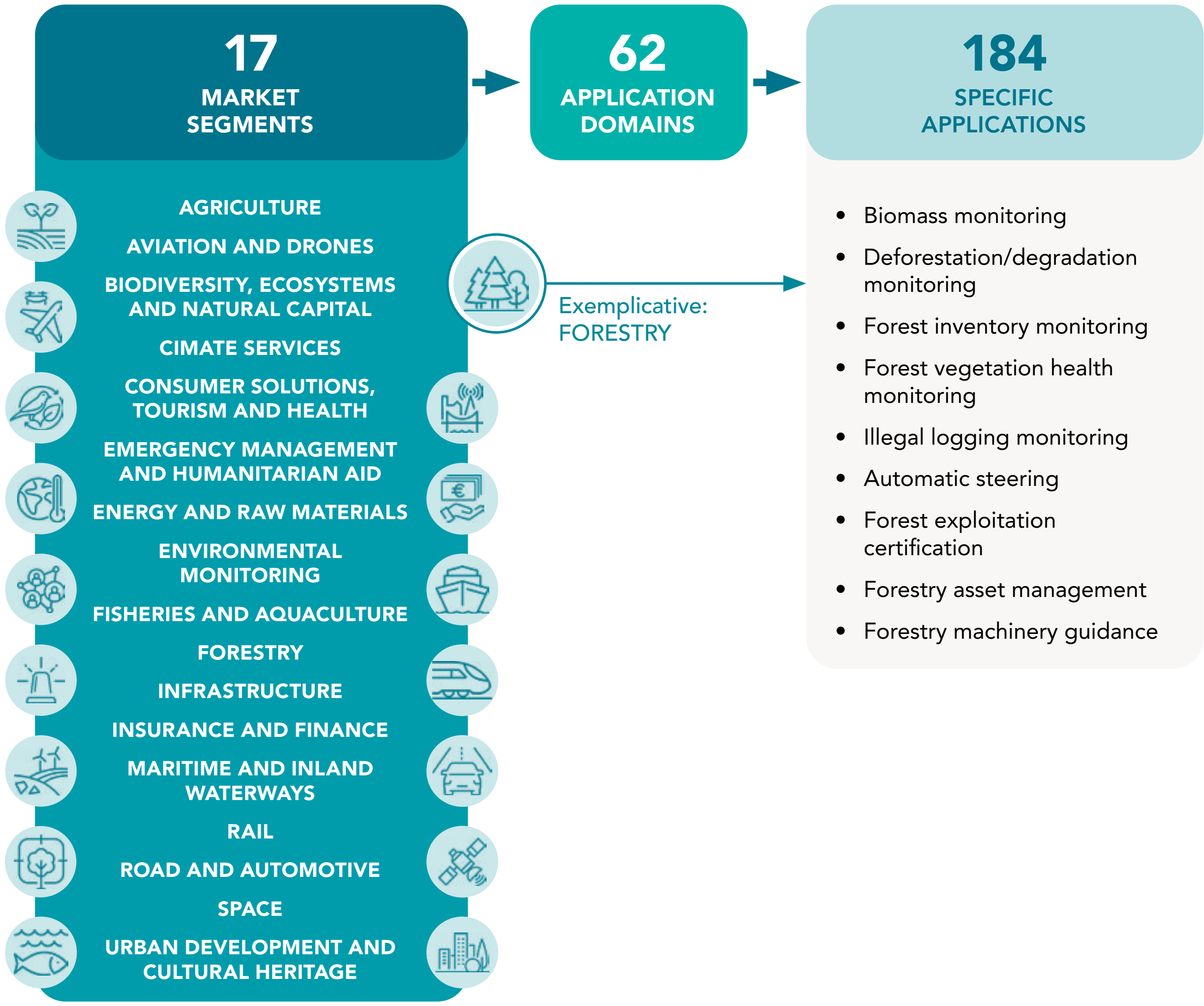
Satellite navigation data, on the other hand, has become, in the last decades, a somewhat hidden but fundamental component of many every day applications: since May 2000, when the accuracy-degrading selective availability on the GPS navigation signals was removed, the market for GNSS applications services and applications continues to bloom. From transportation to consumer solutions, from agriculture to timing and emergency management applications, there is basically no field of application in which the almost 7 billion GNSS receivers installed (almost as many GNSS receivers as persons) nowadays fail to provide relevant socioeconomic benefits directly to their users, to the related industry, and thus to society as a whole. Going forward, GNSS and Earth observation markets are set to become even more relevant, with the related global GNSS- and Earth observation-enabled revenues set to reach almost €500 billion by 2031 (they were around €200 billion in 2021) according to the latest EUSPA estimation.

Finally, SatCom can underpin, secure and complement a myriad of GNSS/Earth observation applications, addressing different challenges. For example, when disaster strikes and ground stations are destroyed or in a communications-denied environment, SatCom can be used to coordinate emergency response actors.

Within this context, EU Space provides a comprehensive contribution:

- *Copernicus*, with over 20 TB of geodata delivered every day, is the largest Earth observation data provider and the third biggest data provider in the world
- *EGNSS*
  - EGNOS, which provides improved GNSS (GPS and GPS + Galileo in the near future) positioning and integrity, addressing the safety of life navigation to aviation or location-based services for maritime and land-based users over Europe

**EXHIBIT 8.** THE EUSPA EO AND GNSS MARKET SEGMENTATION




- Galileo, which is the only global satellite navigation system intended primarily for civilian use with an offer of services designed for commercial use rather than for military purposes. Galileo offers unique global and free services, such as OS-NMA, which increases robustness to spoofing, HAS, which will provide high-accuracy service at a global scale or SAR, which helps to quickly locate people in distress while they are ensured their request for help has been received

- *GOVSATCOM*, will soon provide secure and cost-efficient communications capabilities to the European Union and its Member States, including national security actors and European Union agencies and institutions, supporting crisis management (natural or human-made disasters, humanitarian crises, and maritime emergencies), maritime or border surveillance or support key infrastructure operation and monitoring

- *Other EU Space components and services* in the future, such as STM, EWS or IRIS² will further complement and enhance the EU Space capabilities

This section aims to assess, in a descriptive manner and by means of use cases, how the use of EU Space (EGNSS and/or Copernicus and/or GOVSATCOM) contribute to overcoming the challenges of a world of 8 billion people. For each of the challenges identified in section 1.2. and following the logic depicted in the exhibit 9 on the next page, following items are provided:

- An introduction characterizes the challenge by providing information of current and future prospects regarding the particular challenge considering the current trends are maintained and what is the risk associated with a "no action scenario". Furthermore, a general introduction explaining what space can offer in general is provided, including a

**EXHIBIT 9.** METHODOLOGICAL APPROACH

**1**

**CHALLENGE CHARACTERIZATION**

Definition of the challenges, relation with global agendas, risks associated with a no risk scenario and a high level explanation of space contribution
[§"Introduction"]

**2**

**ASSESSMENT OF EU SPACE CONTRIBUTION**

**A. SERVICE LEVEL ANALYSIS**

Qualitative assessment of how relevant are EGNSS, Copernicus, GOVSATCOM and their individual services in tackling the challenges

**B. APPLICATION LEVEL ANALYSIS [§"EU space specific support"]**

Identification of the applications enabled by EGNSS and/or Copernicus able to support the challenges fulfillment

**3**

**EXEMPLIFICATION OF SPECIFIC EU SPACE CONTRIBUTION**

Provision of use cases able to demonstrate EGNSS and Copernicus relevance
[§"Use cases"]

non-exhaustive description of what the different technologies could do in view of the challenge.

- The second part emphasizes the "EU Space specific support" and assesses the EU Space contribution to each sustainable challenge, followed by a dedicated analysis performed at two levels:
  - EU Space component level, analysing EGNSS (Galileo and EGNOS), Copernicus and GOVSATCOM components, including the analysis of their services, by assessing the relevance and applicability of the individual services of three EU Space components (EGNSS, Copernicus and GOVSATCOM[45]) for the identified challenges; The relevance of the different EU Space components services is qualitatively assessed according to their relevance for the challenge using different criteria such as strategic value, growth potential, socioeconomic benefits, etc.
  - Application level,[46] by identifying EGNSS- and Copernicus-based applications and their relevance and contribution to ''8 billion world" challenges. This analysis leverage uses the *2022 EUSPA EO and GNSS Market Report*[47] as a taxonomy. The Market Report provides an exhaustive list of applications underpinned by EU Space which is used to understand where the contribution of the four EU Space components is stronger. Additionally, the EUSPA Market Report features 17 market segments, each addressing users as well as providers with different characteristics and needs, trying to minimize overlap. The market segments are a way of understanding the different economic dimensions underpinning the challenges and are by no means unique.
- Finally, the last section provides real-life examples of EGNSS, Copernicus and/or GOVSATCOM usage by means of relevant use cases, including the ones from European Union-supported research and design initiatives such as H2020 and Horizon Europe,[48] providing tangible examples of the use of EGNSS and Copernicus.

Exhibit 9 above provides a representation of the three steps methodology approach used to showcase the EU Space contribution with regard to the selected challenges.

[45] Based on preliminary mapping of potential GOVSATCOM applications; This analysis includes not only operational services but also services that will be rolled out soon, expanding the applicability of satellite communication services.

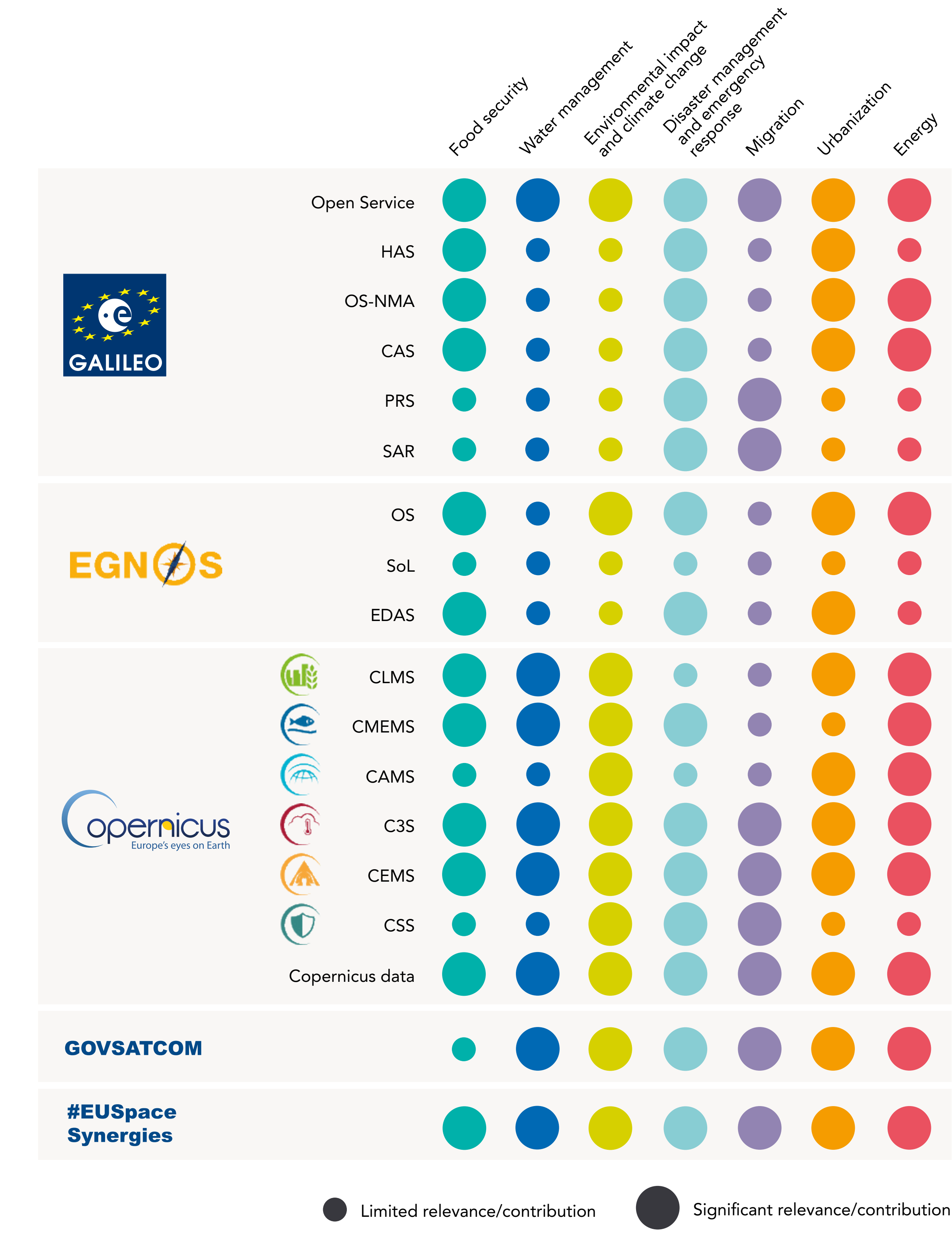
[46] While analysis at the space components/services level assesses also the GOVSATCOM contribution, the one at application level is only focusing on EGNSS and Copernicus as only these two components were included in *EUSPA EO and GNSS Market Report.*

[47] Within this classification, the GNSS and Earth observation market is segmented in groups called "market segment" underpinning homogeneous features (e.g., type of users, requirements, etc). Each market segment is further segmented in application domains (i.e., families of homogenous applications) and specific *applications.*

[48] More details are available at: https://research-and-innovation.ec.europa.eu/funding/funding-opportunities/funding-programmes-and-open-calls/horizon-europe_en

**EXHIBIT 10.** QUALITATIVE ASSESSMENT OF THE RELEVANCE OF EU SPACE COMPONENTS SERVICES FOR THE IDENTIFIED CHALLENGES (STEP 2.A)

*Note: For the sake of completeness and simplicity, access to Copernicus open data, given its importance for the development of downstream space-based applications and services, was added at the level of the Copernicus Services.*



The overview of the relevance of individual services of EU Space components (EGNSS, Copernicus, GOVSATCOM) for all the identified challenges is shown in exhibit 10, while in the following sections, the analysis of the relevance of EU Space components services is additionally underpinned by some examples of products and applicability.

As can be seen in exhibit 10, EGNSS (Galileo and EGNOS together) and Copernicus support all seven identified challenges, while GOVSATCOM contributes to six challenges. Indeed, each of the EU Space components can greatly contribute to the "8 billion world" challenges separately, however, the full potential is unleashed by its synergies and complementarity.

Zooming in on the services of the four EU Space Programme components (EGNSS, Copernicus, GOVSATCOM, step 2.A), the analysis revealed that four services (Galileo Open Service, Copernicus C3S and CEMS but also Copernicus data) contribute (significant relevance/contribution) to tackling all seven challenges and that 10 of the 17 services (>55 per cent) analysed support for at least four challenges. More importantly, the joint use of the four EU Space components services *(*synergies and complementarity*)* contributes to all the challenges**.**

Concerning applications and challenges, this report has considered the 184 applications featured in the *EUSPA Market Report* and 118 of those contribute to addressing the seven challenges, by using EGNSS and/or Copernicus products, eventually together with other GNSS and Earth observation services. Those applications touch on 16 of the 17 market segments considered. Therefore, addressing the "8 billion world" challenges requires almost the full spectrum of providers and will equally impact the full spectrum of users, as challenges are multifaced.

Specifically, it is worth noting how Earth observation- and Copernicus-based solutions are especially effective in addressing the challenges: indeed, 52 Earth observation/Copernicus applications out of the overall 66 Earth observation applications (i.e. around 79 per cent of the total) resulted as enablers for tackling "8 billion world" challenges, while only 50 per cent of the GNSS and EGNSS applications have been assessed as capable of doing so. Such an outcome is, however, largely anticipated and in line with what is presented in exhibit 10, given the direct relevance of Copernicus products and information for tackling environment-related challenges.

Exhibit 12 below further details how the different market segments are interlinked with the challenges. Each market segment is underpinned by a variable number of applications. To get a better idea of the interlinkages, all 17 EUSPA market segments are identified in the x-axis, while the y-axis gives information about the total number of applications per market segment (blue bar). In addition, a grey bar has been added to show the number of specific applications of each segment that could contribute towards solving the challenges. Moreover, market segments have been sorted, from left to right, according to the percentage of applications contributing towards solving the challenges, therefore, giving an indication of the degree of involvement of each market segment.
For example, the agriculture market segment provides a higher number of applications, and they can all be used to address the challenge in different ways, making this a key market segment. This information can help decision and policymakers in providing incentives for the development of this specific market segment to build resilience given its central role. Only applications with a direct impact in addressing the challenges have been considered.

**EXHIBIT 11.** A GENERAL OVERVIEW OF THE ASSESSMENT OF EU SPACE CONTRIBUTION TO SUSTAINABLE CHALLENGES PERFORMED AT THE MARKET SEGMENT AND APPLICATION LEVEL (STEP 2.B), LEVERAGING THE OUTCOME OF THE EUSPA EO AND GNSS MARKET REPORT 2022

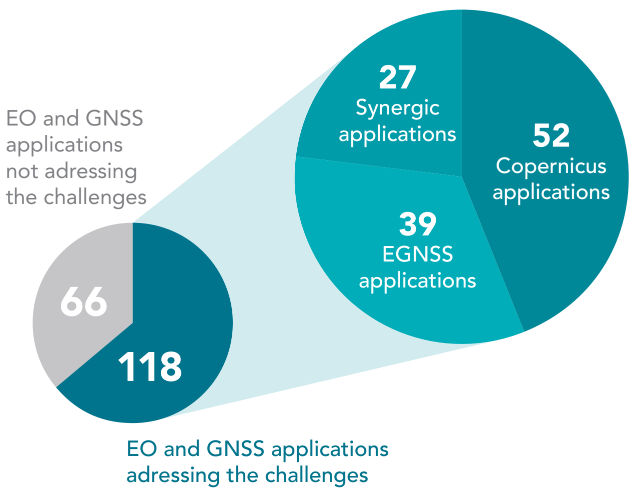
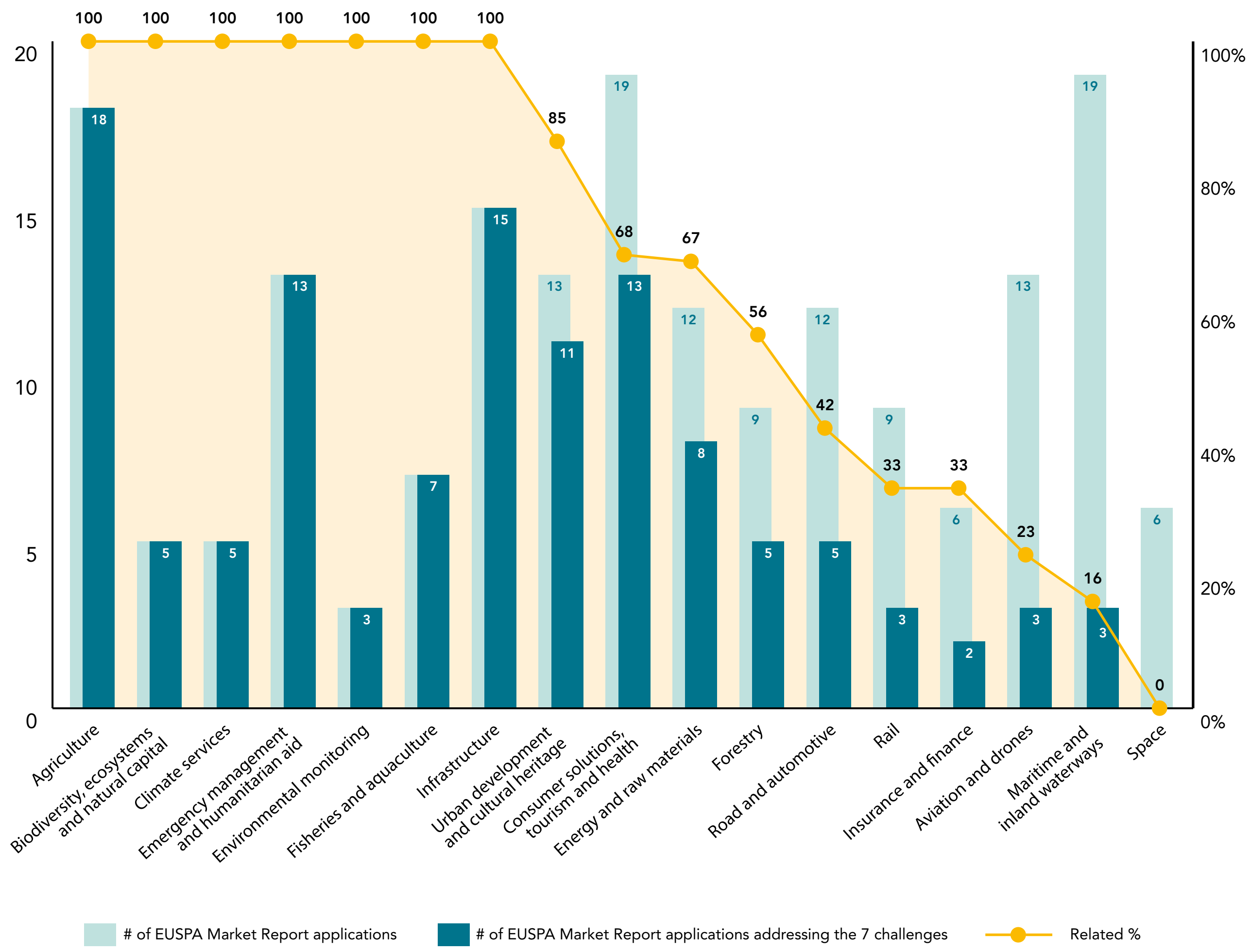


**EXHIBIT 12.** CONTRIBUTION OF EACH EUSPA MARKET REPORT MARKET SEGMENT TO SUPPORTING THE SEVEN SUSTAINABILITY CHALLENGES (STEP 2.B)




Indirect impacts have been discarded, which is why the market space segment, although central to this report from the market perspective, is the least important as it needs the application layer on top to be connected to the challenges. Therefore, it only has indirect links and none of their applications have a direct positive impact on the challenges.[49]

Finally, exhibit 13 provides an overall summary of EU Space contributions to the fulfilment of the seven sustainable challenges, including a snapshot with examples of applications. The analysis at the application level will be further elaborated in the following sections. For each challenge two points are described:

- The relevance at the user/application level of EGNSS, Copernicus and their synergetic usage
- An exemplificative list of the main related applications

The following sections of the present report provide additional details on how EU Space (EGNSS, Copernicus and GOVSATCOM) contributes to the fulfilment of each of the seven sustainable challenges.

[49] It should be noted, however, that this representation is highly dependent on the granularity level of the market segmentation and its applications adopted, and might penalize those market segments that include a relatively higher number of specific applications, such as maritime and aviation.

**EXHIBIT 13.** OVERVIEW OF EU SPACE CONTRIBUTION TO THE FULFILMENT OF THE SEVEN SUSTAINABLE CHALLENGES, INCLUDING A SNAPSHOT WITH EXAMPLES OF APPLICATIONS

| SUSTAINABILITY CHALLENGE | Galileo | EGNOS | Copernicus | GOVSATCOM | Synergies | EXAMPLE OF MAIN APPLICATIONS USING EUSPA MARKET REPORT TAXONOMY |
|---|---|---|---|---|---|---|
| Migration | ● | • | ● | ● | ● | Disaster management including<br>– preparedness,<br>– rapid mapping and<br>– post-event analysis<br>Monitoring and management of refugee camps<br>Telematics for humanitarian aid<br>Earth observation human displacement monitoring<br>Dark vessel monitoring<br>Used as a common communication channel for various actors (e.g., land and sea border surveillance) |
| Environmental impact and climate change | ● | ● | ● | ● | ● | Earth observation-based climate modelling<br>GNSS-based climate modelling<br>Ecosystems monitoring (terrestrial, coastal, snow and ice)<br>Environmental impact monitoring<br>Climate change mitigation and adaptation<br>Environmental resources management<br>Air quality and renewables<br>Biomass monitoring<br>Maritime surveillance and ship detection<br>Support to multiple crisis management zones |
| Energy | ● | ● | ● | ● | ● | Support for renewable energy: site selection, planning and monitoring<br>Power plant design optimization, assessment potential and forecast,<br>Energy network conditions monitoring<br>Phasor measurement units (PMU) timing in systems providing frequent measurements relevant to the network status<br>Remote control of renewable energy plants<br>Energy network operation and (conditions) monitoring for grid operators or renewable energy |
| Disaster management and emergency response | ● | ● | ● | ● | ● | GNSS-enabled ocean monitoring buoys<br>Beacons for SAR operations in aviation, land and sea<br>Support for civil protection, emergency management and humanitarian aid:<br>– Disaster [e.g., landslides, floods, wildfires] preparedness,<br>– Disaster early warning<br>– Disaster rapid mapping<br>Post-event analysis<br>Coordination of emergency response actors in communications-denied environment |

*continued*

Legend:

• Low relevance/contribution

● Significant relevance/contribution

EO application

GNSS application

GOVSATCOM application

Synergetic application (combined use of EO and GNSS)

**EXHIBIT 13.** OVERVIEW OF EU SPACE CONTRIBUTION TO THE FULFILMENT OF THE SEVEN SUSTAINABLE CHALLENGES, INCLUDING A SNAPSHOT WITH EXAMPLES OF APPLICATIONS *(continued)*

| SUSTAINABILITY CHALLENGE | Galileo | EGNOS | Copernicus | GOVSATCOM | Synergies | EXAMPLE OF MAIN APPLICATIONS USING EUSPA MARKET REPORT TAXONOMY |
|---|---|---|---|---|---|---|
| Urbanization | ● | ● | ● | ● | ● | ◐ Urban modelling, 3D modelling, digital twins<br>● Urban planning (EO)<br>◐ Monitoring urban environment such as<br>  ● air, heat islands and<br>  ◐ greening<br>○ Smart cities: smart management for streetlights and waste management (GNSS)<br>◐ Surveying and mapping<br>○ Navigation for smartphone users (GNSS)<br>● Settlements and population monitoring (EO)<br>◌ Maintaining public order and ensuring public safety (GOVSATCOM) |
| Food security | ● | ● | ● | • | ● | ◐ Agriculture monitoring such as<br>  ◐ soil condition monitoring<br>  ◐ crop yield forecasting and<br>  ● carbon capture (EO)<br>● Climate services (EO)<br>○ Smart agriculture operation management including asset monitoring and machinery guidance (GNSS)<br>◐ Smart farm management systems<br>◐ Precision irrigation |
| Water management | ● | • | ● | ● | • | ● Water ecosystems monitoring (including suspended particulate matter and algal blooms) (EO)<br>◐ Early warning and rapid mapping for urban flooding<br>● Marine pollution monitoring (EO)<br>◐ Aquaculture operations optimization<br>◌ Early warning systems (e.g., sensors, monitoring) (GOVSATCOM)<br>◌ Pollution detection (GOVSATCOM) |

Legend:

• Low relevance/contribution

● Significant relevance/contribution

● EO application

○ GNSS application

◌ GOVSATCOM application

◐ Synergetic application (combined use of EO and GNSS)

# 3.2 THE FOOD SECURITY CHALLENGE AND THE ROLE OF EU SPACE

## 3.2.1 Introduction

After remaining unchanged since 2015, the prevalence of malnutrition jumped from 8.0 to 9.3 per cent from 2019 to 2020 and rose at a slower pace in 2021 to 9.8 per cent. Between 702 and 828 million people were affected by hunger in 2021. The number has grown by about 150 million since the outbreak of the COVID-19 pandemic – 103 million more people between 2019 and 2020 and 46 million more in 2021. Projections are that nearly 670 million people will still be facing hunger in 2030 – 8 per cent of the world population, which is the same as in 2015 when the 2030 Agenda was launched. The numbers show persistent regional disparities, with Africa bearing the heaviest burden. One in five people in Africa (20.2 per cent of the population) was facing hunger in 2021, compared to 9.1 per cent in Asia, 8.6 per cent in Latin America and the Caribbean, 5.8 per cent in Oceania, and less than 2.5 per cent in Northern America and Europe. After increasing from 2019 to 2020 in most of Africa, Asia and Latin America and the Caribbean, the prevalence of undernourishment continued to rise in 2021 in most subregions, but more slowly.

