UNITED NATIONS
OFFICE FOR OUTER SPACE AFFAIRS

European Global Navigation Satellite System and Copernicus:

Supporting the Sustainable Development Goals

BUILDING BLOCKS TOWARDS THE 2030 AGENDA

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Foreword by the Director of the Office for Outer Space Affairs

The 2030 Agenda for Sustainable Development came into effect on 1 January 2016. The Agenda is anchored around 17 Sustainable Development Goals (SDGs), which set the targets to be fulfilled by all governments by 2030. The demanding Goals set out by this Agenda cannot be reached without a concerted effort on the part of institutions and will require the use of the right tools. In SDG 17, the Agenda itself stresses the need for partnerships to reach its Goals.

Partnerships are key to achieving the SDGs, especially at a time when we frequently hear the phrase “you have to do more with less” which, by definition, requires innovation and new approaches. However, the use of this phrase also emphasizes that we should make better use of the resources we have. So, in reality, “do more with less” can be interpreted as “improve, optimize, find synergies”, as with the SDGs. We have one planet, and we have to optimize and improve how we use its resources.

Space has been used as a tool for humankind for over 50 years already; it is not new to the area of development and is a critical resource for developed nations. However, there is room for improvement, particularly through partnerships that have a multiplier effect on the use of space tools. This report shows clearly that the two European flagship projects are capable of great achievements separately, but it is through synergies that their true potential is unleashed. The same is true for other satellite systems used around the world. The best results will be achieved when telecommunications, global navigation satellite systems (GNSS) and Earth observation (EO) satellites and services collaborate to achieve common goals and meet clear user requirements.

Although all the SDGs can benefit from the contribution of space, not all the systems have equal capabilities or equal focus. This brochure expresses the contribution of the two European flagship space projects to the SDGs. The United Nations Office for Outer Space Affairs is putting together a global partnership for the SDGs as a mechanism where different actors can express their needs, develop their systems and set up services that will result in worldwide collaboration in the monitoring and achievement of the SDGs for the benefit of humankind.

Ms Simonetta Di Pippo
Director, Office for Outer Space Affairs

Foreword by the Executive Director of the European Global Navigation Satellite Systems Agency

It is with great pleasure that I present this joint study on the role of global navigation satellite systems (GNSS) and Earth observation (EO), with special focus on European GNSS and Copernicus, in supporting the United Nations Sustainable Development Goals (SDGs).

While GNSS determines a precise position anytime, anywhere on the globe, EO provides information on the Earth's surface, its atmosphere and marine systems. As this study clearly shows, the joint use of both systems unleashes an array of synergies that will have a substantial impact on sustainable development.

Out of many areas where we are already seeing the benefits of combining the GNSS and EO data, there are two that provide already evident societal benefits: precision farming and the contribution of space technologies to the development of smart cities. Additionally, in all modes of transport, more precise positioning means more efficient and direct routes—key to reducing greenhouse emissions. From providing the maps needed to find the best locations for renewable energy infrastructure to outlining the most fuel-efficient flight paths, optimizing road transportation routes and infrastructure monitoring, applications using both GNSS and EO provide the answer to many societal challenges.

I look forward to working with the United Nations as we enhance the convergence of GNSS and EO to create new solutions that will help us achieve the SDGs.

Carlo des Dorides
Executive Director of the European GNSS Agency

List of abbreviations

AR	Augmented reality
CEOS	Committee on Earth Observation Satellites
CGLS	Copernicus Global Land Service
CLMS	Copernicus Land Monitoring System
CMEMS	Copernicus Marine Environment Monitoring Service
DAS	Driver Advisory System
DIAS	Data and Information Access Services
EC	European Commission
ECMWF	European Centre for Medium-Range Weather Forecasts
ECV	Essential climate variables
EDAS	EGNOS Data Access Service
EEA	European Environment Agency
EGNOS	European Geostationary Navigation Overlay Service
EGNSS	European Global Navigation Satellite Systems
EMS	Emergency Management Service
EMSA	European Maritime Safety Agency
EO	Earth observation
ESA	European Space Agency
FOC	Full operational capability
GAGAN	GPS-aided geo-augmented navigation
GCC	Galileo Control Centres
GCOS	Global Climate Observing System
GDP	Gross domestic product
GEO	Group on Earth Observations
GIS	Geographic information systems
GLONASS	GLObal NAvigation Satellite System
GLS	Global Land Service
GMES	Global Monitoring for Environment and Security
GNSS	Global navigation satellite system
GPS	Global Positioning System
GRC	Galileo Reference Centre
GRSP	Geodetic reference service provider
GSC	GNSS Service Centre
GSMC	Galileo Security Monitoring Centre
GST	Galileo System Time
GTRF	Galileo Terrestrial Reference Frame
IoT	Internet of Things
KASS	Korean Augmentation Satellite System

LBS	Location-based services
MCC	Mission Control Centres
MDG	Millennium Development Goals
MoU	Memorandum of Understanding
MTG	Meteosat Third Generation
MTSAT	Multifunctional transport satellite
NLES	Navigation Land Earth Stations
NRT	Near-real-time
NTC	Non-time-critical
PBN	Performance-based navigation
PRS	Public regulated service
R&D	Research and development
RIMS	Ranging and integrity monitoring stations
RUC	Road user charging
SAR	Search and rescue
SBAS	Satellite-based augmentation system
SDCM	System of differential correction and monitoring
SDG	Sustainable Development Goals
SEA	Support to external action
SGDSP	SAR/Galileo Data Service Provider
SLSTR	Sea and land surface temperature radiometer
SNASS	Satellite navigation augmentation system
SRAL	SAR radar altimeter
STC	Short-time-critical
TSP	Time service provider
UAS	Unmanned aircraft systems
UCP	User consultation platform
UNOOSA	United Nations Office for Outer Space Affairs
VAS	Value-added services
VHR	Very high resolution
VMS	Vessel monitoring system
VRA	Variable rate application
WAAS	Wide-area augmentation system

Contents

1. Executive summary

Despite the growing global economy and the technological progress observed in the past decades, there are still many societal challenges that need to be overcome to enhance human development. The United Nations, involving more than 190 Member States, has developed the 2030 Agenda for Sustainable Development in order to address these challenges in the form of 17 Sustainable Development Goals (SDGs) with 169 associated specific targets.

The role of Earth observation (EO) and geolocation (provided by global navigation satellite systems (GNSS)) is recognized by the United Nations[1] in supporting the achievement of the SDGs. Among the space technologies, the two European flagship programmes—the European GNSS European Geostationary Navigation Overlay Service (EGNOS) and Galileo, and the European EO programme Copernicus—could be used to support the achievement of the SDGs not only in Europe but worldwide. The European Union's efforts in infrastructure deployment and market uptake have resulted in the launch of EGNOS, Galileo and Copernicus operational services. These services are supporting a continuously increasing number of users in many different market application domains: from transport-related services (for example aviation, road, maritime and rail) and consumer solutions to professional applications (for example agriculture, construction and infrastructure monitoring).

This report investigates how European Union space technologies support the fulfilment of the SDGs. It has been jointly prepared by the United Nations Office for Outer Space Affairs (UNOOSA)—in charge of promoting international cooperation in the peaceful use and exploration of space, and in the utilization of space science and technology for sustainable economic and social development—and the European GNSS Agency (GSA), which is the European Union agency operating EGNOS and Galileo and is in charge of ensuring the maximization of socioeconomic benefits from the use of the European Union satellite navigation systems.

[1] General Assembly resolution 70/1.

The analysis shows that all the SDGs are positively impacted by the benefits stemming from the use of European Global Navigation Satellite Systems (EGNSS) and Copernicus applications and, out of the 169 indicators associated, 65 (almost 40 per cent) directly benefit from using the EGNSS and Copernicus services, either helping monitor the status of achievement of a given SDG or actively contributing to its fulfilment.

The 17 SDGs have been grouped into two tiers according to the relevance of their impact, based strictly on the contribution of Copernicus and EGNSS, as illustrated in figure I:

- Significant Contribution Tier SDGs (13 out of 17) are the SDGs that benefit most from the use of EGNSS and Copernicus applications, including “Climate Action”, “Sustainable Cities and Communities” and “Industry Innovation and Infrastructure”.
- Limited Contribution Tier SDGs (4 out of 17) are those SDGs which are positively impacted by applications making use of the European Union space programme, but whose fulfilment is not necessarily dependent on the use of EGNSS and Copernicus, including “Quality Education”, “Reduced Inequalities” and “Peace and Justice”. Although from this split it might seem that space has little to contribute to those four SDGs, this is not correct. The Office for Outer Space Affairs is fully committed to the monitoring and achievement of all the SDGs through the use of space, and to this end has created the Global Space Partnership for the Sustainable Development Goals. In particular, it is worth noting that the main activity of the Office is focused on capacity-building, and for women in particular, which is fully aligned with SDG 4 and SDG 5. Space technologies and infrastructures can help in reducing inequality (SDG 10), closing the gap between developed and developing countries, if they are properly used. In addition, the Office maintains the Register of Objects Launched into Outer Space, which is one of the most important tools for enhancing transparency and confidence in space activities, and is therefore a building block for peace (SDG 16).

The analysis is supported by 38 use cases detailing how EGNSS and Copernicus tangibly contribute to achieving the SDGs. These examples constitute best practices of specific implementations in Europe and worldwide and, if implemented on a larger scale, they would contribute to the achievement of SDG targets and indicators ahead of their deadlines. In some cases the use of space technologies can be maximized only if certain infrastructures are available (for example agricultural machinery for precision farming). In some other cases the use of space technologies can compensate for a lack of infrastructure, or can support the improvement of existing infrastructure (for example safer aircraft approaches where no ground infrastructure is available). The use cases and opportunities presented in this report should, however, be adapted to local or regional needs based on socioeconomic conditions and existing infrastructures.

Analysis of the use cases and the contribution of geospatial data to the SDGs revealed that additional value can be created by the combined use of EGNSS and Copernicus in the same application. Indeed, GNSS is the most efficient and widespread technology for geo-referencing and precisely time-stamping all EO measurements, and is extensively used for in situ observations. On the other hand, placing a point on a map where EO data provide

Figure I.

information on safe routes, distances to danger, static and whenever possible dynamic environmental features, allows for safe and efficient navigation.

Providing different geospatial information in one solution enhances the benefits across various sectors. For example, both Copernicus and Galileo can be used in precision agriculture to optimize crop production by combining geospatial data, for example on land humidity, and applying high-precision agriculture techniques for spraying and harvesting. It is estimated that using Galileo/EGNOS and Copernicus together can contribute to increasing yields by more than 10 per cent and reduce consumption of inputs such as fuel, fertilizer and pesticides by up to 20 per cent.[2] Both EGNSS and Copernicus will play a key role in urban development and planning sustainable smart cities. Precise construction surveying and infrastructure monitoring, as well as optimized traffic management, will contribute to fighting many of the challenges faced by modern cities. This is especially critical given that more than 60 per cent of the global population will live in cities by 2030. With growing concerns about risks to health linked to urbanization and pollution, both EGNSS and Copernicus support cities in becoming greener. For example, Copernicus is used to determine the components of air over cities which, when combined with precise location data from GNSS, could identify the main polluting units and ensure better implementation of environmental policies. Copernicus supports also the determination of vertical displacements of land masses with sub-centimetre precision, while Galileo helps to

[2] European Commission, *D 3.1. Current and future agricultural practices and technologies which affect fuel efficiency*, https://ec.europa.eu/energy/intelligent/projects/sites/iee-projects/files/projects/documents/efficient20_review_of_agricultural_practices_and_technologies_en.pdf, 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.

precisely detect horizontal displacements; together they facilitate the monitoring of land masses and help predict natural disasters produced by land motions, such as landslides. Overall the highest impact of synergetic use of both technologies is observed today in the SDG targets that are linked with either agricultural or transport industries (such as "Zero Hunger", "Sustainable Cities" or "Life on Land"). In both cases the EGNSS and Copernicus technologies are enabling many applications that support the reduction of poverty, famine and pollution, and optimize the mobility of citizens.

However, the synergies between the programmes go beyond the application level. In fact, by integrating the two space technologies alongside the value chain and deploying best practices already in use, the overall socioeconomic effect can be maximized. Integrated actions targeting application developers, data resellers, hardware manufacturers and users may further stimulate innovation and continue to increase the usage of both technologies, augmenting their impact on the achievement of the SDGs. An overall campaign showing how both programmes are helping concretely to reach SDGs could be developed between institutional stakeholders. The recommendations of such a campaign should be tailored to the developing/developed countries in order to capture the needs derived from the local socioeconomic conditions and existing infrastructures and mechanisms. The technical convergence and the synergies in creating additional common GNSS-EO products and services could be optimized by an enhanced coordination of related R&D, market development and communication activities.

Bearing in mind the increased international investment in the areas of both GNSS and EO and the fact that Europe's systems have both entered the operational phases, the contribution to the SDGs could be achieved in time for the completion of the 2030 Agenda. The opportunities presented have a global value since the EGNSS and Copernicus data are available worldwide and therefore can be used by States and regions in and outside of Europe, in complementarity with their own infrastructures.

2. Background of the study

Context

The General Assembly resolution entitled "Transforming our World: the 2030 Agenda for Sustainable Development"[3] calls for the exploitation of a wide range of data, including Earth observation (EO) data and geospatial information, in order to support the sustainable development of nations and regions. Space technology is one of several technologies essential for successfully implementing the 2030 Agenda. It provides data, information and services that directly or indirectly contribute to achieving the Sustainable Development Goals (SDGs) or to assessing and monitoring progress towards achieving the Goals.

The international space community is now on a mission to develop a new agenda for its work in future decades. With this aim in mind, UNISPACE+50 will be held in June 2018 to commemorate the fiftieth anniversary of the first of a series of United Nations conferences on the exploration and peaceful uses of outer space. UNISPACE+50 aims to define concrete deliverables of space activities for the development of countries under the four pillars of space economy, space society, space accessibility and space diplomacy. To this end, the United Nations Office for Outer Space Affairs (UNOOSA), in line with its vision to bring the benefits of space to humankind, is putting together a global partnership to coordinate the development, operation, and utilization of space-related infrastructure, data, information and services, including EO, which will target the solutions that space can provide for the fulfilment of the SDGs, and will be an integral part of UNISPACE+50. This global partnership, including public and private partners, has as its ultimate objective to close existing gaps that prevent countries from making full use of space assets. Therefore, countries are the beneficiaries, and a progressive increase in their access to space and in their use of space assets will be the key indicator of the success of the global partnership.

UNISPACE+50 provides a unique window of opportunity to set up this partnership, as all the preparatory work on thematic priorities and on the programmatic framework defined

[3] General Assembly resolution 70/1.

by the four pillars (space economy, space society, space accessibility and space diplomacy) have been agreed and directly address the needs of the 2030 Agenda for Sustainable Development. In addition, UNISPACE+50 is viewed as an opportunity to strengthen unified efforts at all levels and among all relevant stakeholders in shaping the global "Space 2030" agenda, identifying ways to promote the effective use of space tools to contribute to achieving the SDGs.

In parallel, to contribute to the effective exploitation of space technology, UNOOSA and the European GNSS Agency (GSA) signed a Memorandum of Understanding (MoU) in July 2016 to develop activities, which include the development of educational activities and common awareness-raising actions. The MoU follows the line established in the European Parliament resolution of 8 June 2016 (2016/2731(RSP)). Paragraphs 9 and 26 of this resolution read as follows:

> *"9. Supports the development of integrated applications using both EGNOS/Galileo and Copernicus.*
>
> *[…]*
>
> *26. Encourages the Commission to investigate opportunities for deploying European GNSS and Copernicus in the Union's neighbourhood and development policy and in negotiations on cooperation with non-EU countries and international organisations;"*

UNOOSA-GSA have identified that the goals established by this line of action are complementary to the 17 SDGs that entered into force in January 2016. These new goals are a call for action by all countries and, although not legally binding, Governments are expected to take ownership and seek their achievement.

In this context, the current study explores the synergies between the two flagship European Union space programmes, the European Global Navigation Satellite Systems (EGNSS: Galileo and the European Global Navigation Overlay Service (EGNOS)) and Copernicus, to show their potential to help countries in achieving the targets set by the SDGs and to be contributors of the UNISPACE+50 process, as two important elements to be considered for the Global Space Partnership for the Sustainable Development Goals.

This study has been carried out by UNOOSA in cooperation with the GSA as part of its mandate to promote and foster the market development of EGNSS.

Introduction to the Sustainable Development Goals

The Millennium Summit, held in September 2000 at United Nations Headquarters in New York, represented the largest gathering of world leaders in history. In the course of the meeting the United Nations Millennium Declaration was ratified and nations committed to a new global partnership aimed at enhancing human development by setting out a series of time-bound targets with a deadline of 2015, which became known as the Millennium Development Goals (MDGs). These Goals had a list of associated quantified targets to address extreme poverty, hunger, disease, lack of adequate shelter and exclusion, while promoting gender equality, education, and environmental sustainability. Although significant progress was made in a number of areas, it has been uneven, and some of the MDGs remained off-track. As a consequence, in September 2015, the United Nations, through a deliberative process involving its 193 Member States, adopted a new set of goals to be achieved over the following 15 years to end poverty, protect the planet, and ensure prosperity for all, as part of a new sustainable development agenda: the 2030 Agenda for Sustainable Development.

Although built on the MDGs—in an attempt to complete what had not been fully achieved—this new Agenda goes far beyond the previous framework. Alongside continuing the focus on priorities such as poverty eradication, health, education and food security and nutrition, the Agenda sets out a wide range of economic, social and environmental objectives. It also promises more peaceful and inclusive societies and, crucially, defines means for implementation. Reflecting its integrated approach, there are deep interconnections and many cross-cutting elements across the new Goals and their associated targets.

This Agenda has defined 17 SDGs with 169 associated targets towards sustainable development. These are integrated, indivisible and collectively devoted to the pursuit of global development and of "win-win" cooperation, which can bring huge gains to all countries and all parts of the world. The Goals and targets are the result of over two years of intensive public consultation and engagement with civil society and other stakeholders around the world, which paid particular attention to the voices of the poorest and most vulnerable. This consultation included valuable work done by the General Assembly Open Working Group on Sustainable Development Goals and by the United Nations, whose Secretary-General provided a synthesis report in December 2014.

The 17 SDGs are shown in table 1.

Table 1. Sustainable Development Goals

Goal N°	Objective
1	End poverty in all its forms everywhere
2	End hunger, achieve food security and improved nutrition and promote sustainable agriculture
3	Ensure healthy lives and promote well-being for all at all ages
4	Ensure inclusive and equitable quality education for all and promote lifelong learning opportunities for all
5	Achieve gender equality and empower all women and girls
6	Ensure availability and sustainable management of water and sanitation for all
7	Ensure access to affordable, reliable, sustainable and modern energy for all
8	Promote sustained, inclusive and sustainable economic growth, full and productive employment and decent work for all

9	Build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation
10	Reduce inequality within and among countries
11	Make cities and human settlements inclusive, safe, resilient and sustainable
12	Ensure sustainable consumption and production patterns
13	Take urgent action to combat climate change and its impacts* * Acknowledging that the United Nations Framework Convention on Climate Change is the primary international, intergovernmental forum for negotiating the global response to climate change.
14	Conserve and sustainably use the oceans, seas and marine resources for sustainable development
15	Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss
16	Promote peaceful and inclusive societies for sustainable development, provide access to justice for all and build effective, accountable and inclusive institutions at all levels
17	Strengthen the means of implementation and revitalize the Global Partnership for Sustainable Development

The Goals are accepted by all countries—developed and developing countries alike—and are applicable to all, taking into account different national realities, capacities and levels of development, and respecting national policies and priorities. The scale and ambition of the new Agenda requires a revitalized global partnership to ensure its implementation.

Governments have the primary responsibility for follow-up and review, at the national, regional and global levels, in relation to the progress made in implementing the Goals and targets over the 15-year period.