As the world population continues to grow, much more effort and innovation will be urgently needed to sustainably increase agricultural production, improve the global supply chain, decrease food losses and waste, and ensure that all who are suffering from hunger and malnutrition have access to nutritious food. Land, healthy soils, water and plant genetic resources are key inputs into food production, and their growing scarcity in many parts of the world makes it imperative to use and manage them sustainably. Boosting yields on existing agricultural lands, including restoration of degraded lands, through sustainable agricultural practices would also relieve pressure to clear forests for agricultural production. Wise management of scarce water through improved irrigation and storage technologies, combined with the development of new drought-resistant crop varieties, can contribute to sustaining drylands productivity.

In low-income countries but also in some lower-middle-income countries agriculture is key for the economy, jobs and livelihoods. Support for agricultural production largely concentrates on staple foods, dairy and other animal source protein-rich foods, especially in high- and upper-middle-income countries. Rice, sugar and meats of various types are the foods most incentivized worldwide, while fruits and vegetables are less supported overall, or even penalized in some low-income countries. There are many elements of traditional farming knowledge that, enriched by the latest scientific knowledge, can support productive food systems through sound and sustainable soil, land, water, nutrient and pest management, and the more extensive use of organic fertilizers.

In the fight to reduce food insecurity, space technologies can be an extremely helpful ally.

*"Ending hunger is within our reach. There is enough food in our world now for everyone, if we act together."*

António Guterres,
Secretary-General of the United Nations

**Fact**

In 2021, the prices of fertilizers rose **80%**.
In 2022, from January until April, fertilizer prices rose nearly **30%**.

### 3.2.2 Food security and space

Monitoring crop growth and health and producing early forecasts of planted crops are of immense importance for planners and policymakers at the international and national level in areas related to food security. Reliable, timely and credible information enables planners and decision makers to handle deficits or surpluses of food crops in a given year in an optimal manner. Up-to-date and reliable national agricultural statistics can be obtained through the establishment of an adequate, periodic national agricultural survey based on probability-sampling methods, image classification and adherence to well-defined and reproducible techniques.

Spectral analysis of high-resolution satellite images enables the real-time monitoring of crop vegetation indices for different fields and crops as well as the identification and tracking of positive and negative dynamics of crop development. Such dynamics, revealed by differences in vegetation indices, indicate imbalances in development within the same culture or field. In addition to crop health and change detection, space-based platforms provide inputs for environmental analysis, irrigated landscape mapping, yield determination and soil analysis. All these techniques, when integrated in decision-making models, may inform of the necessity of specific agricultural interventions in particular field zones.

The use of a number of ancillary data, including the integral use of remotely sensed data, is a key component in effective monitoring of agricultural production. Earth observation data is now used regularly to monitor the crop season, and satellite imagery coverage integrated with field surveys allows the quantification of areas planted and to be harvested during crop seasons.

As mentioned earlier, the price of fertilizers is increasing dramatically. The use of GNSS for planting crops can also determine where to apply fertilizers, thereby reducing their consumption as well as that of fuel and pesticides. In fact, it is estimated that using Earth observation and GNSS together can contribute to increasing yields by more than 10 per cent and reducing consumption of inputs such as fuel, fertilizer and pesticides by up to 20 per cent.

### 3.2.3 EU Space specific support

Space technologies, including EGNSS and Copernicus, can help tackle the food security challenge in multiple ways. In a short-term perspective, the use of satellite data and technologies in agriculture and fisheries has the potential to boost the related outputs while reducing the environmental footprint. Nevertheless, and to some extent even more importantly, the role of satellite data such those from Earth observation also supports initiatives aimed at fighting climate change and improving soil health, thus ensuring food security in the long run.

Keeping in mind this twofold aspect, the list of the GNSS/Galileo- and Earth observation/Copernicus-related applications capable of supporting food security are several and relate to four market domains, following the taxonomy featured in the *EUSPA EO and GNSS Market Report*: agriculture, climate services, biodiversity, ecosystems and natural capital, and fisheries and aquaculture.

In the agricultural domain, EGNSS and Copernicus are key enablers for operations management, increasing the productivity of agricultural cultivation through informed management processes, improving the efficiency of the utilization of existing assets, as well as of natural and anthropogenic resources (including land, seeds, fertilizers, plant protection agents and water), enabling applications such as farm machinery guidance, precision irrigation and variable rate application. Decisions are supported by software services based on data generated by space systems (GNSS and Earth observation), as well as by terrestrial technologies.

Satellite-based Earth observation is the most accessible way to acquire information on site-specific crop properties over broad areas, generating intelligence around natural resource monitoring. In combination with agro-ecological crop growth and management models, Earth observation data can increase the efficiency of farming operations. The Copernicus Land Monitoring System (CLMS) can also provide useful inputs, as it delivers important information on the vegetation, the water cycle and the energy budget (e.g., crop yield forecasting and soil condition monitoring).

EGNSS is already being used for precision farming, helping optimize the space between planted seeds and the use of fertilizers to boost productivity. The addition of Earth observation is a perfect complement to further enhance agriculture productivity: relevant data obtained via remote sensing are of major help to farmers. The combination of EGNSS and Earth observation data can help farmers increase yields by more than 10 per cent, and reduce input costs such as fertilizer, fuel and pesticides by 10 to 20 per cent.[50]

In addition, information regarding soil moisture can support best practices regarding the use of water resources, especially in areas/periods of the year when these are scarce. Similarly, images taken by satellites and complemented by EGNSS can be used to evaluate and provide early warnings concerning drought and crop yields, giving governments a tool to tackle famine in a timely fashion. Finally, Copernicus data, combined with data from meteorological satellites, also supports the elaboration of weather services for agriculture.

The use of Galileo and Copernicus is also proving to be useful for livestock management: Galileo-enabled collars – used to monitor livestock – support the activities of the breeders while Earth observation/Copernicus data help them identify the most suitable grazing. Similarly, natural scientists and researchers make use of GNSS and Earth observation to ensure the sustainable reproduction of domesticated animals, as well as wild species.

Also, in the fisheries and aquaculture domain, the use of EU Space data can be differentiated into short and long-term improvements. From a short-term viewpoint, EU Space data contribute strongly to output improvement:

- Within fisheries, Earth observation/Copernicus is used to support the assessment of fish stocks and to potentially optimize fishing efforts (i.e., catch optimization). Optical and radar data is also used to trace and "see" fishing vessels and assess the legality of their actions, thus also helping to prevent and combat illegal, unreported and unregulated (IUU) fishing, also leveraging the maritime surveillance component of the Copernicus Security Service. GNSS also contributes to IUU detection with its traditional use in the field, namely tracking the location of vessels through the Automatic Identification System (AIS) and Vessel Monitoring System (VMS). An additional relevant application of GNSS data for fisheries relates to improving safety at sea for fishing vessels and their crews by using GNSS-enabled navigation devices as well as AIS for collision avoidance.
- In the field of aquaculture, Earth observation-based applications support site selection for future fish farms (with input of environmental conditions, forecasts and predictions, often in the form of maritime spatial planning products) and aquaculture operations by determining water quality in lakes and reservoirs or in coastal areas. Both Earth observation and GNSS applications contribute to the optimization and planning of aquaculture operations by providing a host of information to aquafarmers.

Finally, although not specifically listed among the EU Space applications capable of helping to tackle the food security challenge, it is worth noting that EGNSS constitutes a vital building block of the food supply chain when it comes to the logistic value chain, as a relevant enabler of transportation activities by air, land or sea. For example, GNSS is helpful in tracking the origin of agriculture and fisheries products.

While the environmental and climate change challenge is specifically described in a separate chapter, at a second and indirect level, Copernicus and EGNSS have the potential to ensure food security in a long-term perspective by guaranteeing the sustainability of the related natural resources:

- Within biodiversity, ecosystems and natural capital
  - Copernicus helps to further our understanding of the health of terrestrial, marine and coastal ecosystems and the existing and potential stressors therein, thus paving the way towards more concrete and effective measures against ecosystem and biodiversity loss. While most biodiversity assessments are still performed on-site, the use of Earth observation in the field is growing in view of its scalability.
  - Galileo-enabled wearables are used to geolocate animals for the purposes of monitoring migrations, habitats and behaviours. These are becoming more accurate and additional biodiversity applications are emerging (e.g., botanical mapping).

[50] European Commission, D 3.1. Current and future agricultural practices and technologies which affect fuel efficiency, European Parliament, Precision Agriculture: an opportunity for EU farmers – potential support with the CAP 2014- 2020 study, Policy Department B, Directorate-General for Internal Policies (Brussels, 2014): http://www.europarl.europa.eu/RegData/etudes/note/join/2014/529049/IPOL-AGRI_NT%282014%29529049_EN.pdf

- Climate services
  - The role of Earth observation in climate services is well-established and contributes with invaluable data for climate modelling. The integration of Copernicus with innovative technologies and the number of policies requiring close monitoring is set to further boost the market of Earth observation applications related to climate resilience and adaptation.
  - Galileo has limited but important application in the climate services domain. The technology supports a range of geodetic applications that measure properties of the earth (magnetic field, atmosphere) with direct impact on the Earth's climate. GNSS is expected to play an increasing role in the growing market of climate modelling.
- Environmental monitoring
  - Various environmental parameters obtained by Earth observation data contribute to an increasing number of international, regional and local policies related to, or impacting, the environment. Additionally, private companies are increasingly using Earth observation data for including sustainability elements into their ESG reports (e.g., Mondelez is using services from the Satelligence SME to ensure that the palm oil they use comes from sustainable sources[51])

Most of the space-based solutions presented above rely on some infrastructure to be in place and are therefore mainly valid for developed countries. Additional efforts in capacity-building are indeed needed to reduce the so-called space divide to eliminate the gap between countries with significant development in their use of space, and those without. For example, capacity-building initiatives have been kicked off to develop the needed tools for visualization and analysis of data, with special emphasis on the specificities of the regions (and therefore best achieved by involving local specialists).

Within this context, GEOGLAM – the Group on Earth Observations Global Agricultural Monitoring Initiative,[52] whose goal is to improve food security by producing and disseminating information on agricultural conditions and outlooks of production at national, regional and global scales – produce several ground validated crop monitoring products based on Copernicus Sentinel-1 and Sentinel-2:[53]

- In-season and end-of-season crop type maps and crop masks
- In-season and end-of-season crop area statistics

In the context of such an initiative and leveraging Copernicus data, several crop monitoring platforms have been created around the world and especially in developing countries (e.g., Cropwatch in China).

The relevance of the four EU Space components services (Copernicus, Galileo, EGNOS and GOVSATCOM) for the food security challenge is assessed in the following exhibit, including examples of products and applicability for services with high relevance.

[51] Source: https://satelligence.com/mondelez
[52] Source: https://earthobservations.org/geoglam.php
[53] Source: https://land.copernicus.eu/global/about-copernicus4geoglam

**EXHIBIT 14.** EXAMPLES OF RELEVANCE OF EU SPACE COMPONENTS SERVICES FOR FOOD SECURITY

| Component | Service | Relevance | Examples |
|---|---|---|---|
| GALILEO | Open Service | ⬤ | • Open Service, used in GNSS multi-constellation and multi-frequency positioning, increases the performance of augmentation techniques such as RTK or PPP-RTK, used for a myriad of applications such as machine guidance, variable rate applications, UAVs, etc. It can also be used for livestock tracking<br>• OS-NMA and CAS increase robustness to spoofing to various applications, including autonomous machinery<br>• HAS offers global and free-of-charge 20cm high-accuracy positioning service for machine guidance applications, field delineation, UAVs, geo-tagging photos, etc. |
| | HAS | ⬤ | |
| | OS-NMA | ⬤ | |
| | CAS | ⬤ | |
| | PRS | ● | |
| | SAR | ● | |
| EGNOS | OS | ⬤ | • OS and EDAS offer real-time and free-of-charge improved GPS (GPS + Galileo in future) positioning service over Europe. An affordable and entry-level solution for precision agriculture |
| | SoL | ● | |
| | EDAS | ⬤ | |
| Copernicus (Europe's eyes on Earth) | CLMS | ⬤ | • Copernicus Sentinel-1 and -2 data have brought about a revolution in the agricultural sector, providing world-class data in a free and open manner for multiple agricultural applications at an adequate resolution and appropriate revisit time. Innovative companies are making use of Sentinel data to provide farm management support, soil moisture measurements and agricultural supply chain insights<br>• Additional products from CLMS (e.g., land use/land cover and various vegetation indices), as well as C3S products (e.g., temperature and precipitation) also contribute to agricultural activities or CMEMS to identify the most favourable fishing zones or to monitor the existing ones<br>• The European and Global Drought Observatories of CEMS also contributes to early warning and monitoring of drought episodes |
| | CMEMS | ⬤ | |
| | CAMS | ● | |
| | C3S | ⬤ | |
| | CEMS | ⬤ | |
| | CSS | ● | |
| | Copernicus data | ⬤ | |
| GOVSATCOM | | ● | • Institutional and diplomatic support<br>• Civil-military interaction |
| #EUSpace Synergies | | ⬤ | • Very high level of synergies, for example, Earth observation data can provide information on crop health, soil moisture and other important indicators, while EGNSS data can provide high-precision positioning data. Together, this enables farmers to target irrigation, fertilization and other operations to where they are most needed, powering precision agriculture solutions |

● Limited relevance/contribution ⬤ Significant relevance/contribution

**EXHIBIT 15.** LIST OF EGNSS AND COPERNICUS APPLICATIONS ADDRESSING THE FOOD SECURITY CHALLENGE

| MARKET SEGMENT | APPLICATION DOMAIN | EXAMPLES OF SPECIFIC APPLICATIONS |
|---|---|---|
| AGRICULTURE | Environmental monitoring | Carbon capture and content assessment<br>Environmental impact monitoring |
| | Natural resources monitoring | Biomass monitoring<br>Crop yield forecasting<br>Soil condition monitoring<br>Vegetation monitoring |
| | Operations management | Asset monitoring<br>Automatic steering<br>CAP monitoring<br>Farm machinery guidance<br>Farm management systems<br>Field definition<br>Livestock wearables<br>Pastureland management<br>Precision irrigation<br>Variable rate application |
| | Weather services for agriculture | Climate services for agriculture |
| BIODIVERSITY, ECOSYSTEMS AND NATURAL CAPITAL | Animal tracking for biodiversity purposes | Animal tracking for biodiversity purposes |
| | Coastal ecosystems monitoring | Coastal ecosystems monitoring |
| | Terrestrial ecosystems monitoring | Terrestrial ecosystems monitoring |
| CLIMATE SERVICES | Climate change mitigation and adaptation | Climate change mitigation and adaptation |
| | Climate modelling | Earth observation-based modelling<br>GNSS-based climate modelling |
| | Climate monitoring and forecasting | Climate forecasting<br>Climate monitoring |
| ENVIRONMENTAL MONITORING | Environmental auditing | Environmental auditing |
| | Environmental resources management | Environmental resources management |
| | Impact studies and environmental, social, and corporate governance (ESG) | Impact studies and environmental, social, and corporate governance (ESG) |
| FISHERIES AND AQUACULTURE | Aquaculture | Aquaculture operations optimization<br>Aquaculture site selection |
| | Fisheries | Catch optimization<br>Illegal, unreported and unregulated (IUU) control<br>Fishing aggregating devices<br>Fish stock detection<br>Fishing vessels navigation |
| INSURANCE AND FINANCE | Insurance for natural disasters | Index production |

Copernicus application   EGNSS application   Synergetic application (combined use of Copernicus and EGNSS)

### 3.2.4 Use cases

#### *Meteorological assimilation from Galileo and drones for agriculture*

The Horizon Europe Meteorological assimilation from Galileo and drones for agriculture (MAGDA) project aims at developing a toolchain for atmosphere monitoring, weather forecasting and severe weather/irrigation/crop monitoring advisory, with GNSS (including Galileo) at its core, to provide useful information to agricultural operators.

MAGDA exploits the untapped potential of assimilating GNSS-derived, drone-derived, Copernicus Earth observation-derived data sets, in situ weather sensors into very high-resolution, short-range (1-2 days ahead) and very short-range (less than 1 day ahead) numerical weather forecasts to provide improved prediction of severe weather events (rainfall, snow, hail, wind, heat and cold waves), as well as of weather-driven agriculture pests and diseases for the benefit of agriculture operations, also in light of the ongoing effects of climate change.

These targets are achieved by setting up a database of variables of interest and an assimilation system to feed a numerical weather prediction model, which in turn drives a hydrological model for irrigation performance and water accounting to assess water use and related productivity. In addition to already existing observational networks, new dedicated networks of sensors, including GNSS and drones, to monitor atmospheric variables at high spatial resolution are deployed in the vicinity of large farms and cultivated areas, to provide data with high spatial and temporal resolutions for the assimilation into the weather model.

The delivery of the augmented forecasts and irrigation advisories to farmers is enabled by a dedicated dashboard and APIs to already existing farm management systems. The tools developed within MAGDA represent the technical and methodological components based on which services to support agricultural operations will be defined.[54]

#### *Growing innovation to support organic farming by leveraging space-based and cutting-edge technologies*

The aim of the H2020 PestNu project is to conduct in-field testing and demonstration of digital and space-based technologies (DST) with agroecological and organic practices (AOP) in a systemic approach to reduce the use of pesticides and fertilizers, and loss of nutrients.

The project brings novel DST, including:

- AI robotic traps for real-time pest monitoring; autonomous mobile robots for pesticide monitoring and 3D spot spraying
- Earth observation missions with robust Agroradar AI algorithms to map soil/plant nutrients and pest plant inputs using Copernicus data/services
- In situ and real-time nutrient analysers

All the DST are interconnected to a user-centric cloud-based farm management system, which features a robust decision support system integrated with a blockchain-based system for DST data evidence, integrity and AI models verification and with a cybersecurity platform to prevent cyberattacks and IoT vulnerabilities.
The AOP include the following: on-site production of biofertilizers from agricultural wastewaters through a robust automated drainage recycling system via an innovative enzymatic hydrolysis procedure; a novel foliar biopesticide formulated by circular bioeconomy operations, targeting fungal diseases with biostimulant effect; and advanced nutritional programmes for organic farming.[55]

#### *FaST – a tool to increase the sustainable use of nutrients*

The vision of FaST (the Farm Sustainability Tool for Nutrients) is to become a world-leading platform for the generation and reuse of solutions for sustainable and competitive agriculture based on space data (Copernicus and Galileo) and other public and private data sets. The modular platform supports European Union agriculture and the Common Agricultural Policy by also enabling the use of solutions based on machine learning applied to image recognition, as well as the use and reuse of IoT data, various public sector data and user-generated data.

[54] www.euspa.europa.eu/horizon-europe-projects

[55] www.euspa.europa.eu/horizon-europe-projects

FaST helps lay the foundations of a comprehensive digital ecosystem for sustainable farm and land management in Europe. It will support farmers in their administrative decision-making processes, for farm profitability and environmental sustainability. At the same time, it provides a reliable on-farm landing spot for digital solution developers (including satellite-based solutions) and service providers. It will reduce administrative burdens for farmers and paying agencies, and streamline communication between farmers and public authorities.

The project is supported by the European Commission's DG Agriculture and Rural Development, by the EU Space Programme (DG DEFIS) and by the EU ISA2 Programme (DG DIGIT).[56]

## 3.3 THE WATER MANAGEMENT CHALLENGE AND THE ROLE OF EU SPACE DATA

*"Water can be a source of conflict but also of cooperation. It is essential that we work together to provide better stewardship of all water sources, including the world's supply of groundwater."*

António Guterres,
Secretary-General of the United Nations

### 3.3.1 Introduction

Water is at the core of sustainable development and is critical for socioeconomic development, energy and food production, healthy ecosystems and for human survival itself. Water is also at the heart of adaptation to climate change, serving as the crucial link between society and the environment.

Water is also a rights issue. As the global population grows, there is an increasing need to balance all the competing commercial demands on water resources, so that communities have enough for their needs. Women and girls must have access to clean, private sanitation facilities to manage menstruation and maternity in dignity and safety.

At the human level, water cannot be seen in isolation from sanitation. Together, they are vital for reducing the global burden of disease and improving the health, education and economic productivity of populations.

Contaminated water and a lack of basic sanitation are undermining efforts to end extreme poverty and disease in the world's poorest countries.

In 2017, 2 billion people worldwide did not have access to basic sanitation facilities such as toilets or latrines. Some 673 million people still practised open defecation. According to the WHO/UNICEF Joint Monitoring Programme for Water Supply and Sanitation, at least 1.2 billion people worldwide are estimated to drink water that is not protected against contamination from faeces. Even more drinking water is delivered through a system without adequate protection against sanitary hazards.[57]

The links between lack of water and sanitation access and the development goals are clear, and the solutions to the problem are known and cost-effective. A 2012 WHO study shows that every US$1 invested in improved sanitation translates into an average global economic return of US$5.5. Those benefits are experienced specifically by poor children and in the disadvantaged communities that need them most.

[56] https://fastplatform.eu/
[57] Global Issues: Water | United Nations

### 3.3.2 Space and water management

Satellite-based Earth observation relies on the use of remote sensing techniques for collecting information on the physical, chemical and biological systems of planet Earth to monitor land and marine habitats as well as freshwater bodies such as rivers, lakes and reservoirs, as well as groundwater and atmosphere. Earth observation data has become an invaluable resource for supporting decision makers in all sectors of society, including responding to the SDGs and the Convention on Wetlands.

Technological advances and significant reductions in the costs of operation and maintenance of satellites together with the Copernicus free and open data policy has allowed the generation of a large amount of geospatial data that are freely available to a wide range of users – such as researchers, service providers and small businesses, NGOs, and society – to benefit from Earth observation data.

In 2016, the United Nations Office for Outer Space Affairs (UNOOSA) and the Prince Sultan Bin Abdulaziz International Prize for Water (PSIPW) signed an agreement to collaborate on their common goal of promoting the use of space-based technology for increased access to water.

The Space4Water Project was launched in 2018 with the aim of promoting the use of space-based technology and data for increased access to water. The project comprises three pillars:

- Foster scientific exchange via conferences, to inform decision-making and have an impact on policy
- Reach and inform users worldwide, via the Space4Water Portal, to showcase excellent work and allow users to find partners based on their expertise or regional focus
- Community building via interactive Space4Water Portal stakeholder meetings with the aim of creating an experts committee for quality assurance and scientific guidance.

The Space4Water can be accessed at space4water.org.

### 3.3.3 EU Space specific support

EU Space data, especially those supplied by Copernicus, provide several opportunities to monitor water availability and quality, and surface water ecosystems. It supports national governments, water authorities and river basin commissions with vital data on basin hydrology and infrastructural development projects (e.g., planning dam construction, irrigation schemes and enforcing laws and practices to protect freshwater ecosystem integrity) and it is also crucial knowledge for irrigation and livestock watering and monitoring water-related ecosystems. To this end, an increasing number of private companies are providing this type of intelligence to public authorities and national governments.

With regard to water availability, Copernicus Sentinels contribute to a better understanding of the Earth's water cycle thanks to their ability to obtain data on issues such as soil moisture content and evapotranspiration and water quality (e.g., algal blooms and pollution).

In addition, the Copernicus Global Land Service provides, in a timely manner, biophysical variables describing how water is partitioned on the ground and in the soil. For example, the soil water index quantifies the water content in the first few centimetres of soil. In addition, global maps of water bodies delineate the zones permanently covered by water, such as lakes, those with a seasonal frequency, such as backwater ponds, and those that occur occasionally because of flooding. These biophysical products are useful for hydrological modelling as well as short- and medium-term meteorological forecasting since they control the water and heat exchanges between land and the atmosphere.

In terms of monitoring water ecosystems, Sentinel-1 and Sentinel-2 and -3 provide data enabling the monitoring of coastal and inland vegetated wetlands (e.g., floodplains, lakes, peatlands and deltas). The existence of some kind of vegetation, such as mangroves, is extremely important to protect against flooding and serve as buffers against saltwater intrusion and erosion. Inland wetlands such as the Okavango can reduce the risk of drought.

The capability of Copernicus to monitor water ecosystems is also confirmed by the fact that – among other Earth observation data – it is currently employed by the United Nations Environment Programme (UNEP), the custodian agency responsible for supporting countries with monitoring and reporting official SDG data of 26 SDG indicators.

Indeed, UNEP updated in March 2020 its *"Measuring change in the extent of water-related ecosystems over time (SDG 6, indicator 6.6.1)"* to specifically include more detailed information about how to leverage satellite-based Earth observation data to compute the related subindicators.[58] For example, the European Union's Copernicus space programme has been deemed useful in estimating lake water parameters such as turbidity and trophic state index, which are respectively key indicators of underwater light availability and eutrophication, two fundamental parameters to monitor lake ecosystems.

Furthermore, the Copernicus Sentinel-2 and -3 satellites provide data that can be used to measure several water quality parameters, namely scums containing chlorophyll-a and phycocyanin cyanobacteria, total suspended matter and many other parameters. Notably, those parameters provide indications on the proliferation of harmful algae blooms that have negative repercussions on tourism and human health and are monitored in the European Union within the Water Framework Directive. They also provide analytical support to assess the diffusion of waterborne diseases such as Escherichia coli. Additionally, they support aquaculture by optimizing many operational phases of the aquaculture plants and ensuring the selection of ideal aquaculture sites. Within this application area, Galileo also plays a role by providing positioning and navigation services to fully automated vessels, underwater drones and innovative robotics that are increasingly adopted by water farmers.

SAR-based and optical satellite data provided by Copernicus can be used to monitor marine pollution and help in the detection of oil spills and marine litter. Earth observation also provides information on sea-surface height (altimetry), sea-surface salinity (in situ data), sea-surface temperature, ocean colour and sea-ice data that are useful for monitoring and forecasting the course of pollution. Moreover, remote sensing data can also contribute to identifying polluters.

It is worthwhile mentioning that along with a myriad of data and information generated by CLMS, CMEMS and C3S, there are new data and applications in C3S that help the sector to better prepare and adapt to climate change. Climate change is bringing us much more than global warming. From more frequent severe weather events to rising sea levels, its effects are widespread. The water sector is particularly vulnerable to changing rainfall patterns. While overall some places are experiencing more rainfall and others less, almost everywhere is seeing more frequent flooding and longer periods of drought.[59] To this end, the "European water and climate data explorer"[60] application enables you to explore how a wide variety of climate indicators are expected to change during the twenty-first century for three different emissions scenarios.[61] It includes more general indicators, such as temperature and precipitation, as well as water-specific indicators, such as flood recurrence and the amount of nitrogen in the water. Meanwhile, the "Hydrological seasonal forecast explorer"[62] application provides forecasts of river discharge up to seven months ahead. It is designed to give an overview of the general situation in rivers around Europe, as well as to help users plan how water will be managed on a regional scale. The application provides an automatically generated "most probable forecast", as well as information on the skill of the model to aid interpretation of the quality of the forecast.

Although GNSS technology is certainly less effective than Earth observation in addressing water management challenges, some specific use cases, along with the water level monitoring, demonstrate the potential of Galileo to preserve water ecosystems. For example, within the FloatEco (floating ecosystem) project,[63] a consortium of partners including the University of Hawaii and the United States non-profit Ocean Voyages Institute employed GNSS-enabled trackers to study the dynamics of the so-called "garbage patch", a huge collection of marine debris in the North Pacific Ocean. GNSS trackers were attached to fishing gear and other debris to better understand drift patterns. As a result, the trackers contributed to identifying areas of the ocean where much larger collections of plastic debris had gathered, which was subsequently removed. An additional use case showcasing the relevance of Galileo in addressing this challenge relates to the employment of GNSS receivers to time stamp measurements across a wide geographical area through supervisory control and data acquisition (SCADA) systems. Those systems refer to complex, digital networks that automatically monitor and control each step of the water treatment process. Given the high number of sensors and components involved,

[58] Source: www.unwater.org/sites/default/files/app/uploads/2020/04/SDG-indicator-661-methodology_English.pdf
[59] For more information: https://climate.copernicus.eu/c3s-launches-data-and-apps-water-management
[60] Copernicus Climate Data Store
[61] Emissions Scenarios — IPCC
[62] https://cds.climate.copernicus.eu/cdsapp#!/software/app-hydrology-seasonal-forecast-explorer?tab=app
[63] Source: https://www.floateco.org/

GNSS receivers constitute the most effective solution to ensure the needed synchronization, resulting in overall better water management.

Finally, GOVSATCOM can play an essential role in water management, enabling early warning systems (e.g., sensors and monitoring), RPAS/UAV surveillance network support, pollution detection, critical key infrastructure management and most importantly cybersecurity support to the infrastructure grids.

The relevance of the four EU Space components services (Copernicus, Galileo, EGNOS and GOVSATCOM) for the water management challenge is assessed in the following exhibit, including examples of products and applicability for services with high relevance.

**EXHIBIT 16.** EXAMPLES OF RELEVANCE OF EU SPACE COMPONENTS SERVICES FOR THE WATER MANAGEMENT CHALLENGE

| Component | Service | Relevance | Examples |
|---|---|---|---|
| GALILEO | Open Service | Significant | • Open Service can be utilized to monitor water levels, such as seas, lakes, rivers and reservoirs. Also, it can provide accurate and reliable timing that can be used to time stamp measurements across a wide geographical area through SCADA systems or can be used in cameras with GNSS systems on vessels using deep learning to detect and map plastic debris in the ocean<br>• OSNMA and CAS increasing robustness against spoofing of T and S |
| | HAS | Limited | |
| | OS-NMA | Limited | |
| | CAS | Limited | |
| | PRS | Limited | |
| | SAR | Limited | |
| EGNOS | OS | Limited | • OS and EDAS for GIS mapping |
| | SoL | Limited | |
| | EDAS | Limited | |
| Copernicus – Europe's eyes on Earth | CLMS | Significant | • CLMS, for example, provides data about lake and reservoir surface water temperature, water quality, water level or monitor snow and ice at high resolution<br>• CMEMS provide a wealth of ocean products, e.g., monitor variables such as salinity, sea surface height, sea ice, currents, temperature, etc.<br>• C3S, for example, provides a variety of hydrology-related climate indicators, such as temperature and precipitation, as well as water-specific indicators, such as flood recurrence and the amount of nitrogen in the water that is expected to change during the twenty-first century<br>• CEMS service includes an on-demand mapping component and an early warning component, including the European and Global Flood Awareness Systems and European and Global Drought Observatories<br>• Sentinel-1 data for monitoring surface water dynamics in cloud-prone regions; Sentinel-2 to assess the historical surface water resources worldwide; Sentinel-3 to estimate the changes in water levels in rivers and lakes or marine pollution |
| | CMEMS | Significant | |
| | CAMS | Limited | |
| | C3S | Significant | |
| | CEMS | Significant | |
| | CSS | Limited | |
| | Copernicus data | Significant | |
| GOVSATCOM | | Significant | • Early warning systems (e.g., sensors, monitoring)<br>• Institutional and diplomatic support<br>• Civil-military interaction<br>• RPAs/UAV surveillance<br>• Support to multiple crisis management zones<br>• Pollution detection<br>• Critical key infrastructure management<br>• Cybersecurity support |
| #EUSpace Synergies | | Significant | • EGNSS and Copernicus complementarity at different phases of the water management |

● Limited relevance/contribution ⬤ Significant relevance/contribution

**EXHIBIT 17.** LIST OF EGNSS AND COPERNICUS APPLICATIONS ADDRESSING THE WATER MANAGEMENT CHALLENGE

| MARKET SEGMENT | APPLICATION DOMAIN | EXAMPLES OF SPECIFIC APPLICATIONS |
|---|---|---|
| BIODIVERSITY, ECOSYSTEMS AND NATURAL CAPITAL | Water ecosystems monitoring | ● Water ecosystems monitoring |
| EMERGENCY MANAGEMENT AND HUMANITARIAN AID | Early warning | ◐ Early warning (for floods and droughts) |
| | Rapid mapping | ◐ Rapid mapping |
| ENVIRONMENTAL MONITORING | Environmental resources management | ● Environmental resources management |
| FISHERIES AND AQUACULTURE | Aquaculture | ◐ Aquaculture operations optimization<br>● Aquaculture site selection |
| MARITIME AND INLAND WATERWAYS | Environmental monitoring | ● Marine (and inland) pollution monitoring |

● Copernicus application ● EGNSS application ◐ Synergetic application (combined use of Copernicus and EGNSS)

## 3.3.4 Use cases

### *Monitoring the world's freshwater ecosystems*

Understanding the state of the world's freshwater ecosystems is an essential first step in their protection and restoration. Recognizing how multiple pressures interact to cause changes in freshwater ecosystems is complex. For example, growing populations drive ecosystem changes through increased demand to generate locally stored fresh water, which alters hydrological systems, or by deforesting and urbanizing areas, which increases run-off, flooding rates and nutrient and sediment loss, thereby degrading water bodies.

In March 2020, UNEP launched the Freshwater Ecosystems Explorer – a free and easy-to-use data platform providing accurate, up-to-date, high-resolution, geospatial data to monitor freshwater ecosystems. The platform was developed to help decision makers readily access and understand ecosystem changes and enable countries to track progress towards the achievement of Sustainable Development Goal Target 6.6.

The Earth observation data used to support the monitoring and reporting on freshwater ecosystems come from several space agencies. ESA, NASA and JAXA provide various satellite-derived imagery at different temporal coverage. The NASA Landsat satellites have been orbiting Earth since the early 1970s and provide high-quality global coverage of surface water extent from 2000. Both Copernicus Sentinel and the JAXA Synthetic Aperture Radar (SAR) satellites are more recent and, thanks to advances in technology, allow image and data capture for mangroves, wetlands and water quality monitoring. Copernicus Sentinel-2 allows for monitoring of the optical property of water and consequent derivation of important water quality characteristics such as chlorophyll concentration and turbidity.

Data are updated annually and produced to align with the SDG indicator 6.6.1 methodology. They can be visualized and downloaded at national, subnational and basin levels. The data are available for the following: permanent and seasonal surface waters, reservoirs, wetlands, mangroves and water quality.

As explained, the Freshwater Ecosystems Explorer supports countries with monitoring and reporting on SDG indicator 6.6.1 data. However, all interested practitioners and managers are encouraged to access the platform and use the data.[64]

### *Developing a road map for Copernicus Water Services*

Inland and coastal waters play a crucial role in human health and well-being, in the global carbon and nutrient cycles, as well as supporting high levels of biodiversity.

The H2020 project "Water scenarios For Copernicus Exploitation", Water-ForCE, is developing a road map for Copernicus water services. Such a road map will provide a user- and stakeholder-driven concept for water services (water quantity, water quality, hydrological parameters, ice, snow, etc.), by assessing the existing and emerging needs, the opportunities presented by the current and future technical capabilities of satellite and in situ sensors, and addressing the current disconnects between remote sensing, in situ observations and modelling communities.

Critically, the road map aims at fostering closer cooperation between remote sensing, in situ and modelling communities to build an optimal water service that provides necessary information to policymakers, managers, researchers and the public.[65]

## 3.4 THE ENVIRONMENTAL AND CLIMATE CHANGE CHALLENGE AND THE ROLE OF EU SPACE

### 3.4.1 Introduction

Former Secretary-General Ban Ki-moon said: "no Plan B for climate action as there is no planet B" and more recently his successor António Guterres added: "Climate change is the defining issue of our time, and we are at a defining moment". Thus, the strong worldwide focus on environmental and climate change, as global climate targets are at risk of not being met. António Guterres expressed it very clearly when stating that "The 1.5-degree goal is on life support, it is in intensive care". The implications of not meeting the goal highlighted in the Paris Agreement to limit future warming to 1.5-degree are numerous and, in one way or another, the other challenges are closely linked to the evolution of climate and environment.

It is worth noting that climate change and global warming, although sometimes used interchangeably, do not refer to the same thing. Climate change refers to long-term weather patterns, including temperature changes, while global warming refers specifically to the long-term heating of Earth's surface and atmosphere. Climate change encompasses global warming, and both have an effect on the environment.

**Climate Adaptation and Mitigation**

**Adaptation refers to adjustments in ecological, social, or economic systems in response to actual or expected climatic stimuli and their effects or impact. Mitigation refers to efforts to reduce or prevent emission of greenhouse gases.**

Global warming has profound and impactful consequences on the environment; therefore, it is of the utmost importance to keep it constrained within the limits set under the Paris Agreement 2015. The IPCC Special Report points out the consequences of not keeping to the 1.5°C limit:[66]

*Climate-related risks for natural and human systems are higher for global warming of 1.5°C than at present, but lower than at 2°C (high confidence). These risks depend*

[64] SDG 6.6.1 (sdg661.app)
[65] Water-ForCE (waterforce.eu)
[66] Extracted from IPCC Special Report: Global Warming of 1.5 C, summary for policymakers.

**Heat islands**

**Heat islands are areas of urbanized land which experience higher temperatures than their surroundings as they absorb more of the sun's heat than they emit.**

*on the magnitude and rate of warming, geographic location, levels of development and vulnerability, and on the choices and implementation of adaptation and mitigation options (high confidence).*

It is important to stress that the risk depends on the adaptation and mitigation choices made, as they might be the target of local policies, which can have a great impact at local level on the effects of climate change. In general, the impact is higher on those who are less able to protect themselves.

*Several regional changes in the climate are forecasted with a global warming of up to 1.5°C compared to pre-industrial levels, including warming and extreme temperatures in many regions (high confidence), increases in frequency, intensity, and/or amount of heavy precipitation in several regions (high confidence), and an increase in intensity or frequency of droughts in some regions.*

At the time of writing, there have been severe heat waves in the northern hemisphere, and their frequency and intensity are likely to grow as the mean temperature of the planet increases. In particular, the impact is amplified in cities due to heat islands.

It is not only the increase in the frequency and intensity of some disasters, but also risks to health, livelihoods, food security, water security, human security and economic growth are expected to increase as global warming increases.

*Risks from some vector-borne diseases, such as malaria and dengue fever, are forecasted to increase with warming from 1.5°C to 2°C, including potential shifts in their geographic range (high confidence).*

*Limiting warming to 1.5°C compared with 2°C is forecasted to result in smaller net reductions in yields of maize, rice, wheat and potentially other cereal crops, particularly in sub-Saharan Africa, South-East Asia, and Central and South America, and in the $CO_2$-dependent nutritional quality of rice and wheat (high confidence). Reductions in the forecasted food availability are larger at 2°C than at 1.5°C of global warming in the Sahel, southern Africa, the Mediterranean, central Europe and the Amazon (medium confidence). Livestock may also be adversely affected by rising temperatures, depending on the extent of changes in feed quality, spread of diseases and water resource availability (high confidence).*

Depending on future socioeconomic conditions, limiting global warming to 1.5°C compared to 2°C may reduce the proportion of the world population exposed to a climate change-induced increase in water stress by up to 50 per cent, although there is considerable variability between regions (medium confidence).

Although in this report, an effort has been made to decouple the different challenges they are all related to some degree, as the examples above show and, ultimately, they are all related to what two Secretaries-General of the United Nations considered extremely urgent to tackle collectively ("Collective action or collective suicide" said António Guterres about the need for meeting the 1.5-degree goal).

## 3.4.2 Space and climate change

Space has played an important role in the awakening call for environmental and climate action. Not only showing the fragility of planet Earth, but also monitoring very closely the climate. In fact, about 60 per cent of the 54 essential climate variables can be addressed by satellite data.[67]

Thanks to satellites today we know that:

- Sea level is rising at a rate of more than three millimetres per year, and this finding is supported by more than 27 years of satellite observations.[68] However, this value is only the average; the increase in sea level accelerated during that period.

[67] https://atmosphere.copernicus.eu/cop27-draws-attention-vital-importance-earth-observation-data
[68] 24WMO.pdf (un.org)

- Satellites have shown that the land ice sheets in both Antarctica and Greenland have been losing mass since 2002.[69]
- Satellite data show a stable increase in land surface temperature of 0.2°C per decade over the last 25 years. However, it is worth noting that there is significant regional variability.[70]
- Satellites track the health of the ozone layer by monitoring its evolution. Satellites have been instrumental in following the implementation of the Montreal Protocol.[71]

Today the number of Earth observation satellites stands at around 1,000, the highest in history. Space agencies are jointly working to maximize the benefits of this large number of satellites and obtain continuous and consistent measurements. The Committee of Earth Observation Satellites works to ensure that satellites and associated ground segments are operating collaboratively, in the form of virtual constellations that overlap or complement coverage and measurements to meet Earth observation needs. Virtual constellations can be composed of individual constellations, one of them being Copernicus.

UNOOSA, with the support of the UK Space Agency, has published a report on the use of space technology to support climate action at the global level, which aims to improve understanding of how selected stakeholders are using space technology to support climate action. The report shows that climate observation, research, science and policy are well-coordinated and evolving in an expanding stakeholder landscape. However, inconsistencies in the definition of climate action and services are rendering coordination among stakeholders challenging.

Gaps have been identified in information-sharing efforts and networks that could increase awareness, understanding and collaboration in the use of space for climate action. More could also be done to improve cooperation and coordination in capacity-building as an important component of successful and sustainable short and long-term actions.

UNOOSA aims to address potentially existing niches through supporting and promoting the use of space for climate action. The Office serves as a conduit for facilitating international coordination, cooperation, capacity-building and providing a multiplying-effect for existing efforts. Crucially, through capacity-building, the Office facilitates the access of developing countries to space technologies and applications. Additionally, in collaboration with several partners and supported by the Government of Austria the Office works towards providing capacity-building opportunities as well as in-person forums for information exchange and also a "Space4Climate Action" website (https://space4climateaction.unoosa.org/) in order to maximize the benefit of space for all humankind.

### 3.4.3 EU Space specific support

Copernicus and, to a lesser extent EGNSS, provides extraordinary support for tackling environmental impact and climate change challenges. This is indeed one of the fields where the use of Earth observation data can make the largest difference, as it has the unique capability to capture environmental and socioeconomic data over a range of spatial, spectral and temporal resolutions. Fuelled by the growing awareness of the climate crisis and the urgent need for informed adaptation and mitigation actions, Copernicus-derived intelligence integrating existing land, marine, atmosphere and climate change services can provide the tools necessary to meet the global challenges in the delivery of sustainable development and carbon neutral cities.

Primarily, by providing data on air and sea surface temperatures, sea level and GHG concentration, Copernicus observations and measurements allow climate scientists and modellers to understand, monitor and forecast the extent of climate change. The Copernicus Sentinel-5 Precursor mission carrying the TROPOspheric Monitoring Instrument (TROPOMI) is the first Copernicus mission dedicated to monitoring the atmosphere and, since 2017, has been measuring several atmospheric trace gases, including methane. In addition, the upcoming CO2M Copernicus Expansion Mission will support emission measurements, focusing on anthropogenic $CO_2$ (carbon dioxide) monitoring and methane from human activity.

Those data, together with other Copernicus Sentinel satellites providing additional parameters at sea and land levels, are the base of climate models that support

[69] Ice Sheets | Vital Signs – Climate Change: Vital Signs of the Planet (nasa.gov)
[70] Increases in land surface temperature and water vapour analysed in new satellite data (climatechangenews.com)
[71] Satellites track the health of the ozone layer - Earth Online (esa.int)

the forecasting of phenomena in the atmosphere, the oceans and on land over seasonal, decadal and centennial time-scales. The importance of those models goes well beyond the scientific community. They indeed became important decision-making tools for environment-related national and international public bodies – notably policymakers and environmental agencies – non-governmental organizations, corporations and even the general public. Within this context, Copernicus, together with data from other Earth observation systems, is already successfully contributing to awakening global consciousness around the climate change issue.

EU Space data, however, do not only contribute to understanding the issue, but rather and most importantly they actively support the mitigation of the impacts of climate change by informing sustainable business decisions. The 2021 United Nations Climate Change Conference (also known as COP26) held in Glasgow made it clear that it is imperative to identify potential opportunities to increase sustainable practices and develop a posture of resilience.[72] In 2022, the United Nations Climate Change Conference 2022 (COP27) focused on accountability, fairness and an assessment of non-State progress at COP27,[73] and featured keynote speeches from the High-level Climate Champions who presented the Summary of Global Climate Action.[74]

In this sense, Copernicus becomes an active instrument for business organizations to reduce emissions, end deforestation and protect oceans, ensuring sustainable prosperity without compromising the future.

The focus of Copernicus on climate change mitigation is emphasized by the fact that the Copernicus Climate Change Service[75] (C3S) is one of the six thematic services provided by Copernicus, supporting society by providing authoritative information about the past, present and future climate in Europe and the rest of the World. Implemented by ECMWF on behalf of the European Commission, C3S provides open and free access to state-of-the-art climate data and tools for use by governments, public authorities and private entities around the world.

## Fact

Approximately **60 terabytes of data** are downloaded from the C3S Climate Data Store every day

C3S makes use of **350 million observations** every day to produce data provided in the Climate Data Store

The C3S key dataset is **7,000 terabytes**

*Source: climate.copernicus.eu*

It provides information on climate change and on impacts for many sectors through the Climate Data Store, a powerful cloud-based infrastructure providing access to a vast range of global and regional information, including climate data records derived from observations, the latest ECMWF reanalyses, seasonal forecast data from multiple providers and a large collection of climate projections. Zooming in, C3S supports its users by sharing regular climate updates relating to surface air temperature, sea ice cover, precipitation and soil moisture, as well as river discharge, alpine glaciers and land surface information. These include the annual European State of the Climate report[76]and monthly climate bulletins.[77]

C3S data is also used by The European Climate Adaptation Platform Climate-ADAPT,[78] which is a partnership between the European Commission and the European Environment Agency (EEA). Climate-ADAPT is maintained by the EEA with the support of the European Topic Centre on Climate Change Impacts, Vulnerability and Adaptation (ETC/CCA). The platform aims at supporting Europe in its adaptation to climate change by helping users access and share data and information on topics such as expected climate change in Europe, current and future vulnerability of regions and sectors, national and transnational

[72] https://ukcop26.org/
[73] https://unfccc.int/news/un-climate-change-high-level-champions-contribution-of-the-all-of-society-global-climate-action
[74] https://unfccc.int/sites/default/files/resource/GCA_COP27_Summary_of_Global_Climate_Action_at_COP_27_1711.pdf
[75] For more information: https://climate.copernicus.eu/
[76] https://climate.copernicus.eu/ESOTC
[77] https://climate.copernicus.eu/climate-bulletins
[78] https://climate-adapt.eea.europa.eu/

adaptation strategies and actions, adaptation case studies and potential adaptation options, and tools that support adaptation planning.

Similarly, the Copernicus Atmosphere Monitoring Service (CAMS)[79] supports the monitoring and understanding of greenhouse gases, the hole in the ozone layer and air pollution levels. This service provides vital data to support policymakers, businesses and individuals in dealing with air pollution episodes and understanding the shifts in the context of a changing atmosphere.

Consistent information from CAMS allows users to assess the past and to predict air quality up to five days into the future. The data used and interpreted come from satellites and in situ sensors on the ground and in the air. Furthermore, CAMS has a key role in the development of the $CO_2$ Monitoring and Verification Support Capacity (CO2MVS) that will monitor anthropogenic $CO_2$ emissions supporting the global efforts to curb emissions. Finally, every 12 hours, CAMS observations are provided in five main categories: air quality and atmospheric composition; solar energy; the ozone layer and ultraviolet radiation; emissions and surface fluxes of pollution and greenhouse gases; and climate forcing.

C3S and CAMS are game changers for the 2015 United Nations Climate Change Conference (known as COP21), which negotiated the Paris Agreement on climate change,[80] where it was agreed to hold the global average temperature rise to well below 2°C above pre-industrial levels, and to pursue efforts to limit it to 1.5°C. These services can help nations and businesses around the world work to implement this global treaty but also to take advantage of the economic opportunities it presents.

It is worth mentioning that CAMS and C3S made a wide-ranging contribution to the Conference of the Parties of the United Nations Framework Convention on Climate Change (COP27) in 2022. ECMWF organized several side events highlighting the wealth of Earth observation data provided by CAMS and C3S and their applications. The presence of ECMWF at COP underlined the strategic role that the institution plays in supporting the development and monitoring of European climate policy.[81]

In a broader context, exhibit 19 lists many commercial applications that support businesses in implementing sustainable practices: from agriculture, in which farmers use Copernicus and EGNSS to optimize agricultural output while optimizing the use of pesticides and natural resources, to aviation in which EU Space data are used to monitor aircraft emissions or optimize the use of fuel while avoiding diversions.

Nevertheless, another potentially impactful way EU Space data can contribute to mitigating the effects of climate change relates to the role of Copernicus in supporting companies operating under ESG criteria. Copernicus, together with big data analysis and machine learning techniques that enable the extraction of insights, can, for example, effectively determine how businesses and industries are managing their carbon emissions, how they are impacting (or polluting) the environment, what their GHG emission levels are or whether their supply chain truly adheres to certification programmes ensuring sustainable plantations (e.g., of cocoa, oil palm or coffee). The power of satellite data resides in the fact they reveal insights based on real, observed data that can be measured and compared over time and not on proxies by estimates or reporting. Earth observation in general and Copernicus in particular have the potential to support a real paradigm shift involving not only financial institutions and socially responsible investors, but also supporting and driving purchase decisions by customers, ultimately avoiding "greenwashing" practices. In this context, EUSPA published the report *EU Space for Green Transformation: a new tool for companies to monitor their sustainability targets*.[82]

Finally, GOVSATCOM may play a role in the environmental and climate change challenge, enabling RPAS/UAV surveillance networks support, pollution detection or by providing a common communication channel to exchange information between various actors.

The relevance of the three EU Space components services (Copernicus, EGNSS and GOVSATCOM) for the environmental and climate change challenge is assessed in exhibit 18, including examples of products and applicability for services with high relevance.