The role of space in the 2030 Agenda for Sustainable Development

The SDGs developed in 2015 include much more accountability than the MDGs, with a strong emphasis on data acquisition (for example demographic, statistical, environmental), and their essential link to geolocation in support of monitoring and measuring the SDG targets and indicators. Therefore, from the very inception of the SDGs, space technologies have been viewed as integral for their achievement. The signatories agreed to "promote transparent and accountable scaling-up of appropriate public-private cooperation to exploit the contribution to be made by a wide range of data, including earth observation and geospatial information".

Space assets and technologies can be used to support most, if not all, the SDGs; in some cases, the use of space technology and the availability of space-based services is nowadays so common that it is taken for granted, even if the role of space is not specifically acknowledged. One main advantage is that space provides non-invasive tools, with capacity for repeatable objective measurements, which will enable a more equitable and fair decision-making process. For the 2030 Agenda for Sustainable Development to be successful, the use of space services shall become the norm. A global partnership is needed to ensure that countries are fully aware of the potential of space to implement and monitor the SDGs, and to ensure that the needs of all countries are taken into account, reducing existing gaps, when designing and operating new space-based infrastructure. Throughout this report, the contributions of Copernicus and EGNSS towards the achievement of the SDGs are showcased, demonstrating the benefits that space can bring, considering the two European space flagship programmes.

Traditionally, the use of space-related technologies has been associated with large-scale projects. However, nowadays the maturity of these technologies and their increased accessibility provide significant added value also when used in projects of a smaller scale. UNOOSA, through its different programmes, works on building the necessary capacity to enable an effective use of space by all nations. For the European GNSS, the European Union, the European Commission, the European Space Agency and the European GNSS Agency have responsibilities respectively with regard to the political oversight, the infrastructure deployment and the service provision and commercialization of the services. Additionally, in the case of Copernicus, other European Union Agencies and organizations are involved such as: the European Environment Agency (EEA), the European Agency for the Management of Operational Cooperation at the External Borders of the Member States of the European Union (FRONTEX), the European Maritime Safety Agency (EMSA), the European Satellite Centre (SatCen) and the European Organisation for the Exploitation of Meteorological Satellites (EUMETSAT).

Orbiting in space, satellites equipped with specialized sensors can cover vast and remote areas of the Earth. Today, thanks to the accumulated knowledge of more than 50 years of observation, the "Earth system" is better understood, with improved knowledge of the various components of this system, including its atmosphere, land, oceans and ice coverage. The detection of global patterns of environmental change would not have been possible without satellite information.

In addition to EO, global navigation satellite systems (GNSS), such as Galileo, are used to pinpoint the user's position on the globe with great accuracy. GNSS systems provide information for receivers on the ground to measure their position, velocity and time. Initially after its emergence, this technology was used for site-surveying applications, while today it has become central and ubiquitous, being widely employed in all modes of transport, (road, aviation, maritime, etc.), fleet management, high-precision and consumer applications, provision of time information in critical national infrastructures as well as scientific applications such as measuring the impact of space weather on the Earth, of earthquakes and climate change on human communities, and so on.

Additional value for users and society can be generated by using the two space technologies in synergy. In fact, the data coming from EO need to be geo-referenced with the use of GNSS and the other way round; typical GNSS applications such as urban planning, traffic management or high-precision agriculture can be complemented by imagery and, for example, soil moisture data coming from EO. The maturity and diversity of systems and data availability allow unprecedented potential for the combination of the two technologies, GNSS and EO, unleashing integrated applications that were not possible 10 years ago.

Space technology and space applications can help governments not only in achieving the SDGs, but also in monitoring the progress of their implementation. The European Union's flagship programmes the European GNSS (EGNSS, Galileo and EGNOS) and Copernicus can become fundamental contributors towards the achievement of the SDGs not only in the European Union but also worldwide. The exploitation of their synergies and complementarities, including the sharing of best practices among United Nations Members can reinforce such a contribution even further.

International context for global navigation satellite systems

A satellite navigation system comprises infrastructure that allows users with a compatible device to determine their position, velocity and local time by processing signals from satellites in space. Satellite navigation system signals are provided by a variety of satellite positioning systems, including global constellations and satellite-based augmentation systems (SBAS).

Global navigation satellite system (GNSS) is the term used for a satellite navigation system with worldwide coverage. Typically, GNSS architecture consists of three components: a space segment, which comprises a satellite constellation, a ground segment to control and monitor the space segment, and the end user receivers. By measuring the transmission time delay, a receiver can calculate the distance between it and an orbiting satellite in view. The receiver can precisely determine its three-dimensional position through geometrical trilateration by collecting data from at least four satellites.

Among the global constellations, there are currently two fully operational and two in the deployment phase:

- *United States Global Positioning System (GPS):* The first GNSS, fully operational since 1995, is managed by the United States Department of Defense.
- *The Russian Federation GLObal NAvigation Satellite System (GLONASS):* The Russian GNSS, completed in 1995 and fully operational since 2011, is managed by the Russian Aerospace Defence Forces.
- *Galileo:* The European GNSS, currently under deployment with Initial Services declared in 2016, is owned and managed by the European Union (the only GNSS under civilian control).
- *BeiDou Navigation Satellite Systems (BDS):* The Chinese GNSS, also under deployment, is set to supersede the COMPASS regional system operating since 2000. It is managed by the governmental China Satellite Navigation Office.

Satellite-based augmentation systems allow compatible GNSS receivers to compute position estimates with improved accuracy with respect to the accuracy computed with GNSS stand-alone and associated integrity warnings. The corrections for the GNSS satellites in view and of ionospheric delay estimates are broadcast by geostationary communications satellites. There are currently four operational SBAS operating in different regions: the Wide-area Augmentation System of the United States (WAAS, North America), the European Geostationary Navigation Overlay Service (EGNOS, Europe), the Japanese Multifunctional Transport Satellite (MTSAT) SBAS (MSAS, Japan) and the Indian GPS Aided Geo Augmented Navigation (GAGAN, India); and another three in various phases of development: the Russian System of Differential Correction and Monitoring (SDCM, Russian Federation), the Korean Augmentation Satellite System (KASS, Republic of Korea) and the Satellite Navigation Augmentation System (SNASS, China).

In 2005 the International Committee on Global Navigation Satellite Systems (ICG), for which UNOOSA acts as Executive Secretariat, was established under the umbrella of the United Nations, as an informal, voluntary body to consider all matters regarding GNSS on a worldwide basis. In this context, the ICG provides a unique platform for multilateral dialogue to discuss the use of GNSS for sustainable development, human benefit and security, particularly in developing countries.

The formation of the ICG was preceded by joint efforts by Member States of the United Nations to establish a forum for the purpose of promoting cooperation on matters of mutual interest related to civil satellite-based positioning, navigation, timing and value-added services. With a rising need to monitor sustainable growth, and the simultaneous development of GNSS technology that could be used for this purpose, the Third United Nations Conference on the Exploration and Peaceful Uses of Outer Space (UNISPACE III), held in 1999 in Vienna, proposed the use of space science and technology for sustainable development as well as human security and welfare. The establishment of the ICG followed a recommendation from a GNSS Action Team consisting of 38 Member States as well as 15 governmental and non-governmental institutions. The ICG was specifically designed to provide a central platform, where GNSS operators from around the world could introduce new cooperative ventures, and define common goals and objectives with a special focus on applications that can contribute to sustainable development.

ICG and its Providers' Forum work to promote the introduction and utilization of GNSS services and their future enhancement, including in developing countries, providing assistance, as necessary, for the integration of GNSS into existing infrastructures. ICG also assists GNSS users with their development plans and applications by encouraging coordination and serving as a focal point for information exchange. Participation in ICG is open to all countries and entities that are either GNSS providers or users of GNSS services and that are interested, and willing to actively engage, in ICG activities.

As regards EGNSS, specifically Galileo and EGNOS, the governance foresees the European Commission, the European Space Agency (ESA) and the GSA as the main European organizations in charge of the EGNSS programmes, with different responsibilities:

- The European Commission is responsible for the political dimension and the high-level mission requirements. Its role is the management of the GNSS programmes and the funding, ensuring coordination among stakeholders and defining the key decision stages for the implementation of the programmes.

- The GSA has been delegated the responsibility for the EGNSS service operations by the European Commission. Its main activities include the commercialization and exploitation of the systems, the security accreditation of the systems and the management of European Union GNSS research framework programmes.
- The ESA responsibility covers the definition, development, and in-orbit validation of the space segment and related ground elements of EGNSS programmes and its future evolutions.

International context for Earth observation

Since the 1960s, more than 320 EO satellites have been launched worldwide. This highlights the importance of this technology for our modern society and it is specifically mentioned in the 2030 Agenda for Sustainable Development resolution (A/RES/70/1). At international level there are several actors that play an important role for the promotion of EO:

- The *Group on Earth Observations (GEO):* the mission of GEO is to connect the demand for sound and timely environmental information with the supply of data and information about the Earth. Advocacy for broad, open data policies helps ensure that the data collected through national, regional and global observing systems are both made available and applied to decision-making.
- The *Committee on Earth Observation Satellites (CEOS):* coordinates civil space-borne observations of the Earth. Participating agencies strive to enhance international coordination and data exchange, and to optimize societal benefit. Currently, there are 52 members and associate members, consisting of space agencies and national and international organizations; participating in CEOS planning.
- *UNOOSA:* as part of the preparation of UNISPACE+50, the Office is putting together a Global Partnership for the Coordination of the Development, Operation, and Utilization of Space-Related Infrastructure, Data, Information and Services, including EO.

As regards Europe, individual European nations and national institutions have made substantial R&D efforts in the field of EO in recent decades: since 1966 with the launch of Diapason, the first French geodesy satellite, many other European countries (including Germany, Italy and the United Kingdom of Great Britain and Northern Ireland) have independently sent EO satellites into space. These efforts have resulted in tremendous achievements, but the idea for a global and continuous European EO system was developed only in 1998 with the definition of the Global Monitoring for Environment and Security (GMES) programme, which was later turned into Copernicus after the European Union became involved in its financing and development. Copernicus, declared operational in 2012, represents the world's largest single EO programme.

Study objectives and adopted methodology

In the context of the United Nations 2030 Agenda for Sustainable Development, the study takes a closer look at how space, and in particular the two European flagship space programmes EGNSS and Copernicus, contribute to the fulfilment of the global SDGs. Based on the existing and potential applications of both technologies, an assessment has been made of how their expanded use can benefit directly the users and indirectly societies and citizens around the world. Supported by the presented case studies and examples, States and regions may evaluate a more targeted use of the existing space technologies supporting them in achieving the SDGs.

Special focus has been put on the combined use of the two space technologies at application level with a view to maximizing even further their socioeconomic impact. Analysing the similarities in the value chains of both programmes, specific recommendations have also been developed on how to deploy best practices from EGNSS and Copernicus service provision and involvement of industry stakeholders in order to expand the user base in Europe and worldwide.

The remainder of the report is structured as follows:

- Chapter 3 introduces the European Union space programmes, namely EGNSS and Copernicus, including the overall description of the programmes, the status of implementation of the infrastructure on the ground and in space, the available services, the user base and applications today, and market trends leading to their expanded use in the future.
- Chapter 4 reviews EGNSS and Copernicus synergies in support of the SDGs, analysing in detail the commonalities and differences in the value chains of both technologies, from satellite launches to final end users, and identifying areas where sharing best practices and exploring synergies would contribute to enhanced socioeconomic impact at application level.
- Chapter 5 provides an assessment on how European Union space programmes contribute to each individual SDG, identifying for each Goal the main application areas that support the fulfilment of the associated targets, and providing relevant examples and use cases.

To achieve the optimal contribution of the European space technologies EGNSS and Copernicus to the fulfilment of each individual SDG, all 169 targets and associated indicators of the 17 Goals have been analysed in detail and mapped against the typical benefits derived from using EGNSS and Copernicus across all application areas.

This assessment uses the following methodology:

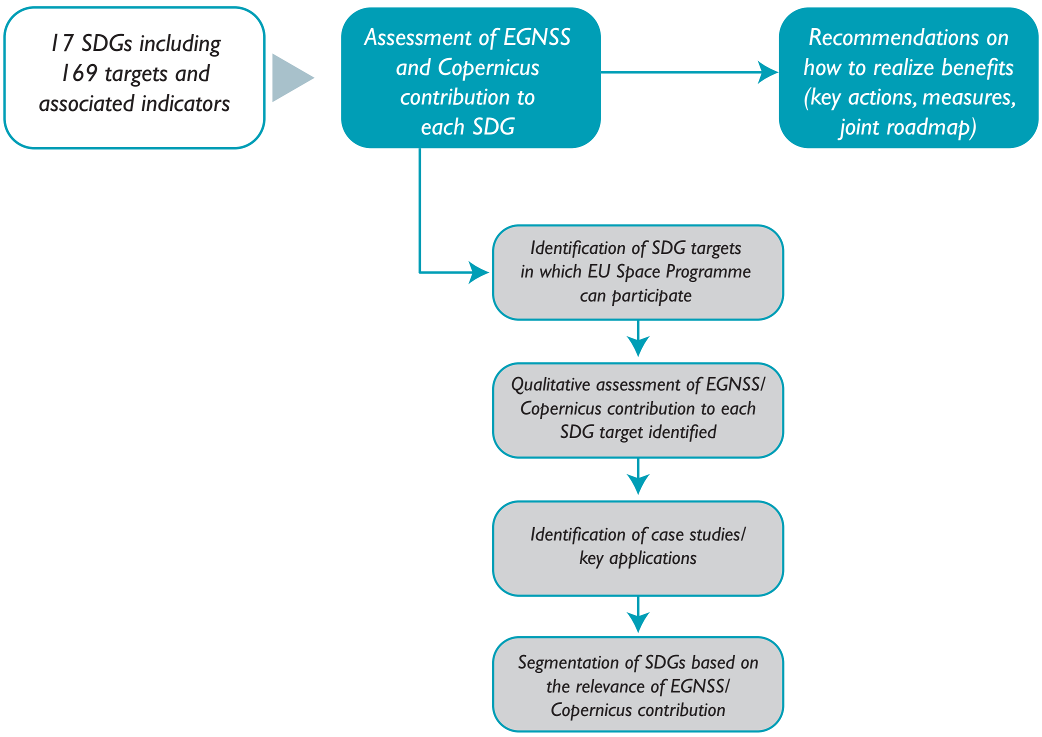
- Identifying which SDG targets and related indicators are impacted by the use of EGNSS and Copernicus-related applications.
- Assessing, by means of Harvey Balls, the contribution of European Union space programmes to each SDG target previously identified. This assessment has been

performed by using in-house knowledge developed by UNOOSA and GSA from their core activities over the years.

- Identifying case studies and key examples tangibly demonstrating how European Union space programmes effectively support the fulfilment of SDGs.
- Segmenting the 17 SDGs into three homogeneous groups based on the relevance of the contribution of European Union space programmes, identifying the "Tier 1" Goals that may be best supported by EGNSS and Copernicus.

Ultimately some key recommendations on how to foster synergies and actually support the realization of the European Union space programmes' contribution to SDGs are provided.

Figure II. Study methodology



3. The European Union space programmes: European Global Navigation Satellite System and Copernicus

European Global Navigation Satellite System

The following sections introduce the infrastructure and market aspects of Galileo and EGNOS as well as their main application areas.

Galileo programme overview

Galileo is the state-of-the-art GNSS of the European Union, under civilian control. It provides improved positioning, navigation and timing information everywhere in the world, with significant positive implications for many European services and users.

Its development follows a stepwise approach, in line with the launch of Galileo satellites:

- *Initial Services* were declared operational in December 2016. Thanks to a constellation of 18 satellites, Galileo enhances the accuracy of the position computed by multi-constellation receivers and supports Search and Rescue operations.
- *Full Operational Capability* is scheduled for 2020, when the satellite constellation will be complete and the range of services fully provided.

Thanks to its unique features and innovative technology, it aims to assist an extremely broad range of users in different market segments including transport, mass-market and professional services.

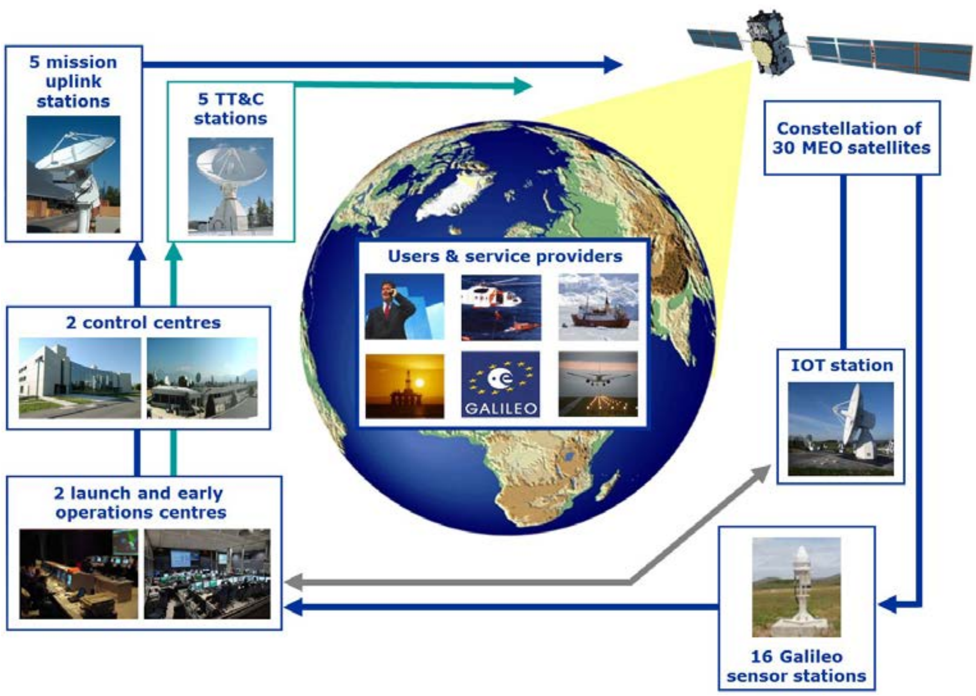
Space component and ground segment

Currently under deployment, the complete Galileo constellation will comprise 30 satellites spread evenly around three circular orbital planes with semi axes of about 23,222 km above the Earth's surface. The system's orbit and signal accuracy is controlled by a ground segment consisting of two *Galileo Control Centres* (GCC) situated in Oberpfaffenhofen, Germany and Fucino, Italy.

The Galileo core infrastructure is complemented by services facilities which support the provision of the Galileo services:

- The *European GNSS Service Centre* (GSC) is the interface between the Galileo Open Service and Commercial Service user communities and the Galileo system (additional information can be found in the section 'The European Service Centre'). This facility is located in Torrejón, Spain.
- The *Geodetic Reference Service Provider* (GRSP) supports the GCC in establishing the Galileo Terrestrial Reference Frame (GTRF) and its coordination with the International Terrestrial Reference Frame (ITRF).
- The *Time Service Provider* (TSP) supports the GCC in establishing Galileo System Time (GST) and its alignment with Coordinated Universal Time (UTC).
- The *Galileo Security Monitoring Centre* (GSMC) is in charge of monitoring system security. These facilities are located in St. Germain-en-Laye, France, and Swanwick, United Kingdom.
- The *SAR/Galileo Data Service Provider* (SGDSP) is the entity in charge of coordinating operations related to the SAR/Galileo service. This facility is located in Toulouse, France.
- The *Galileo Reference Centre* (GRC) is responsible for monitoring and assessment of the performance of the Galileo services, completely independently from the Galileo core infrastructure and its operations. This facility will be located in Noordwijk, the Netherlands.