[79] https://atmosphere.copernicus.eu/
[80] https://unfccc.int/process-and-meetings/the-paris-agreement/the-paris-agreement
[81] https://climate.copernicus.eu/ecmwfs-copernicus-services-cop27 and https://climate.copernicus.eu/copernicus-cop27-power-partnership (Accessed December 2022)
[82] www.euspa.europa.eu/newsroom/news/eu-space-helps-drive-green-transformation (Accessed December 2022)

**EXHIBIT 18.** EXAMPLES OF RELEVANCE OF EU SPACE COMPONENTS SERVICES FOR THE ENVIRONMENTAL AND CLIMATE CHANGE CHALLENGE

| Component | Service | Relevance | Examples |
|---|---|---|---|
| GALILEO | Open Service | Significant | • Open Service/HAS - Although there is limited use of GNSS, there are a number of techniques such as GNSS radio occultation sounding and GNSS reflectometry that support climate modelling. Both techniques can benefit from improved performances offered by Galileo and its services. GNSS is also used for biodiversity mapping or smart waste management |
| | HAS | Limited | |
| | OS-NMA | Limited | |
| | CAS | Limited | |
| | PRS | Limited | |
| | SAR | Limited | |
| EGNOS | OS | Significant | • OS and EDAS offer real-time and free-of-charge improved GPS (GPS + Galileo in future) positioning service over Europe that can be used, for instance, for GIS mapping of protected areas, species monitoring, etc. |
| | SoL | Limited | |
| | EDAS | Limited | |
| Copernicus – Europe's eyes on Earth | CLMS | Significant | • C3S combines observations of the climate system with the latest science to develop authoritative, quality-assured information about the past, current and future states of the climate in Europe and worldwide, e.g., provide data on climate indicators (temperature, sea ice, sea level, greenhouse gas concentrations/fluxes, glaciers and ice sheets), climate projections, re-analysis, etc.<br>• CAMS provides a wealth of data about air pollution and health and greenhouse gases, for instance, data on pollutants such as PM2.5 and PM10, pollen, ozone, $CO_2$, methane, etc.<br>• CMEMS, for example, provides key data products for sea ice monitoring to assess environmental, safety and societal impacts in both poles or provide accurate forecasts concerning ocean currents and waves that can be used to compute oil spill drift forecasts, it also provides biogeophysical data and indicators to support ecosystem monitoring and restoration as well that sustainable exploitation of the oceans.<br>• CLMS provides data on land cover to a broad range of users in the field of environmental terrestrial applications, including information on land use, land cover characteristics and changes, vegetation state, water cycle and earth surface energy variables (e.g., CORINE land cover, snow and ice monitoring, NATURA 2000, etc.). It also provides, over Europe, the European Ground Motion Service (EGMS).<br>• CEMS, for example, provides drought-relevant information and early warnings for Europe and globally or monitors forest fire risk or activity in near-real time<br>• The Copernicus Maritime Surveillance Service (CMS) in the framework of the CSS provides for the detection of discharges of oil, assists in identifying polluting vessels, as well as monitoring the evolution of accidental spills during emergencies |
| | CMEMS | Significant | |
| | CAMS | Significant | |
| | C3S | Significant | |
| | CEMS | Significant | |
| | CSS | Significant | |
| | Copernicus data | Significant | |
| GOVSATCOM | | Significant | Common communication channel to exchange information between various actors<br>• Maritime surveillance and ship detection<br>• Institutional and diplomatic support<br>• Civil-military interaction<br>• Member States ministries support (e.g., agriculture, civil protection)<br>• RPAs/UAV surveillance<br>• Mission location support<br>• Support to multiple crisis management zones |
| #EUSpace Synergies | | Significant | • EGNSS and Copernicus complementarity; some emerging applications, e.g., combining CAMS data with in situ air pollution monitoring devices on vehicles within city, leveraging GNSS positioning. Furthermore, GOVSATCOM may complement many applications by providing communication channel |

● Limited relevance/contribution ⬤ Significant relevance/contribution

**EXHIBIT 19.** LIST OF EGNSS AND COPERNICUS APPLICATIONS ADDRESSING THE ENVIRONMENT AND CLIMATE CHANGE CHALLENGE

| MARKET SEGMENT | APPLICATION DOMAIN | EXAMPLES OF SPECIFIC APPLICATIONS |
|---|---|---|
| AGRICULTURE | Environmental monitoring | ● Carbon capture and content assessment<br>● Environmental impact monitoring |
| | Natural resources monitoring | ◐ Soil condition monitoring<br>● Vegetation monitoring |
| | Weather services for agriculture | ● Climate services for agriculture |
| AVIATION | Environmental monitoring | ◐ Aircraft emission measurement and monitoring<br>● Particulate matter monitoring |
| BIODIVERSITY, ECOSYSTEMS AND NATURAL CAPITAL | Coastal ecosystems monitoring | ● Coastal ecosystems monitoring |
| | Snow and ice ecosystems monitoring | ● Snow and ice ecosystems monitoring |
| | Terrestrial ecosystems monitoring | ● Terrestrial ecosystems monitoring |
| | Water ecosystems monitoring | ● Water ecosystems monitoring |
| CLIMATE SERVICES | Climate change mitigation and adaptation | ● Climate change mitigation and adaptation |
| | Climate modelling | ● Earth observation-based modelling<br>○ GNSS-based climate modelling |
| | Climate monitoring and forecasting | ● Climate forecasting<br>● Climate monitoring |
| CONSUMER SOLUTIONS, TOURISM AND HEALTH | Health and lifestyle | ● Air quality monitoring |
| ENERGY AND RAW MATERIALS | Environmental impact monitoring | ● Environmental impact assessment of energy and mineral resources plants |
| ENVIRONMENTAL MONITORING | Environmental auditing | ● Environmental auditing |
| | Environmental resources management | ● Environmental resources management<br>● Impact studies and environmental, social and corporate governance (ESG) |
| FORESTRY | Environmental monitoring | ◐ Biomass monitoring<br>● Deforestation/degradation monitoring |
| | Natural resource monitoring | ◐ Forest inventory monitoring<br>● Forest vegetation health monitoring<br>● Illegal logging monitoring |
| INFRASTRUCTURE | Environmental monitoring | ● Environmental impact assessment of infrastructure |
| MARITIME AND INLAND WATERWAYS | Environmental monitoring | ● Marine pollution monitoring |
| | Ocean services | ● Metocean (meteorology over oceans, and offshore weather and sea state monitoring) |

● Copernicus application ○ EGNSS application ◐ Synergetic application (combined use of Copernicus and EGNSS)

### 3.4.4 Use cases

#### *Satellites for wilderness inspection and forest threat tracking*

Forests are essential to life on Earth. They provide habitats for fauna and flora and combat climate change through carbon sequestration. However, our forests are threatened by insect outbreaks, fires, windthrow and droughts. Notably, insect pest outbreaks are one of the leading causes of forest loss globally. Pests are responsible for damaging 35 million hectares of forest around the world every year. In the Mediterranean region alone an area the size of Slovakia – five million hectares – is affected by pests annually, according to the United Nations Food and Agriculture Organization (FAO).

At the same time, wildfires destroy millions of hectares of forests annually on a global scale, according to data from the Global Wildfire Information System. The wind is also a significant forest disturbance agent in the temperate forests of France, Germany and most of Europe.

Climate change affects forests, causing insects to breed more frequently. It also provides more dry fuel for global wildfires. The dry conditions increase the length of the fire season and the size of areas affected by the fires. In addition, both the frequency and the severity of large storms causing windthrow can be attributed to climate change. As a result, countless habitats are lost, and a large volume of absorbed $CO_2$ is released back into the atmosphere.

The Horizon Europe SWIFTT project provides a scientifically sound and technically feasible way to help monitor and manage forest risks: windthrow, insect outbreaks, and forest fires. SWIFTT enables forest managers to adapt to climate change with affordable, simple and effective remote sensing tools backed up by powerful machine learning models. This solution offers a monthly health monitoring service using Copernicus satellite imagery to detect and map the various risks to which forests and their managers are exposed. Early threat detection aids timely intervention. SWIFTT has been tested in real conditions by several end users from the forest industry, which include Fürstliches Forstamt, Groupe Coopération Forestière and the Rigas Mezia. The project anticipates monitoring and protecting up to 40 million hectares of global forests by 2030, saving foresters over €468 million in monitoring costs.[83]

#### *Monitoring the human impact on $CO_2$ emissions*

To support European Union countries in assessing their progress towards the targets agreed in the Paris Agreement, monitoring global compliance and supporting the European Green Deal, the European Commission aims to provide observation-based information on $CO_2$ emissions.

In line with these objectives, The H2020 CoCO2 project builds the prototype systems for a European Monitoring and Verification Support capacity for anthropogenic $CO_2$ emissions, which will be implemented as part of Copernicus. Since 2021 CoCO2 is bringing together expertise, existing capacities and innovative ideas from a wide range of European and international players.

The CoCO2 project is a continuation of the $CO_2$ Human Emissions (CHE) project and builds on some of the work initiated in the Verifying Greenhouse Gas Emissions (VERIFY) project.

The prototypes are designed to leverage as much as possible the already existing Copernicus infrastructure while ensuring that all the components needed for the attribution of $CO_2$ emissions are properly developed (e.g., Earth system models, data assimilation techniques, prior emission estimation, etc.).[84]

Considering the importance of the environmental and climate change challenge, two more examples of other European Union initiatives are provided below.

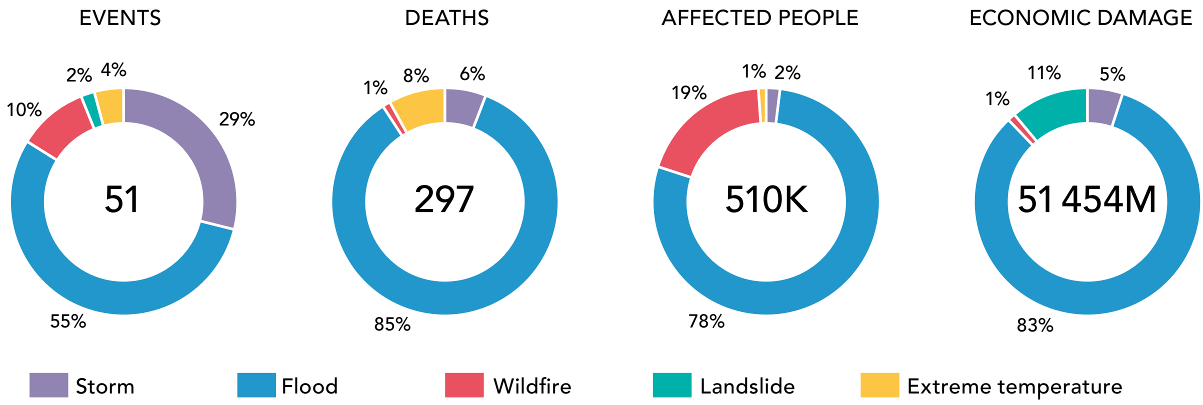
#### *State of the climate in Europe – the first edition of the joint WMO – C3S State of the Climate in Europe report*

Europe is the fastest warming World Meteorological Organization (WMO) region and the direct impacts of climate change affected hundreds of thousands of citizens during 2021, according to a new report issued by the WMO and the C3S.

[83] www.euspa.europa.eu/horizon-europe-projects
[84] https://coco2-project.eu/

**EXHIBIT 20.** WEATHER, CLIMATE AND WATER-RELATED DISASTERS IN EUROPE DURING 2021

*Note: Impacts for some disaster occurrences may be missing due to data unavailability*




*Source: State of the Climate in Europe 2021. Source of data: EM/DAT, accessed on 9 August 2022.*

This first edition of the joint State of the Climate in Europe report[85] was released on 2 November 2022 and is part of a global WMO-led effort to provide essential climate data and information tailored to the specific needs of each region, enhancing adaptation and mitigation strategies. An interactive story map with the main findings completes the nearly 50-page assessment.

The State of the Climate in Europe report gives a comprehensive assessment of 2021, its key extreme weather events, their impacts and future scenarios for the region.

### *EU Space contribution to a "digital twin" of the Earth*

Copernicus will also play a role in Destination Earth (DestinE),[86] the European Commission initiative which aims to develop a very high-precision digital model of the Earth (a "digital twin") to monitor and predict environmental change and human impact to support sustainable development.

DestinE will provide unique digital modelling capabilities of the Earth to enhance the ability of the European Union to monitor and model environmental changes, predict extreme events, and adapt European Union actions and policies to climate-related challenges. DestinE builds on European Union investment in high-performance computing, the massive space and socioeconomic data sources at our disposal, and on European excellence in data and AI technologies. The Commission, ESA, EMCWF and EUMETSAT will gradually develop the DestinE systems,

*"With Destination Earth, we are building on Europe's strong cards. From artificial intelligence, cloud computing, high-speed connectivity networks to our successful Copernicus Earth observation programme and our world leading EuroHPC supercomputers, we are combining our assets to make our future more safe and secure".*

Thierry Breton,
Commissioner for the Internal Market

[85] https://climate.copernicus.eu/first-edition-joint-wmo-c3s-state-climate-europe-report-unveils-impacts-climate-change
[86] https://digital-strategy.ec.europa.eu/en/policies/destination-earth

called Digital Twins. By the end of 2024, the DestinE system will consist of the following:

- Core Service Platform. It will provide decision-making tools, applications and services, based on an open, flexible and secure cloud-based computing system
- Data Lake. Storage space and seamless access to the data sets. The data lake will leverage existing scientific data sets, such as the Copernicus Data Access infrastructure, complemented by other non-space sources, such as sensor-based environmental data and socioeconomic data
- Digital Twins that combine data from real-time observations and simulations:
  - The Digital Twin on weather-induced and geophysical hazards will focus on floods, droughts, heat waves and geophysical phenomena such as earthquakes, volcanic eruptions and tsunamis. In case of floods, for example, this Digital Twin will help local and regional authorities to test actions with greater accuracy that will help save lives and reduce property damage
  - The Digital Twin on climate change adaptation will provide observation and simulation capabilities to support activities and mitigation scenarios for climate change. To help achieve carbon neutrality, information will be made available from different domains such as sustainable agriculture, energy security and protection of biodiversity

## 3.5 THE DISASTER MANAGEMENT AND EMERGENCY RESPONSE CHALLENGE AND THE ROLE OF EU SPACE

*"Extreme weather events will happen. But they do not need to become deadly disasters."*

António Guterres,
Secretary-General of the United Nations

**Fact**

While disasters are claiming fewer lives annually, they are also costing more and increasing poverty

### 3.5.1 Introduction

If current trends continue, the number of disasters per year globally may increase from around 400 in 2015 to 560 per year by 2030 – a forecasted increase of 40 per cent during the lifetime of the Sendai Framework. The number of extreme temperature events per year is also increasing and, based on current trends, will almost triple between 2001 and 2030.

Risk is increasing globally, as are the frequency and costs of disasters. Intensive and extensive risks are growing at an unprecedented rate. Human activities are creating greater and more dangerous risk. As risk multiplies, it has increasing impacts on communities and on entire systems. Everyone is living downstream of something else. Global impacts become local, and vice versa. They cascade across sectors, creating new challenges. For droughts, there is a significant year-to-year variation, but research indicates a likely increase of more than 30 per cent between 2001 and 2030. While disasters are claiming fewer lives annually, they are also costing more and increasing poverty. Economic losses from disasters have more than doubled over the past three decades, showing an increase of 145 per cent from an average of around US$70 billion per year in the 1990s to over US$170 billion per year in the decade ending in 2020. Approximately 40 per cent of this loss is insured. However, such coverage is overwhelmingly concentrated in developed countries, with insurance coverage rates in the developing world averaging less than 9 per cent. There are many systemic risks and trends, such as sea level rise, for which insurance is not an option.[87]

## 3.5.2 Space and disaster management and emergency response

Reliable and timely information is essential when it comes to dealing with natural hazards and the resulting disasters – especially when infrastructure is hindered or ineffective. Satellites provide this information in a variety of ways. They help disaster responders by giving a clear picture of inaccessible, flooded or damaged areas. They allow for disaster risk reduction by informing, for example, urban planners. They enable communication in emergency situations and the identification of precise locations of first response teams, shelters, disaster areas or vulnerable populations. The information gathered by satellites can help anticipate or plan for the consequences of disasters such as earthquakes, floods, landslides, wildfires or tsunamis.

Earth observation satellites provide valuable additional input that can be used to:

- Track the path of tropical storms including typhoons, cyclones and hurricanes worldwide while enabling the monitoring of their impact
- Assess the changing morphology of volcanic domes, the dispersion of ash emitted when eruptions occur, or the ground deformation during seismic episodes
- Visualize the geographical extent and impact of floods even under cloudy conditions or at night thanks to radar data, and the extent and consequences of forest fires
- Detect accidental or voluntary oil spills and predict their drifting pattern
- Monitor droughts and their effects on soils, vegetation and crops

Global navigation and positioning satellites orbit the Earth on a permanent basis and are used to assess the relative motion of tectonic plates and the magnitude of the most powerful earthquakes, particularly when seismometers become saturated. The global coverage of the signals provided by these constellations of satellites allows emergency responders to supply coordinates of landing sites to helicopter pilots in areas affected by disasters. They also help develop more accurate maps of disaster areas and facilitate interoperability of data and information.

Communication satellites are essential when there is a need to transmit messages very rapidly across vast areas. The transmission of messages regarding tsunamis is of relevance, not only from one continent to another, but also to small, populated islands which may otherwise be unreachable. Communication satellites also allow devices such as deep-sea buoys, rainfall and river level gauges, and seismographs to transmit their data to specialized centres where they are processed to identify disasters. Simple applications of georeferenced photographs also allow crowdsourcing of in situ data to assess damage. The COSPAS-SARSAT programme is especially useful, in that it allows maritime vessels, airplanes and people to send distress alerts and location information for search and rescue operations.

In its resolution 61/110 of 14 December 2006, the General Assembly agreed to establish the "United Nations Platform for Space-based Information for Disaster Management and Emergency Response - UN-SPIDER" as a new United Nations programme as part of UNOOSA, with the following mission statement: "Ensure that all countries and international and regional organizations have access to and develop the capacity to use all types of space-based information to support the full disaster management cycle".

A number of initiatives in recent years have contributed to making space technologies available for humanitarian aid and emergency response. Yet, UN-SPIDER is the first to focus on the need to ensure access to and use of such technologies during all phases of the disaster management cycle, including the risk reduction phase which is crucial for reducing the losses of lives and property. The UN-SPIDER programme is achieving this by focusing on being a gateway to space information for disaster management support, by serving as a bridge to connect the disaster management, risk management and space communities and by being a facilitator of capacity-building

[87] GAR2022: Our World at Risk | UNDRR

and institutional strengthening for developing countries. UN-SPIDER is being implemented as an open network of providers of space-based solutions to support disaster management activities.

### 3.5.3 EU Space specific support

EGNSS and Copernicus contribute to addressing the disaster management and emergency response challenge by enabling several applications thanks to the provision of specific services:

- Copernicus provides supporting information for emergency response and disaster management in relation to different types of disasters, including meteorological hazards (for example, severe storms, floods), and geophysical hazards (volcanic eruptions and earthquakes or tsunamis), wildfire hazards, or deliberate and accidental human-made disasters (e.g., industrial accidents) and other humanitarian disasters and different stages of emergency management.
- The main contribution of EGNSS is its SAR capability to locate persons in distress to ensure the quickest response time. EGNSS (Open Service or PRS) is crucial to guiding or navigating first responders or drones safely. Furthermore, the above-mentioned services are complemented by Galileo HAS which increases the positioning accuracy down to 20cm globally, and OSNMA or CAS which increase the robustness of positioning.

Furthermore, Copernicus provides information for emergency response and disaster risk management at each of the following stages:

- For preparedness, prevention, risk reduction and recovery phases, Copernicus provides risk, hazard and vulnerability assessments and simulation models.
- For early warning, Earth observation/Copernicus data provide continuous observations and forecasts for many types of disasters such as flooding (e.g., hydrological modelling), earthquakes (e.g., surface deformation), landslides (e.g., ground motion), volcanic eruptions (e.g., atmospheric composition), tsunamis (e.g., wave height), wildfires (e.g., soil moisture conditions) and others. Galileo receivers can then help to detect earthquakes and floods and assess their magnitude. This could bring an additional 10 to 30 seconds of warning to a city or nuclear reactor of an imminent quake, which could result in enormous social benefits.
- During a disaster, Earth observation/Copernicus data provide rapid mapping, while GNSS provides support to ancillary data sources (e.g., crowdsourced mapping updates, geolocalized social media posts, precision guidance for surveying drones, etc.), allowing emergency response to be coordinated as efficiently as possible.
- Finally, during post-event analysis, the comparison of recent and archive Earth observation/Copernicus data assists relevant actors with an accurate damage assessment and has been used in international efforts such as the Recovery Observatory, assisting the elaboration of the post-disaster needs assessment which is the basis for allocating recovery funds

Specifically, the Copernicus Emergency Management Service[88] (Copernicus EMS) is the European Union tool developed to provide the actors involved in all the phases of the disaster management cycle, and of humanitarian crises, with timely and accurate geospatial information derived from Earth observation satellite data and completed by available in situ or open data sources. The Copernicus EMS consists of the following components:

- *Copernicus EMS on-demand mapping* provides on-demand detailed information for selected emergency situations that arise from natural or human-made disasters anywhere in the world.
- *Rapid mapping* provides geospatial information within hours or days of a service request to support emergency management activities in an urgent mode.
- *Risk and recovery mapping* supplies geospatial information in support of disaster management activities, including prevention, preparedness, risk reduction and recovery phases.
- *Exposure mapping:*
  - The exposure mapping component provides highly accurate and continuously updated information on the presence of human settlements and population with the Global Human Settlement Layer (GHSL). The following data sets are provided:

[88] For more information: https://emergency.copernicus.eu/

- Population grids representing the amount of resident population at a fine spatial resolution
- Built-up surface grids representing human settlements and their characteristics (such as land use and density)
- Detailed information on exposure is fundamental to manage crisis and assess disaster risk. It allows answering questions like how many people are living in a flooded area or how many settlements will be affected by a cyclone.

➘ Early warning and monitoring with critical geospatial information at the European and global level through continuous observations and forecasts for floods, droughts and forest fires:

- European Flood Awareness Systems (EFAS) and Global Flood Awareness Systems (GloFAS) provide complementary flood forecast information to relevant stakeholders that support flood risk management at the national, regional and global level.
- The Global Flood Monitoring tool provides automatic and continuous processing of Copernicus Sentinel-1 radar data to extract flooded areas and is reprocessing the entire Sentinel-1 archive to provide times series from 2015 for urban planning, territorial management and insurance applications.
- The European Forest Fire Information System (EFFIS) monitors forest fire activity in near-real time over non-cloudy areas and delivers fire risk estimate forecasts. EFFIS supports wildfire management at the national and regional level for European Union Member States and across the Middle East and North Africa. Its pre-operational counterpart, the Global Wildfire Information System, supplies similar information at a global level
- The European and Global Drought Observatories (EDO and GDO) provide drought-relevant information and early warnings and analyses. The service publishes short analytical reports (Drought News) in anticipation of an imminent drought.

As an example of the usefulness of CEMS for involved operators, between June and September 2022, the peak of the European wildfire season, the CEMS rapid mapping (RM) and risk and recovery mapping (RRM) modules were activated 50 times in the case of RM and 6 times in the case of RRM in order to assess the damage caused by wildfires in Europe.[89]

Also, other Copernicus services (in a limited number of cases) can provide relevant information and data for disaster and emergency management, such as the Copernicus CSS (only to authorized users), which is described in section 3.6 below on the migration challenge or CMEMS with ocean products that can help to develop early warning systems or services related to extremes and hazards.

In all previously mentioned examples of disasters, GNSS also plays a crucial role in search and rescue operations through the Galileo SAR Service, which is contributing to the Cospas-Sarsat MEOSAR programme. Specifically, Galileo provides a unique contribution via the provision of the Galileo Return Link Service (RLS), declared operational by the European Commission on 21 January 2020. RLS is a free-of-charge global service available to Cospas-Sarsat RLS-compatible beacons and it enables a communication link that relays return link messages (RLM) back to the originating beacon through the Galileo Navigation Signal in Space. The uniqueness of the RLS message resides in the fact that beacon owners receive the confirmation that their emergency rescue has been initiated and search and rescue teams know exactly where they are. By knowing this, thanks to Galileo RLS, users in distress are provided with the needed confidence to patiently wait for help, avoiding any risky operations.

If the Galileo SAR service is primarily intended to assist people in distress with no connectivity, Galileo and EGNOS also greatly contribute to the functioning of everyday emergency response solutions such as eCall. This service ensures rapid assistance to motorists involved in a collision anywhere within the European Union by automatically sharing, as soon as the call is initiated, the Galileo-derived incident location to the nearest public safety answering point. This substantially improves the existing accuracy provided by mobile network operators via network-based location solution (Cell-ID) technologies. By speeding up emergency response times

[89] Information Bulletin 163 - Exceptional mobilisation of Copernicus Emergency Management Service during the 2022 wildfire crisis | COPERNICUS EMERGENCY MANAGEMENT SERVICE

**EXHIBIT 21.** EXAMPLES OF RELEVANCE OF EU SPACE COMPONENTS SERVICES FOR THE DISASTER MANAGEMENT AND EMERGENCY RESPONSE CHALLENGE

| Component | Service | Relevance | Examples |
|---|---|---|---|
| GALILEO | Open Service | Significant | • Galileo SAR/Return Link Service (RLS) offers a free-of-charge global service available to COSPAS-SARSAT RLS compatible beacons. The new functionality enables a communication link that relays return link messages (RLM) back to the originating beacon, thus informing people in distress that emergency rescue has been initiated and search and rescue teams know exactly where they are<br>• Open Service and HAS in GNSS multi-constellation and multi-frequency increase the robustness and accuracy of the positioning, allowing emergency responses to be coordinated as efficiently as possible, helps rapid mapping, safe navigation of UAVs (such as those used by the new Copernicus EMS aerial component) or detect/assess earthquake magnitude; OS-NMA and CAS increase robustness to spoofing<br>• PRS with an encrypted navigation service for governmental authorized users and sensitive applications that require high continuity (for users such as fire brigade, health service, humanitarian aid, search and rescue or police, etc.) |
| | HAS | Significant | |
| | OS-NMA | Significant | |
| | CAS | Significant | |
| | PRS | Significant | |
| | SAR | Significant | |
| EGNOS | OS | Significant | • OS and EDAS offer real-time and free-of-charge improved GPS (GPS + Galileo in future) positioning service over Europe, used for mapping or navigation. |
| | SoL | Limited | |
| | EDAS | Significant | |
| Copernicus (Europe's eyes on Earth) | CLMS | Limited | • CEMS provides information for prevention, preparedness, response and recovery activities for different natural and human-made disasters and other humanitarian crises. The service includes an on-demand mapping and an Early Warning component, complemented by wildfire information services (EFFIS), Flood Awareness Systems (EFAS, GLOFAS and Global Flood Monitoring tool) and the Drought Observatories (EDO and GDO)<br>• As part of the CSS[a], for example, Support to European Union External Action assists non-European Union countries in situations of crisis or emerging crisis and can provide rapid, on-demand geospatial information for monitoring of events or activities outside Europe<br>• Various CMEMS[b] ocean products are helpful for the development of early warning systems or services that relate to extreme weather and hazards (e.g., sea surface temperature as a driver of hurricanes)<br>• C3S data and information, for example, helps to better understand extreme hydrometeorological events or the climate projections can foresee an increase in heavy rain events |
| | CMEMS | Significant | |
| | CAMS | Limited | |
| | C3S | Significant | |
| | CEMS | Significant | |
| | CSS | Significant | |
| | Copernicus data | Significant | |
| GOVSATCOM | | Significant | • Coordination of emergency response actors in communications-denied environment<br>• Early warning systems<br>• Satellite radio broadcasting for sharing emergency messages with population<br>• Smart emergency response vehicles<br>• Institutional support<br>• Civil-military operation<br>• RPAs/UAV surveillance<br>• Mission location support<br>• Support to multiple crisis management zones<br>• Intense density areas, assets surveillance<br>• Law enforcement support operations<br>• Search and rescue operations<br>• Pollution detection<br>• Response environmental monitoring<br>• Critical key infrastructure management |
| #EUSpace Synergies | | Significant | • EGNSS, Copernicus and GOVSATCOM complementarity; EU Space components contribute to all phases of the disaster/emergency management cycle |

[a] Only to authorized users and in a limited number of cases.
[b] In a limited number of cases.

● Limited relevance/contribution ⬤ Significant relevance/contribution

by 40 per cent in urban areas and 50 per cent in the countryside, it is estimated that eCall could help prevent 2,500 road deaths and save EUR 26 billion every year.[90]

In addition, Galileo PRS provides an encrypted navigation service for governmental authorized users and sensitive applications that require high continuity and the service more resistant to spoofing or jamming. PRS can give support to a range of European public safety and emergency services, including but not limited to fire brigades, health services (ambulance), humanitarian aid, critical infrastructure, search and rescue, police, coastguard, border control or civil protection units.

As explained in this chapter, when disaster strikes, public authorities rely on Copernicus to detect and monitor the evolving situation. On the ground, firefighters and emergency first responders use EGNSS to safely guide themselves or drones through the smoke, fog or flames. But what happens when an incident occurs where there are no ground stations, either because they were destroyed (e.g., during an earthquake) or because they never existed in the first place (e.g., in remote regions such as the Arctic)? Or what if the end users require secure communication? Such is the case during cyberattacks and other security-related incidents. For situations like these, there is GOVSATCOM, the fourth pillar of the EU Space Programme. For example, GOVSATCOM can be used for applications such as the coordination of emergency response actors in the communications-denied environment, early warning systems, satellite radio broadcasting for sharing emergency messages with the population or smart emergency response vehicles.

The relevance of the four EU Space components services (Copernicus, Galileo, EGNOS and GOVSATCOM) for the disaster management and emergency response challenge is assessed in exhibit 22, including examples of products and applicability for services with high relevance.

**EXHIBIT 22.** LIST OF EGNSS AND COPERNICUS APPLICATIONS ADDRESSING THE DISASTER MANAGEMENT AND EMERGENCY RESPONSE CHALLENGE

| MARKET SEGMENT | APPLICATION DOMAIN | EXAMPLES OF SPECIFIC APPLICATIONS |
|---|---|---|
| EMERGENCY MANAGEMENT AND HUMANITARIAN AID | Early warning | Early warning (Copernicus); GNSS-enabled ocean monitoring buoys (EGNSS) |
| | Post-event analysis | Post-event analysis (Copernicus) |
| | Preparedness | Preparedness (Copernicus) |
| | Rapid mapping | Rapid mapping (Synergetic) |
| | Search and rescue | Beacons for aviation (EGNSS); Beacons for maritime (EGNSS); Beacons on land (EGNSS) |
| MARITIME AND INLAND WATERWAYS | Ocean services | Metocean (meteorology over oceans, and offshore weather and sea state monitoring) (Copernicus) |
| INSURANCE AND FINANCE | Insurance for natural disasters | Event footprint (Copernicus); Risk modelling (Copernicus) |

● Copernicus application ● EGNSS application ◐ Synergetic application (combined use of Copernicus and EGNSS)

[90] Source: www.euspa.europa.eu/newsroom/news/ecall-2-years-saving-lives

### 3.5.4 Use cases

#### *Integrated holographic management map for safety and crisis events*

The need for higher-performance crisis planning and command tools and new methodologies arises from the increasing frequency and impact of a variety of natural hazards, including floods, earthquakes, droughts, landslides and wildfires that are responsible for fatalities, or displaced people and severe destruction and disruption of property and industry with a clear impact on the economy for years after the event. In Europe, 1,672 recorded disasters (floods, storms, wildfires, heatwaves) cumulated in 159,438 deaths and US$ 476.5 billion in economic damage from 1970 to 2019.[91]

The objective of the Horizon Europe OVERWATCH project is to develop an integrated holographic management system for response, recovery and mitigation of emergencies and disasters by enabling the authorities to quickly deploy and manage air, water and ground assets and personnel through decision support tools integrated in an immersive and decentralized command platform. This system will be supported by combining several services already offered by EGNSS and Copernicus with digital technologies, artificial intelligence, drones, 5G and augmented reality, which will provide the required performance to make this system a valuable resource for citizen, land and infrastructure protection.[92]

#### *A proof-of-concept for the implementation of a European Coastal Flood Awareness System*

Due to climate change and rising sea levels, weather-induced climate risks affecting coastal zones are expected to grow in number. Copernicus Earth observation data can support societies to better respond to weather-related emergencies. The European Union-funded H2020 ECFAS project demonstrated the technical and operational feasibility of a European Coastal Flood Awareness System. Technically, the ECFAS system has two components: the Early Warning System, and the Mapping Component. Both are based on cutting-edge technology and the best available data. The Early Warning System, based on Copernicus Marine Service data, can predict storm-triggering water levels up to three days in advance. The ECFAS Mapping Component was based on complex modelling using the ECFAS database of extreme events and test cases, which provided a catalogue of flood maps for most of the European coast. Leveraging satellite imagery, ECFAS has produced a novel tool for shoreline analysis and extraction as well as rapid mapping and risk and recovery mapping capabilities. The technical operational feasibility of the products has been demonstrated through a performance assessment of the service in selected test cases for past events, as well as in forecasting mode. The availability and accessibility of generated data and derived products has been assessed via specific consultation with involved coastal stakeholders and end users.

## 3.6 THE MIGRATION CHALLENGE AND THE ROLE OF EU SPACE

### 3.6.1 Introduction

Today, over 80 per cent of the world's migrants move between countries in a safe and orderly fashion. However, this means that the remaining 20 per cent do not. In the words of Secretary-General António Guterres: "We need more effective international cooperation and a more compassionate approach to migration. This means managing borders humanely, fully respecting the human rights and humanitarian needs of everyone […]. It means recognizing the value of pathways for regular entry for both migrants and host countries. And it means addressing the underlying drivers behind migration, including deep inequalities, and combating human smuggling and trafficking in people."[93]

For high-income countries between 2000 and 2020, the contribution of international migration to population

[91] Weather-related disasters increase over past 50 years, causing more damage but fewer deaths | World Meteorological Organization (wmo.int)
[92] https://overwatchproject.eu
[93] Secretary-General's remarks at the International Migration Review Forum | United Nations Secretary-General

**Fact**

Over the next few decades, **migration** will be the sole driver of population growth in high-income countries.

growth (net inflow of 80.5 million) exceeded the balance of births over deaths (66.2 million). Over the next few decades, migration will be the sole driver of population growth in high-income countries. By contrast, for the foreseeable future, population increase in low-income and lower-middle-income countries will continue to be driven by an excess of births over deaths.[94]

In 2020, there were 281 million international migrants, 135 million female, 146 million male.[95] Also, in 2020, 30.7 million people were internally displaced by conflict and violence and 9.8 million by natural disasters. The number is expected to increase as population grows, leading to unprecedented migration patterns. For example, at present, the vast majority of people who are moving because of the impacts of climate change are displaced within their own country. People and communities moving across borders due to the effects of climate change are smaller in numbers but face a critical legal protection gap. Since December 2020, Angolan citizens started crossing the border into Namibia in search of food, water, health care and employment because of the drought in their country.[96]

In November 2020, Honduras was hit by two consecutive hurricanes – Eta and Iota – which caused massive displacement and significant damage and destruction to crops and harvests. Families already facing economic hardship due to the COVID-19 pandemic and, in some cases poverty, saw their livelihoods undermined. Some 937,000 people in the country were newly displaced by disasters in 2020 and over 3 million people suffered from food insecurity. These adverse impacts of climate change have contributed to people's decisions to leave their homes and join the "migrant caravans" headed towards the north of the continent, crossing countries such as Guatemala and Mexico.[97]

In some cases, migrant smuggling comes into play, although the data are shrouded in considerable uncertainty. According to rough estimates, for 2016 there were more than 1.5 million. The revenues generated account for several billion USD for the smugglers. These numbers will rise as population increases and as conflict and socio-economic or environmental conditions create the necessary triggers.

### 3.6.2 Space and migration

Satellites can play an important role in tracking migration flows and provide data to feed early warning systems that can alert in advance of the onset of a trigger event. Researchers and involved operators increasingly rely on new data sources, such as mobile phones, social media and satellite imagery, to understand international migration and human mobility. Those "big data", once adequately analysed, complement information from traditional sources, such as national population censuses, surveys and administrative sources, and they are recognized by organizations such as the International Organization for Migration's Global Migration Data Analysis Centre, as "particularly promising for the study of migration-related phenomena". For instance, call records from mobile phones combined with satellite data can be used to map movements between cross communities[98] and to focus the delivery of humanitarian help where it is most needed. It is also a tool to assess informal settlements.

Concerning the smuggling of migrants, GNSS data can be used for tracking location and device history to uncover smuggling routes. Moreover, it is possible to use optical and radar satellite technology to locate vessels suspected to be engaged in people smuggling that often put the lives of migrants in danger.

[94] World Population Prospects 2022
[95] UN DESA Policy Brief No. 133: Migration Trends and Families | Department of Economic and Social Affairs
[96] Displacement in a Changing Climate: Localized humanitarian action at the forefront of the climate crisis - Mozambique | ReliefWeb
[97] Ibid.
[98] Migration Data Portal: Big data, migration and human mobility (migrationdataportal.org)

### 3.6.3 EU Space specific support

Specifically, satellite data provided by Copernicus and Galileo can address the migration challenge throughout its entire life cycle:

- Before the migration phenomenon:
  - In a long-term perspective, Copernicus data provide relevant information to support the prediction of future mass migration. For example, by providing vegetation, phenological and productivity indices, Copernicus contributes to determining the extent to which an area could support human life and predicting desertification, deforestation and the long-term effects of pollution and climate change. These predictive analyses can support policymakers in forecasting future emergencies and undertaking the needed mitigation measures in due time.
  - In a medium to short-term perspective, Earth observation and Copernicus data can contribute to preparing the stakeholders involved to put in place precautionary measures in the face of potential disasters. Indeed, although some geohazards or weather and climate-induced (e.g., floods, drought, landslide, tsunami, fires) and human-made disasters (e.g., hazardous material spills) can be precisely predicted or avoided, by combining multiple sets of information, satellite data can contribute to highlighting specific risks over given areas and thus support involved organizations (e.g., United Nations aid agencies, non-government organizations, national governments, military and the private sector) to address mission-critical disaster preparedness, for example, by pre-positioning emergency equipment and solutions, or taking anticipatory measures such as evacuations
- During the migration phenomenon, both EGNSS and Copernicus can assist the national, international and private organizations involved by providing the necessary humanitarian response, both in terrestrial and marine environments; and
- After the migration phenomenon, Copernicus data can contribute to the development of the intelligence information required to evaluate the effectiveness of the humanitarian response following migration-related events induced by, for example, natural disasters.

To refer to some practical examples, Copernicus Sentinel-1 and -2 satellites, possibly combined with very high-resolution data, provide radar and optical data that can identify and monitor migration routes, identify dwelling structures, including the temporary ones and overall enable applications such as refugee camps, population counting, human displacement monitoring, informal settlements mapping as well as mapping and management of refugee camps.

In this context, it is worth mentioning the GHSL (Global Human Settlement Layer) product of the Copernicus Emergency Management Service[99] that is supported by the Joint Research Centre (JRC) and the DG for Regional and Urban Policy (DG REGIO) of the European Commission, together with the international partnership GEO Human Planet Initiative.[100] GHSL provides open and free data and tools for assessing the human presence and settlements on the planet. This is in the form of built-up maps, population density maps and settlement maps. This information is generated with evidence-based analytics and knowledge using new spatial data mining technologies, also leveraging the Exposure Mapping (Copernicus GHSL), a new component in the Copernicus Emergency Management Service[101] intended to periodically produce global geospatial information on human settlements in the form of built-up area and population grids.

Since migration phenomena and humanitarian crises are sometimes induced by natural (e.g., floods, droughts, landslides, tsunami) or human-made disasters (e.g., hazardous material spills), Copernicus satellites and in situ data allow us to assess the expected impact of those phenomena and support preparedness-related activities, for example by pre-positioning emergency equipment and solutions or by implementing preparatory measures. The relevance of Copernicus data and services (in particular CEMS) to disaster management, emergency response and humanitarian aid challenges is further elaborated in section 3.5.2.

[99] Global Human Settlement - GHSL Homepage - European Commission (europa.eu)
[100] GEO Work Programme (earthobservations.org)
[101] https://ghsl.jrc.ec.europa.eu/copernicus.php

**EXHIBIT 23.** EXAMPLES OF RELEVANCE OF EU SPACE COMPONENTS SERVICES FOR THE MIGRATION CHALLENGE

### GALILEO

| Service | Relevance |
|---|---|
| Open Service | Significant |
| HAS | Limited |
| OS-NMA | Limited |
| CAS | Limited |
| PRS | Significant |
| SAR | Significant |

- Galileo SAR/Return Link Service (RLS) for fast localization, including the new functionality that informs the user that the alert has been detected and localized
- Open Service, for example, part of telematics solutions, navigating drones for rapid mapping, device location history to uncover smuggling routes or gathering crowdsourced location data to complement Earth observation data
- PRS with an encrypted navigation service for governmental authorized users that require high continuity such as fire brigade, health service, humanitarian aid, search and rescue or police

### Copernicus (Europe's eyes on Earth)

| Service | Relevance |
|---|---|
| CLMS | Limited |
| CMEMS | Limited |
| CAMS | Limited |
| C3S | Significant |
| CEMS | Significant |
| CSS | Significant |
| Copernicus data | Significant |

- CSS: Support to European Union External Action component can, for instance, provide refugee or internally displaced people (IDP) camp analyses that use a combination of new and past satellite imagery to measure and monitor the changes in the size and distribution of IDP or refugee camps. The main aim is to support accurate assessments of needs, in order to enable a proportional and adapted humanitarian response, but other questions, such as assessing the security and safety and the morphology of the camp, can also be addressed.
- CSS: The border surveillance component supports border management authorities in their efforts to assess risk and detect irregular migration and cross-border crime
- CSS: The Copernicus Maritime Surveillance (CMS) component provides customs or coast guard authorities with the monitoring, identification and early warning of potentially suspicious vessels involved in trafficking and smuggling
- CEMS, for example, can be activated for risk and recovery or rapid mapping to assess the situation in a refugee camp after a fire event
- C3S climate change data, in combination with other data such as socioeconomic contextual information can be used to understand, quantify and predict climate-induced migration flow effects

### GOVSATCOM

Relevance: Significant

Used as a common communication channel for various actors

- Management of refugee camps
- Support to asylum operations
- Support to emergency team/vehicles (e.g., reach back and local network capability)
- Land border surveillance (e.g., trafficking vehicles)
- Pre-frontier intelligence (e.g., illegal routes)
- Sea border surveillance (e.g., trafficking boats, tracking no AIS ships)
- Institutional and diplomatic support
- Cybersecurity (e.g., during migration operations)
- Support to multiple crisis management zones

### #EUSpace Synergies

Relevance: Significant

- EGNSS, Copernicus and GOVSATCOM complementarity. For example, EGNSS and GOVSATCOM support emergency vehicles and the team are supported by geo-intelligence derived from Earth observation data
- Some emerging applications, such as combining crowdsourced data from mobile phones, complementing Earth observation data

● Limited relevance/contribution ⬤ Significant relevance/contribution

Additionally, Copernicus provides a specific service by providing information in response to Europe's security challenges called Copernicus Security Service (CSS).[102] It improves crisis prevention, preparedness and response in three key areas:

- *Border surveillance*. Data from Earth observation satellites is combined with other surveillance sources, such as ship reporting systems and other intelligence, to support border management authorities in their efforts to assess risks and detect irregular migration and cross-border crime.
- *Maritime surveillance*. Supports users by providing a better understanding and improved monitoring of activities at sea that have an impact on maritime safety and security, fisheries control, marine pollution, customs and general law enforcement, as well as the overall economic interests of the European Union. Recognizing that human activity at sea is intrinsically dynamic, the service aims to provide timely, relevant and targeted Earth observation information to Member States and European Union bodies.
- *Support to European Union External Action* assists the European External Action Service and Member States' security stakeholders in crisis or emerging crisis situations, for instance, when undertaking peacekeeping operations, conflict prevention activities or assessing risks for global and trans-regional threats leading to destabilization. This service can provide rapid, on-demand geospatial information for monitoring events or activities outside Europe that may have implications for European and global security.

In addition, satellite data from Copernicus and EGNSS provide important support for humanitarian organizations in the field. For example, EGNSS being a core component of telematics applications, by enabling rapid mapping products to facilitate the deployment of aid and permitting the functioning of search and rescue beacons, it can permit the fast localization of unseaworthy ships carrying migrants and refugees.

Finally, GOVSATCOM can complement both Copernicus and EGNSS by underpinning a myriad of applications such as the management of refugee camps, support to asylum operations or land/sea border surveillance. GOVSATCOM can provide a common communication channel for various actors involved in the operation or processes.

The relevance of the four EU Space components services (Copernicus, Galileo, EGNOS and GOVSATCOM) for the migration challenge is assessed in exhibit 23, including examples of products or applicability for services with high relevance.

Exhibit 24 summarizes all the Copernicus and EGNSS applications – as presented in the *EUSPA EO and GNSS Market Report* – capable of tackling the migration challenge.

## 3.6.4 Use cases

### *Earth observation helps to understand, quantify and predict migration flows induced by climate change in Africa*

DeepCube – "Explainable AI pipelines for big Copernicus data" – is a three-year project funded by the Horizon 2020 programme of the European Union under the topic "Big data technologies and artificial intelligence for Copernicus".

The project unlocks the potential of Copernicus data, leveraging on advances in the fields of artificial intelligence and the Semantic Web. The ultimate goal of DeepCube is to address new and ambitious problems with high environmental and societal impact, enhance our understanding of Earth's processes that are correlated with climate change, and generate high business value.

DeepCube develops architectures that extend to non-conventional data and problem settings, such as Interferometric SAR, social network data and industrial data, and introduces a novel hybrid modelling paradigm for data-driven AI models that respect physical laws, opening-up the deep learning black box through explainable AI and causality.

The DeepCube technologies are showcased in six use cases:

- Forecasting of localized extreme drought and heat impacts in Africa
- Climate-induced migration in Africa
- Fire hazard short-term forecasting in the Mediterranean

[102] For more information: www.copernicus.eu/en/copernicus-services/security

**EXHIBIT 24.** LIST OF EGNSS AND COPERNICUS APPLICATIONS ADDRESSING THE MIGRATION CHALLENGE

| MARKET SEGMENT | APPLICATION DOMAIN | EXAMPLES OF SPECIFIC APPLICATIONS |
|---|---|---|
| EMERGENCY MANAGEMENT AND HUMANITARIAN AID | Migration and settlement | ● EO human displacement monitoring (Copernicus)<br>● Management of refugee camps (Copernicus)<br>● Population counting (Copernicus)<br>● Telematics for humanitarian aid (EGNSS) |
| | Post-event analysis | ● Post-event analysis (Copernicus) |
| | Preparedness | ● Preparedness (Copernicus) |
| | Rapid mapping | ● Rapid mapping (Synergetic) |
| | Search and rescue | ● Situational awareness supporting search and rescue (Synergetic) |
| MARITIME AND INLAND WATERWAYS | Vessel tracking | ● Dark vessel monitoring (Synergetic) |

● Copernicus application ● EGNSS application ● Synergetic application (combined use of Copernicus and EGNSS)

- Global volcanic unrest detection and alerting
- Deformation trends change detection for critical infrastructure monitoring
- Copernicus services for sustainable and environmentally-friendly tourism

Climate-induced displacement is a significant issue: 25 million displacements per year, 95 per cent from vulnerable regions.[103] Use case "Climate-induced migration in Africa" is focused on uncovering the underlying mechanisms of how changing climate conditions cause migration through modern observational causal inference models to understand, quantify and predict migration flow effects from socioeconomic contextual information, as well as from environmental variables extracted from Earth observation data.

There is a growing body of scientific evidence on the link between climate change, conflicts and forced migration. The issue is that this kind of cause-effect chain is not assessed empirically from reliable data or by employing rigorous advanced statistical tools. Currently, there is no theoretical approach that adequately represents the causal mechanisms through which climate change induces human displacement and migration flows. This climate-induced displacement problem needs to be tackled with advanced AI methods of regression, interpretability and causality.

This use case approaches the issue in three main steps, yielding a set of useful products: the harmonization of explanatory data from diverse Earth observation and non-Earth observation data sources; the derivation of causal graphs by the systematic characterization of data dependencies and deployment of causal inference methods; and the translation of causal graphs into explanatory narratives, storylines and prediction models taking into account only causally relevant features.[104]

[103] https://deepcube-h2020.eu/use-cases/climate-induced-migration-in-africa/
[104] https://deepcube-h2020.eu/

## *Earth observation in support of decision makers to increase urban resilience*

According to the United Nations 2018 Revision of World Urbanization Prospects,[105] in today's increasingly global and interconnected world, more than 55 per cent of the world's population lives in urban areas. By 2050, urbanization is expected to further increase by 66 per cent.[106] Under these circumstances, sustainable development challenges will increasingly concentrate in cities. This is where the SMURBS project comes in.

Under the umbrella of the ERA-PLANET Network,[107] the SMURBS project aims at setting the stage for the integration of still fragmented Earth observation resources to promote and coordinate the "smart city" concept into a European network of cities, serving the need for a common approach to enhance environmental and societal resilience to specific pressures. The project endeavours to increase urban resilience by targeting challenges with respect to air quality, urban growth, disasters and relevant impacts and more entangled issues such as the migration crisis and the health implications of such environmental pressures.

SMURBS leverages Copernicus and brings together different Earth observation platforms, namely in situ networks, satellites, state-of-the-art models and new technologies (e.g., UAVs, smart sensors), while also engaging citizens in collecting and sharing data. Its partners refocus their high degree of Earth observation expertise on the urban scale and set the stage to exploit synergies between the various Earth observation resources. The project maps "what is already out there" and "what the users want" to stimulate strategic planning and decision-making by key stakeholders. To sum up, SMURBS unfolded the full range of technologically available methods for the next generation of urban monitoring capacities and high-resolution city-scale modelling focusing on the following applications: air quality and health, urban growth and migration.

- *Migration.* The SMURBS project explores a novel field: Earth observation supporting certain aspects of the European migrant crisis. The vulnerability of refugee hotspots and hosting campuses to natural and human-made disasters will be at the epicentre of SMURBS efforts, contributing to the current lack of concrete criteria for location appropriateness. The project strives to identify patterns and processes in support of decision makers to prepare for, withstand and respond faster to the increasing migration process.[108]
- *Urban growth.* SMURBS exploits the capacity provided by the Copernicus Land Monitoring Service and the Sentinel-2 mission, as well as the availability of high- and very high-resolution imagery to define updated urbanization indicators, to adopt state-of-the-art classification schemes and to develop urban metrics for efficient city management methods, addressing soil sealing and the urban sprawl phenomenon.
- *Air quality and health.* The seamless bridging of regulatory networks with IoT/smart sensors and supersites is the direction that SMURBS engages in to deliver, inter alia, monitoring of pollutants of emerging importance (e.g., PM1, black carbon) and near real-time source apportionment. New advances, like monitoring the oxidative potential of aerosol in urban environments, in conjunction with supplementary health indicators, are being utilized to delineate cause-effect relations. Moreover, the exploitation and contribution of Copernicus Atmosphere Monitoring Services will further support the air quality objectives.

[105] www.un.org/development/desa/publications/2018-revision-of-world-urbanization-prospects.html
[106] Demographic Trends and Urbanization, World Bank Group, 2020. https://documents.worldbank.org/en/publication/documents-reports/documentdetail/260581617988607640/demographic-trends-and-urbanization
[107] www.era-planet.eu/
[108] https://smurbs.eu/

# 3.7 THE URBANIZATION CHALLENGE AND THE ROLE OF EU SPACE

## 3.7.1 Introduction

According to Secretary-General António Guterres "Cities are central to virtually every challenge we face – and essential to building a more inclusive, sustainable and resilient future. They have been at the front line of the COVID-19 pandemic. As we look to recover, promoting more inclusive, gender-responsive urban infrastructure and services will be critical to give all people – especially young people, women and girls – access to a better future". Today more than 55 per cent of the world population lives in urban areas, however, this amount is expected to rise significantly and, by 2050, two out of three people on Earth will live in cities. Currently, the world's cities occupy just 3 per cent of the Earth's surface, but account for 60–80 per cent of energy consumption and 75 per cent of carbon emissions.[109]

According to data from 2018, by 2030, the world will have 43 megacities, each with over 10 million inhabitants, and most of them in developing regions. However, some of the fastest-growing urban agglomerations are cities with fewer than 1 million inhabitants, many of them located in Asia and Africa. While one in eight people live in 33 megacities worldwide, close to half of the world's urban dwellers reside in much smaller settlements with fewer than 500,000 inhabitants.[110]

**Fact**

World's cities occupy just **3%** of the Earth's land, but account for **60-80%** of energy consumption and **75%** of carbon emissions.

However, challenges remain and, in 2020, data from 1,510 cities around the world indicate that on average only about 37 per cent of their urban areas are served by public transport, measured as a walking distance of 500 m to low-capacity transport systems (such as buses and trams) and/or 1,000 m to high-capacity systems (such as trains and ferries).[111] Furthermore, access to health-care or education centres, the need of waste management solutions adapted to population growth or increase in air pollution are challenges that need to be addressed as the population of the cities surges. Those challenges represent even a bigger burden for disabled people. According to the United Nations, approximately 15 per cent of the world's population lives with some form of disability. Considering that these figures are expected to increase even further in the future due the fact that disabilities are often associated with age and that life expectancy overall is increasing, predictions suggest that around 1 billion disabled individuals will be living in urban centres by 2050. Available evidence reveals a widespread lack of accessibility for disabled persons in built environments, from roads and housing to public buildings and spaces and to basic urban services such as education, transportation, emergency and disaster response, access to information and communications.

Each of those is a complex issue per se, with different driving factors and each requires a complex analysis. In some cases, the trend is driven by the increase in population: for example, if everyone in the world generated waste at the current average OECD per capita rate (data from 2020), total world waste generation would rise to 4.2 billion tons. This could equate to around 42 billion cubic metres of municipal solid waste each year.[112] Although there has been a decrease in the generation of waste per capita in

[109] GOAL 11: Sustainable cities and communities | UNEP - UN Environment Programme
[110] 68% of the world population will be living in urban areas by 2050, according to UN | UN DESA | United Nations Department of Economic and Social Affairs
[111] — SDG Indicators (un.org)
[112] ES_W&S_2010_print (colours)_ES_Slums_28/8 (unhabitat.org) and Waste - Municipal waste - OECD Data

OECD countries, total waste generation has increased from 652,000 tons in 2000 to 732,000 tons in 2020, with population growth driving the trend, although the relationship is not linear. In other cases, policy mechanisms can decouple from population growth. For what concerns air pollution, the impact of population growth is unclear, as there are countries where population growth and air pollution produced opposite trends.[113,114,115]

### 3.7.2 Space and urbanization

The increasing availability of satellite imagery is now allowing service providers and researchers to use standardized approaches to define, measure and compare urban areas globally. For example, scientists have developed approaches based on night-time lights – the artificial light sources visible in satellite images taken at night – to map and measure human settlements. A new approach, developed by the European Commission, the World Bank, OECD, UN-Habitat and FAO, has been endorsed by the United Nations Statistical Commission in March 2020. This method, called the "degree of urbanization", combines census data with a map of built-up areas derived from satellite imagery to produce a population distribution map for the globe. Criteria based on population size and density are then applied to delineate cities, towns, suburbs and rural areas on the map.[116]

This data set is extremely useful and can complement others that provide insights for data-driven policymaking. Earth observation data permit the measurement of subsidence in urban areas, urban growth and provide assistance for urban planning to name a few applications and, when combined with positioning data, lead to road usage, traffic estimates and enable the possibility of measuring the effect of policy measures (e.g., COVID-19 lockdown) sometimes by means of new detection methods.[117]

Another example of a data set to assist decision makers in the allocation of resources is the one developed by UNICEF Innovation, which is building a tool using high-resolution satellite imagery and applying deep learning techniques to map every school in the world. The data generated and visualized through an online platform will help identify where the gaps and information needs are, serve as evidence when advocating for connectivity and help national governments optimize their education systems.