Figure III. Galileo infrastructure



Services

Since 15 December 2016, Galileo has started its operational phase with the Declaration of Initial Services allowing Galileo-compatible receivers to receive signals provided by Galileo for positioning, navigation and timing purposes. Based on the current constellation consisting of 18 satellites, Galileo now offers three Initial Services:

- *Open Service:* a free mass-market service for positioning, navigation and timing.
- *Public Regulated Service (PRS):* for government-authorized users, such as civil protection services, customs officers and the police. This system is particularly robust and fully encrypted to provide service continuity for government users during emergencies or crisis situations.
- *Search and Rescue Service (SAR):* Europe's contribution to the international distress beacon locating organization COSPAS-SARSAT. Galileo's data help to locate beacons and rescue people in distress in every kind of environment.

Galileo Initial Services represent an intermediate milestone towards the achievement of the Full Operational Capability (FOC) phase, planned for 2020 and including the full 30-satellite constellation. Once fully deployed, Galileo will also offer a Commercial Service: a service complementing the Open Service by providing an additional navigation signal and added-value services in a different frequency band. The Commercial Service signal can be encrypted in order to control access to the Galileo Commercial Services.

Compared to other GNSS, Galileo introduces several innovations:

- The free-of-charge Galileo Open Service will be the first to broadcast authentication data through its *Navigation Message Authentication* (OS NMA). Providing users with information about the received signal's authenticity and preventing the spoofing of the GNSS signal, this feature will benefit all GNSS-enabled applications in which a liability risk would arise from a falsification of the signal, including regulated applications (for example, smart tachograph) and consumer applications (for example, commercially sensitive ones) and many other still unforeseen future applications.
- The *Galileo Commercial Service* will complement the Open Service and provide unprecedented positioning accuracy and improved signal robustness due to authentication. This service will provide a significant added value to the GNSS downstream market and is likely to pave the way for new business models for service providers. Indeed, the Galileo Commercial Service will meet the level of accuracy required for many applications in cadastral, construction, and mine surveying, while delivering *Precise Point Positioning* corrections around the world directly via the Galileo satellites, avoiding the need for an additional communication channel.
- The *Galileo SAR Service* will comprise two components, namely an automatic *forward link distress call* (initial service declared in December 2016) and a *return link alert service* that will inform the sender of the distress call that their message has been received (initial service to be declared by the end of 2018). The return link alert service represents a unique feature—not provided by other GNSS—that will enhance the effectiveness of SAR operations.

European Geostationary Navigation Overlay Service programme overview

The *European Geostationary Navigation Overlay Service* (EGNOS) is Europe's regional satellite-based augmentation system that is used to improve the performance of GNSSs. The system started its initial operations in July 2009 and obtained certification for use in safety-of-life applications in March 2011.

EGNOS has been deployed to provide safety-of-life navigation services to aviation, maritime and land-based users over most of Europe, since GNSS systems alone do not meet the necessary operational requirements set by the civil aviation authorities.

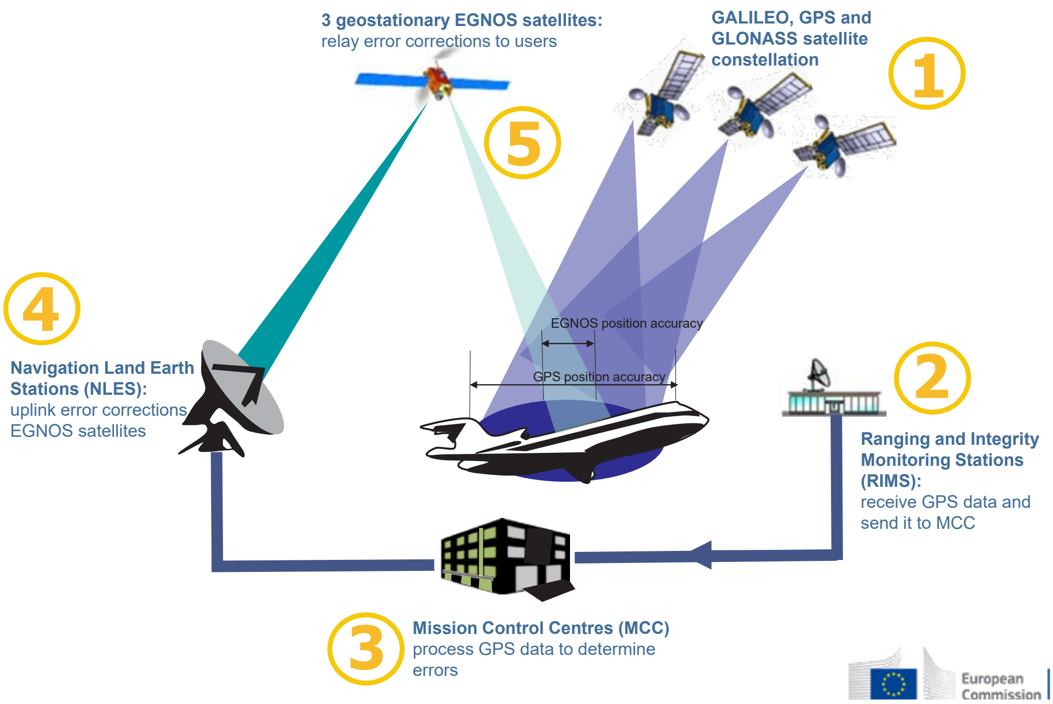
Space component and ground segment

The system is based on a network of ground stations, control centres and three geostationary satellites. The ground stations gather data on the current accuracy of GPS signals (and of Galileo in the future) and embed it in the EGNOS signal, which is uplinked to the satellites to be transmitted to users. In more detail:

- The EGNOS signal is transmitted by three geostationary satellites:
  - two Inmarsat-3 satellites, one over the eastern part of the Atlantic, the other over the Indian Ocean
  - one ESA Artemis satellite above Africa

  Unlike GNSS satellites, these three do not have signal generators on board. A transponder transmits signals uplinked to the satellites from the ground, where all the signal processing takes place;
- Forty *Ranging and Integrity Monitoring Stations* (RIMS) measure the positions of each EGNOS satellite and compare accurate measurements of the positions of each GPS satellite. The RIMS then send this data to the mission control centres, via a dedicated communications network.
- Two *Mission Control Centres* (MCC) receive the information from the RIMS and generate correction messages to improve satellite signal accuracy and information messages on the status of the satellites (integrity). The MCCs act as the EGNOS system's "brain".
- Six *Navigation Land Earth Stations* (NLES): the NLESs (two for each GEO for redundancy purposes) transmit the EGNOS message received from the central processing facility to the GEO satellites for broadcasting to end users.

Figure IV. EGNOS infrastructure



Services

EGNOS is already operational, sharpening the accuracy of GPS signals across Europe (and of Galileo in the future). In addition, it informs users about the current integrity (level of reliability) of the system based on the GPS satellites' orbits, atomic clock accuracy and ionospheric delay. EGNOS offers integrity: if the accuracy of the signal falls below a given threshold, users are warned within six seconds. Two services are currently offered by EGNOS:

- *The Open Service*, for applications where human life is not at stake, such as personal navigation, goods tracking and precision farming, has been available since October 2009.
- The *Safety-of-Life Service*, where human lives depend on the accuracy and integrity of the signals, became available for its primary purpose of aircraft navigation (beginning with vertical guidance for landing approaches) in March 2011.

Additionally, EGNOS provides a terrestrial data service called the *EGNOS Data Access Service* (EDAS). EDAS disseminates EGNOS data in real time without relying on the signals from the three EGNOS satellites. It can therefore be used in constrained environments such as when signals are blocked, not visible, or are disturbed by interference.

European Global Navigation Satellite System and Global Navigation Satellite System market and users

The GNSS market is composed of a downstream and upstream component:

- The *upstream side* comprises those entities that build the space infrastructure (satellites, ground segment) and provide a signal to users.
- The *downstream component*, on the other hand, supplies the products and services that use GNSS-based positioning and navigation as a significant enabler.

In terms of revenue, the global downstream market is expected to peak at €120 billion in 2017, including both devices and augmentation services and added-value services. The latter are set to witness skyrocketing growth between 2015 and 2020 at 20 per cent annually thanks to the advent of 5G, Automated Driving, Smart Cities and the Internet of Things (IoT).

Users

Their unique features and perfect complementarity with many other technologies make Galileo and EGNOS able to support an extremely broad range of users in different market segments. Indeed, with an estimated 5 billion GNSS devices in use around the world, almost everybody is making use of a GNSS device.

Generally speaking, three macro groups of users can be envisaged:

- *Transport-related*, either by land, air or water; they rely on Galileo and EGNOS to ensure safety and efficiency of their transportation.
- *Mass-market*, enabling location-based services and applications that make easier the lives of owners of smartphones and other personal devices. These include specific applications targeting users with special needs to achieve social inclusion, and safety related applications.
- *Professional*, including users making use of Galileo and EGNOS for surveying and mapping activities or for precise agriculture.

Nevertheless, the ubiquity of GNSS technology makes even the broadest classification not wide enough to include all the use cases. For example, additional types of uses for Galileo include those related to scientific or governmental work.

EGNSS and GNSS downstream market

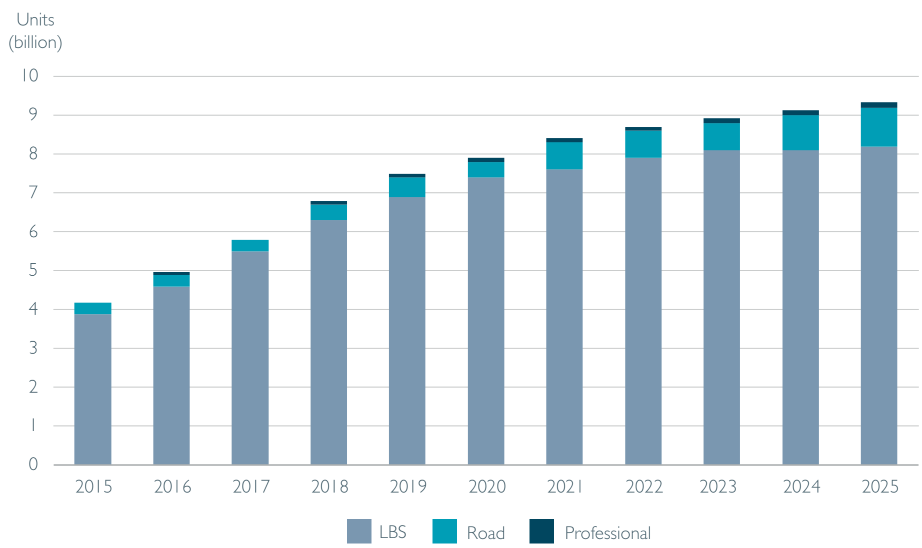
Focusing on the worldwide GNSS downstream market, the related value chain is broadly classified into three groups of companies:

- *Components manufacturers*, producing receivers for stand-alone use or integration into systems, including chipsets, antennas and safety beacons
- *Systems integrators*, integrating GNSS capability into larger products, such as vehicles and consumer electronics, as well as dedicated GNSS devices

- *Value-added service providers*, whose services improve access and use of GNSS, including map providers, augmentation service providers and GNSS calibration or testing activities

The global downstream GNSS market has experienced constant growth since 2000, when the United States Government discontinued the use of Selective Availability of GPS and de facto kicked off the use of GPS for civil and commercial users worldwide. Indeed, according to the GSA "*GNSS Market Report 2017*" the global installed base is forecast to increase from the approximately 5.8 billion GNSS devices in use in 2016 to approximately 8 billion in 2020, with mass-market devices (location-based services (LBS) and road in figure V) accounting for the largest part.

Figure V. Global installed base by segment



This impressive growth has been fuelled by the intensive use of GNSS and SBAS in many different market domains and applications, and also as a result of a continuous fall in component costs and a consistent improvement in GNSS performance in this period. Indeed the evolution of performances of key users' requirements related to the availability, accuracy, continuity and integrity of GNSS signals made the use of GNSS ubiquitous in many field applications. In the future—also thanks to the market uptake of GNSS currently under development, including Galileo—additional enhancements in performance features, such as robustness to spoofing and better penetration in urban environments, will further expand use cases for GNSS.

To provide an idea of how GNSS is used across different market segments, the GSA classifies the GNSS market into eight market segments, including transport, high-precision, and mass-market domains:

- *LBS:* The LBS market segment covers a broad range of applications supported by several categories of devices: mainly smartphones and tablets, but also specific equipment such as personal tracking devices and wearables. Indeed, the capability of receiving signals from different GNSS has become a standard feature in modern smartphones, also thanks to a flourishing market for location-aware applications satisfying both leisure and professional needs. The list of LBS applications is as follows:

– *Navigation:* Route planning and turn-by-turn instructions based on GNSS support for both pedestrian and road navigation.
– *Mapping and Geographic Information Systems (GIS):* Smartphones enable users to become map creators thanks to the democratization of digital mapping.
– *Geo marketing and advertising:* Consumer preferences are combined with positioning data to provide personalized offers to potential customers.
– *Safety and emergency:* GNSS, in combination with network-based methods, provides accurate emergency caller location.
– *Enterprise applications:* Mobile workforce management and tracking solutions help companies to improve productivity.
– *Sports:* GNSS enables the monitoring of users' performance through a variety of fitness applications.
– *Games/augmented reality:* GNSS enables a wide range of location-based games on smartphones and tablets. In augmented reality games, positioning and virtual information are combined to entertain the user.
– *mHealth (mobile health):* In combination with other technologies, GNSS enables a vast array of applications from patient monitoring to guidance systems for the visually impaired.
– *Personal tracking:* GNSS facilitates innovative tracking solutions, including the deployment of local geo-fences that trigger an alarm when a user leaves the perimeter.
– *Social networking:* Friend locators embedded in social networks use GNSS to help users keep in touch and share travel information.

In an LBS context, all major chipset manufacturers (for example, Qualcomm, Broadcom) have integrated Galileo, with the first Galileo-enabled smartphones already available on the market (for example, BQ, Samsung, and Huawei).

• *Road:* GNSS in road transport supports the efficient and safe transportation of persons and goods. Currently there are approximately 400 million devices globally and the fields of applications include:
  – *Smart mobility*, where dedicated on-board units and smartphones provide information to improve road transportation by offering navigation, fleet management and satellite road traffic monitoring services
  – *Safety-critical applications,* using accurate and secure positioning for scenarios of potential harm to humans or damage to a system/environment (for example, cooperative intelligent transport systems (ITS), advanced driver assistance systems, dangerous goods tracking)

– *Liability-critical applications,* in which the GNSS positioning is used to compute the costs associated with a given service (for example, road user charging and insurance telematics)
– *Regulated applications,* referring to institutional-led initiatives regulating road transportation, such as eCall and smart tachograph

The use of GNSS and SBAS in road transport is key to reducing traffic, decreasing negative environmental effects and increasing safety. Also in view of this, EGNOS has already been implemented in four European Union road user charging schemes, and eCall and Digital Tachograph regulations leveraging EGNSS have been adopted at European Union level.

- *Aviation:* Historically, navigation in aviation was mainly based on ground-based navigation aids. With implementation of the PBN (performance-based navigation) concept, satellite-based navigation systems became the main drivers towards more precise navigation and optimized airspace. EGNSS, in particular EGNOS, plays a crucial role in this, providing the much-needed integrity information. With this, aircraft approaches with decision heights down to 200 ft can be implemented, giving airports greater accessibility without the need for expensive ground infrastructure. Indeed, more than 440 EGNOS-based procedures have been implemented in Europe in 236 airports in 19 European countries since EGNOS was declared operational.

  Applications are grouped as:

  – *Regulated applications,* including PBN, Emergency Locator Transmitters and Automatic Dependent Surveillance – Broadcast
  – *Unregulated applications,* such as moving maps, infringement alarms and Personal Locator Beacons

- *Maritime transport:* GNSS is used mainly in maritime for en route navigation and in support to the Vessel Traffic Services (VTS) system, which are maritime traffic collision and traffic control mechanisms. Applications include: track control, container ship-to-ship coordination, port approach and navigation, ship-to-shore coordination, shore-to-ship management, calamity abatement. GNSS contribute to a safer and more efficient navigation owing to the better accuracy and availability provided. Also in view of this, in 2016 Galileo was recognized by the International Maritime Organization as a *"World Wide Radio Navigation System"* for use in regulated domains.

  Maritime applications include:

  – *Navigation*, both offshore and on inland waterways
  – *Positioning*, including traffic management and surveillance, SAR, fishing vessel control, port operations and marine engineering

- *Rail transport:* From passenger information systems and asset management systems, to high- and low-density command and control systems and signalling applications, the use of GNSS in railway applications provides increased safety and reduces the costs of infrastructure management and operations compared to legacy signalling solutions. Rail applications include:

- Main Line Command and Control Systems
- Low Density Line Command and Control Systems
- Asset Management
- Passenger Information
- Driver Advisory System (DAS)

In terms of adoption it is worth mentioning that GNSS technology has been included in the European Railway Traffic Management System roadmap in view of its expected operational and safety benefits.

- *Agriculture:* GNSS can be used by farmers for what is called variable rate application (VRA), a practice used in precision farming. VRA requires the use of GNSS sensors, aerial images, and other information management tools to determine optimal herbicide doses, fertilizer requirements and other inputs to help farmers save money, reduce their impact on the environment and increase crop yields. With VRA farmers adjust their doses in field operations to the observed variability in the field. For example, only sections of a field with weeds are treated with herbicide. Specific GNSS applications are:
  - Farm machinery guidance
  - Automatic steering
  - Yield monitoring
  - Biomass monitoring
  - Soil condition monitoring
  - Livestock tracking and virtual fencing
  - Forest management
  - Farm machinery monitoring and asset management
  - Geo-traceability
  - Field definition

  In agriculture, EGNOS has already proved its utility, with 72 per cent of farmers in Europe using GNSS.

- *Mapping and Surveying:* An obvious example of GNSS use is the production of surveys and maps. Given the high level of accuracy required, the use of high-end dual frequency multi-constellation receivers is usually foreseen, often complemented by GNSS augmentation techniques. Simpler stand-alone GNSS receivers might not have the required precision for some users' requirements. Mapping and surveying applications include:
  - Applications in land surveying, such as cadastral surveying, construction surveying, mapping, mine surveying, infrastructure monitoring
  - Marine surveying

In a mapping and surveying context, the relevance of EGNOS is widely recognized as being integrated in all newly sold handheld mapping devices.

- *Timing and synchronization:* precise time and synchronization is crucial for a range of strategic activities. GNSS provides direct and accurate access to Coordinated Universal Time (UTC) and allows precise synchronization between receivers at different locations. GNSS is often used as a precise source of timing and synchronization in critical infrastructures such as telecommunication networks, energy grids and financial applications.

EGNSS and GNSS market trends

With 6.4 per cent annual growth in revenue forecast between 2015 and 2020, many trends are impacting the global GNSS downstream market:

- In *LBS*, more and more smartphones and handheld devices integrate multi-constellation GNSS, boosting GNSS performance, also in view of the fact that over 90 per cent of context-aware apps now rely on GNSS.
- In *road*, GNSS meets the needs of Autonomous Driving for reliable and accurate positioning, with automotive original equipment manufacturers (OEMs) and technology companies leading the development of this technology.
- In *aviation*, unmanned vehicles such as drones are increasingly relying on GNSS, and SAR beacons manufacturers are developing solutions for Aircraft Distress Tracking using GNSS.
- In *rail*, GNSS is becoming a generic system widely used in non-safety relevant applications.
- In *maritime*, GNSS is becoming the primary means of obtaining position, navigation and timing (PNT) information at sea.
- In *agriculture*, GNSS applications represent a key enabler for the integrated farm management concept, also in conjunction with EO data. Moreover, GNSS is contributing to the uptake of drones in agriculture.
- In *surveying*, advanced post-processing techniques are being developed in view of the uptake of innovative GNSS, including Galileo. Moreover, a new plethora of geospatial applications integrate EO data with navigation and map information.
- In *timing and synchronization*, the evolution of telecom networks makes GNSS increasingly essential, especially with regard to 5G uptake.