In short, satellite data can help cities to become more resilient, sustainable and safe for their citizens, to ensure their capability to address the problems associated with urbanization, such as high population density, unsafe infrastructure, pollution, slum creation and congestion.

### 3.7.3 EU Space specific support

In the context of the urbanization challenge, EU Space data can provide valuable support in fulfilling the following needs:

- Up-to-date and reliable information to ensure the appropriate decision-making around urban planning and the related interventions so as to ensure a balance between short-term needs and the long-term desired outcomes of a competitive economy, high quality of life and sustainable environment
- Satellite data and services capable of ensuring the development of solutions that improve the cities operations with regard to the provision of basic services and make citizens lives better

For example, Urban Atlas,[118] a local component of the Copernicus Land Monitoring Service (CLMS), provides urban planners and decision makers with reliable baseline information about land use and urban development patterns (useful for cross-country or cross-region comparison). Such a product has been available since 2006 and its latest version provides very high-resolution pan-European land cover and land-use data generated for cities and surroundings according to the functional urban areas for the EU27, EFTA countries, the West Balkans, Türkiye and the United Kingdom.

[113] Frontiers | Does the New Urbanization Influence Air Quality in China? (frontiersin.org)
[114] Air pollution levels rising in many of the world's poorest cities (who.int)
[115] acp-2021-739.pdf (copernicus.org)
[116] Using Satellite Imagery to Measure Urbanization | PennIUR (upenn.edu)
[117] Imprints of COVID-19 Lockdown on GNSS Observations: An Initial Demonstration Using GNSS Interferometric Reflectometry - Karegar - 2020 - Geophysical Research Letters - Wiley Online Library
[118] The service is available at https://land.copernicus.eu/local/urban-atlas

The extensive amount of reliable data provided under the Urban Atlas product allows public authorities and planners to better understand changes, pressures and needs within urban communities and thus, more adequately plan. Many local, national and supranational authorities are currently using the CLMS Urban Atlas to monitor and evaluate various kinds of developments, such as the spatial extent and distribution of residential buildings, logistics hubs and industrial parks or retail areas. For example, the City of Prague leveraged Copernicus to gain a more realistic picture of land-use development over time.[119] Such comparisons showed the trends in development and provided guidelines for future planning policies.

On a global scale, the GHSL (Global Human Settlement Layer) component of CEMS, which was already mentioned in the section related to the migration challenge, helps to improve the collective understanding of the process of urbanization. GHSL provides key resources such as open and free data, visualization and tools related to the degree of urbanization, population and settlement analysis. Since 2021, Exposure Mapping (Copernicus GHSL) has been introduced as a new CEMS component that produces global geospatial information on human settlements in the form of built-up area and population grids.

With reference to the second need, Copernicus and especially the positioning capability provided by Galileo effectively empowers many solutions that support local authorities and private companies in providing efficient and cost-effective services and overall make the lives of citizens easier. City managers are indeed increasingly seeking to use space data solutions to achieve climate-neutrality and climate-resilience targets with Copernicus and Galileo enabling applications in the field of:

- *Environmental monitoring.* Copernicus is being used with Galileo to monitor the air quality in cities or to support urban greening applications.
- *Smart cities operations.* Galileo is being used to ensure efficiency in streetlight and waste management.
- *Infrastructure planning.* Copernicus provides the foundation of all the technical analyses needed before building given infrastructure such as bridges, pipelines or buildings (e.g., related to permits, site selection or vulnerability). This is extremely relevant in cities developing at fast pace or in old cities that have been developed in an uncontrolled manner in the past.
- Galileo is a key component of city telecommunication infrastructure, allowing for efficient timing and synchronization of telecommunications networks.
- Satellite-based technologies also offer a fundamental contribution to the preservation and sustainable management of cultural heritage sites.

Equally, if not more importanty, Galileo and Copernicus enable many applications in the consumer solutions and tourism and health domain capable of facilitating our way of living in cities that are set to become more and more densely populated. Navigation and tracking services enabled by Galileo have become fundamental tools which enable efficient and sustainable commuting, transportation and delivery of goods between different places. Galileo is also a pivotal component of safety- and health-related tools and applications such as eCall, emergency numbering such as 112 and mHealth devices. Finally, many businesses also rely on EU Space data to set up workforce management schemes.

The relevance of the four EU Space components services (Copernicus, Galileo, EGNOS and GOVSATCOM) for the urbanization challenge is assessed in exhibit 25, including examples of products and applicability for services with high relevance.

[119] Source: The ever-growing use of Copernicus across Europe's regions - A selection of 99 user stories by local and regional authorities, NEREUS, EC, ESA 2019.

**EXHIBIT 25.** EXAMPLES OF RELEVANCE OF EU SPACE COMPONENTS SERVICES FOR THE URBANIZATION CHALLENGE

| Component | Service | Relevance | Examples |
|---|---|---|---|
| GALILEO | Open Service | Significant | • Open Service in GNSS multi-constellation and multi-frequency positioning increases the performance of augmentation techniques such as RTK or PPP-RTK, used for a myriad of applications such as mapping, GIS or cadastre measuring but also provides precise T and S for telco incl. 5G but is also enabler of eCall and 112<br>• OS-NMA and CAS increase robustness to spoofing to various applications, including autonomous urban robots<br>• HAS will offer global and free-of-charge 20cm high-accuracy positioning service for applications such as navigation of UAVs, GIS mapping, asset management or location-based services |
| | HAS | Significant | |
| | OS-NMA | Significant | |
| | CAS | Significant | |
| | PRS | Limited | |
| | SAR | Limited | |
| EGNOS | OS | Significant | • OS and EDAS offer real-time and free-of-charge improved GPS (GPS + Galileo in future) positioning service over Europe, used for GIS mapping or asset management |
| | SoL | Limited | |
| | EDAS | Significant | |
| Copernicus (Europe's eyes on Earth) | CLMS | Significant | • CAMS provide daily analyses and forecasts of worldwide long-range levels and transport of atmospheric pollutants<br>• C3S, for example, provides climate data that can be downscaled for metropolitan areas to generate projections of urban heat island effect<br>• Sentinel-2 data is further applied to mapping green urban areas, urban sprawl, and classification of (urban) land use<br>• The European Ground Motion Service (EGMS) of CLMS or Sentinel-1 supports InSAR monitoring of urban infrastructures such as tunnels, bridges and roads, sewage collection systems, identifying potential displacement or ground motion<br>• CLMS with Urban Atlas provides harmonized landcover and land-use maps or information about the population of several hundreds of cities in the European Union and EFTA countries, as well as specialized products such as the "Small Woody Features" high-resolution layer |
| | CMEMS | Limited | |
| | CAMS | Significant | |
| | C3S | Significant | |
| | CEMS | Significant | |
| | CSS | Limited | |
| | Copernicus data | Significant | |
| GOVSATCOM | | Significant | • Communication services for local governments and institutional network management or telecommunications infrastructure monitoring<br>• Maintaining public order and ensuring public safety<br>• Welfare support (e.g., private communication support)<br>• Information assurance services<br>• Rail traffic management<br>• Intelligent transport systems allocation<br>• Machine to machine low data rate applications (e.g., IoT) |
| #EUSpace Synergies | | Significant | • EGNSS and Copernicus complementarity, e.g., in urban planning, various geo/GIS data layers that are either created using GNSS or Earth observation are be used |

● Limited relevance/contribution ⬤ Significant relevance/contribution

**EXHIBIT 26.** LIST OF EGNSS AND COPERNICUS APPLICATIONS ADDRESSING THE URBANIZATION CHALLENGE

| MARKET SEGMENT | APPLICATION DOMAIN | EXAMPLES OF SPECIFIC APPLICATIONS |
|---|---|---|
| AVIATION AND DRONES | Navigation | ○ Open drone navigation |
| CONSUMER SOLUTIONS, TOURISM AND HEALTH | Corporate | ◐ Mapping and GIS<br>○ Workforce management |
| | Health and lifestyle | ● Air quality monitoring<br>○ mHealth<br>○ Safety and emergency<br>○ Social networks<br>◐ Sport, fitness and wellness incl. specialist support tracking<br>● UV monitoring |
| | Navigation and tracking | ○ Navigation for smartphone users<br>○ Personal and asset tracking<br>○ Visually impaired support |
| | Robotics | ○ Consumer robotics |
| | Tourism | ○ Points of interest |
| INFRASTRUCTURE | Environmental monitoring | ● Environmental impact assessment of infrastructure |
| | Infrastructure planning | ● Permitting<br>◐ Site selection and planning<br>● Vulnerability analysis |
| | Infrastructure construction and monitoring | ◐ Construction operations<br>● Monitoring of impact of human activities on infrastructures<br>● Oda support monitoring<br>◐ Post-construction operations<br>◐ Pipeline monitoring |
| | Timing and synchronization of telecommunications networks | ○ Data centre<br>○ Digital cellular network (DCN)<br>○ Professional mobile radio (PMR)<br>○ Public switched telephone network (PSTN)<br>○ Satellite communication (SATCOM)<br>○ Small cells |
| RAIL | Attractiveness enhancement | ○ Passenger information systems<br>○ Public transport – tram and light rail |
| | Train driving optimization | ○ Rail fleet management |
| ROAD AND AUTOMOTIVE | Fleet management systems | ○ Bike-sharing<br>○ Public transport – buses<br>○ Road fleet management |
| | Smart mobility | ○ Navigation (IVS and PND)<br>◐ Congestion control |

*continued*

● Copernicus application ○ EGNSS application ◐ Synergetic application (combined use of Copernicus and EGNSS)

**EXHIBIT 26.** LIST OF EGNSS AND COPERNICUS APPLICATIONS ADDRESSING THE URBANIZATION CHALLENGE *(continued)*

| MARKET SEGMENT | APPLICATION DOMAIN | EXAMPLES OF SPECIFIC APPLICATIONS |
|---|---|---|
| URBAN DEVELOPMENT AND CULTURAL HERITAGE | Environmental monitoring | Air quality monitoring in urban environments<br>Urban greening<br>Urban heat islands |
| | Smart cities operations | Smart streetlights<br>Smart waste management |
| | Urban planning and monitoring | Cultural heritage monitoring<br>Informal dwellings<br>Real estate<br>Surveying and mapping<br>Urban modelling, 3D modelling, digital twins<br>Urban planning |

Copernicus application  EGNSS application  Synergetic application (combined use of Copernicus and EGNSS)

## 3.7.4 Use cases

### *Enabling innovative space-driven services for energy-efficient buildings and climate resilient cities*

The Horizon Europe BUILDSPACE project aims to couple terrestrial data from buildings (collected by IoT platforms, BIM solutions and others) with aerial imaging from drones equipped with thermal cameras and location annotated data from satellite services (i.e., EGNSS and Copernicus) to deliver innovative services for building and urban stakeholders and support informed decision-making towards energy-efficient buildings and climate resilient cities.

The platform intends to allow integration of these heterogeneous data and will offer services at the building scale, enabling the generation of high fidelity multi-modal digital twins and at the city scale, providing decision support services for energy demand prediction, urban heat and urban flood analysis. The services will enable the identification of environmental hotspots that increase pressure on local city ecosystems and raise the probability of disasters (such as flooding) and will issue alerts and recommendations to local governments and regions for action (such as the support of policies for building renovation in specific vulnerable areas).

BUILDSPACE services will be validated and assessed in four European cities with different climate profiles. The digital twin services at building level will be tested during the construction of a new building in Poland, and the city services validating the link to digital twins of buildings will be tested in three cities (Piraeus, Riga, Ljubljana) across the European Union. BUILDSPACE will create a set of replication guidelines and blueprints for the adoption of the proposed applications in building resilient cities in general.[120]

### *Decision toolbox for cities to improve air quality, biodiversity and human well-being, and reduce climate risks by planting more trees in our cities*

Rapid urbanization often triggers serious problems: poor air quality, noisy surroundings and lack of recreational spaces are among the biggest issues for the urban population. Many cities have indeed few green areas and consist of too much "concrete jungle" which makes for a harsh environment for all living things. With the changing climate, the weather is expected to become more extreme.

One such effect will be urban heat islands, which will be even more profound, with heatwaves expected to increase 3 to 10-fold by 2100 in many regions throughout midlatitudes, even if the Paris Agreement goal of limiting

[120] Enabling Innovative Space-driven Services for Energy Efficient Buildings and Climate Resilient Cities | EU Agency for the Space Programme (europa.eu)

global warming to 2°C is met.[121] A way of tackling all these issues is to plant more trees within the urban fabric – a well-recognized and relatively cheap and efficient measure for cities to adapt to future climatic challenges.

In view of this, the ambition of the Horizon Europe 100KTREEs project is to make cities better and healthier places to live by encouraging municipalities to plant more trees and optimize the impact of tree planting. The team will support cities by mapping the existing trees and by showing a solid business case for planting new trees, as well as attracting third-party sponsorship to make it happen.

100KTREEs will develop a mapping and modelling toolbox to optimize the planting of trees and to monitor the health of the trees, based on Copernicus and in situ data. By assigning monetary value to the key attributes of a tree, e.g., pollution absorption, cooling effects, noise abatement, flood risk reduction and increased biodiversity, a number of business cases will be developed for our two partner cities, Copenhagen and Sofia. Such business cases will also be used to attract third-party financing. By means of a crowd science app, the project will engage with citizens and create awareness of the wonders of trees, also extending to improved life quality and mental health impacts.[122]

## 3.8 THE ENERGY CHALLENGE AND THE ROLE OF EU SPACE

### 3.8.1 Introduction

As population grows, the use of energy will increase, in fact, the energy consumption rate has already increased 67 per cent in the period 1990–2019,[123] approximately 15 per cent more than the increase in population over the same period. Since the second industrial revolution, modern society has become more and more dependent on electricity and, in turn, the use of electric power has enabled accelerated development. In the 2030 Agenda for Sustainable Development, adopted in 2015, energy is covered by SDG 7, "Affordable and Clean Energy", laying out clear targets on energy efficiency, reliability, research, infrastructure and, the use of renewable sources of energy to be achieved by 2030. Emphasis is made on renewable energy by Secretary-General António Guterres "Fossil fuels are a dead end – for our planet, for humanity, and yes, for economies. A prompt, well-managed transition to renewables is the only pathway to energy security, universal access and the green jobs our world needs", linking the transition to renewables to energy security. Therefore, this challenge is dual, not only is there the need for more energy, as energy demands grow faster than the population increase, there is also the need for more renewable energy to reduce emissions and mitigate climate change.

*"Fossil fuels are a dead end – for our planet, for humanity, and yes, for economies."*

António Guterres,
Secretary-General of the United Nations

Currently 91 per cent of the world population has access to electricity but only 18 per cent of the total final energy consumption comes from renewable sources.[124] It is worth noting that between 2010 and 2020, every region in the developing world showed consistent progress in electrification. Sub-Saharan Africa remained the least electrified region. Among people without access to electricity, around 75 per cent – about 568 million people – lived in sub-Saharan Africa in 2020. Electricity access in that region rose from 46 per cent in 2018 to 48 per cent in 2020, an annual growth rate of one percentage point.[125]

[121] Probabilistic projections of increased heat stress driven by climate change | Communications Earth and Environment (nature.com)
[122] Decision Toolbox for cities to improve air quality, biodiversity, human wellbeing and reduce climate risks by planting more trees in our cities | EU Agency for the Space Programme (europa.eu)
[123] 2019 Energy Statistics Yearbook (un.org)
[124] SDG 7 progress
[125] sdg7-report2022-executive_summary.pdf (esmap.org)

### 3.8.2 Space and energy

Earth observation and Global Navigation Satellite Systems are able to support rural electrification planning, renewable energy resource assessment, distributed generation, and grid operation and reliability among others. There are many existing applications for space-based data, such as the use of night-time lights imagery for estimations of rural electrification, Earth observation-derived normalized difference vegetation index (NDVI) products for vegetation monitoring for overhead transmission line management, solar radiance or sea currents/waves data for renewable energy project planning, monitoring and operations, and nowcasting for extreme weather events and other disaster monitoring which can hinder energy production. These and other applications can enhance energy security through improved governance of and access to modern and reliable electricity, renewable energy management, and disaster risk assessment in developing nations, paving the way for more sustainable social and economic development.[126]

### 3.8.3 EU Space specific support

The world is set to face several energy-related issues in the upcoming years. Among these, the two major ones relate to an energy supply shortage and the environmental impact associated with conventional energy sources.

In this respect, the European Green Deal has already accelerated the use of renewable energy, the diversification of energy supplies and a reduced dependency on fossil fuel markets (in particular, oil and gas). In addition, in response to the global energy market disruption, the European Commission presented the RePowerEU Plan[127] on 18 May 2022, which addresses the Union's green ambitions through energy savings, diversification of energy supplies, and accelerated roll-out of renewable energy to replace fossil fuels in homes, industry and power generation. In this context, the Commission proposed to increase the headline 2030 target for renewables from 40 per cent to 45 per cent under the ''Fit for 55" package.[128]

To this end, EGNSS and Copernicus play a role in many applications related to renewable energy. For example, EU Space data and services can be used to identify optimal sites for renewable energy and to assess the energy output potential – one of the first steps to undertake when planning solar and wind power plants or marine renewable energy installations that is essential for defining the viability of a project. In this domain, Copernicus provides a wealth of data (from past, current and forecasts) about solar radiation, wind, ocean waves, currents and temperature but also other variables useful for maintenance, such as information about dust and aerosol or pollen. Copernicus data and information can also support hydropower utilities by assessing future reservoir levels or river flows from snow and ice products.

Copernicus and EGNSS can also support biomass production monitoring and allow the tracing of biomass along the value chain. Reflected GNSS (GNSS-R) signals also have potential in the energy domain. For example, by producing scatterometry models also in the presence of challenging atmospheric conditions such as clouds and rain, GNSS-R is employed to determine ocean roughness, wind speed and wind direction, thus supporting logistical planning in offshore energy.[129]

In addition, satellite technologies can assist various stakeholders such as governmental authorities, energy and utility companies, energy traders, supply chain managers and mining companies in undertaking many energy-related tasks and analyses. To mention some, EGNSS and Copernicus can be employed within energy network fidelity applications to contribute to the monitoring of critical infrastructures such as energy networks. In particular, Galileo provides accurate and secure timing and synchronization for phasor measurement units (PMU) – an emerging technology that is essential for various smart grid applications.

Furthermore, Copernicus and EGNSS assist other directly or indirectly energy-related segments and their applications along their entire life cycle, such as the oil and gas and mining industry: from site selection planning to mine surveying applications. For example, augmented GNSS solutions leveraging the Galileo signal enable the accurate guidance of heavy mining machinery, while thanks to its capacity to detect landscape changes, Copernicus

[126] Frontiers | Using Earth Observation to Help Developing Countries Improve Access to Reliable, Sustainable, and Modern Energy (frontiersin.org)
[127] https://ec.europa.eu/commission/presscorner/detail/en/IP_22_3131
[128] https://ec.europa.eu/commission/presscorner/detail/en/IP_21_3541
[129] https://www.ion.org/publications/abstract.cfm?articleID=12373

also supports governmental authorities in monitoring illegal mining activities, while also, over Europe providing ground motion data and land-use/land cover data to inform impact assessments.

Also, in an urban environment, satellite data can support smart city operations such as smart streetlights, in which low-cost GNSS receivers can support the remote management of those lights for more efficient operation.

Finally, GOVSATCOM can play an essential role in the energy segment, enabling remote control of renewable energy plants and underpinning applications such as energy network operation and (conditions) monitoring used by grid or renewable energy operators.

The relevance of the four EU Space components services (Copernicus, Galileo, EGNOS and GOVSATCOM) for the energy challenge is assessed in exhibit 27 below.

**EXHIBIT 27.** EXAMPLES OF RELEVANCE OF EU SPACE COMPONENTS SERVICES FOR THE ENERGY CHALLENGE

| Component | Service | Relevance | Examples |
|---|---|---|---|
| GALILEO | Open Service | Significant | • Open Service already provides very accurate T and S that can be used for PMU in smart grids or positioning during the construction phase (construction surveying)<br>• OS-NMA and CAS increase the robustness against spoofing of T and S in (smart) grids<br>• HAS provides high-accuracy positioning for UAVs that can be used for mapping, inspection, etc. |
| | HAS | Limited | |
| | OS-NMA | Significant | |
| | CAS | Significant | |
| | PRS | Limited | |
| | SAR | Limited | |
| Copernicus (Europe's eyes on Earth) | CLMS | Significant | • CAMS, for example, provides solar radiation data important for site selection, energy potential estimation, planning and operating of solar installations; Also, information about dust and pollen for maintenance<br>• CMEMS, for example, provides data about ocean waves, ocean currents or temperature useful for marine renewable energy<br>• C3S Energy operational service delivers key information about climate-related indicators relevant for the energy sector<br>• CLMS, for example, Copernicus Digital Elevation Model (DEM) or information about land use/landcover useful for renewable energy impact assessments, as well as the European Ground Motion Service |
| | CMEMS | Significant | |
| | CAMS | Significant | |
| | C3S | Significant | |
| | CEMS | Significant | |
| | CSS | Limited | |
| | Copernicus data | Significant | |
| GOVSATCOM | | Significant | • Remote control of renewable energy plants<br>• Energy network operation and (conditions) monitoring for grid operators or renewable energy<br>• Institutional and diplomatic support<br>• Civil-military interaction (e.g., protection of key energy infrastructures)<br>• RPAs/UAV surveillance<br>• Mission location support<br>• Support to multiple crisis management zones<br>• Support to emergency team/vehicles (e.g., reach back and local network capability) |
| #EUSpace Synergies | | Significant | • EGNSS, Copernicus and GOVSATCOM complementarity, e.g., EGNSS for secure and reliable T and S in smart grid, GOVSATCOM can provide a backup system for the terrestrial network or enable remote control of wind farms, while boosting the interconnectivity and digitization of power grids, Copernicus then can be used to assess energy potential, and supply and demand |

● Limited relevance/contribution ⬤ Significant relevance/contribution

**EXHIBIT 28.** LIST OF EGNSS AND COPERNICUS APPLICATIONS ADDRESSING THE ENERGY CHALLENGE

| MARKET SEGMENT | APPLICATION DOMAIN | EXAMPLES OF SPECIFIC APPLICATIONS |
|---|---|---|
| ENERGY AND RAW MATERIALS | Energy network fidelity | ● Energy network conditions monitoring<br>● Phasor measurement units (PMU) |
| | Market intelligence | ● Supply chain insights |
| | Renewable energy | ● Power plant design optimisation<br>● Renewable energy assessment potential and forecast<br>● Risk assessment for energy assets |
| MARITIME AND INLAND WATERWAYS | Ocean services | ● Metocean (meteorology over oceans, and offshore weather and sea state monitoring) |

● Copernicus application ● EGNSS application ● Synergetic application (combined use of Copernicus and EGNSS)

## 3.8.4 Use cases

### *Renewable energy sources power forecasting and synchronization for smart grid networks management*

Renewable energy sources (RES) play a major role in the transformation to a climate-neutral economy. Their integration into the power grid is pivotal to the green transition and to the decarbonization of the energy sector. However, as the most used RES (solar, wind and hydropower) are also weather-dependent, their power generation capacity varies according to the local microclimatic conditions.

This power production variability makes RES challenging to integrate into the power grid and to provide seamless, stable and secure amounts of power. On the other hand, power demand also affects the power grid operation, since there must always be a supply/demand balance in the power grid. Grid power imbalances can cause frequency fluctuations and other unwanted transient phenomena, which can compromise grid stability and operation. For that matter, advanced grid monitoring techniques have been developed, employing phasor measurement units (PMUs) to measure the electrical signals in a precise and synchronized way, based on a reliable timing reference.

The Horizon Europe RESPONDENT project comes to address the challenges of RES power generation forecasting, demand forecasting, smart power grid monitoring and supply/demand balancing. An AI/ML RES power generation forecasting algorithm is proposed, exploiting both Copernicus and site-specific weather data, along with renewable energy power conversion models. Furthermore, an AI/ML – Multiphysics model for the power demand of certain communities is also developed. Lastly, RESPONDENT will build a Galileo-enabled PMU and develop a monitoring module to test and verify the advantages the Galileo timing and synchronization services offer in smart grid monitoring, power balancing and overall operation.[130]

### *A dedicated solution for electrical power network maintenance and upgrade*

Access to electricity is a big challenge worldwide, affecting 775 million people.[131] Also, according to the International Energy Agency (IEA), the number of people around the world who live without electricity is set to rise by nearly 20 million in 2022, the first global increase since IEA began tracking the numbers 20 years ago. IEA stated that the rise is mostly in sub-Saharan Africa, where the number of people without access is nearly back to its 2013 peak.

[130] Renewable Energy Sources Power FOrecasting and SyNchronisation for Smart GriD NEtworks MaNagementT | EU Agency for the Space Programme (europa.eu)
[131] www.iea.org/commentaries/for-the-first-time-in-decades-the-number-of-people-without-access-to-electricity-is-set-to-increase-in-2022

Nowadays, emerging countries face a pre-existing infrastructure whose topology is unknown and request new technologies to support them for maintenance and planning of new deployment.

In this context, the H2020 AMPERE (Asset Mapping Platform for Emerging countRies Electrification) project aims at providing an important contribution to decision makers and stakeholders, planning cost-efficient maintenance and new affordable strategies.