In addition to specific market-segment trends, as a cost-effective and globally available source of location and timing information, GNSS is contributing to a rapidly diversifying range of technologies and applications. GNSS has become an essential element of major contemporary technology developments, notably including:

- *Internet of Things (IoT),* where GNSS is, among other sensors, a major enabler providing localization and timing information
- *Big data*, with GNSS being a major data source

- *Mobile Health (mHealth)* in which key mHealth application categories include disability assistance, preventive medicine and emergency services that also benefit from the fusion of big data with GNSS
- *Augmented reality (AR)*, where GNSS provides a globally available source of georeferenced information that allows the creation of a direct link between the surrounding reality and digital objects
- *Smart cities,* with GNSS as one of the key technologies used within infrastructure design and mobility of smart cities, offering numerous opportunities to citizens, local governments and city planners alike
- *Multimodal logistics*, in which GNSS contributes to the monitoring of cargo along the entire supply chain and enables pivotal asset management applications, thus enhancing overall efficiency, security and safety

Galileo and EGNOS, thanks to their differentiators, are key enablers of these trends, with their adoption progressing consistently in all mass-market, transport and professional domains. The website www.useGalileo.eu, managed by GSA, includes an up-to-date list of all available Galileo-compatible products.

Copernicus

Copernicus programme overview

Copernicus is the EO and monitoring programme of the European Union, looking at our planet and its environment for the ultimate benefit of all European citizens. As a publicly funded European Union programme, Copernicus is first and foremost the property of all European citizens, who remain its ultimate owners and beneficiaries.

Copernicus primarily builds on the data collected from EO satellites—the Copernicus space component—but it also relies on a vast amount of information collected by in situ (meaning on-site or local) measurement systems put at the disposal of the programme by the European Union Member States.

The Copernicus services transform this wealth of satellite and in situ data into value-added information by processing and analysing the data, integrating it with other sources and validating the results. With more than 8 petabytes per year, Copernicus is the third largest data provider in the world. No previous EO initiative has ever provided such a volume and diversity of data at such an impressive rate.

The full, free and open data provided by Copernicus support regional, national, European and international efforts to identify, respond and adapt to global phenomena, such as climate change, land management, atmospheric pollution, state of the seas, to name just a few. Thus, Copernicus brings benefits not only to European Union citizens but also to the entire international community.

Furthermore, by making the vast majority of its data, analyses, forecasts and maps freely available and accessible, Copernicus contributes towards the development of new innovative applications and services.

Space component and ground segment

The Copernicus space component comprises two types of satellite missions: a series of EU-owned satellite missions fully dedicated to the Copernicus programme, called the 'Sentinels', and 'Contributing Missions' operated by the ESA, the European Organisation for the Exploitation of Meteorological Satellites (EUMETSAT), the European Union Member States and other third countries and commercial providers.

The development of the space component, including the launch of the dedicated Sentinel satellites, has been delegated to ESA, which also acts as the overall system architect of the space component and ensures its technical coordination. The operations of the Sentinels have been entrusted to ESA and to EUMETSAT, on the basis of their specific know-how.

The Sentinels family provides a unique set of observations performed thanks to a range of technologies, such as radar and multispectral imaging instruments for land, ocean and atmospheric monitoring. It consists of the following satellite missions (please refer to the table in annex 2 for more details on Copernicus missions):

- *Sentinel-1* is a polar-orbiting mission which provides all-weather, day and night radar imagery for land and ocean monitoring. The twin satellites Sentinel-1A and Sentinel-1B were launched in April 2014 and April 2016 respectively.
- *Sentinel-2* is a polar-orbiting mission which provides multispectral high-resolution imaging for land monitoring and emergency management. The twin satellites Sentinel-2A and Sentinel-2B were launched in June 2015 and March 2017 respectively.
- *Sentinel-3* is a polar-orbiting mission which provides high-accuracy optical, radar and altimetry data for marine and land monitoring. The first Sentinel-3 satellite was launched in February 2016.
- *Sentinel-4* and *Sentinel-5* will provide data for atmospheric composition monitoring. Both missions will consist of payloads aboard meteorological satellites. They will be carried respectively on the geostationary Meteosat Third Generation (MTG) satellite and on the polar-orbiting MetOp Second Generation satellite. A Sentinel-5 Precursor mission is being developed to reduce data gaps between Envisat and the launch of Sentinel-5.
- *Sentinel-6* will carry a radar altimeter to measure global sea-surface height, primarily for operational oceanography and for climate studies.

The Contributing Missions provide Copernicus with complementary data collected through synthetic aperture radars, optical sensors, altimetry systems, radiometers and spectrometers. Thus, a total of around 30 Contributing Missions support Copernicus and ensure that a whole range of observational requirements is satisfied.

Each Sentinel Mission and Contributing Mission has a ground segment which is operated independently and includes elements for monitoring and controlling the satellites and for downloading, processing and disseminating data to users.

These independent ground segments are all linked together to form the Copernicus ground segment. This large space capacity is coordinated through the Space Component Data Access System, which streamlines the data flows from the various ground segments to the users.

In situ component

The term "in situ data" covers a wide range of data collected through airborne sensors (sensors fitted on aircraft or balloons and, increasingly, on drones), seaborne (sensors aboard boats or mounted on floats) or ground-based sensors. In situ data also include (aerial) photographs and maps as well as information on transport networks, hydrology or socioeconomic data about populated areas.

The Copernicus in situ component relies on existing capacities operated at national and European level, and on global observing systems. Access to in situ data is provided either by the Copernicus services or by the EEA when overall coordination is required.

In situ data are used to calibrate, verify and supplement the information provided by satellites, which is essential in order to deliver reliable and consistent data over time.

Services

The Copernicus services transform satellite and in situ data into value-added information by processing and analysing the data, integrating them with other sources and validating the results. Data sets stretching back for decades are made comparable and searchable, thus ensuring the monitoring of changes. Patterns are examined and used to create better forecasts, for example, of the ocean and the atmosphere. Maps are created from imagery, features and anomalies are identified and statistical information is extracted.

Copernicus services are implemented through six thematic service lines: Atmosphere Monitoring, Marine Environment Monitoring, Land Monitoring, Climate Change, Emergency Management and Security. These benefit users in a wide range of application domains, such as environment monitoring, climate change, agriculture and forestry, marine activities, public health, urban and regional planning, civil protection and humanitarian aid, renewable energies, development and cooperation, tourism, transport, insurance or security.

The operational implementation of the Copernicus services is either performed directly by the competent services of the European Commission (notably the Joint Research Centre - JRC) or is entrusted to European entities and agencies with the appropriate expertise. The European agencies involved are the European Environment Agency (EEA), the European Agency for the Management of Operational Cooperation at the External Borders of the Member States of the European Union (FRONTEX), the European Maritime Safety Agency (EMSA) and the European Satellite Centre (SatCen). Other competent organizations involved are the European Centre for Medium-Range Weather Forecasts (ECMWF) and Mercator Océan.

Copernicus market and users[4]

Similarly to the EGNSS case, the EO market includes:

- The *upstream market*, including EO satellites, payloads and ground segment manufacturers, launch services providers, and space agencies' EO programmes
- The *downstream market*, composed of all the actors involved in the exploitation of EO data, providing EO-related products and services to end users

In 2014, the revenues of the European EO economy were valued at between €2.1 and €2.4 billion, with EO satellite operations (upstream segment) representing €1.55 billion, the rest being shared between EO data acquisition and storage (midstream segment) and EO data processing to provide value-added services to end users (downstream segment).

Earth observation and Copernicus downstream markets

The EO downstream market includes, in particular, value-added services companies and geo-information companies, developing products that exploit EO data. In the sectoral value chains analysis these actors are termed "intermediate users".

The global EO data and value-added services market has been growing steadily over the past decade, reaching €2.75 billion in 2015. It is expected to keep rapidly expanding in the coming decade, at an annual growth rate of 13 per cent. The European market share, estimated at €632 million in 2015, is growing.

The variety of EO data creates commercial opportunities across numerous market sectors such as:

- *Agriculture:* historically one of the first domains to exploit EO, it is the most promising market in terms of the impact of Copernicus. The intermediate users have various profiles, from start-ups and small and medium enterprises (SMEs) to large companies and purely scientific players. It is also the market with the highest penetration rate of Copernicus, which already enables 13 per cent of the revenues of the sector.
- *Forestry:* depending on the country, forests may be owned either by public or private entities. As with agriculture, Copernicus enables a substantial share of the revenues of VAS providers, estimated at close to 12 per cent on average. End users, by contrast, are mostly public bodies, and few commercial applications exploit forestry EO-based products, making it difficult to quantify end users' benefits.
- *Urban monitoring:* the sector offers a wide span of applications for EO and hence for Copernicus. Intermediate users are mainly SMEs, operating in a well-developed market of which Copernicus already enables about 10 per cent of the revenues. Urban monitoring products are expected to benefit from the high growth of smart cities markets, and hence the influence of Copernicus should continue to increase. The majority of end users are local authorities, which often face budget constraints

[4] *Copernicus Market Report, Issue 1,* November 2016.

when developing the use of innovative products such as EO, but which show encouraging trends.

- *Ocean monitoring:* applications for EO are diverse, and involve various types of stakeholders. Intermediate users include private actors from micro-companies to large companies, public authorities, scientific laboratories or research centres. End users are also both public entities and private actors such as fish farmers and cooperatives. The rapidly changing environment requires near-real-time EO data, which results in a lower penetration of Copernicus data, around 6 per cent. The Sentinel-3 satellite family is expected to have a significant impact on the benefits of Copernicus for ocean monitoring applications.
- *Air quality monitoring:* information and applications have only recently started to make use of EO data, which has traditionally been based on meteorological data, statistics and measurements. Intermediate users are mostly environmental and meteorological agencies, or publicly funded organizations. End users' needs tend to be addressed by public authorities as individuals demonstrate low willingness to pay for air quality information or products.
- *Renewable energies:* this sector exploits EO data particularly for biomass and solar energy. Commercial applications are relatively new for intermediate users. The total EO market represents less than €23 million, of which Copernicus represents 10 per cent of revenue.
- *Natural disaster insurance:* the benefits to intermediate users from Copernicus are estimated to be low as a gap still exists between the very specific needs of (re)insurers and the available EO products on the market. This leads either to an in-house handling of EO raw data by the end users who can afford the infrastructure, or to a decision not to use satellite images, which are regarded as a non-critical source of data. End users' benefits can potentially be much higher, considering the high amounts involved in natural disaster insurance.
- *Oil and gas:* in this commercially oriented value chain, EO is mostly exploited in the upstream activities of oil and gas companies. Intermediate users generate substantial revenues based on Copernicus data, but in the form of GIS products rather than pure EO data. End users' benefits can be expected to be much higher considering the large markets involved.

Market trends

The EO downstream market is experiencing a rapid change. The emergence of new actors from the public sector (such as emerging countries investing in the development of their own EO activities) is creating many opportunities for users and application developers. The private sector competitive landscape is changing, with new players and business models emerging to pose challenges to the 'traditional' space players.

In this context, EO satellite manufacturers are pursuing vertical integration strategies to capture new revenue streams, while the downstream sector is characterized by the following trends:

- The EO downstream market is more and more dependent on GIS. The strong growth of the GIS market should constitute a potential growth opportunity for downstream EO players if they manage to adapt well to a market in which there are multiple sources of data.
- New space players are emerging in the EO imagery market, using constellations of small satellites, and lower launcher costs, therefore providing EO imagery data at more competitive prices than traditional space players.
- Cloud computing, which offers a new way to access and process data and facilitates large-volume storage, will play an increasing role in facilitating access to EO data. The strong competition among cloud providers, together with the establishment by the European Commission of the Copernicus *Data and Information Access Services (DIAS)* should help to bring down the costs of storage and processing.
- Unmanned Aircraft Systems (UAS) are a potential threat to satellite-based imagery. UAS can be used as a substitute for Very High Resolution (VHR) satellite data to cover limited local areas or defined areas, but are generally seen as complementary to satellite data, such as the in situ UAS contribution to the Copernicus programme. The UAS market is expected to grow in the future.

Publicly owned EO programmes such as Copernicus or Landsat tend to provide open and free-of-charge EO data. An open data policy gives all types of users access to free, low and medium spatial resolution data with interesting temporal resolution. This acts as a game changer for numerous applications across many economic sectors.

Analysing the application areas and market trends of GNSS and EO, it becomes evident that EGNSS and Copernicus are complementary technologies that are increasingly used together, and this integrated use will increase in the future. The following chapter details the process by which the respective satellite services are adopted by downstream industry and users in practice and identifies commonalities between the two programmes that, if explored, could lead already today to an expanded user base and maximized socioeconomic impact.

4. European Global Navigation Satellite System-Copernicus synergies in support of the SDGs

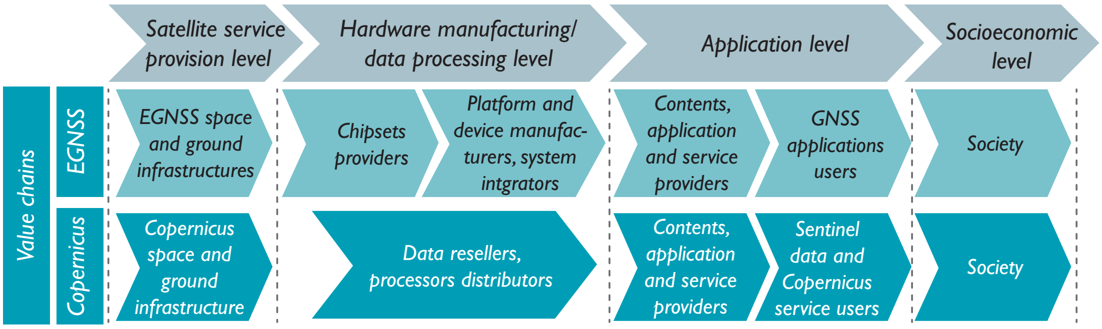
Synergies alongside the value chains

Between the providers of satellite signals/data and final users there are many actors that support the final implementation of end-to-end solutions. Their overall role in offering the best value to users and citizens is critical and may have a large impact on how the space technologies eventually contribute to the SDGs. The value chains of the two European flagship programmes EGNSS and Copernicus present many commonalities, despite the complementary nature of the services they provide. As highlighted in figure VI, four common levels can be identified between the two value chains:

- The satellite service provision level: the different bodies responsible for the implementation and operations of the space systems
- The signal/data processing level: the manufacturing of user equipment (EGNSS), data processing and reselling level (Copernicus)
- The application level: where end users are provided with value-added end-to-end solutions
- The socioeconomic level: where the wider impacts of the use of EO and GNSS technologies are generated by the use of downstream applications

The roles of stakeholders represented in each of the four value chain levels are similar for both space programmes. A difference may only be observed at the data/signal processing level. While specific hardware support is necessary to receive GNSS signals (that is, a receiver integrated into a more complex device), Copernicus data are available via resellers and distributors as well as via a dedicated online platform with free access. The same roles do not necessarily imply the same companies or organizations, nevertheless a similar approach can be applied to incentivize the actors along the value chain to innovate and deliver high-value services and solutions to maximize the socioeconomic impact.

Figure VI. EGNSS and Copernicus value chains



Over the past 15 years the European Union, through its decision-making, programme management, and delegated and implementing bodies, has dedicated numerous actions to address the various levels of both value chains. They include programme definition and management, service requirements identification, provision of incentives to industry to use EGNSS signals and Copernicus data (for example, R&D funding for hardware and application development), end user awareness-raising, etc. These activities have already delivered results, especially at the end of each value chain (see the market-related part of chapter 3 of this report), whereas the activities fostering the development of applications have led to a relevant number of applications making joint use of EGNSS and Copernicus. Such joint use is also expected to translate into public benefits for the economy and society that may help achieve the United Nations SDGs to various degrees.

The remainder of this chapter presents how European Union actions in both programmes have been addressed in a holistic and synergistic approach, capitalizing on the technical convergence of the two systems while optimizing the use of European Union resources and maximizing the impact at user level. In addition, applications using both EGNSS and Copernicus create additional value compared to a stand-alone use of EGNSS and Copernicus and, consequently, economic growth is expected through job creation, commercialization of end-to-end applications and cost reductions.

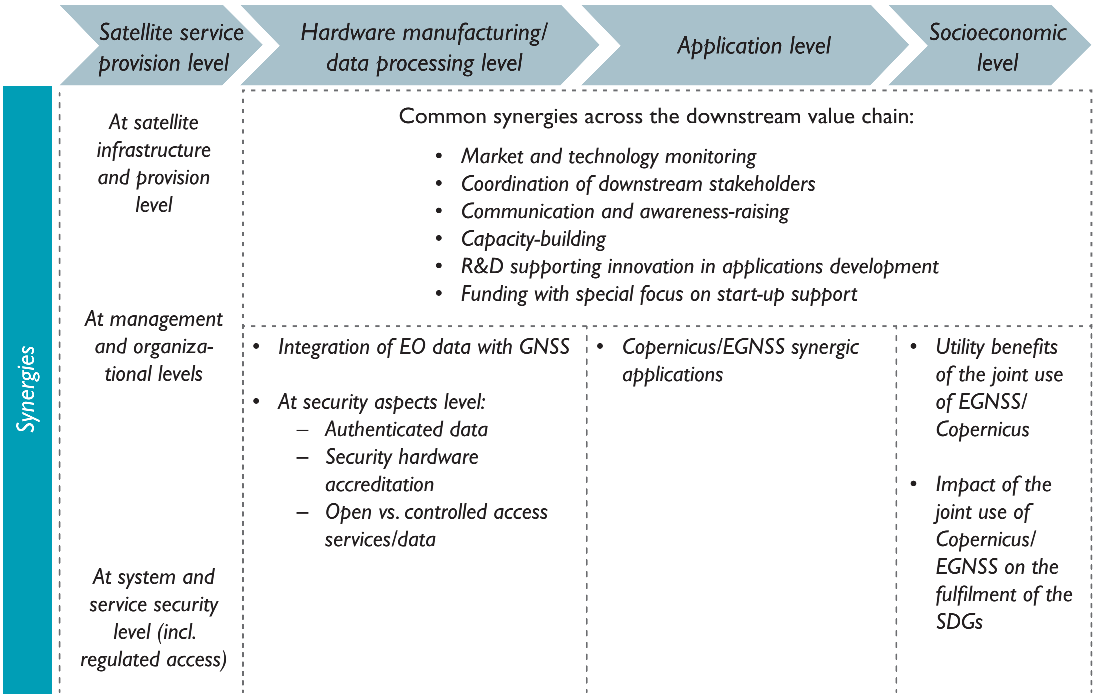
The synergies identified at the four levels common to the Copernicus and EGNSS value chains are summarized in figure VII.

Synergies at the satellite service provision level

At the satellite service provision level, two types of synergies between EGNSS and Copernicus have been identified:

- Synergies at the *satellite infrastructure level* and in the provision of satellite services
- Synergies at *management and organizational* levels

Figure VII. EGNSS and Copernicus synergies



Synergies in satellite infrastructure and in the provision of satellite services

Synergies at the satellite infrastructure level refer to the possibility for future generations of satellites to support both programmes: although currently navigation satellites and EO satellites do not show any commonality, future synergies might occur as both systems evolve.

Additionally, the possibility for EGNOS to use EO data has also been investigated. Despite the existence of technical constraints,[5] the analysis preliminarily identified the possibility for Copernicus data to support the assessment of delays in GNSS signal transmission caused by the troposphere. Currently, the estimation of the tropospheric delay is computed every second by EGNOS, following the applicable standard[6] based on a theoretical "tropo-spheric correction model". Although it represents a topic to be further explored, the use of real data gathered by Copernicus appears promising in guaranteeing better mitigation of delays caused by the troposphere.

[5] For example, the altitude of the Sentinel satellites.