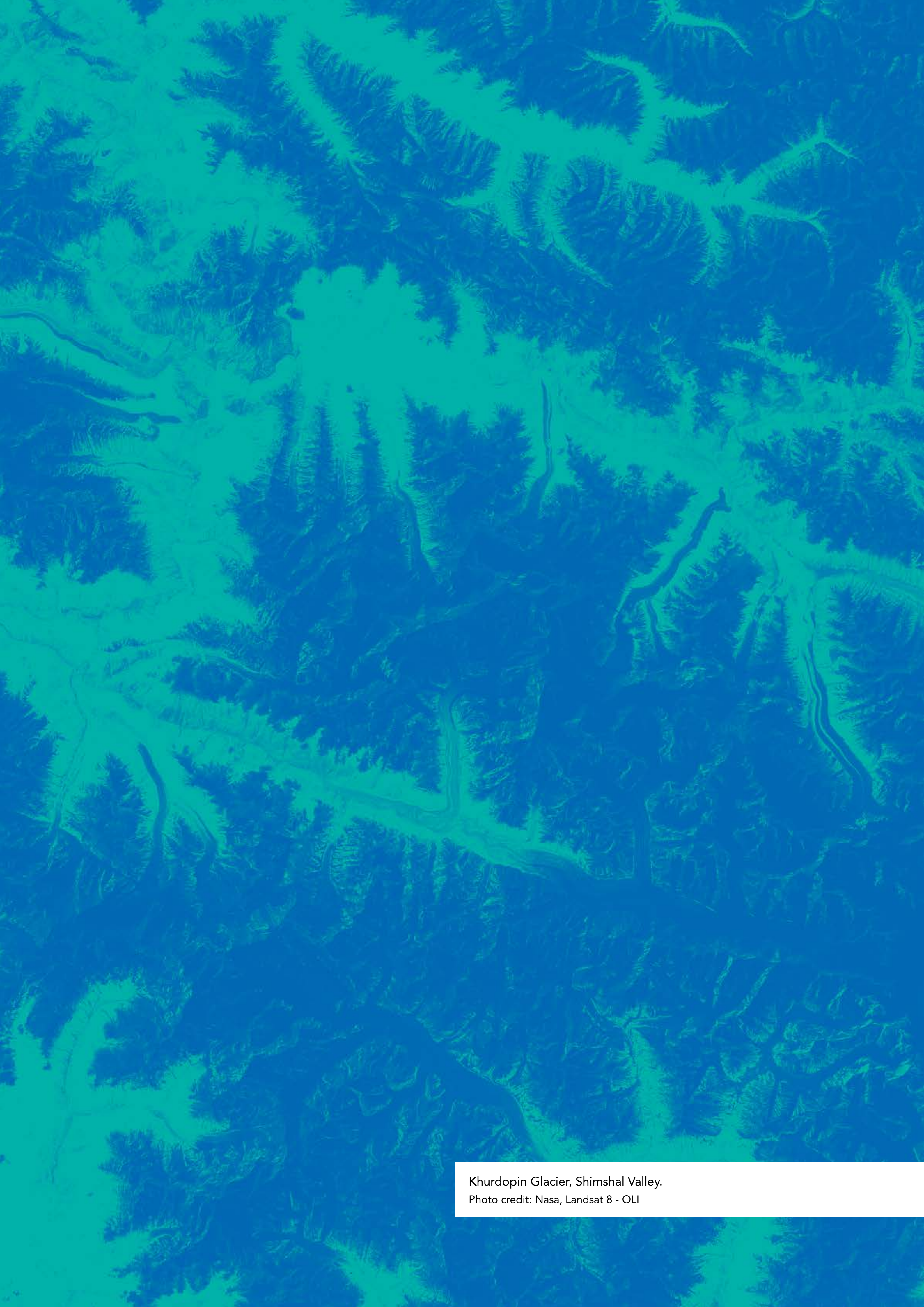
The purpose of the AMPERE project is to provide a dedicated solution for electrical power network information gathering. It will support decision-making actors (e.g. institutions and public/private companies in charge of managing electrical networks) to collect all the information needed to plan electrical network maintenance and upgrade.

Indeed, the challenge facing such communities goes beyond the lack of infrastructure assets. What is needed is a mapping of already deployed infrastructure (not known) to perform a holistic assessment of the energy demand and its expected growth over time.

AMPERE proposes a solution based on a GIS Cloud mapping technology, collecting on field data acquired with optical/thermal cameras and LiDAR installed on board a remote piloted aircraft (RPA). An RPA will be able to fly over selected areas performing semi-automated operations to collect optical and thermal images as well as 3D LiDAR-based reconstruction products. Such products are post-processed at the central cloud GIS platform, allowing operators to plan and monitor activities by means of visualization and analytics tools that can resolve data accessibility issues and improve the decision-making process. In such a context, EGNSS represents an essential technology ensuring automated operations in a reliable manner and guaranteeing high performance.

These aspects confer to the AMPERE project a worldwide dimension, with European industry in the clear role of bringing innovation and know-how to allow network intervention planning with a limited afforded financial risk, above all for emerging non-European countries.[132]

[132] H2020 AMPERE (h2020-ampere.eu)



Khurdopin Glacier, Shimshal Valley.
Photo credit: Nasa, Landsat 8 - OLI

# 4. FINAL REMARKS

The world population has reached the 8 billion milestone. According to the current scenarios, the population will continue to grow in the coming years, reaching a peak of between 9 billion and 11 billion between 2050 and the end of the century. This increase in population creates challenges and opportunities which need to be addressed through the correct policies to ensure development while addressing the sustainability of activities of humankind. Space-based data and services can support the ''8 billion world" challenges and the successful implementation of the global agendas as described in this document.

The challenges have been derived from an analysis of the "Space2030" Agenda, in particular the objective 2 "Harness the potential of space to solve everyday challenges and leverage space-related innovation to improve the quality of life" and validated by independently establishing the links between the "Space2030" Agenda and other global agendas, namely the 2030 Agenda for Sustainable Development, the Sendai Framework Disaster for Disaster Risk Reduction 2015–2030, the Paris Agreement and the New Urban Agenda. Through this approach, eight challenges for an 8 billion world were determined:

1. Food security
2. Water management
3. Environmental impact and climate change
4. Disaster management and emergency response
5. Migration
6. Urbanization
7. Energy
8. Health

The challenges represented in this report correspond to those where the usage of space technologies, data and infrastructure can be maximized through the lens of the "Space2030" Agenda, and therefore, do not constitute an exhaustive list of challenges that the world faces.

This report continues the work carried out by UNOOSA and EUSPA (formerly GSA) to inform decision makers of the benefits of Earth observation, GNSS and satellite communications, and how these technologies can be leveraged through concrete examples and use cases. This document does not provide an extensive view, but an overview of what the current technologies are capable of.

Following the success of the report entitled *European Global Navigation Satellite System and Copernicus: Supporting the Sustainable Development Goals. Building Blocks towards the 2030 Agenda* published in 2018, UNOOSA and EUSPA signed a memorandum of understanding in March 2022 to continue the cooperation, shortly after the "Space2030" Agenda was adopted, enabling the possibility of creating a report to analyse the impact of selected technologies vis-à-vis the "Space2030" Agenda.

This report aimed to assess from both a descriptive viewpoint and by means of tangible use cases how the use of core space-based technologies, namely Earth observation, GNSS and SATCOM, and its EU Space components (Galileo, EGNOS, Copernicus and GOVSATCOM) support the challenges of a world hosting 8 billion people, through the overarching objective 2 of the "Space2030" Agenda, in line with the mandate given to the Office by its implementation plan in promoting and facilitating the use of space-based solutions, including in the implementation of the "Space2030" Agenda. The Office should continue, within its mandate, functions and existing resources to pursue partnerships, including with research institutions, academia, industry and the private sector, to provide broader opportunities to access space for purposes of science, innovation, research and development, education and capacity-building. In that regard, it should implement activities to promote the use of space-based applications and technologies to support Member States in meeting the objectives of the global development agendas.

It also aligns with the role of EUSPA in facilitating and promoting international industrial cooperation, supporting global scientific, academic and research activities, collaborating with other international agencies and entities to promote interconnectivity with other space systems, supporting non-European Union partner countries in developing a favourable ecosystem for EU Space components market uptake, monitoring and analysing the international EU Space components market and raising awareness of EU Space components through events, conferences and workshops across the globe.

For each of the sustainability challenges identified, a description of the challenge has been provided with a general description of the role of Earth observation, satellite communications and GNSS, followed by the analysis of their relevance in tackling the sustainability challenges. The analysis has been performed at two levels: first, at

**EXHIBIT 29.** EU SPACE COMPONENTS RELEVANCE AND CONTRIBUTION TO ''8 BILLION PEOPLE'' CHALLENGES

| SUSTAINABILITY CHALLENGE | GALILEO | EGNOS | Copernicus | GOVSATCOM | #EUSpace Synergies |
|---|---|---|---|---|---|
| Migration | Significant | Low | Significant | Significant | Significant |
| Environmental impact and climate change | Significant | Significant | Significant | Significant | Significant |
| Energy | Significant | Significant | Significant | Significant | Significant |
| Disaster management and emergency response | Significant | Significant | Significant | Significant | Significant |
| Urbanization | Significant | Significant | Significant | Significant | Significant |
| Food security | Significant | Significant | Significant | Low | Significant |
| Water management | Significant | Low | Significant | Significant | Low |
| Health | Significant | Low | Significant | Low | Significant |

*While the Health challenge was not detailed in this report – as plenty of health-related reports have been published recently – this challenge is analysed in this summary table for the sake of completeness, including examples of applications mentioned in this section.*

● Low relevance/contribution

⬤ Significant relevance/contribution

the EU Space components level, also including a focus on their specific services,[137] and secondly, at the application level, identifying Galileo, EGNOS, Copernicus and GOVSATCOM and their synergetic relevance and contribution to the ''8 billion world" challenges.

The overview of the relevance of EU Space components and its synergies is illustrated in the exhibit 29.

It has been determined that EGNSS and Copernicus support all seven challenges analysed in detail within this report, while GOVSATCOM contributes to six challenges. Although each of the EU Space components can contribute to the "8 billion challenges" separately, the full potential is unleashed due to synergies and complementarity:

*Food security.* A good example of synergies between the systems can be found when it comes to the food security challenge. In precision farming, georeferenced NDVI maps derived from Copernicus Sentinel images are combined with highly accurate Galileo-based machine positioning in variable rate application systems that make agriculture more resource-efficient and reduce its environmental impact. In this context, EGNSS and Copernicus provide farmers with the tools needed to maximize agricultural output.

*Water management.* The Space4Water portal maintained by UNOOSA and supported by PSIPW provides a good overview of what space can do for water management and it is an excellent entry point. EU Space data also proved to be relevant in addressing the water challenge: the data generated by Copernicus services CLMS, CMEMS and C3S provide the stakeholders involved with the fundamental intelligence needed to understand the Earth's water cycle and thus ensure the safe usage of water, both regarding the water intended for human consumption and the diffusion of harmful waterborne diseases such as Escherichia coli. GOVSATCOM, on the other hand, offers many solutions to ensure the continuity of water-related critical infrastructures.

*Environmental impact and climate change.* In particular, EU Space data and services have been assessed as useful in addressing a key challenge such as environmental and climate change where the possibility to perform spatio-temporal analyses enable relevant environmental monitoring tools and climate indicators to determine global and regional trends. Climate change requires data-driven approaches and methods for proper modelling and monitoring to provide past, current and future climate information to support policy and decision-making. For example, more than 50 per cent of essential climate variables are only measurable from space. Policymakers can use Copernicus data to ensure compliance with regulations for abating carbon emissions and therefore GHGs and the contribution of these gases to climate change. For example, the capability to monitor climate indicators such as global temperature, carbon dioxide, methane, sea level and ice extent over time is a key feature enabled by the Copernicus C3S service that can help policymakers to address future actions and it is a recurring capability across other challenges (i.e., in water management, migration and disaster management). Copernicus services C3S, CLMS, CEMS and CAMS serve as the backbone for the monitoring of climate in a wide range of applications across different areas including GHG emissions, forest monitoring, soil carbon capture, soil moisture, ice and snow extent, pollen concentrations, UV indexes, extreme weather events such as flooding, heatwaves, fires detection and monitoring. The contribution of GNSS is related to GNSS Radio Occultation and GNSS Reflectometry Techniques supporting the modelling and estimation of information relevant to climate such as soil moisture, vegetation, snow and sea ice. GOVSATCOM can be used to address climatic emergencies related to extreme events.

Nevertheless, the added value of EU Space data at user level goes beyond the monitoring of natural phenomena as it provides a direct, relevant information for decision-making to meet the expectations of the world of tomorrow.

*Disaster management and emergency response.* Space is crucial for disaster management and emergency response as has been proven during the almost 20 years of operations of UN-SPIDER. UN-SPIDER was the first to focus on the need to ensure access to and use of space technologies during all phases of the disaster management cycle, including the risk reduction phase which is crucial for reducing the losses of lives and property. In terms of systems, when disaster strikes, public authorities can rely on Copernicus to detect and monitor the evolving situation. On the ground, firefighters and emergency first responders use EGNSS to safely guide themselves or drones through the smoke, fog or flames. In addition, GOVSATCOM can be used for applications

[137] The analysis at the level of EU Space components includes not only operational services but also services that will be rolled out soon.

such as coordinating emergency response actors in the communications-denied environment, early warning systems, satellite radio broadcasting for sharing emergency messages with the population or smart emergency response vehicles. We can take another example, maritime emergencies. First, Copernicus provides the near real-time data needed to evaluate the state of the sea, currents and temperature. Galileo, on the other hand, makes navigation easier and more reliable, thanks to its accurate signals. Completing the maritime safety trifecta is GOVSATCOM, which ensures uninterrupted communications, even on the open seas. In addition, take for example the ground-breaking Galileo Return Link Service (RLS), part of the Galileo SAR service. Thanks to the RLS, sailors in distress, when equipped with the appropriate beacon, will see a light verifying that their distress signal has been received by emergency first responders and that their location has been established.

*Migration.* Specific use cases show the usefulness of European Union space infrastructures to address the migration challenge. GOVSATCOM, for example, by providing a common communication channel for various actors involved in supporting orderly migration, representing a key element to ensure land/sea border surveillance and to support asylum operations. The Global Human Settlement Layer provided by the Copernicus CEMS exposure mapping component, provides open and free data and tools for on-demand mapping and early warnings, to monitoring the presence of settlements and population including degree of urbanization, population size, population density in urban-rural areas. For example, it can be used to understand how many people are living in certain areas or how many settlements are affected by extreme events and monitor spatio-temporal changes over time. In addition, the information is relevant for other challenge domains such as urbanization, disaster management and emergency response and climate change.

*Urbanization.* Space has supported urban development and data-driven decision-making concerning cities. The Copernicus GHSL (Global Human Settlement Layer) component and Copernicus CLMS help to improve the collective understanding of the urbanization process. They can be applied to mapping green urban areas, urban sprawl and population density, global land use, land cover classification and imperviousness. Additionally, Copernicus CAMS provides daily analyses and forecasts of atmospheric pollutants and C3S then provides climate data to generate projections of the urban heat island effect, to mention just a few. EGNSS is then essential for GIS, cadastre and asset mapping, infrastructure construction and monitoring but is also fundamental for smart city operations.

*Energy.* Within energy, EGNSS is a vital component to ensure network synchronization, while Copernicus truly allows the optimization of energy production within renewable energy plants. For example, the Copernicus C3S energy operational service delivers key information for climate-related indicators relevant to the European energy sector including data of electricity demand and the production of power from wind, solar and hydro sources. While Copernicus CAMS solar radiation services provide historical values of global, direct and diffuse solar irradiance, as well as of direct normal irradiance. Finally, EGNSS and Copernicus are relevant enablers of many energy-related applications within the smart city concept and will really contribute to ensuring a sustainable way of living in cities expected to become more and more densely populated and prone to increasing mobility issues.

*Health.* While the health challenge was not analysed in this report, as plenty of reports have recently been released. Resolution A/RES/77/120 requests the Office for Outer Space Affairs to strengthen, within existing resources, capacity-building and networking in Africa, Asia and the Pacific, and Latin America and the Caribbean, through regional technical cooperation projects, and to support field projects for strengthening collaboration between the space and global health sectors as an efficient strategy for making better use of space science and technology for access to global health for beneficiary States and taking better advantage of opportunities offered by bilateral or multilateral collaboration. The establishment of the Space and Global Health Network and the Space and Global Health Platform, based in Geneva, aims to promote effective collaboration on space and global health issues. EU Space supports many applications across the health-care segment, used by people and governments across the world. For instance, Copernicus and Galileo provide essential contributions towards better responses to evolving global health-care needs. This covers examples of the way the health-care ecosystem can benefit from medical drone deliveries (especially in remote areas), GNSS-IoT trackers adapted for ageing population needs and the way Earth observation data monitors can prevent future pandemics or outbreaks of (for example) mosquito-borne diseases.

In addition, Galileo takes the emergency response to the next level, as illustrated by the role of accurate positioning in each step of the emergency response chain (including access to automated external defibrillators and supporting next generation (NG) 112 architecture. Finally, GOVSATCOM can provide support to telemedicine, such as access to specialists that rely on information communication and technology, to the remotest of areas where teams are deployed. The secured provision of telemedicine is critical for saving lives.

Zooming in on the services of the four EU Space components (EGNSS (Galileo and EGNOS), Copernicus, GOVSATCOM) as illustrated in exhibit 10, the analysis revealed that four services (Galileo Open Service, Copernicus C3S, CEMS and Copernicus data) contribute to tackling all seven challenges and that 10 out of 17 services (>55 per cent) analysed support at least four challenges. More importantly, the joint use of the four EU Space components services (synergies and complementarity) contributes to all the challenges.

At the application/user level, 118 out of the total 184 applications featured in 16 out of the 17 market domains included in the *EUSPA EO and GNSS Market Report* have been identified as fit to support the identified sustainable challenges.

In general, the four EU Space components provide a unique set of services that complement each other or work in synergies, thus underpinning its overall contribution. The EU Space contribution to the challenges is even more boosted when adding to the EU Space Traffic Management with SSA that ensure sustainable, safe and secure "space", and the IRIS$^2$ constellation that will offer enhanced space-based secure communication capacities to governmental users, businesses, while ensuring high-speed Internet broadband to cope with connectivity dead zones.

To fully unlock the potential of space synergies at continents and countries, the cooperation at different levels between the systems (Earth observation, GNSS, SATCOM, meteorology) and technologies (AI, big data, …) and between the organizations (private and public partnerships, networks of academia and entrepreneurs) is central and of paramount importance.

In this context, with the Copernicus full, free and open data policy, the European Commission seeks to facilitate access to Copernicus data and information for interested international partners. Administrative cooperation arrangements on Copernicus data access and Earth observation data exchange have already been signed with several countries: the United States, Australia, Brazil, Chile, Colombia, India, Serbia, Ukraine and the African Union. Discussions towards similar cooperation have been started with other countries and regions (including United Nations agencies and Asia-Pacific countries).[138] Another example, this time from the GNSS domain – the European Union cooperates with African countries wishing to foster the development of SBAS – the European Union is supporting the development of an autonomous SBAS system by the Agency for Aerial Navigation Safety in Africa and Madagascar (ASECNA), based on an international agreement in force since November 2018.[139]

Taking the "Space2030" Agenda as the basis, this report has identified challenges that can be supported by space technology and provided an assessment of the benefits of applying them in the context of an 8 billion world. Although it was elicited in the "Space2030" Agenda, after a thorough analysis conducted in this report, the conclusion is clear, space science and technology are now intrinsic to our daily lives and bring an abundance of unique and fundamental benefits to Earth and its population. Space tools are highly relevant for the attainment of the global development agendas and their fulfilment requires improved access to space-based data and applications and space infrastructure.

138 https://ec.europa.eu/
139 www.euspa.europa.eu/newsroom/news/asecna-provides-africa%E2%80%99s-first-early-sbas-open-service-based-european-egnos-technology

# ANNEX. DEFINITION OF GNSS AND EARTH OBSERVATION APPLICATIONS

The list below provides the definition of all the applications featured in this report, as segmented in the *EUSPA EO and GNSS Market Report/* ISSUE 1, explaining the use of Earth observation, GNSS or both.

| | |
|---|---|
| Earth observation application | GNSS application |
| Synergetic application (combined use of Earth observation and GNSS) | |

## AGRICULTURE

### Environmental monitoring

**Carbon capture and content assessment**: The monitoring of agricultural vegetation and grassland cover through Earth observation can help inform carbon sink capacity of different terrains. Earth observation can also be used to monitor the maintenance of agricultural practices which pertain to $CO_2$ sequestration.

**Environmental impact monitoring**: Earth observation can be used to monitor greenhouse gas emissions associated with agricultural activities; evaluate the impact of fertilization on the environment; explore the potential of carbon sequestration in agricultural land cover; and assess the level of biodiversity present in agricultural lands.

### Natural resources monitoring

**Biomass monitoring**: The use of various optical measurements, including radar measurements in situ sensors, enables Earth observation and GNSS to monitor the biomass present in a region. This can help in understanding the capacity for $CO_2$ absorption of a given ecosystem or potentials for biomass energy production.

**Crop yield forecasting**: Earth observation facilitates remote-monitoring and forecasting of harvest potentials, while GNSS allows in situ positioning information of field sensors to feed forecast information.

**Soil condition monitoring**: Earth observation enables monitoring of soil condition and moisture levels. GNSS positioning help to identify the exact position of the soil samples sent to laboratories. Soil condition monitoring is important for understanding the growth potential and health status of plants.

**Vegetation monitoring**: Earth observation enables the monitoring of vegetation coverage and health (through the generation of various indices such as NDVI). This information can be used to understand land cover statistics and provide inputs for efficient farm management practices.

## Operations management

**Asset monitoring**: GNSS provides insightful telematics data from tractors and other farm vehicles/ assets to help increase efficiency when conducting operations, monitor workforce activity and reduce costs.

**Automatic steering**: Automatic steering completely takes over steering of the farm equipment from the driver allowing the operator to engage in core agricultural tasks.

**CAP monitoring**: The enforcement of certain agricultural practices mandated by the Common Agricultural Policy, such as the maintenance of permanent grassland or the diversification of crop species, can all be monitored and enforced using Earth observation data or geotagged photos using GNSS.

**Farm machinery guidance**: GNSS positioning is used to assist drivers of farm machinery in following the optimal path when conducting activities such as variable rate application, thus minimizing risks of overlaps.

**Farm management systems**: Both Earth observation and GNSS can inform part of an overall farm management system, considering various types of practical, operational and financial data to help in the holistic management of a farm.

**Field definition**: Both Earth observation and GNSS allow for the precise measurement and definition of field boundaries.

**Livestock wearables**: Animals can be fitted with devices which use GNSS to track and monitor their activity and health status.

**Pastureland management**: Earth observation can monitor the growth and maintenance of grasslands. Mowing and grazing activities on grassland can be detected and verified using Earth observation. Grasslands are also an important component of Natura 2000 areas and are monitored with Copernicus Sentinel imagery with the EU Grassland Watch of the EC's DG ENV.

**Precision irrigation**: Like the Variable Rate Application, precision irrigation combines GNSS positioning with Earth observation information to distribute the appropriate amount of water for irrigating crops.

**Variable rate application**: Variable rate application combines GNSS positioning with Earth observation information to distribute varying amounts of agrichemicals and seeds across a given area. Discrepancies in performance and areas of lower crop yields can be identified and specifically targeted with extra input treatments (fertilizers, pesticides) or seeds by farmers. This can help improve overall performance and reduce agricultural input usage.

## Weather services for agriculture

**Climate services for agriculture**: long-term forecasting and monitoring of climate variables relevant to agriculture using remotely sensed data. Air quality and land temperature can be understood using Earth observation, which in turn can help in understanding how our climate could affect future harvests and yields.

**Weather forecasting for agriculture**: short-term weather forecasting. Air quality, land temperature and cloud cover can all be understood using Earth observation, which in turn can help form weather forecasts relevant to precise locations. This allows farmers to plan operations such as irrigation or fertilizer scheduling.

# AVIATION AND DRONES

## Environmental monitoring

Aircraft emission measurement and monitoring enables monitoring of trace gas composition of the Earth's atmosphere at different altitudes to understand more accurately the impact aviation has on the environment at those different altitudes.

**Particulate matter monitoring**: enables air traffic services to monitor particulates in airspace, enabling them to provide avoidance instructions (e.g., to avoid volcanic ash clouds) and allowing improved planning of routes and flight efficiency.

## Navigation

**Open drone navigation**: Uncertified use of GNSS for very low-level navigation supporting functions such as return to home, position holds, waypoint navigation, geo-awareness etc.

# BIODIVERSITY, ECOSYSTEMS AND NATURAL CAPITAL

**Animal tracking for biodiversity purposes**: GNSS-beacons are used to geo locate animals for the purposes of monitoring migrations, habitats and behaviours.

**Coastal ecosystems monitoring**: Earth observation provides information on multiple parameters needed to assess the conditions and the equilibrium in coastal ecosystems, such as coastal wetland loss, land-use cover and change, wetland mapping, coastal geomorphology, water optical properties, waterbody nutrients (chlorophyll-a), littoral and subtidal habitat, erosion and sedimentation mapping, long time series of ocean colour products including uncertainties estimates or health issues such as algal bloom detection.

**Snow and ice ecosystems monitoring**: Snow and ice cover data (multispectral and thermal, and to a lesser extent microwave), mapping the structural glaciology of big and small glaciers, mapping of glacier change, conducting glacier inventories, mapping glacier thinning, measuring thinning ice shelves, glacier velocity, mapping glacier landforms and measuring the ice-sheet bed. Snow and ecosystem monitoring applications are also used in high-altitude environments.

**Terrestrial ecosystems monitoring**: Plant species respond differently to light emitted by the sun or by various artificial energy sources, with specific reflection characteristics in the electromagnetic spectrum. This makes Earth observation data of adequate spectral and spatial resolution and a useful tool to distinguish different species. Advantages associated with using this method include the reproducibility, transferability, and the increased possibility for quantification. Other relevant data derived from Earth observation related to air/water quality complete the information for the status/forecasting of the ecosystem.

**Water ecosystems monitoring**: Earth observation provides information on multiple parameters needed to assess the conditions and the equilibrium in water ecosystems, such as: biogeochemical analyses and forecasts for global and regional seas, topography, bathymetry, ocean colour, sea-surface temperature, ocean currents, fish quantification, and others.

# CLIMATE SERVICES

**Climate change mitigation and adaptation**: Various types of Earth observation data can be used to aid formation of short and long-term climate change mitigation and adaptation strategies.

**Earth observation-based modelling**: Many types of Earth observation data, despite being unavailable for a long period, is used as an input into climate modelling. This results in computer simulated dynamic projections of the Earth's systems behaviour used for various purposes.

**GNSS-based climate modelling**: GNSS supports a range of geodetic applications that measure properties of the Earth (magnetic field, atmosphere) with direct impact on the Earth's climate.

**Climate forecasting**: Many types of Earth observation data can be used in climate forecasting services. Air quality, land temperature and cloud cover can all be understood using Earth observation, which in turn can be built into the relevant models and contribute to climate forecasting.