[6] See http://www.navipedia.net/index.php/Tropospheric_Delay.

Synergies at management and organizational levels

At governance level, EGNSS and Copernicus clearly present multiple similarities:

- Both programmes are funded and owned by the European Union.
- The European Commission has the overall responsibility on behalf of the European Union for both the programmes, and is responsible for the political dimension and the high-level mission requirements. Specifically, it is in charge of managing the programmes and the funding, defining key decision stages for their implementation, monitoring existing risks and ensuring coordination among stakeholders.
- The European Space Agency is in charge of developing the space infrastructure of both programmes under a delegation agreement from the European Commission.

In addition, European Union Member States also take part in both programmes, either by participating in the decision-making process at European Council level as well as via their representatives at the European Parliament. Additionally they contribute to the development and the implementation of the systems through their involvement in the ESA and via national agencies and institutions.

A relevant difference, however, lies in the fact that the European Commission has delegated the operational management of the EGNSS programmes and the development of applications, market and downstream segments to the GSA, which is in particular in charge of achieving the highest return on EGNSS investment, in terms of benefits to users and economic growth. As regards Copernicus, on the other hand, the European Commission is undertaking these tasks directly with support in operational management from the various entrusted entities involved in the Copernicus programme.

Synergies across the downstream value chain

The common synergies identified across the value chain are:

- Market and technology monitoring
- Coordination of downstream stakeholders
- Communication and awareness-raising
- Capacity-building
- R&D supporting innovation in application development
- Funding with a special focus on start-up support

These synergies are explained in detail below.

Market and technology monitoring

In the Copernicus and EGNSS programmes, the European Commission and the European GNSS Agency, with regard to GNSS, have developed tools and processes to understand the evolution of the markets related to these programmes and to predict future market dynamics. These tools aim at supporting the adoption of services developed under the two European Union programmes by illustrating the differentiators of the two European Union systems that make them a valuable choice for industry, users and all the other interested stakeholders. Drawing on market evidence, they also demonstrate the profitability of the European Union investments.

Based on solid internal knowledge acquired over years of analysis specifically aimed at understanding market supply and demand, the most visible results of these efforts are:

- The *"GNSS Market Report"*, periodically produced by the GSA since 2010. The fifth edition was issued in May 2017
- The *"GNSS Technology Report"*, issued for the first time in 2016 by the GSA
- The *"Copernicus Market Report"*, issued by the European Commission for the first time in 2016

These publications, divided according to market segment, clearly show how the two flagship space programmes share many market areas, including agriculture, transport, maritime, disaster management and surveying.

Coordination of downstream stakeholders

The European Commission and the European GNSS Agency (as regards GNSS) have established tools to cooperate and interact with relevant stakeholders such as user communities and downstream industry for both programmes. This cooperation aims at:

- Identifying the needs of the various stakeholders, which are ultimately used to form the basis for the definition of system specifications, thereby ensuring that the systems and their evolution respond to the various stakeholders' needs
- Promoting and incentivizing the adoption of both programmes, thereby increasing the uptake of Copernicus and EGNSS

Interaction with user communities is essential for the success of the European Union space programmes. Continuous user feedback is indispensable to ensure that their needs are met, to improve the services delivered and to enhance existing applications.

In light of this, the European Commission and the GSA have decided to establish a formal user consultation platform (UCP) in order to facilitate a continuous dialogue with key user communities. Providing a forum for a dynamic exchange of information, the UCP aims to facilitate the sharing of information on the European Union GNSS user communities' trends, needs and requirements. The outputs will be further used in various processes of the European satellite programmes, such as planning of evolutions and next generations of EGNSS. Four sub-forums are foreseen: mass market, professional market, transport and research and development. This best practice could be expanded to involve Copernicus users.

With regard to the commercialization of the systems, as of 2017, the European Union is maintaining its efforts in both programmes in order to maximize the adoption of the services provided by the European owned infrastructures. *"A Space Strategy for Europe"* published by the European Commission in October 2016 illustrates this commitment to encourage the uptake of space services and data, and combines the priorities of both EGNSS and Copernicus in one agenda.

Communication and awareness-raising

Communicating to European citizens and industry about EGNSS and Copernicus is key to fostering the widest use of the two European technologies.

Many of the activities targeting timely communication and effective awareness-raising are already being carried out as part of a synergistic approach, including:

- The *European Space Solutions*, a conference targeting more than 1000 professionals every two years, showcasing innovative applications using EGNSS and Copernicus
- The *European Space Expo*, travelling to major European cities and highlighting to more than one million visitors over the duration of the action the many ways in which the European Union space programmes help European Union citizens "on the ground" every day
- Events targeting specific user segments where synergies are obvious, such as those targeting surveyors (for example, Intergeo, Geospatial) or farmers (for example, Agri-show)
- Competitions/prizes for users where synergies are highlighted, such as Galileo and Copernicus Masters (http://www.esnc.eu/)

Capacity-building

As there are many applications in which knowledge of both the programmes is needed, there is significant potential for synergies at the capacity-building level. Although European Union institutions' initiatives targeting capacity-building for EGNSS and Copernicus are separate at management level, many other initiatives already tend to integrate knowledge related to the two programmes. This is the case, for example, with:

- The *ESA Summer School*, aiming at providing a theoretical and practical knowledge of both
- The *International Space University*, based in Strasbourg, in which study programmes jointly refer to EGNSS and Copernicus

On the other hand, within European Commission-funded FP7 and H2020 projects aimed at building GNSS competencies (for example, Genius, E-Knot, BELS), the scope is limited to GNSS due to the projects' constraints, although an increasing interest in Copernicus is expressed by the participants involved.

Research and development supporting innovation in application development

Since 2007, the European Commission's Seventh Framework programme for Research and Technological Development (FP7) and successor Horizon 2020 (H2020) have supported the development of end-to-end applications, acting across all the levels of the value chain:

from developing hardware, but also data-processing algorithms, to end-to-end applications that help tackle societal challenges.

Both programmes have generated a significant amount of innovative knowledge. Dissemination efforts were also successful, exploiting strong links among European Union partners, bridging gaps between research and market communities and improving relations among businesses and end users. The most common research outputs were prototypes, product innovations, proofs of concept, trademarks and patents, process innovations and successful trials. They have also had a considerably positive impact on the GNSS market with commercial products or services that have been launched at the end of R&D projects.[7] The GSA is in charge of managing all the H2020 projects that use European GNSS and it has implemented several innovations to maximize the project outcomes and, at the same time, their socioeconomic impact. One of the innovations introduced was the business plan requirement at proposal level, specifying how the prototype/product would be commercialized and the business coaching within project duration that fostered the creation of new businesses and start-ups. R&D project management is also directly integrated with other market development activities, ensuring synergies between R&D and the overall strategy to foster the adoption of EGNSS, capacity-building and stakeholder relationship actions.

As an example of a project making a combined use of GNSS and EO, the *GEO VISION* project provides visual situational awareness capability anywhere in the world, with the aim of enabling "*observation to action*" within one minute. One of the main fields of application is the management of humanitarian crises. Products and applications developed within the project are already being used by the United Nations to map the effects of earthquakes in Nepal, in order to enhance the effectiveness of SAR operations.

Additionally, the 2016-2017 Horizon 2020 work programme specifically encourages applications that explore synergies between GNSS and EO. The participating consortia are invited to develop synergistic applications under *Horizon 2020 Societal Challenges* that focus on themes such as food security, sustainable agriculture and forestry.[8]

Funding with a special focus on start-up support

Given the high degree of innovation intrinsic to both programmes, specific funding instruments have been created to support the development of applications, with a special focus on start-up ventures. These are:

- The Copernicus accelerator
- The EGNSS accelerator
- The *"Farming by satellite"* prize, awarding the most promising applications in agriculture that make use of EGNSS and Copernicus

[7] Source: https://www.gsa.europa.eu/sites/default/files/FP7-brochure2015_7.pdf.
[8] Source: https://ec.europa.eu/programmes/horizon2020/en/h2020-section/societal-challenges.

- The GSA special section in the *"Young Surveyor"* prize, awarding the most promising applications in surveying and mapping that make use of EGNSS and Copernicus
- Hackathons are being organized by both the GSA, related to EGNSS and by the European Commission for Copernicus

Given that both systems have entered their operational phases, the number of activities and support actions for start-up funding is expected to increase.

Moreover, privately led initiatives already tend to focus on both Copernicus and EGNSS start-up support. This is the case, for example, with the Polish space accelerator Space3ac.

Synergies at hardware manufacturing/data processing level

Considering the midstream players in the Copernicus value chain (namely, data processing and distributors) synergies have been identified at data processing level, with innovative uses of GNSS (for example, GNSS reflectometry[9] and radio occultation[10]) to integrate and validate EO data. For the time being, these synergies are mostly in the R&D phase, nevertheless products and services based on these data processing techniques can become real commercial products, given their potential:

- GNSS reflectometry (GNSS-R) can support the creation of land-use maps, soil moisture condition, information about sea level, while
- GNSS radio occultation can support applications such as monitoring of atmospheric water vapour content.

To further support such a shift from the R&D phase to market commercialization, on top of the required pure R&D efforts, the capability of processing data according to the *big data paradigm* represents a key success factor. Furthermore, in this case relevant synergies can be envisaged, given that the GNSS industry is a pioneer in the use of big data—especially in transportation domains—and useful spillovers can be envisaged towards EO value chain stakeholders.

Synergies at application level

Many service providers integrate EGNSS and Copernicus data so that users can take advantage of integrated applications that benefit society as a whole. Synergies are identified in many different domains, as explained in the above-mentioned GNSS and Copernicus Market Reports released by the GSA and European Commission respectively.

[9] Information on the characteristics of reflective surfaces (for example water, ice, vegetation) is obtained by an analysis of the quality of reflected GNSS signals.

[10] The refractive index of the atmosphere is calculated by comparing the expected and actual phase measurements of GNSS signals to a receiver mounted on a low earth orbit (LEO) satellite.

The two technologies provide different geospatial information to the same application. Indeed, all considered Earth observations must be geo-referenced, and precisely time tagged. GNSS is the most efficient and widespread technique for that purpose, and is already extensively used for all in situ observations.

EO, on the other hand, allows the rapid generation of large-scale and small-scale maps that do not include only "static" geophysical parameters (such as terrain height and vegetal cover), but also dynamic ones (such as likely positions of icebergs in the Arctic Ocean) and man-made artefacts.

Beyond this first level, EO can contribute to GNSS in less obvious ways, for instance:

- By providing independent knowledge of physical parameters of the (land or sea) surface and of the atmosphere that may affect the propagation of radio waves, it allows the correction of corresponding errors in radio navigation systems (for example, 3D city map, or ground conductivity map).
- By providing detailed maps of specific physical/chemical parameters or *features*, it enables a positioning technique known as "features correlation" (the best-known example being "terrain-relative navigation").

The main application areas to benefit from the combined use of the technologies are:

- Urban planning
- Natural resources management
- Smart mobility
- Disaster management

In the *urban planning* domain, EO data represents a valuable asset to define and characterize relevant areas for planning and management purposes, while GNSS makes it possible to accurately geo-reference objects and points of interest. Applications include surveying, cadastral activities, mapping, infrastructure and environmental monitoring, hydrographic/offshore surveying, forest and park management, and prospecting for solar and wind farm locations.

Natural resources management also represents an extremely promising area for a synergetic use of the two European Union infrastructures, given that EGNSS and Copernicus support operations able to improve agricultural outcomes and to ensure sustainable environmental management. GNSS, for example, is a fundamental enabler of precision agriculture applications. The addition of EO data makes it possible to enhance the whole agricultural lifecycle: from the assessment of crop characteristics (EO), to operations in the field (GNSS navigation and steering) and the monitoring of results (GNSS together with additional in situ sensors). A tangible example of EO and GNSS synergy is given by the soil monitoring application, in which the integration of EGNSS with Copernicus makes it possible to produce maps of soil parameters that are precise to the centimetre level. This enables extremely targeted irrigation and specific treatments at the soil level—including the use of pesticides and fertilizers—with positive benefits in terms of maximizing agricultural yields.

In environmental management applications, on the other hand, the combined use of EGNSS and Copernicus allows for a better preservation of the environment by enabling in-depth monitoring and facilitating interventions in the most problematic areas.

In *smart mobility* domains there are many synergies, as GNSS and EO data can contribute to detecting and contextualizing phenomena that are difficult to observe by other means (for example traffic flows within cities, atmospheric events, oil spills, position of unauthorized vessels). There are thus several synergies in transport domains on a large scale:

- This is especially true in the *maritime domain*, where both technologies can be used in many application areas, including maritime safety and law enforcement, border surveillance, coastal planning, monitoring of restricted waters, fishery and living marine resource protection, oil spill monitoring and intervention planning.
- In the *road domain*, mobility and traffic management applications use both technologies to design new mobility policies and to safeguard citizen well-being in cities (for example by monitoring the air quality).
- In *rail* the integration of EGNSS and Copernicus allows for a cost and time-efficient monitoring of railway infrastructure.

Quick situational awareness is also enabled by a joint use of GNSS and EO within *disaster response management* activities. Relevant applications here include: maritime surveillance, maritime SAR, disaster response management, traffic flow management and fishery and living marine resource protection.

Specific reference on how EGNSS and Copernicus support these domains has been provided in chapter 5 (notably concrete examples of the use cases mentioned). However, there are many more synergistic applications still at the R&D phase. The widespread availability of GNSS signals in vehicle navigation units and smartphones has opened up a new world of geospatial applications that integrate EO data with navigation and map information. Over the last two decades, we have seen increasing numbers and types of EO satellite missions collecting more data for an increasing range of sectors, users and applications, and many more are expected to follow in the future.

Synergies at socioeconomic level

At the economic and societal level, the wider impacts of the use of EO and GNSS technologies are generated by the adoption of synergistic applications by end users. The synergistic applications identified in the previous section are relevant for the fulfilment of all the United Nations SDGs.

The way EGNSS, Copernicus and synergistic applications specifically contribute to achieving these Goals is further detailed in the following section, also showing the roles played by Copernicus-only and EGNSS-only applications.

5. European Global Navigation Satellite System-Copernicus contribution to individual SDGs

Even though the SDGs are not legally binding, governments are expected to take ownership and establish national frameworks for the achievement of the 17 Goals introduced previously, and presented in figure VIII. Countries have the primary responsibility for follow-up and review of the progress made in implementing the Goals, which will require quality, accessible and timely data collection.

Figure VIII. Overview of SDGs

Although the SDG targets and associated indicators are well-defined, the specific mechanics for monitoring SDG progress are decided individually by each country, and it is ongoing. Within this context, the adoption of innovative approaches to data collection is widely recognized as a relevant opportunity to generate a comprehensive monitoring framework. This is also the case for GNSS and EO technologies. The *"United Nations Sustainable Development Solutions Network"* (SDSN)—which designed the SDG and currently drives their implementation—specifically recognizes the particular importance of *"geo-referenced data that can now be collected easily using mobile phones to provide location-specific information on government facilities, water points, and environmental challenges"*.[11]

It represents an example of how space programmes and systems such as Copernicus and EGNSS support the fulfilment of the SDGs, both independently and in a synergetic way. Specifically, the combination of the two (Copernicus and EGNSS) will allow both the *monitoring* and the *achievement* of some of the targets that are associated with the Goals:

- *Monitoring*, which covers the contribution of *EGNSS* and *Copernicus* to national and supranational organizations in terms of enhancing the quality of data collected to help monitor the status of SDG implementation.
- *Achievement*, which envisages direct support from EGNSS and Copernicus in achieving specific SDGs. For example, EGNSS-enabled applications such as precision farming can directly contribute to achieving the "zero hunger" Goal in developing countries by offering a cheap, entry-level solution for crop monitoring, while for developed countries it enables the use of precision farming machinery, which further increases the crop production.

Based on this approach, the SDGs have been divided in two groups, according to the extent EGNSS and Copernicus contribute to their fulfilment:

- *Significant Contribution Tier* includes the SDGs that benefit the most from the use of EGNSS and Copernicus applications.
- *Limited Contribution Tier* refers to those SDGs that, although positively impacted by applications making use of European Union space programmes, the use of EGNSS and Copernicus has not been considered crucial to their fulfilment.

The following sections present in detail how European Union space technologies contribute to each individual SDG from the *"*Significant Contribution Tier*"* category where the contribution is the highest, and summarize the impact of space technologies on the remaining two categories. It should be stressed, however, that even in the most fortunate cases listed in the "Significant Contribution Tier", *space technologies can only support the achievement of SDGs if integrated into a broader operational framework* in which adequate public and private investments are in place to guarantee access to space-enabled technologies (for example to install precision farming equipment) or to follow up space-derived information with the appropriate countermoves (for example to undertake the actions needed on the ground in the event of Copernicus flood warnings).

[11] UN Sustainable Development Solutions Network, *Indicators and a Monitoring Framework for the Sustainable Development Goals, Launching a data revolution for the SDGs*, 2015.

Significant Contribution Tier

The first category, called "Significant Contribution Tier", includes all the SDGs that are highly dependent on space technologies to be fully achieved. After detailed analysis, 13 Goals have been allocated to this category. These are presented in table 2.

Table 2. Significant Contribution Tier SDGs, high-level assessment of contribution of European Union space programmes

Global Goals for Sustainable Development	EGNSS	Copernicus	Synergies	Examples of applications
1 NO POVERTY	◑ ●	◑ ●	◑ ●	Natural disaster forecast Crop productivity optimisation
2 ZERO HUNGER	● ●	● ●	● ●	Crop productivity optimisation Livestock management optimisation
3 GOOD HEALTH AND WELL-BEING	◑ ●	● ●	● ●	Prevention of vector diseases Disability assistance Air quality monitoring Reduction of air pollution through road traffic optimisation eCall emergency response service Wearables for health promotion and disease prevention
6 CLEAN WATER AND SANITATION	◑ ●	● ●	● ●	Water quality monitoring Meteorological forecasting
7 AFFORDABLE AND CLEAN ENERGY	● ●	◑ ●	● ●	Infrastructure monitoring Power grid synchronisation Seismic surveying Solar and wind energy production forecasting
8 DECENT WORK AND ECONOMIC GROWTH	● ●	◑ ●	● ●	Supporting global economies GDP growth Lone workers monitoring

KEY

Level of contribution in monitoring/achieving part of a target/indicator

◑ ◑ Limited contribution

● ● Significant contribution

9 INDUSTRY, INNOVATION AND INFRASTRUCTURE	●●	◐●	●●	Infrastructure mapping and monitoring Construction surveying Smart mobility
11 SUSTAINABLE CITIES AND COMMUNITIES	●●	●●	●●	Urban planning Infrastructure monitoring Improvement of city services Air quality monitoring Disaster management Search and rescue operations
12 RESPONSIBLE CONSUMPTION AND PRODUCTION	◐●	●●	●●	Natural resources management Food and dangerous goods traceability
13 CLIMATE ACTION	●●	●●	●●	Climate change monitoring Disaster management Search and rescue operations
14 LIFE BELOW WATER	◐●	●●	●●	Mapping and monitoring of natural and protected areas
15 LIFE ON LAND	●●	●●	●●	Bio-geophysical land surface monitoring Animal tracking
17 PARTNERSHIPS FOR THE GOALS	●◐	●◐	●◐	International cooperation initiatives

In the following pages the way EGNSS and Copernicus contribute to each SDG belonging to the "Significant Contribution Tier" is described in detail, followed by the identification of targets and specific key performance indicators associated with each Goal that are in particular impacted by the use of space technologies. This is further complemented by the selection of relevant use cases and examples, illustrating the use of EGNSS and Copernicus contributing to the achievement of each specific SDG.

Goal 1 – No Poverty

No Poverty: End poverty in all its forms everywhere

SDG 1 calls for an end to poverty in all its manifestations by 2030. It also aims to ensure social protection for the poor and vulnerable, increase access to basic services and support people harmed by climate-related extreme events and other economic, social and environmental shocks and disasters.

QUICK FACTS

- 836 million people still live in extreme poverty.
- About one in five persons in developing regions lives on less than $1.25 per day.
- Globally, 18,000 children still die each day from poverty-related causes.
- Economic losses from internationally reported disasters, principally large-scale disasters, have grown steadily since 1990, reaching an estimated annual average of $200 billion in 2013.

Eradicating poverty in all its forms remains one of the greatest challenges facing humanity. The international poverty line is currently defined at US$ 1.90 or below per person per day using 2011 United States dollars purchasing power parity. Globally, more than 800 million people are still living on less than $1.25 a day, many lacking access to adequate food, clean drinking water and sanitation. Rapid economic growth in countries like China and India has lifted millions out of poverty, but progress has been uneven. Women are more likely to live in poverty than men due to unequal access to paid work, education and property.

Progress has been made in the last decades; the number of people living in extreme poverty dropped by more than half between 1990 and 2015—from 1.9 billion to 836 million—but too many are still struggling for the most basic human needs.

Progress has also been limited in other regions, such as South Asia and sub-Saharan Africa, which account for 80 per cent of those living in extreme poverty. New threats brought on by climate change, conflict and food insecurity, mean even more work is needed to bring people out of poverty.

EGNSS and Copernicus supporting Sustainable Development Goal 1

EGNSS and Copernicus enable many applications that contribute to tackling the poverty challenge worldwide. Thanks to remote sensing and EGNSS, governments and supranational institutions can:

- Forecast natural disasters and better coordinate subsequent aid
- Maximize the exploitation of natural resources
- Contribute to providing more efficient support to vulnerable people

In combination, space technologies can contribute to preventing more people from falling below the poverty line and help target specific support to those in need.

An example of this is the development of precision agriculture and food security applications for monitoring the health of crops or providing early warnings for natural disasters. In particular, in developed countries integrated farm management enabled by Copernicus and EGNSS make agriculture more efficient by improving crop productivity, thus giving fairer access to food. Meanwhile, cost-efficient solutions employing free EO data and affordable GNSS receivers can provide essential information for farmers to monitor their crops. In fact, solutions integrating GNSS and EO data can achieve yield increases in excess of 10 per cent, while reducing inputs such as fuel, fertilizer and pesticides by up to 20 per cent.

In addition, GNSS and Copernicus also support the eradication of the poverty in developing countries. On top of a direct contribution to the agriculture productivity (still minimal given the low, yet increasing, rate of adoption of satellite-enabled agriculture by local farmers), EO and navigation data are becoming extremely useful tools for measuring the impact on the overall development of the region. International development banks, for example, rely on satellite data to monitor and evaluate the status of projects in remote or dangerous regions. Objective observations consistently enabled by satellites—for example concerning the water or air quality—allow institutions such as the *World Bank*, the *European Investment Bank* or the *Asian Development Bank* to measure the effectiveness of financed measures.

From a different perspective, the development of Copernicus and EGNSS has significantly contributed to job creation and economic growth. For instance, the European space manufacturing industry is worth €5.4 billion per year and employs a workforce of more than 31,000 people.

EGNSS enables the creation of precise maps and the integration of Copernicus imagery in GIS (geographic information systems), using precise geo-referencing data and information. These maps, together with countries' information on the location of basic services (health, sanitization or schools) can assist in mapping poverty and also in identifying human settlements and offering cadastral services needed to secure property rights. The Copernicus and EGNSS-generated maps and images can enable low-cost tools to support local authorities in building required infrastructure.

Specifically, following natural disasters, both Copernicus and EGNSS play a crucial role. Offering an SAR service, Galileo satellites are able to pick up signals from emergency beacons (for example carried on ships, planes or persons) with positioning integrated and send these back to national rescue centres, so that the precise location of the person in distress is shared and rescue missions can be promptly organized. Copernicus, on the other hand, offers an Emergency Management Service (EMS) providing information for emergency response in relation to different types of disasters, including meteorological hazards, geophysical hazards, deliberate and accidental man-made disasters and other humanitarian disasters as well as prevention, preparedness, response and recovery activities.

Finally, EGNSS can contribute to implementing measures targeting persons with disabilities, through telemedicine and social inclusion applications, and in actively limiting the number of work-injury victims (for example by lone worker monitoring systems). Although there are efforts to reduce the gap, in some developing countries, more capacity-building is necessary to develop tools for visualization and analysis of data: this can be achieved through dedicated R&D initiatives building on the synergetic use of the two European space programmes.

As space technologies are a key asset contributing to the achievement of SDG 1, their contribution is linked to a subset (five out of a total of seven) of the SDG 1 targets, which are listed below:

1.1 By 2030, eradicate extreme poverty for all people everywhere, currently measured as people living on less than $1.25 a day

1.2 By 2030, reduce at least by half the proportion of men, women and children of all ages living in poverty in all its dimensions according to national definitions

1.3 Implement nationally appropriate social protection systems and measures for all, including floors, and by 2030 achieve substantial coverage of the poor and the vulnerable

1.a Ensure significant mobilization of resources from a variety of sources, including through enhanced development cooperation, in order to provide adequate and predictable means for developing countries, in particular least developed countries, to implement programmes and policies to end poverty in all its dimensions

1.b Create sound policy frameworks at the national, regional and international levels, based on pro-poor and gender-sensitive development strategies, to support accelerated investment in poverty eradication actions

The degree of contribution is specified in table 3.

Table 3. Qualitative assessment of European Union space programmes' contribution to SDG 1 targets

Targets	EGNSS	Copernicus	Synergies
1.1	◐●	◐●	◐●
1.2	◐●	◐●	●●
1.3	◐◐	◐◐	◐◐
1.a	◐◐	●●	◐◐
1.b	◐●	◐●	◐◐

Level of contribution in monitoring/achieving part of a target/indicator

◐◐ Limited contribution ●● Significant contribution

CASE STUDIES

Case study 1. A platform reducing disaster risks contributes to achieving the "no poverty" Goal

Disasters are widely acknowledged to affect disproportionately the poorest in a community as those people have a relatively higher sensitivity to disaster events compared with more developed communities. A large-scale hazard that hits a highly vulnerable community with low capacity to cope reverses hard-won development gains, entrenching people in poverty cycles, and increasing their vulnerability.

iReact is a European-funded project that aims to provide greater readiness for emergency situations in order to allow civil protection services and policy-makers to effectively prevent and/or react during natural disasters. The system integrates and analyses in real time data coming from different sources. European monitoring systems, EO imagery, historical information and weather forecasts will be combined with data gathered by new technological developments created by the consortium, including a GNSS-based smartphone application that collects crowdsourcing data from users.

For more information: http://www.i-react.eu/

Case study 2. Satellite data as a key enabler of improved disaster response management

The H2020 project GEO-VISION aims to save lives and to protect critical infrastructures during emergencies and disasters by optimizing the use of satellite data, ranging from satellite communication and navigation to EO.

The core of the project is visual communications, whereby end users supply imagery from disaster-struck areas to disaster response and emergency management operators. GNSS can fuse geo- and time-stamped visual imagery and EO imagery.

GNSS is also used to navigate micro-drones for live observations or mapping. Copernicus and the Sentinels are helpful in collecting a large amount of data to assist in the disaster response management.

The project has already resulted in the creation of three smartphone apps available for iOS and Android, with the end user group encompassing the United Nations, European Union, World Bank and insurance companies.

For more information: https://ec.europa.eu/research/participants/documents/downloadPublic?documentIds=080166e5a6cdb39a&appId=PPGMS

Case study 3. Farming by satellite Special Africa Prize, helping to improve Africa's capacity for self-sustainability and food safety

The GSA is co-sponsoring the Farming by Satellite contest, a competition for students and young people across Europe and Africa focused on the use of Galileo/EGNOS and Copernicus to improve agriculture and reduce its environmental impact.

Each edition has a special Africa Prize, which has a double benefit for the regional participants: it rewards tailored solutions for agriculture, as well as creating additional future employment possibilities for the young talents participating.

http://www.farmingbysatellite.eu/

2 ZERO HUNGER

Goal 2 – Zero Hunger

End hunger, achieve food security and improved nutrition and promote sustainable agriculture

SDG 2 aims to end hunger and all forms of malnutrition. It also commits to universal access to safe, nutritious and sufficient food at all times of the year. This will require sustainable food production systems and resilient agricultural practices, equal access to land, technology and markets and international cooperation on investments in infrastructure and technology to boost agricultural productivity.

To increase the productive capacity of agriculture, more investment is needed, both public and private, from domestic and foreign sources. However, recent trends in government spending are not favourable. The agriculture orientation index, defined as agriculture's share of government expenditures divided by the sector's share of gross domestic product (GDP), fell globally from 0.37 to 0.25 between 2001 and 2013. The decline in the index was interrupted only temporarily during the food price crisis of 2006 to 2008, when governments increased agricultural spending.

The fight against hunger has progressed over the past 15 years. Globally, the prevalence of hunger has declined, from 15 per cent according to figures for 2000 to 2002, to 11 per cent according to figures for 2014 to 2016. However, more than 790 million people worldwide still lack regular access to adequate dietary energy. If current trends continue, the zero hunger target will be largely missed by 2030.

EGNSS and Copernicus supporting Sustainable Development Goal 2

Space technologies are key enablers for 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). Decisions are supported by software services based on data generated by space systems (GNSS and EO), as well as by terrestrial technologies.

Satellite-based EO is the most feasible way to acquire site-specific crop properties over broad areas. In combination with agroecological crop growth and management models, EO data can increase the efficiency of farms. The Copernicus Land Monitoring System can also serve in this direction, providing important information to monitor the vegetation, the water cycle and the energy budget.

European GNSS 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 EO 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 EO 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. 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

QUICK FACTS

- 500 million small farms worldwide provide up to 80% of food consumed in a large part of the developing world.
- Globally, in 2014, nearly 1 in 4 children under the age of 5, an estimated total of 159 million children, had stunted growth. Stunting is defined as inadequate height for age, an indicator of the cumulative effects of undernutrition and infection.
- Poor nutrition causes nearly half (45 per cent) of deaths in children under 5 – 3.1 million children each year.
- One in nine people in the world today (795 million) are undernourished, lacking regular access to adequate dietary energy..

complemented by GNSS 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. The open and free data policy of Copernicus, moreover, ensures a widespread use of satellite images, increasing their penetration of use. In addition, UNOOSA provides the necessary capacity-building to allow users from developing countries to benefit as much as possible from outer space.

The use of GNSS and EO is proving to be useful also for livestock management. The use of GNSS collars to monitor livestock supports the activities of the breeders and EO data help them in identifying the most suitable grazing. Similarly, natural scientists and researchers make use of GNSS and EO to ensure sustainable reproduction of domesticated animals as well as wild species.

Most of the space-based solutions above need the basic infrastructure to be in place and therefore are mainly valid for developed countries.

Additional efforts in capacity-building should assist in reducing the so-called space divide—an increasing gap between countries with significant development in their use of space, and those without. Capacity-building shall be used to fully exploit the potential of the space technologies. Additional capacity-building is necessary for developing tools for visualization and analysis of data, with special emphasis on the specificities of the regions (and therefore best achieved by involving local specialists).

Table 4 describes the contribution of space technologies related to SDG 2, which have been evaluated taking into account only their direct contributions:

2.1 By 2030, end hunger and ensure access by all people, in particular the poor and people in vulnerable situations, including infants, to safe, nutritious and sufficient food all year round

2.3 By 2030, double the agricultural productivity and incomes of small-scale food producers, in particular women, indigenous peoples, family farmers, pastoralists and fishers, including through secure and equal access to land, other productive resources and inputs, knowledge, financial services, markets and opportunities for value addition and non-farm employment

2.4 By 2030, ensure sustainable food production systems and implement resilient agricultural practices that increase productivity and production, that help maintain ecosystems, strengthen capacity for adaptation to climate change, extreme weather, drought, flooding and other disasters and that progressively improve land and soil quality

2.5 By 2020, maintain the genetic diversity of seeds, cultivated plants and farmed and domesticated animals and their related wild species, including through soundly managed and diversified seed and plant banks at the national, regional and international levels, and promote access to and fair and equitable sharing of benefits arising from the utilization of genetic resources and associated traditional knowledge, as internationally agreed

The degree of contribution is specified in table 4.

Table 4. Qualitative assessment of European Union space programmes' contribution to SDG 2 targets

2 ZERO HUNGER

Targets	EGNSS	Copernicus	Synergies
2.1	●●	●●	●●
2.3	●●	●●	●●
2.4	●●	●●	●●
2.5	◐◐	●●	◐◐

Level of contribution in monitoring/achieving part of a target/indicator

◐◐ Limited contribution ●● Significant contribution

CASE STUDIES

Case study 4. GNSS-Reflectometry (GNSS-R) technology provides valuable soil moisture information for agriculture

Agriculture uses around 70 percent of all freshwater worldwide. To feed an additional two billion people by 2030, water demand is expected to increase tremendously in the next decades. Extreme weather events challenge water managers, who need new tools to monitor soil moisture and to understand waterlogging and flooding.

Knowledge of the spatial variability in soil moisture content supports farmers in making more efficient decisions on where and when to irrigate. By using GNSS-Reflectometry, the European-funded Mistrale H2020 project produces soil moisture content maps using a Remotely Piloted Aircraft System (RPAS) equipped with a GNSS-R measurement device. GNSS-R is a remote sensing technique in which measurements are obtained by sensing the GNSS signals reflected from the Earth. Besides soil moisture maps, the system can also produce maps of waterlogging, the extent of flooding and other soil moisture related information products.

For more information: http://www.mistrale.eu/

Case study 5. Improving food security through satellite technology

Accurate and timely information on agricultural production helps farming communities to make informed decisions to achieve sustained growth in agriculture activity. This information plays an important role in enabling early warning of harvest shortfalls, increasing crop production and ensuring agricultural sustainability.

An example of the use of EO data in agricultural monitoring is "remote sensing- based information and insurance for crops in emerging countries" (RIICE): a public-private partnership aiming to reduce the vulnerability of smallholder rice farmers in low-income countries. The objective of this programme is to make use of remote sensing technologies to map and observe rice growth in selected areas. Sentinel-1A's national-scale data are used in this project for monitoring rice crops in seven countries.

For more information: https://www.asean-agrifood.org/projects/riice/

Case study 6. GNSS-based tracking system informs farmers about the condition of cattle and pasture

There has been increasing pressure on the livestock sector to meet the growing demand for high-value animal protein. This demand is resulting in an increased need to improve the efficiency of livestock production. A better understanding of animal behaviour and environmental interactions can serve to optimize the management of livestock and the environment in which they are grazing.

The University of New England (UNE) developed GNSS-based tracking technology to remotely monitor the condition of cattle and pastures. The UNE tracking system can send notifications to farmers, warning them that their stock is running out of feed or overgrazing a paddock. As the animals start to run out of feed in the paddock, their behaviour changes. By monitoring this, the system informs the farmers when cattle are starting to become stressed and pastures degraded.

Similarly, within the EU-funded project E-track, an animal-tracking and analysis tool for sophisticated behavioural research on wild and domestic animals has been developed by using EGNOS corrections to enhance the accuracy of GPS.

For more information: http://www.project-e-track.eu/

Goal 3 – Good Health and Well-being

Ensure healthy lives and promote well-being for all at all ages

Goal 3 seeks to ensure health and well-being for all, at every stage of life. The Goal addresses all major health priorities, including reproductive, maternal and child health; communicable, non-communicable and environmental diseases; universal health coverage; and access for all to safe, effective, quality and affordable medicines and vaccines. It also calls for more research and development, increased health financing, and strengthened capacity of all countries in health risk reduction and management.

There have been great developments in reducing child mortality, improving maternal health and fighting HIV/AIDS, malaria and other diseases. Since 1990, there has been an over 50 per cent decline in preventable child deaths globally. Maternal mortality also fell by 45 per cent worldwide. New HIV/AIDS infections fell by 30 per cent between 2000 and 2013, and over 6.2 million lives were saved from malaria.

Despite this incredible progress, more than 6 million children still die before their fifth birthday every year. Globally, approximately 16,000 children die every day from preventable diseases such as measles and tuberculosis, and high mortality among pregnant women is still an issue. In many rural areas, only 56 per cent of births are assisted by skilled professionals. AIDS is now the leading cause of death among teenagers in sub-Saharan Africa, a region still severely devastated by the HIV epidemic.

EGNSS and Copernicus supporting Sustainable Development Goal 3

Information derived from EO and meteorological satellites in combination with GIS and GNSS has increasingly been used to study disease epidemiology, enabling increased use of spatial analysis to identify the ecological, environmental and other factors, such as movements of population, that contribute to the spread of vector-borne diseases by locating "hotspots", monitoring disease patterns and defining the areas that require disease-control planning. Traditionally, obtaining the necessary data on environmental health determinants has been a major challenge in certain regions due to the large territory to cover. Data from population or environmental determinants may be derived from EO images, particularly in regard to the impact of natural or man-made ecosystem changes. Operationally, EO images have demonstrated their usefulness in the prevention and control of persistent and new diseases. Remotely sensed factors such as greenness, brightness, temperature and especially moisture positively correlate with the over-occurrence of mosquitoes. Knowing the location of high concentrations of mosquitoes can guide risk assessment for disease-carrying pathogens and mosquito-fogging efforts. Thus, the incorporation of space-based information helps prevent the spread of the disease and—through localized eradication campaigns for insect-borne diseases in identified hotspots—the use of space helps reduce the population affected. Using this technology, it is possible to monitor and detect the areas where action is required, distributing vaccines to areas where they are most needed. Additionally, the use of EGNSS helps direct the intervention teams and medical services to the precise position of the hotspots.

Regarding well-being, GNSS-based products in this category are mainly designed to address issues related to vision (for example, navigation solutions for visually impaired persons) and cognition (for example tracking solutions aimed at geo-fencing and/or locating patients with Alzheimer's). Additionally, a category of GNSS-based navigators is specially designed to provide support to upper and lower body-impaired individuals.

Space programmes also contribute to air quality management, which has a direct impact on global health. It is estimated that air pollution causes around 467,000 premature deaths in Europe every year. The Copernicus satellite Sentinel-5 precursor is equipped with the necessary instruments to monitor and forecast the concentration of trace gases such as ozone, nitrogen dioxide, methane and aerosols affecting both climate and air quality.

QUICK FACTS

- In 2012, over three quarters of premature deaths (under the age of 70) were caused by cardiovascular disease, cancer, diabetes and chronic respiratory disease.
- Substance use and substance-use disorders have also created a significant public health burden. Worldwide, average alcohol consumption in 2015 was estimated at 6.3 l of pure alcohol per person among those aged 15 or older.
- The incidence of major infectious diseases, including HIV, tuberculosis and malaria, has declined globally since 2000.
- The likelihood of dying in the first 28 days of life declined from 31 deaths per 1,000 live births in 2000 to 19 deaths per 1,000 live births in 2015.

Space not only plays a role in monitoring the quality of the air but also directly in reducing the emissions. Transport is one of the main sources of air pollution, for which evidence on direct effects on mortality as well as on respiratory and cardiovascular disease is firmly established. Use of satellite navigation systems in road vehicles can reduce journey times by more than 10 per cent and thus contribute to reducing emissions of harmful and polluting substances. GNSS simplifies road user charging systems, which reduce pollution by limiting road usage and reducing urban traffic congestion. Moreover, GNSS increasingly makes our cities smarter and more sustainable. For instance, Reykjavik implemented a prioritization system of green lights for public transport and emergency vehicles based on GNSS, thanks to which buses are more punctual, traffic is safer, and there are significant energy and pollution savings.