**Climate monitoring**: Many types of Earth observation data can be used in climate monitoring. Air quality, land temperature, cloud cover and several other parameters relevant for the climate can all be understood with Earth observation data.

# CONSUMER SOLUTIONS, TOURISM AND HEALTH

## Corporate

**Mapping and GIS**: Smartphones enable users to become map creators because of the democratization of digital mapping. Mapping services comprise all consumer applications that draw on Earth observation information for map features, which includes location or navigational services, including navigation, tracking and local search and discovery applications.

**Workforce management**: Aims to manage employees working outside the company premises and to improve operational efficiency.

## Health and lifestyle

**Air quality monitoring**: Earth observation enables air quality applications which measure the presence of harmful substances and particulate matter in the air (e.g., sulphur dioxide and PM 2.5). Measurements of air quality are used to inform analytics, such as air quality indexes, and to provide recommendations to users (e.g., to stay indoors and keep windows closed if air quality is very poor).

**mHealth**: In combination with other technologies, GNSS enables a vast array of applications from patient monitoring to guidance systems for vulnerable groups (people with reduced mobility, visual impairment and seniors).

**Safety and emergency**: GNSS, in combination with network-based methods, provides accurate emergency caller location.

**Social networks**: Friend locators embedded in social networks use GNSS to facilitate keeping in touch and sharing travel information.

**Sport, fitness and wellness incl. specialist support tracking**: GNSS enables monitoring of users' performance a variety of fitness applications. It records data such as real-time distance, speed/pace, location, elevation, travelled distance, step counters to monitor users' performance. Speed and elevation charts are provided (includes running, biking, hiking, swimming, etc.).
A growing use of Earth observation information is embedded in outdoor apps to provide information on snow coverage and depth, forest elevations, etc.

**UV monitoring**: Earth observation data is used in consumer UV monitoring applications to provide UV exposure, measurements for particular geolocations and to inform analytics about safe levels of UV exposure.
This allows them to make recommendations for user behaviour (e.g., recommendations to remain indoors when the UV index is very high).

### Navigation and tracking

**Navigation for smartphone users**: Route planning and turn-by-turn instructions enabled by GNSS for both pedestrian and road users through a smartphone.

**Personal and asset tracking**: GNSS facilitates innovative tracking solutions, including the deployment of local geofences that trigger an alarm when users leave a specific perimeter.

**Visually impaired support**: solutions providing turn-by-turn instructions based on GNSS positioning that help visually impaired people get around more easily.

### Robotics

**Consumer robotics**: GNSS signals are used along with other sensors integrated in consumer electronics for localization and navigation purposes. e.g., gardening robots, delivery robots, security and surveillance robots, personal assistant robots, painting robots, automated guided vehicle/logistics.

### Tourism

**Points of interest**: Provides content relative to the end user's location. Such location may include location-based landmarks, restaurants, petrol stations, banks, ATMs, hospitals, etc.

### Early warning

**Early warning**: The early warning subsegment comprises all applications related to forecasting the likelihood of a disaster event using Earth observation sensor data, including disaster prediction tools, risk indexes and early warning mass notification systems

**GNSS-enabled ocean monitoring buoys**: in combination with location (GNSS) intelligence.
Early warning is available for both natural and human-made disasters.
This application consists of multiple type of buoys, deployed at sea and in oceans, to provide early warning for natural events following seismic activities (e.g., volcanoes, earthquakes, tsunamis, floods, etc.).

## EMERGENCY MANAGEMENT AND HUMANITARIAN AID

### Migration and settlement

**Earth observation human displacement monitoring**: Monitoring of displacement patterns, due to conflict or disaster for example, to plan humanitarian responses. Earth observation data can be used to monitor migration routes, as well as for the identification or temporary dwelling structures.

**Management of refugee camps**: Comprises applications where Earth observation data is used for planning of camp layouts, and for the distribution of resources e.g., wells and medicine, by displaying settlement concentrations and estimating population in different areas of a camp.

**Population counting**: Population estimation based on (semi-) automated dwelling counting from very high-resolution optical satellite imagery, which can be used for vaccination campaigns for example, in underserved areas as well as for emergency response planning.

**Telematics for humanitarian aid**: real-time satellite geo-positioning and fleet-management solutions used by humanitarian organizations, non=governmental organizations and United Nations agencies, as well as national or European Union agencies for their safety and security.

## Post-event analysis

**Post-event analysis**: Post-event analysis includes all applications which rely on archival Earth observation data to assess the impact of past disaster events, as well as those that compare the impact of past disaster events to identify patterns, and those which assess the effectiveness of disaster response and mitigation efforts.

## Preparedness

**Preparedness**: Preparedness refers to a science-based set of actions, based on Earth observation data and services, which are taken as precautionary measures in the face of potential disasters, both natural and human-made. Typically, disasters (e.g., floods, drought, landslide, tsunami etc.) nor human-made disasters (e.g., fires, hazardous material spills) can be precisely foreseen or avoided but preparedness helps to minimize the eventual risks and initiate emergency actions. Satellite solutions are being applied by the United Nations aid agencies, non-government organizations, host-nation governments, military, and the private sector to address mission-critical disaster preparedness and long-term development requirements. The main usage will be pre-positioning emergency equipment and solutions.

## Rapid mapping

**Rapid mapping**: Use of geospatial information in support of emergency management activities immediately following disaster (e.g., map the damage level in particular locations to inform emergency response efforts including crowdsourced map updates facilitate deployment of aid).

## Search and rescue

**Beacons for aviation**: Aircraft should be equipped with emergency locator transmitters (ELTs) or a PLB that help search and rescue operations in the event of an incident. In line with requirements in ICAO Annex 10 (and standards set in ICAO annex 6) as well as the implementation of the Global Aeronautical Distress and Safety System, many ELTs utilize GNSS to report their position when triggered.

**Beacons for maritime**: Ship and person-registered beacons, i.e., emergency position indicating radio beacons and personal locator beacons (PLBs) transmit, once activated, the necessary information for rescue to authorities via COSPAS / SARSAT payloads carried by GNSS satellites. The AIS-SART (Search and Rescue Transmitter) and AIS-MOB (Man Overboard) beacons not only transmit the position of the person in distress, but also share this location through the Automatic Identification System (AIS) with nearby vessels, by pinpointing an AIS distress signal onto the nearby vessel's Electronic Chart Display Information System.

**Beacons on land**: Climbers and hikers are advised to equip themselves with a PLB in case they find themselves in distress.

**Situational awareness supporting search and rescue**: Earth observation services can assist Maritime and Joint Rescue Coordination Centres in a wide range of activities at sea, including support to search and rescue operations and exercises. Earth observation information, combined with maritime data and external sources, can provide you with a better understanding and improved monitoring of activities at sea (incl. detection of ships in distress, search and rescue response support, etc.).

# ENERGY AND RAW MATERIALS

## Energy network fidelity

**Energy network conditions monitoring**: The situational awareness and monitoring capabilities of Earth observation contribute through application such as monitoring the structural integrity of assets including towers, poles, wind plants and solar plants; monitoring land subsidence around energy infrastructure such as pipeline and plants, assessment of vegetation encroachments; and allowing for asset condition management damages, degradation, corrosion, etc.

**Phasor measurement units (PMU)**: GNSS provides accurate timing and synchronization for PMUs, which are deployed across remote locations of the power network (nodes), improving the reliability of power systems.

## Environmental impact monitoring

**Environmental impact assessment of energy and mineral resources plants**: Earth observation can support the mitigation of energy/mining effects of the environment through continuous monitoring of relevant environmental characteristics and through the capacity of Earth observation to detect changes. Relevant products and services include coastal ecosystems monitoring, water quality monitoring, air quality monitoring, erosion monitoring, pollution monitoring, vegetation monitoring, etc. In some cases, Earth observation-based products could also include the production of environmental impact assessment "certificate".

## Market intelligence

**Supply chain insights**: Earth observation data support market analysts, traders, investors, energy operators and regulators, governments, international banking institutions and citizens, to better understand the new energy dynamics shifting under the pressure of climate change. AI and advanced analytics are applied to Earth observation for applications such as reservoir monitoring, heavy oil production mapping, underground gas storage, sophisticated methane-detection technologies, etc.

## Renewable energy

**Power plant design optimization**: Earth observation can help optimizing the design of renewable energy power plants (e.g., optimization of the positioning of solar panels, onshore and offshore wind turbines, etc.). Relevant Earth observation-based products include terrain elevation models, solar irradiance, wind speed, precipitation and climate conditions.

**Renewable energy assessment potential and forecast**: Prior to the selection of a power plant site, Earth observation can contribute to the assessment of the potential of a given area based on the analysis of historical data for example, wind, solar irradiation, ocean currents, ocean temperature (e.g., for OTEC or SWAC) and snow cover. During the exploitation phase, Earth observation can help calculating daily production estimates based on plant characteristics coupled with relevant forecasts. This includes for instance solar plant production estimates based on solar irradiation forecasts or hydropower production estimates based on snow cover smelting.

**Risk assessment for energy assets**: Energy assets are exposed to a variety of natural risks which can put at danger the people working on site or, damage equipment or negatively impact production. Earth observation can contribute to the assessment of the level of risk to prevent/mitigate the effects of adverse events on the exploitation of energy (incl. the protection of workers maintaining offshore wind platforms for instance). Relevant Earth observation-based products and services include the monitoring of dangerous subsurface currents, iceberg detection and tracking, etc.

**Site selection, planning and monitoring**: Earth observation can provide a large variety of products and information supporting the identification of the most suitable areas for the exploitation of renewable energy sources. These products and information include for instance data on relevant environmental parameters influencing the production of energy, data on the status of the power plants, geological evaluation, topography mapping, etc. GNSS can enable geomatics applications such as mine and construction surveying, mapping and GIS, photogrammetry, laser scanning and remote sensing, as well as route planning and augmented reality visualization. The GNSS devices that are used for those applications include high-accuracy GNSS receivers (geodetic-grade smart antennas, all-in-one integrated mapping/GIS devices or infrastructure/CORS) and embedded chipsets. On the other hand, a number of CORS networks operate receivers that are powered by renewable energy sources (e.g., solar panels or wind turbines), so the utilization of GNSS for renewable energy operations brings mutual benefits.

# ENVIRONMENTAL MONITORING

## Environmental auditing

**Environmental auditing**: Earth observation data is used in environmental auditing as an input to assess the repercussions of human activity across four different environments:

- *Atmosphere:* Multiple Earth observation satellites and sensors are dedicated to monitoring atmospheric conditions, including air quality and the presence of greenhouse gases (GHG) emissions, enabling the provision of short- and long-term forecasting.
- *Coasts:* For coastal environment, relevant Earth observation data can be acquired relating to wetland loss, land-use cover and change, wetland mapping, coastal geomorphology, water optical properties, waterbody nutrients (chlorophyll-a), littoral and subtidal habitat.
- *Land:* Relevant parameters range from land-use cover and change, vegetation, biomass, and soil monitoring, to the monitoring of human impact, such as waste, constructions, and other infrastructure.
- *Water and oceans:* The relevant parameters for water and ocean environment, which can be acquired through Earth observation include temperature, transparency/turbidity, water depth, tides, currents, and to an extent, flora and fauna. The data also supports the monitoring of infrastructure and other traces of human activities, including waste.

## Environmental resources management

**Environmental resources management**: The use of Earth observation satellites and data provides users the means to properly manage environmental resources across four environments:

- *Atmosphere:* Multiple Earth observation satellites and sensors are dedicated to monitoring atmospheric conditions, including, for instance air quality and the presence of greenhouse gases (GHG) emissions, allowing as well to provide short- and long-term forecasting.
- *Coasts:* Coastal monitoring from Earth observation satellites includes coastal wetland loss, land-use cover and change, wetland mapping, coastal geomorphology, water optical properties, waterbody nutrients (chlorophyll-a), littoral and subtidal habitat, erosion and sedimentation mapping and long time series of ocean colour products including uncertainties estimates or health issues such as algal bloom detection. In terms of compliance monitoring, Earth observation data can be used for reporting (on water quality) under the Water Framework Directive.
- *Land:* The various applications of Earth observation for resource management on land vary from land-use cover and change, vegetation, biomass, and soil monitoring, to the monitoring of human impact, such as waste, constructions, and other infrastructure.
- *Water and oceans:* Earth observation monitors parameters which assess the effects of various human (and natural) activities on the water and ocean environments and to manage resources. The measurements on temperature, transparency/turbidity, water depth, tides, currents, as well as to an extent flora and fauna, and traces of human activities, including waste.

### Impact studies and environmental, social and corporate governance

**Impact studies and environmental, social and corporate governance (ESG)**: Earth observation monitors parameters necessary for the elaboration of impact studies and for the implementation and monitoring of ESG policies across four different environments:

- *Atmosphere:* Multiple Earth observation satellites and sensors are dedicated to monitoring atmospheric conditions, including air quality and the presence of greenhouse gases (GHG) emissions, enabling the provision of short- and long-term forecasting.
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- *Land:* The various Earth observation applications for these activities on land include land-use cover and change, vegetation, biomass, and soil monitoring, to the monitoring of human impact, such as waste, constructions and other infrastructure.
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## FISHERIES AND AQUACULTURE

### Aquaculture

**Aquaculture operations optimization**: Throughout the operational phase of the aquaculture plants, Earth observation can provide water quality monitoring notably on harmful algae blooms, as well as assessment of fish farming environmental impacts and data for modelling of species invasion. Combined in models, such data can provide periodical estimation to aquafarmers about estimated growth and health of the stock. GNSS plays a role when the operation of offshore farms is carried out by fully automated vessels which rely on accurate positioning and navigation, or in the upcoming use of GNSS for the localization of networks of buoys

**Aquaculture site selection**: Considering relevant parameters, Earth observation data and forecasting can help select the aquaculture location and type in both the nearshore and offshore environment.

### Fisheries

**Catch optimization**: Considering relevant parameters, Earth observation data and forecasting can help select the aquaculture location and type in both the nearshore and offshore environment.

**Illegal, unreported and unregulated (IUU) control**: Satellite data has surveillance capabilities for the IUU fishing activities and could contribute to the identification of perpetrators. The data concerned is both Earth observation (optical and radar) and GNSS (providing identification of the vessels, including through positioning systems such as AIS and VMS). With AIS and VMS being mandatory depending on the vessel size (i.e., 15m for AIS, 12m for VMS), the GNSS receiver of these applications is a different to the receiver used for general navigation.

**Fishing aggregating devices**: GNSS-enabled buoys that assist fishermen both in locating their fishing nets and equipment as well as the identification and location of fish stock.

**Fish stock detection**: Earth observation data contributes to biogeochemical analyses and forecasts for global and regional seas, topography, bathymetry, ocean colour, sea-surface temperature and ocean currents, which are key inputs for numerical modelling of fish stock and detection of fish shoals.

**Fishing vessels navigation**: Using GNSS-enabled navigation devices, fishing vessels can accurately and safely navigate their fishing waters as well as navigate towards their equipment such as fishing cages, buoys or fish lines.

## FORESTRY

### Environmental monitoring

**Biomass monitoring**: Earth observation and GNSS enable the monitoring of the biomass present in a forest using various optical measurements, radar measurements and in situ sensors. This can help in understanding the capacity for $CO_2$ absorption of a given forest or potentials for biomass energy production.

**Deforestation/degradation monitoring**: Earth observation and GNSS enable the monitoring of the biomass present in a forest using various optical measurements, radar measurements and in situ sensors. This can help in understanding the capacity for $CO_2$ absorption of a given forest or potentials for biomass energy production.

### Natural resource monitoring

**Forest inventory monitoring**: Earth observation and GNSS enable the monitoring of the timber inventories using various optical measurements, radar measurements and in situ sensors.

**Forest vegetation health monitoring**: The health of forest vegetation can be monitored and managed using Earth observation. Optical and radar data can be used to measure forest vegetation intensity (through the generation of various indices such as NDVI) to infer the health of trees and forest vegetation.

**Illegal logging monitoring**: Earth observation can help in the identification of illegal logging. By using optical and radar data to monitor land-use changes and measure forest vegetation cover, illegal destruction of forests can be detected and monitored.

# INFRASTRUCTURE

## Environmental monitoring

**Environmental impact assessment of infrastructure**: Earth observation can support the analysis of the impact of existing infrastructures (including during the construction phase) on the environment and ecosystem in their surroundings. Relevant Earth observation-based products and services include pollution monitoring (air, water, soil), vegetation and biodiversity monitoring, etc.

## Infrastructure planning

**Permitting**: Earth observation can support the evaluations to be carried out before a permit is delivered for the construction of a new infrastructure. Thus, Earth observation can deliver products and services related to land cover/land-use mapping, forest mapping, geological evaluation, exposure to disaster risk (e.g., floods), ground deformation, etc.

**Site selection and planning**: Earth observation can contribute to the selection of sites (e.g., tailing dams) or routes (e.g., roads/rail) through the provision of products and services such as geological evaluation, topography mapping, historical data on land subsidence. Through geomatics applications like construction surveying, mapping and GIS, photogrammetry, laser scanning and remote sensing, GNSS can significantly speed up the accurate determination of site borders, while also providing adequate methods for development of detailed specialized maps, route planning or establishment of GIS database with accurate positions of all infrastructure site features. In addition, to high-accuracy GNSS devices (smart antennas or integrated mapping/ GIS devices), GNSS chipsets can feed high-accuracy positioning data into LiDAR and imaging devices (drone or land-based), and augmented reality technologies for a-priori in situ infrastructure visualization.

**Vulnerability analysis**: Earth observation can contribute to the vulnerability assessment for locations prone to natural hazards. Relevant Earth observation-based products and services include historical data on floods, droughts, and fires as well as climate projections enabling the assessment of the evolution of risks.

## Infrastructure construction and monitoring

**Construction operations**: Thanks to its capacity to detect surface changes, Earth observation can support the monitoring in near-real-time of the progress achieved anywhere on the construction site. It can also help verifying the alignment between actual building and original plans. While also providing typical surveying techniques on the site, GNSS is an ultimate supplier of positioning and orientation data for heavy machinery (graders, dozers, excavators, compactors), which can be used for either semi-automatic (GNSS serves as a guide to the operator) or fully automatic operations (GNSS data is directly fused into the machine hydraulic control). For the needs of BIM, GNSS can feed the model with high accuracy positioning data of all relevant construction assets.

**Monitoring of impact of human activities on infrastructures**: Earth observation enables the monitoring of the impact on buildings and infrastructures of land subsidence caused by a variety of human activities (e.g., aquifer overexploitation in urban areas).

**ODA support monitoring**: Earth observation can be used to validate that Official Development Assistance (ODA) support (i.e., investment in different development projects) is utilized as planned. This is often directly informing the further release of funds from a donor country to a receiving one.

**Post-construction operations**: Critical infrastructures such as dams, bridges, factories etc. can be damaged in case of Earth's surface deformation. Earth observation offers solutions for the monitoring of infrastructure stability and for the provision of situation awareness as it can accurately monitor land deformation and to detect minor changes (e.g., building subsidence). The stability of critical infrastructure is monitored also via high-precision GNSS methods, e.g., by post-processing of static relative GNSS observations at field control points (established directly into or in the vicinity of the object) with station data from local or global CORS networks. In addition, GNSS data may be utilized to feed various smart sensors, mounted into the infrastructure body for real-time stability monitoring.

**Pipeline monitoring**: Earth observation can contribute to the monitoring of pipelines through the provision of ground deformation information across pipeline networks as well as through the provision of information related to vegetation encroachment or third-party interference. For above-ground pipelines, GNSS provides methods for stability monitoring like post-construction operations, while for underground assets it may feed high-accuracy positioning data into ground-penetration radars to map and detect leakages and other faults.

### Timing and synchronization of telecommunications networks

**Data centre**: A data centre is a dedicated space within a building, or a group of buildings used to house computer systems and associated components, such as telecommunications and storage systems.

GNSS is used as a time source for network synchronization of computing resources.

**Digital cellular network (DCN)**: Telecom operators require accurate and consistent time and frequency at distant points of their networks to meet increasingly demanding broadband requirements.

GNSS is used to provide consistent frequency and time alignment between all base stations within the network.

**Professional mobile radio (PMR)**: Telecom operators require accurate and consistent time and frequency at distant points of their networks to meet increasingly demanding broadband requirements.

GNSS is used for synchronization of time slots and handovers between base stations.

**Public switched telephone network (PSTN)**: Telecom operators require accurate and consistent time and frequency at distant points of their networks to meet increasingly demanding broadband requirements. Originally a network of fixed-line analogue telephone systems, the PSTN is now entirely digital in its core network and in this report, it consists in fixed telephones networks.

GNSS is usually a backup to atomic clocks to provide time slot management.

**Satellite communication (SATCOM)**: Telecom operators require accurate and consistent time and frequency at distant points of their networks to meet increasingly demanding broadband requirements.

GNSS is typically used in satellite control stations and telecommunications gateways, mostly for frequency control.

**Small cells**: Telecom operators require accurate and consistent time and frequency at distant points of their networks to meet increasingly demanding broadband requirements.

GNSS is used to provide frequency and phase alignment in small cells networks.

## MARITIME AND INLAND WATERWAYS

### Environmental monitoring

**Marine pollution monitoring**: SAR-based and optical satellite data can be used for detecting and monitoring of oil spills and marine litter. Earth observation also provides forecasts of sea currents and sea-surface heights (altimetry), sea-surface salinity, sea-surface temperature, ocean colour and sea-ice data – useful for monitoring and forecasting the course of the pollution. Moreover, remote sensing data can also contribute to identifying the polluters.

### Ocean services

**Metocean (meteorology over oceans, and offshore weather and sea state monitoring)**: Earth observation can provide data for quality meteorology over oceans (offshore weather and sea state monitoring) complemented with near-real-time data collection of variables such as wave height and frequency, wind speed, direction, and ocean current velocity on global and regional scales.

### Vessel tracking

**Dark vessel monitoring**: GNSS-enabled long-range identification and tracking as well as AIS or VMS provide the means to monitor and track suspicious vessels. When those vessels turn off or disable their own AIS or VMS, Earth observation data provides enhanced situational awareness that can be used by dedicated maritime authorities to monitor and track "dark vessels" through Earth observation imagery and SAR data.

## RAIL

### Attractiveness enhancement

**Passenger information systems**: GNSS is used to provide enhanced passenger services such as real time location and speed of trains along their route during a journey. Increasingly, GNSS location of trains is also supporting platform and online passenger information services.

**Public transport – tram and light rail**: Currently, GNSS is used in smart mobility applications to optimize the network capacity by managing tram locations or to provide real time information to passengers such as the estimated arrival time of a tram at a designated station. GNSS has started to be used for advanced applications, such as automatic speed limitation, ensuring that the tram speed is lower than a customer-defined speed limit in a specific area. It is also used for maintenance or on-board energy management, ensuring that the tram's on-board battery has sufficient energy level before passing a section without external power supply.

### Train driving optimization

**Rail fleet management**: Train location provided by GNSS could be used to perform fleet analysis to optimize the use of locomotives and railway cars and to properly size rail fleets.

## ROAD AND AUTOMOTIVE

### Fleet management systems

**Bike-sharing**: Bike-sharing and especially free-floating bike-sharing systems rely on GNSS to locate the bike across the city by both end users and the bike-sharing service provider.

**Public transport – buses**: Public transit agencies use GNSS receivers in buses to track their location in real-time to display their position on a map in the control centre and their expected arrival times on digital displays at bus stops.

**Road fleet management**: Fleet management on-board units transmit GNSS positioning information through telematics to support transport operators in monitoring the performance of logistics activities. This application is used within cars that form a so-called fleet such as taxis, rental cars and cars used for sharing schemes. Commercial vehicle fleet owners also adopt it. As subset, dangerous goods tracking is done by transmitting GNSS-based positioning data on the vehicles carrying them, together with other information about the status of the cargo.

### Smart mobility

**Navigation (IVS and PND)**: Navigation is the most widespread application, providing turn-by-turn indications to drivers through portable navigation devices (PNDs) and in-vehicle systems (IVS) built in cars.

**Congestion control**: Satellite road traffic monitoring services collect floating car location data from vehicles through PNDs, IVS and mobile devices. The traffic information is then processed and distributed to users and other interested parties. Remote sensing data can be used as an additional layer of information for monitoring traffic flows.

# URBAN DEVELOPMENT AND CULTURAL HERITAGE

## Environmental monitoring

**Air quality monitoring in urban environments**: Using satellite data and in situ measurements, Earth observation can support detecting, collecting, and interpreting information on a multitude of air pollutants, including their origins, movement, and expected health risks.

**Urban greening**: Earth observation and GNSS can be used to monitor vegetation cover, the health of green space vegetation as well as precise definition, positioning and monitoring green space infrastructure.

**Urban heat islands**: Earth observation can support mapping temperatures and temperature variations across urban areas, e.g., to alert health authorities of related risks for specific demographic groups.

## Smart cities operations

**Smart streetlights**: Smart streetlights incorporate precise GNSS positioning data, in addition to other technologies such as cameras and photocells, to remotely control the output of individual streetlights, detect faults, monitor energy performance. They also facilitate real time alerts for city-wide problems including traffic flow, parking spaces, electrical outages, and accidents.

**Smart waste management**: GNSS can be used in smart waste management by precisely positioning waste containers, thereby helping in the monitoring and collection planning of waste.

## Urban planning and monitoring

**Cultural heritage monitoring**: cultural heritage, including monuments, spaces, and cultural infrastructure can be supported by means of Earth observation, both to assess (e.g., structural) conditions as well as disruptions (e.g., illegal construction, violation of preservation orders).

**Informal dwellings**: Earth observation enables detection of illegal structures outside of planning as well as violations of property lines.

**Real estate**: Earth observation enables detection of illegal structures outside of planning as well as violations of property lines.

**Surveying and mapping**: Earth observation can support mapping of urban land-use and land cover while enabling to classify built structures including building height and urban infrastructure such as roads. GNSS-based cadastral surveying and mapping help in precisely defining and measuring specific location points of interest for cartographic and urban planning purposes (all GNSS cadastral and mapping devices are being quantified under this application, regardless of where they are used e.g., non-urban areas, energy and raw materials, infrastructures). Both Earth observation and GNSS power GIS applications for surveying and mapping of urban areas.

**Urban modelling, 3D modelling, digital twins**: Earth observation data can serve as input to digital surface models, enabling simulations, including shadow effects or street canyon effects. The creation of so-called digital twins of cities would enable the visualization, monitoring and forecasting of natural and human activity in support of sustainable development. GNSS can help in precisely defining and measuring specific location points of interest for urban and 3D modelling purposes.

**Urban planning**: Earth observation can measure urban footprints including sprawl, density, and sealed surfaces. It can also measure change such as increase or decrease of urban deprivation. This information can in turn be used to help inform and plan future urban developments.

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