The European Union-wide eCall system is aimed at speeding up emergency response services in case of a road accident. In the event of an accident the eCall system automatically triggers a distress signal to the 112-based eCall interoperable service, using GNSS technologies to indicate the precise location of the incident. EGNSS therefore plays a key role in reducing the death rate due to road traffic injuries. eCall will be mandatory in all new cars from April 2018 and the European Union is working with extra-European Union countries towards the introduction of global standards and lessons learned for faster implementation. eCall will save more than 2,000 lives in its first 10 years of operation, and avoid almost 20,000 severe injuries over the same period. In addition, the faster response to accidents will reduce congestion and allow better use of the infrastructure.

The field of tele-epidemiology is a new discipline that combines epidemiology and space technology. It involves the monitoring and assessment of the distribution of animal and human illnesses strongly linked to climatic and environmental variations, with EGNSS and Copernicus respectively used for pinpointing the animals and assessing the relationship with the surrounding environment.

Finally, space programmes also play an important role in health promotion and disease prevention. The increasing penetration of wearable devices for both leisure and professional purposes is part of a general trend towards pre-emptive health care and maintaining personal well-being. Measurements of effort, distance and speed of movement enabled by GNSS devices are employed in specific sport applications (for example rowing, golf, athletics, soccer training, skiing, cycling) allowing identification of specific sport aptitudes and improvements. Major benefits can be realized when people take up physical activity, become healthier and gradually reduce the strain on health services. The process of monitoring activity, including everything from simple pedometers to advanced GNSS-based sports devices, has been found to increase physical activity by 27 per cent. Moreover, newly available platforms make it possible to synchronize data to personal health records, eventually providing medical professionals with a real-time view into the lives of their patients, replacing yearly medical check-ups with constant monitoring or integrating this monitoring into the check-ups.

The targets where space can better contribute within SDG 3 are:

- 3.3 By 2030, end the epidemics of AIDS, tuberculosis, malaria and neglected tropical diseases and combat hepatitis, water-borne diseases and other communicable diseases
- 3.6 By 2020, halve the number of global deaths and injuries from road traffic accidents
- 3.8 Achieve universal health coverage, including financial risk protection, access to quality essential healthcare services and access to safe, effective, quality and affordable essential medicines and vaccines for all
- 3.9 By 2030, substantially reduce the number of deaths and illnesses from hazardous chemicals and air, water and soil pollution and contamination

Space helps monitor and track diseases and also environmental conditions related to global health.

Table 5. Qualitative assessment of European Union space programmes' contribution to SDG 3 targets

Targets	EGNSS	Copernicus	Synergies
3.3	◑◑	◑●	◑●
3.6	●●	●◑	●●
3.8	◑◑	◑◑	◑◑
3.9	●◑	●●	●●

Level of contribution in monitoring/achieving part of a target/indicator

◑◑ Limited contribution ●● Significant contribution

CASE STUDIES

Case study 7. Using satellite imagery and GNSS for mapping and prevention of vector diseases

Identifying and predicting the distribution of existing local species and the spread of new exotic ones are essential steps in assessing the risk of potential epidemics. A consortium led by Avia-GIS has developed software called "Vecamp", able to automate and optimize complex tasks related to the mapping of disease vector presences and the tracking of their progress, making it possible to design strategies to contain them and manage the risks they pose.

Satellite information from GNSS and EO enables researchers to find their way to test sites and help field teams locating traps for return and analysis in the lab. Traps are left in target areas chosen from satellite observations. The information helps researchers to choose the most representative testing sites, as well as saving time and reducing the cost of fieldwork—traditionally the most expensive part of gathering data. The results collected online ultimately enable researchers to map high-risk areas using a wide range of satellite images. The new approach greatly reduces the complexity of tracking species compared to traditional methods.

For more information: http://www.vecmap.com/

Case study 8. GNSS location information improves social inclusion of people with disabilities

Mobile health products/services represent an increasing opportunity to improve life for people with disabilities by providing solutions aimed at reducing the barriers that limit their access to public and private services/infrastructures. The mobility of people with disabilities is often hindered by obstacles or barriers, or they have difficulty in reliably identifying a priori accessible routes. It is a fact that people in wheelchairs often move only in limited environments, typically near their home.

The European-funded Inclusion project aims to build a solution capable of providing motor-impaired persons with the possibility of improving their mobility in safe conditions. Relying on GNSS, the project will lead to the definition, design, implementation and testing of a set of location-based applications matching the needs of people in wheelchairs, enabling them to be more independent.

For more information: https://www.gsa.europa.eu/innovative-lbs-socialpublic-dimension

Case study 9. eCall to reduce the number of road fatalities

Nearly 1.3 million of people die in road crashes each year, with approximately 3,287 deaths a day on average. Unless action is taken, road traffic injuries are predicted to become the fifth leading cause of death by 2030.

eCall is a European Union initiative to bring rapid assistance to motorists involved in a collision. In the event of a crash, eCall automatically connects the passengers of the car involved to the nearest emergency centre, while also communicating—thanks to Galileo and EGNOS—their exact location. This system will be mandatory from 31 March 2018 in all new car models sold in the European Union.

According to the European Commission, eCall will help save up to 2,500 lives in Europe and significantly reduce the severity of injuries in 15% of all accidents involving damage to health.

For more information: https://ec.europa.eu/transport/themes/its/road/action_plan/ecall_en

Goal 6 – Clean Water and Sanitation

Ensure availability and sustainable management of water and sanitation for all

Clean, accessible water for all is an essential part of the world we want to live in. There is sufficient fresh water on the planet to achieve this. But due to bad economics or poor infrastructure, every year millions of people, most of them children, die from diseases associated with inadequate water supply, sanitation and hygiene. Clean water, basic toilets and good hygiene practices are essential for the survival and development of children. Today, there are around 2.4 billion people who do not use improved sanitation, and 663 million who do not have access to improved water sources.

Water scarcity, poor water quality and inadequate sanitation negatively impact food security, livelihood choices and educational opportunities for poor families across the world. Drought afflicts some of the world's poorest countries, worsening hunger and malnutrition. By 2050, at least one in four people is likely to live in a country affected by chronic or recurring shortages of fresh water. Safe drinking water is a prerequisite for protecting public health and all human activity. Properly treated wastewater is vital for preventing disease and protecting the environment.

Without these basic amenities, the lives of millions of children are at risk. For children under five, water- and sanitation-related diseases are one of the leading causes of death. Every day, over 800 children die from preventable diseases caused by poor water and a lack of sanitation and hygiene.

QUICK FACTS

- At least 1.8 billion people globally use a source of drinking water that is contaminated.
- Water scarcity affects more than 40 per cent of the global population and is projected to rise.
- 2.4 billion people lack access to basic sanitation services, such as toilets or latrines.
- More than 80 per cent of wastewater resulting from human activities is discharged into rivers or the sea without any pollution removal.
- Each day, nearly 1,000 children die due to preventable water- and sanitation-related diseases.

EGNSS and Copernicus supporting Sustainable Development Goal 6

Over the last couple of decades, the opportunities to monitor water availability from space have become more and more promising. EO is used to obtain precipitation forecasts, soil moisture contents and evapotranspiration data. Currently, the provision of satellite imagery in the field of water management is a growing market and, especially for water quality, there is a significant added value. The Copernicus satellite Sentinel-2 provides data that can be used to measure several water quality parameters, namely Chlorophyll-a, Phycocyanin, Cyanobacteria scums, Total Suspended Matter and many other parameters.

In addition to their important contribution to water resources monitoring, satellites also contribute to a better understanding of the Earth's water cycle. 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 few first centimetres of soil as well as in the root zone. In addition, global maps of water bodies delineate the zones permanent covered by water, such as lakes, those with a seasonal frequency, like backwater ponds, and those that occur occasionally as a result 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. Because soil moisture and water availability are major contributors to plant growth, cattle, and human consumption, they are essential to better quantify the primary production for global crop monitoring, early warning and food security applications.

GNSS technology is used to obtain the location of the user to provide local data on his mobile phone or tablet and for geotagging of in situ measurements required for identification, validation and calibration. The combination of imagery from EO satellites with the very accurate GNSS positioning allows the monitoring of critical infrastructures such as pipelines, dams and bridges. It will also allow monitoring and preparing against natural phenomena such as landslides, melting of glaciers, etc. as EO enables maintenance and inspection of this infrastructure, including the possibility of identifying potential threats such as landslides and displacements. High-accuracy GNSS networks installed on-site make it possible to detect and analyse movements and detect structural risks.

EGNSS can also support the provision of assistance in locations with no water sources. For instance, trucks or drones equipped with GNSS can be used to distribute water in sensitive areas. Such operations rely upon accurate geographic information of the targeted area. Finally, EO can monitor open water pits that can be used as sources of drinking water.

The targets identified where EGNSS and Copernicus can make the biggest contribution are:

- 6.1 By 2030, achieve universal and equitable access to safe and affordable drinking water for all
- 6.3 By 2030, improve water quality by reducing pollution, eliminating dumping and minimizing the release of hazardous chemicals and materials, halving the proportion of untreated wastewater and substantially increasing recycling and safe reuse globally
- 6.4 By 2030, substantially increase water-use efficiency across all sectors and ensure sustainable withdrawals and supply of freshwater to address water scarcity and substantially reduce the number of people suffering from water scarcity
- 6.6 By 2020, protect and restore water-related ecosystems, including mountains, forests, wetlands, rivers, aquifers and lakes
- 6.a By 2030, expand international cooperation and capacity-building support to developing countries in water- and sanitation-related activities and programmes, including water harvesting, desalination, water efficiency, wastewater treatment, recycling and reuse technologies

The degree of contribution of Copernicus and EGNSS to SDG 6 is specified in table 6.

Table 6. Qualitative assessment of European Union space programmes' contribution to SDG 6 targets

Targets	EGNSS	Copernicus	Synergies
6.1	◐●	●●	●●
6.3	◐●	●●	●●
6.4	◐●	●●	●●
6.6	●●	●●	●●
6.a	●●	●●	●●

Level of contribution in monitoring/achieving part of a target/indicator

◐◐ Limited contribution ●● Significant contribution

CASE STUDIES

Case study 10. Satellite technology provides enhanced water availability information

The need for proper and timely information on water availability is probably the most important requirement for water management activities. In many cases, however, data is either not available, or is incomplete or inaccessible, leading to ineffective or erroneous decision-making.

Within the OWASIS-NL ESA feasibility study, a state-of-the-art information service able to provide information on the water storage capacity of the soil and on water use by irrigation in the Netherlands and South Africa has been developed. Within such a service, EO data are used to obtain precipitation forecasts, soil moisture content and evapotranspiration data, while GNSS technology is used to derive the current location of the user to provide, directly on a smartphone or tablet, specific local data for geotagging the in situ measurements required for validation and calibration.

For more information: https://artes-apps.esa.int/projects/owasis-nl

Case study 11. A Copernicus-based water quality system for monitoring inland and coastal waters

Monitoring the quality of inland and coastal water is a requirement for many environment-related governmental entities and contributes to an improved understanding of the aquatic ecosystem. With this in mind, the German company Eomap launched eoApp in 2015. This is a harmonized, high-resolution inland water quality monitoring service based on satellite data.

This online water monitoring tool provides, among other information, maps of turbidity—cloudiness caused by particles in the water—and chlorophyll content of inland and coastal waters. To monitor these parameters the service uses Copernicus data, using the innovative wide swath high-resolution multispectral imager of Sentinel-2. Thanks to these important parameters, governmental entities can monitor sediment plumes from dredging and dumping activities, as well as land run-off.

For more information: http://eoapp.eomap.com/

Case study 12. A satellite-based cyanobacteria monitoring service

Cyanobacteria, especially when forming floating scums, represent a major issue for surface waters, especially in bathing water locations: they are threat to public health, cause a bad smell, affect the aesthetic value of the surface water and result in a low environmental biodiversity.

CyMonS, an on-going project funded by ESA, is developing a service to provide water management organizations with data on several water quality parameters, at a greater spatial and temporal scale. Specifically, it aims to detect the presence of cyanobacteria. EO, including Sentinel-2 data from Copernicus, is one of the main sources of information of this service. GNSS is also used as a way to retrieve the exact coordinates of the user of the service, so that the most accurate information is provided.

For more information: https://artes-apps.esa.int/projects/cymons

7 AFFORDABLE AND CLEAN ENERGY

Goal 7 – Affordable and Clean Energy

Ensure access to affordable, reliable, sustainable and modern energy for all

Energy is central to nearly every major challenge and opportunity the world faces today. Be it for jobs, security, climate change, food production or increasing incomes, access to energy for all is essential. Sustainable energy is an opportunity to transform lives, economies and the planet. Energy is crucial for achieving almost all of the SDGs, from its role in the eradication of poverty through advancements in health, education, water supply and industrialization, to combating climate change.

Efforts to encourage clean energy have resulted in more than 20 per cent of global power being generated by renewable sources as of 2011. But still one in five people lack access to electricity and, as demand continues to rise, there needs to be a substantial increase in the production of renewable energy across the world.

The proportion of the world's population with access to clean fuels and technologies for cooking increased from 51 per cent in 2000 to 58 per cent in 2014, although there has been limited progress since 2010. The absolute number of people relying on polluting fuels and technologies for cooking, such as solid fuels and kerosene, however, has actually increased, reaching an estimated 3 billion people. Limited progress since 2010 falls substantially short of global population growth, and is almost exclusively confined to urban areas.

QUICK FACTS

- One in five people still lacks access to modern electricity.
- Three billion people rely on wood, coal, charcoal or animal waste for cooking and heating.
- Energy is the dominant contributor to climate change, accounting for around 60 per cent of total global greenhouse gas emissions.
- Reducing the carbon intensity of energy is a key objective in long-term climate goals.

EGNSS and Copernicus supporting Sustainable Development Goal 7

EGNSS and Copernicus can contribute to the monitoring of critical infrastructures such as energy networks. Copernicus can be used for pipeline development and surveillance and GNSS provides information on displacements of these infrastructures. Satellite images are used in infrastructure development and safety to reduce the risks of disasters, to protect workers and to be environmentally responsible.

The development of smart grids, which is well under way in developed countries, is not possible without GNSS technology, which provides the accurate timing that the smart grids require for synchronization, to adjust demand to distribution across a wide geographical area. The purpose of such synchronization is to augment power system monitoring, control and protection functions. A disruption of synchronization could potentially lead to a wide-scale blackout and consequently affect tens of thousands of people. By using Galileo timing, the GNSS timing solution for synchronization is even more reliable, having multiple sources of the reference time. Furthermore, Galileo authentication services are likely to trigger the concept of authenticated timing, eliminating the danger of using spoofed signals in such critical infrastructure.

In addition, Copernicus can contribute to making electricity more affordable by supporting both the oil and gas and the renewable energy industries. Satellite images are used, together with other data sources, by the oil and gas industry during early exploration and seismic surveying, to improve planning and correction. Satellite images enable large-scale prospecting in a much more efficient way for both onshore and offshore exploration. Using EO data also allows for greater confidentiality compared to sending helicopters or boats over specific areas of interest.

With regard to renewable energy, Copernicus can support several applications including solar and wind energy production forecasting, which could be used to estimate the amount of energy needed from other sources. Copernicus and EGNSS can also support biomass production monitoring and allow tracing of biomass along the value chain.

The identification of optimal sites for the production of renewable energy is the first step to undertake when establishing solar or wind power plants and is essential for defining the viability of a project. Both GNSS and EO can support energy managers in identifying the best location. EO provides information on the solar radiation resources at the Earth's surface, by offering optical and multispectral imagery and digital elevation models. GNSS adds value by producing scatterometry models by means of GNSS reflectometry techniques. The combination of the two technologies allows energy managers to crosscheck the data collected on the field with the information obtained from EO and GNSS, to ultimately define the optimal location for renewable energy farms.

Together, EGNSS and Copernicus can help achieve more reliable, efficient, and modern energy services worldwide.

The targets to which EGNSS and Copernicus mainly contribute for this SDG are:

7.1 By 2030, ensure universal access to affordable, reliable and modern energy services

7.b By 2030, expand infrastructure and upgrade technology for supplying modern and sustainable energy services for all in developing countries, in particular least developed countries, small island developing States and landlocked developing countries, in accordance with their respective programmes of support

Table 7. Qualitative assessment of European Union space programmes' contribution to SDG 7 targets

Targets	EGNSS	Copernicus	Synergies
7.1	● ●	◐ ●	◐ ●
7.b	● ●	◐ ●	● ●

Level of contribution in monitoring/achieving part of a target/indicator

◐ ◐ Limited contribution ● ● Significant contribution

CASE STUDIES

Case study 13. Copernicus enhances efficiency of solar forecasting

One of the main drawbacks of grid-connected solar farms is the intermittency of the energy produced. Difficulties with forecasting this kind of power generation have been used as an argument by opponents of renewable energy for a long time.

Reuniwatt, a French SME, uses Copernicus to monitor the productivity of solar panels. Its main product is Soleka, which forecasts solar power production for electricity grid managers and photovoltaic electricity producers, enabling them to determine the approximate amount of solar energy they will have at their disposal at a given moment in time. Reuniwatt affirms that, thanks to Copernicus, it is possible to improve the quality of forecasts by 30 per cent while reducing costs by up to 50 per cent for one-day forecasts and up to 15 per cent for six-hour and 30-min forecasts, thanks to time saved in data processing.

For more information: http://reuniwatt.com/en/

Case study 14. Phasor measurement units increase the reliability of electricity distribution systems

Phasor Measurement Units (PMU) enable precise grid measurements of electrical waves to determine the health of an electricity distribution system. This technology has the potential to change the economics of power distribution by allowing increased power flow over existing lines. PMU data could be used to allow power flow up to a line's dynamic limit instead of to its worst-case limit.

PMUs are deployed across remote locations of the power network (nodes), with internal time references based on GNSS receivers which allow PMU from different locations to be synchronised. When data from multiple PMUs are combined, the information provides a precise and comprehensive view of the entire interconnection. PMU measurements enable a superior indication of grid stress, and are often used to trigger corrective actions to maintain reliability.

8 DECENT WORK AND ECONOMIC GROWTH

Goal 8 – Decent Work and Economic Growth

Promote sustained, inclusive and sustainable economic growth, full and productive employment and decent work for all

Roughly half the world's population still lives on the equivalent of about $2 a day, and in too many places, having a job does not guarantee an escape from poverty. Slow and uneven progress in this area requires us to rethink and retool our economic and social policies aimed at eradicating poverty. A continued lack of decent work opportunities, insufficient investments and under-consumption lead to an erosion of the basic social contract underlying democratic societies: that all must share in progress. The creation of quality jobs will remain a major challenge for almost all economies well beyond 2015. Sustainable economic growth will require societies to create the conditions that allow people to have quality jobs that stimulate the economy while not harming the environment. Job opportunities and decent working conditions are also required for the whole working-age population.

Sustained and inclusive economic growth is necessary for achieving sustainable development. The global annual growth rate of real GDP per capita increased by 1.3 per cent in 2014, a significant slowdown compared to 2010 (2.8 per cent growth) and 2000 (3.0 per cent growth). Developing regions grew far faster than developed regions, with average annual growth rates in 2014 of 3.1 per cent and 1.4 per cent respectively.

EGNSS and Copernicus supporting Sustainable Development Goal 8

Both Galileo and Copernicus contribute to job and GDP growth. A European Commission assessment estimated that that 11 per cent of GDP in European Union countries depends on satellite navigation.[12] The study analysed the combined contribution of the industrial sectors most exposed to sat-nav technology: service delivery, utilities, banking and finance, agriculture and communications.

The European space sector is a major high-end engineering, technological and science-intensive sector. Its cutting-edge innovation, research and development create important spillover effects in many other sectors. For example, a 2013 report by Oxera[13] estimated the gross value added of "geo-services" (LBS + geographic mapping) to be $113 billion globally, saving users an estimated 1.1 billion hours per year of wasted journey time.

[12] VVA, *Analysis of GNSS impact on EU Economy*, 2016.

[13] Oxera Consulting, *What is the economic impact of Geo services?*, 2013, http://www.oxera.com/Oxera/media/Oxera/downloads/reports/What-is-the-economic-impact-of-Geo-services_1.pdf?ext=.pdf

QUICK FACTS

- The global unemployment rate stood at 6.1 per cent in 2015, down from a peak of 6.6 per cent in 2009, mostly owing to a drop in unemployment in developed regions.
- Between 2011 and 2014, the proportion of the world's adult population with an account at a financial institution or a mobile money service provider increased from 51 per cent to 62 per cent, meaning that 700 million adults became account holders during this period.
- In 2015, the average worker in developed regions produced 23 times the annual output of an average worker in sub-Saharan Africa (which has the lowest labour productivity in developing regions), and 2.5 times that of an average worker in Western Asia (which has the highest labour productivity in developing regions).

However, GNSS is supporting global economies' GDP growth to a greater extent, for example by generating efficiencies in many industrial sectors such as transportation, where use of GNSS helps reduce travel time and fuel consumption by more than 10 per cent.

Space data offers an enormous opportunity for both people and companies. Today, Europe's space programmes already support over 50,000 jobs in Europe. Moreover, many SMEs have been created through European-funded innovation programmes in the space sector. For example, European Union innovation instruments such as FP7 and H2020 have funded more than 200 EGNSS-related projects in the last decade. While many projects had primarily an R&D scope, most of them turned into real commercial ventures.

Additionally, GNSS technology is directly contributing to establishing safe and secure working environments. It is an enabling technology for lone worker monitoring solutions, which bring peace of mind to individuals working in different environments because they know that their activity is being monitored, and prolonged periods of inactivity triggers an alarm.

The degree of space technologies' contribution to this SDG is specified below:

8.1 Sustain per capita economic growth in accordance with national circumstances and, in particular, at least 7 per cent gross domestic product growth per annum in the least developed countries

8.2 Achieve higher levels of economic productivity through diversification, technological upgrading and innovation, including through a focus on high-value added and labour-intensive sectors

8.8 Protect labour rights and promote safe and secure working environments for all workers, including migrant workers, in particular women migrants, and those in precarious employment.

Table 8. Qualitative assessment of European Union space programmes' contribution to SDG 8 targets

8 DECENT WORK AND ECONOMIC GROWTH

Targets	EGNSS	Copernicus	Synergies
8.1	●●	●●	●●
8.2	●●	●●	●●
8.8	◐●	◐●	◐●

Level of contribution in monitoring/achieving part of a target/indicator

◐◐ Limited contribution ●● Significant contribution

CASE STUDY

Case study 15. GNSS enables lone worker protection solutions and services

Many activities require workers to be left alone and isolated while performing their tasks. Even though the risks faced by lone workers are similar to those faced by other workers, the related level of danger is clearly greater because the worker is on his or her own and thus, in the event of accident, might be not able to call for assistance.

Within this context, many applications and services rely on GNSS to enhance the protection of outdoor lone workers.

Ringway Infrastructure Services is a United Kingdom highways maintenance provider. During work on roads, slips, trips and falls are among the most common causes of injuries. To ensure prompt assistance the company has equipped lone workers with GNSS-enabled tracking devices that automatically send alarms after a sudden impact followed by a period of inactivity – for example if the worker falls down. In an emergency, device locations can be traced using GNSS coordinates transmitted in the alarm message.

For more information: http://skyguard.co.uk/portfolio-item/ringway-infrastructure-services/

9 INDUSTRY, INNOVATION AND INFRASTRUCTURE

Goal 9 – Industry, Innovation and Infrastructure

Build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation

Goal 9 encompasses three important aspects of sustainable development: infrastructure, industrialization and innovation. Infrastructure provides the basic physical systems and structures essential to the operation of a society or enterprise. Industrialization drives economic growth, creates job opportunities and thereby reduces income poverty. Innovation advances the technological capabilities of industrial sectors and prompts the development of new skills.

Investments in infrastructure—transport, irrigation, energy and information and communication technology—are crucial to achieving sustainable development and empowering communities in many countries. It has long been recognized that growth in productivity and incomes, and improvements in health and education outcomes, require investment in infrastructure. Inclusive and sustainable industrial development is the primary source of income generation, allows for rapid and sustained increases in living standards for all people, and provides the technological solutions needed for environmentally sound industrialization. Technological progress is the foundation of efforts to achieve environmental objectives, such as increased resource and energy efficiency. Without technology and innovation, industrialization will not happen, and without industrialization there will be no development.

QUICK FACTS

- Worldwide, about 500 million people are employed in manufacturing.
- One billion to 1.5 billion people do not have access to reliable phone services.
- About 2.6 billion people in the developing world face difficulties in accessing electricity full-time.
- For many African countries, particularly the lower-income countries, infrastructure constraints affect firm productivity by around 40 per cent.
- Basic infrastructure, such as roads, information and communication technologies, sanitation, electrical power and water, remains scarce in many developing countries.

EGNSS and Copernicus supporting Sustainable Development Goal 9

EO and GNSS play a key role in infrastructure mapping and monitoring, including maintenance of road infrastructure in rural environments, where the most efficient and reliable technology is satellite-based. For instance, telecommunications companies use remote sensing as a cost-effective way to optimize capacity requirements. Radio frequency coverage can be augmented with the appropriate antenna type, location and direction. Satellite-derived terrain, land-use and other environmental factors can be modelled to achieve optimal network capacity. Additionally, the monitoring of critical infrastructures by GNSS and Copernicus contributes to making them more resilient.

GNSS provides free and worldwide access to location and time information 24/7. The timing component of GNSS is widely used every day by telecommunication networks, which rely on GNSS as an integral part of their infrastructure for synchronization, easing the development of digital cellular networks, SATCOM networks and the Internet backbone.

The transport industry is benefiting enormously from GNSS-based solutions for fleet management, enabling transport operators to monitor goods and assets during their transfer, thereby improving efficiency and effectiveness of transport activities. In addition, by optimizing navigation routes, GNSS use significantly reduces the fuel consumed in all transport modes, thereby reducing CO2 emissions and therefore alleviating some of the effects of climate change. In addition to satellite navigation, fleet management solutions reduce a company's fuel consumption by more than 5 per cent due to smarter planning and monitored driving behaviour, and further benefits can be realized when the maintenance cycle of vehicles is informed by remote diagnostics. As part of smart cities deployment, CO2 emissions from transportation vehicles are reduced even further thanks to GNSS—for example smart bus stops and efficient phasing of traffic lights.

Another very important area where GNSS is contributing is the construction of buildings and city infrastructure. The use of GNSS for machine control, for example, automates construction activities by controlling the blades and buckets of construction equipment based on information provided by 3D design. GNSS machine control increases the speed of grading by more than 50 per cent relative to non-automated machines, and reduces the consumption of tarmac by 9 per cent when paving because the width and thickness is precisely as prescribed in the plans. Other applications include topographic surveys of construction sites and subsequent infrastructure monitoring.

The contribution of EGNSS and Copernicus mainly applies to the following SDG 9 targets:

9.1 Develop quality, reliable, sustainable and resilient infrastructure, including regional and trans-border infrastructure, to support economic development and human well-being, with a focus on affordable and equitable access for all

9.4 By 2030, upgrade infrastructure and retrofit industries to make them sustainable, with increased resource-use efficiency and greater adoption of clean and environmentally sound technologies and industrial processes, with all countries taking action in accordance with their respective capabilities

9.c Significantly increase access to information and communications technology and strive to provide universal and affordable access to the Internet in least developed countries by 2020

The degree of contribution of EGNSS and Copernicus is specified in table 9.

Table 9. Qualitative assessment of European Union space programmes' contribution to SDG 9 targets

9 INDUSTRY, INNOVATION AND INFRASTRUCTURE

Targets	EGNSS	Copernicus	Synergies
9.1	●●	◑●	◑●
9.4	◑●	●●	●●
9.c	●●	◑●	●●

Level of contribution in monitoring/achieving part of a target/indicator

◑◑ Limited contribution ●● Significant contribution

CASE STUDIES

Case study 16. Infrastructure inspections are more efficient thanks to GNSS and RPAS

Infrastructure maintenance inspections are traditionally performed manually based on slow and costly human inspections that usually yield incomplete and poor-quality results. These time-consuming and costly procedures can be improved by deploying RPAS.

Infrastructure inspection applications need to operate close (a few metres) to the monitored object, sometimes in urban environments and with real-time requirements. Under such conditions, a robust and accurate navigation solution is fundamental. Real is a European-funded project that aims to promote the use of EGNOS in the RPAS sector by developing an EGNOS-based navigation and surveillance sensor, ready to be coupled with a generic RPAS autopilot and ground station system. This development should contribute to the approval of innovative RPAS operations requiring high levels of accuracy and integrity, such as linear infrastructure monitoring (for example power lines, pipelines, railways).

For more information:
https://www.gsa.europa.eu/newsroom/news/14-projects-selected-funding-and-aimed-developing-egnos-regional-airports

Case study 17. Ground motion surveys assist the construction of resilient infrastructure

Land instability may result in landslides, subsidence or ground heave. Failing to deal with this issue could cause harm to human health, local property and associated infrastructure, and, to a wider extent, to the surrounding environment.

The Italian company Tre Altamira has developed SqueeSAR, an algorithm for surface displacement detection which can be used as an important input to all stages of any construction project. The algorithm is able to identify unstable areas affected by ground movements and to reconstruct their displacement history. The detection of the Earth's surface deformation is performed by comparing radar images captured by EO satellites over time. Using the phase properties of these images, deformation can be measured up to millimetre accuracy.

For more information: http://tre-altamira.com/technology/squeesar/

Case study 18. Authenticated time and location for location-based applications and services

With specific applications, local government agencies enable citizens and local actors to take action to improve their neighbourhoods. GNSS provides position information for city infrastructure problems reported by citizens, allowing municipalities to determine the exact location of the problem on a map.

The European-funded ATLAS project deals with the development of an assurance and authentication service for GNSS-derived time and position information for use in liability-critical LBS applications. The targeted LBS application authenticates digital images and video taken from mobile phones and devices using digital watermarking of time and location data. With this service, the evidence recorded is certified on time and location.

For more information: https://www.gsa.europa.eu/autenticated-time-and-location-location-based-application-and-services

Goal 11 – Sustainable Cities and Communities

Make cities and human settlements inclusive, safe, resilient and sustainable

This Goal is focused on cities, as more than half of the world's population lives in them. Cities are hubs for ideas, commerce, culture, science, productivity, social development and much more. At their best, cities have enabled people to advance socially and economically. However, many challenges exist to maintaining cities in a way that continues to create jobs and prosperity without straining land and resources. Common urban challenges include congestion, lack of funds to provide basic services, a shortage of adequate housing and declining infrastructure. The challenges cities face can be overcome in ways that allow them to continue to thrive and grow, while improving resource use and reducing pollution and poverty. The future we want includes cities that provide opportunities for all, with access to basic services, energy, housing, transportation and more. Resiliency of cities is also a key element of the picture; the planning and development of cities needs to be aware and able to face risks arising from natural or man-made disasters, in line with the Sendai Framework for Disaster Risk Reduction 2015-2030.

QUICK FACTS

- More than half the world's population—3.5 billion people—lives in cities. By 2030, it is projected that 6 out of 10 people will be urban dwellers.
- In 2014, around half the global urban population was exposed to air pollution levels at least 2.5 times higher than maximum standards set by the World Health Organization.
- In 2014, 30 per cent of the urban population—828 million people—lived in slum-like conditions
- The world's cities occupy just 3 per cent of the Earth's land, but account for 60-80 per cent of energy consumption and 75 per cent of carbon emissions.
- Rapid urbanisation is exerting pressure on fresh water supplies, sewage, the living environment, and public health.

EGNSS and Copernicus supporting Sustainable Development Goal 11

The combined use of Copernicus and EGNSS is key to understanding cities, how they grow, how their resources are utilized, the distribution of basic services, their impact on the environment and the mapping of informal settlements and inadequate housing.

EGNSS is widely used for urban planning, to pinpoint structures and reference points for cadastral and urban planning purposes. It also allows the monitoring of displacements and detection of potential structural risks due to movement. In addition, EGNSS offers numerous opportunities to design and improve city services such as smart waste management systems with sensor-embedded garbage bins and the synchronization of smart grids as described in SDG 7.

Lighting can account for up to 40 per cent of a city's energy consumption. As a result, city administrations and other agencies operating large streetlight networks are continuously looking to enhance the efficiency of the overall system. As a consequence, the public outdoor lighting market is adopting light-emitting diode (LED) streetlights that can be networked together with communications to become "smart streetlights". Within smart lighting technology, new streetlights are equipped with low-cost GNSS receivers and connected to a mesh radio network that relays their data to a Cloud Gate Gateway device for review and analysis in a centralized location. In this way defective lamps communicate their status in real time and can be precisely located for replacement, improving the maintenance process, which reduces maintenance costs by up to 30 per cent.

Copernicus Satellites such as Sentinel-1 and Sentinel-2 take images over cities that make it possible to monitor them. Copernicus products such as the Urban Atlas are used by both local and regional planners. The Sentinel-5 precursor is able to provide information concerning air pollution and the quality of air over cities through the atmosphere monitoring service, which includes air quality.

An understanding of disaster risk, proper preparations to reduce this risk and to improve resilience, response and the capacity to recover from disasters all need to be considered when planning and managing a city. For example, Copernicus provides the *Copernicus Emergency Management Service (EMS)*, supporting information for emergency response in relation to different types of disasters, including meteorological hazards (for example severe storms, floods and tsunamis), geophysical hazards (volcanic eruption and earthquake), deliberate and accidental man-made disasters (for example fires) and other humanitarian disasters.

The combination of EGNSS and Copernicus, as also explained for SDG 1, are crucial for the disaster management cycle. There are many examples of applications of both technologies for disaster management, as explained in Target 11.5. EGNSS plays a crucial role in SAR operations through the SAR Service, which is contributing to the Cospas-Sarsat MEOSAR programme. In fact, Galileo will send a return link message to a triggered distress beacon, acknowledging the message has been received. EGNSS is also very important when it comes to the mapping with extreme precision of disaster areas that have been already accessed by rescue teams, avoiding the need to survey the same area twice. The satellite images provided by Copernicus could help monitor the risk of a disaster and reduce the economic loss and number of deaths and missing persons if it occurs.

The use of Copernicus can also help in monitoring the world's cultural heritage, increasing awareness and detecting activities that may result in damage to these sites. Similarly EGNSS location data contributes to develop ad hoc AR applications supporting the preservation of the world heritage by recreating 3D models of historical monuments.

Finally, satellite data from both the programmes are beneficial to support, plan and monitor migration and mobility of people, either in the case of human migration between different areas of the world, or mobility within urban centres.

Both programmes, Copernicus and EGNSS, contribute to almost all the targets under SDG 11. The targets that can be monitored or assisted by the two programmes are as follows:

11.2 By 2030, provide access to safe, affordable, accessible and sustainable transport systems for all, improving road safety, notably by expanding public transport, with special attention to the needs of those in vulnerable situations, women, children, persons with disabilities and older persons

11.3 By 2030, enhance inclusive and sustainable urbanization and capacity for participatory, integrated and sustainable human settlement planning and management in all countries

11.4 Strengthen efforts to protect and safeguard the world's cultural and natural heritage

11.5 By 2030, significantly reduce the number of deaths and the number of people affected by disasters and substantially decrease the direct economic losses relative to global gross domestic product caused by disasters, including water-related disasters, with a focus on protecting the poor and people in vulnerable situations

11.6 By 2030, reduce the adverse per capita environmental impact of cities, including by paying special attention to air quality and municipal and other waste management

11.7 By 2030, provide universal access to safe, inclusive and accessible, green and public spaces, in particular for women and children, older persons and persons with disabilities

11.a Support positive economic, social and environmental links between urban, per-urban and rural areas by strengthening national and regional development planning

11.b By 2020, substantially increase the number of cities and human settlements adopting and implementing integrated policies and plans towards inclusion, resource efficiency, mitigation and adaptation to climate change, resilience to disasters, and develop and implement, in line with the Sendai Framework for Disaster Risk Reduction 2015-2030, holistic disaster risk management at all levels

Table 10. Qualitative assessment of European Union space programmes' contribution to SDG 11 targets

11 SUSTAINABLE CITIES AND COMMUNITIES

Targets	EGNSS	Copernicus	Synergies
11.2	●●	●●	●●
11.3	●●	●●	●●
11.4	◐●	◐●	◐●
11.5	●●	●●	●●
11.6	◐●	●●	●●
11.7	●●	●●	●●
11.a	●●	●●	●●
11.b	●●	●●	●●

Level of contribution in monitoring/achieving part of a target/indicator

◐◐ Limited contribution ●● Significant contribution

CASE STUDIES

Case study 19. Air quality monitoring supported by EO and GNSS

An efficient management of air quality is one of the most challenging environment-related tasks faced by industry today. Air pollution is responsible for more than 450,000 premature deaths in Europe each year.

To enhance the monitoring process, Aircheckr has developed a solution providing functional air quality data which otherwise are too complex and coarse for personal use. The Aircheckr air quality data are modelled and enriched with crowdsourced local air quality sensor data and EO-derived contextual information. The Copernicus product "Urban Atlas" provides pan-European comparable land use and land cover data for large urban zones, while GNSS is primarily used to track the precise location of individual users accessing the Aircheckr database through APIs. Additionally, GNSS enables the positioning of newly installed sensors, which is key for contextualizing the collected data.

For more information: https://artes-apps.esa.int/projects/aircheckr

Case study 20. Satellites help to design more habitable cities

In cities, temperatures can be several degrees higher than in surrounding rural areas, especially at night. Prolonged periods of high temperatures increase the demand for energy and water, trigger health problems and increase air pollution and the greenhouse effect.

Copernicus medium and high-resolution multispectral satellites with thermal-infrared sensors provide information about thermal patterns, thereby helping to improve urban climate and weather prediction models. An improved understanding of complex urban heat islands makes it possible to develop more efficient alert systems, helping decision- and policy-makers to adopt effective mitigation strategies and improve urban planning.

For more information: http://www.copernicus.eu/sites/default/files/documents/Copernicus_Briefs/Copernicus_Brief_Issue16_Urban_Heat_Islands_Sep2013.pdf

Case study 21. Copernicus and GNSS help to monitor landslides

In November 2000, a 1.2 million m^3 landslide slid down from Stože Mountain in north-west Slovenia. It partly or totally destroyed 23 buildings and killed seven people. Potential mass debris flows of a similar size occur in many locations across the world and present a hazard to citizens.

Identifying the precursors of such events requires very precise measurement of vertical and horizontal displacements.

The project I2GPS developed a novel, integrated approach for the use of synthetic aperture radar interferometry (InSAR data from Copernicus) and GNSS to monitor subsidence, tectonic changes or other environmental hazards, which can only be identified by millimetric precision survey techniques.

For more information: https://www.gsa.europa.eu/integrated-interferometry-and-gnss-precision-survey

Case study 22. Use of Copernicus for urban housing density analysis

Rapid urban population growth can hinder the execution of any well-thought-out urban plan. To ensure the well-being and productivity of citizens, there is a need to set up the required infrastructure and services, such as water supply, housing and sanitation facilities. It is therefore crucial to have a timely understanding of, and to monitor changes in, urban density, to help policy-makers react promptly to any sudden change in urban dynamics and make the best decision regarding the allocation of resources. This is especially true in developing countries, where urbanization is on the increase.

The Centre for Remote Sensing and Geographic Information Services (CERSGIS) used EO Sentinel-2 imagery to map the urban housing density in Accra (Ghana). By observing similar spectral reflections exhibited by pixels in the images, they identified three urban density levels in built-up areas: high, medium and low density.

For more information: http://cersgis.org/

Case study 23. TehnoGIS: Copernicus-EGNSS enabling cost-effective solutions for surveying and infrastructure development

TehnoGIS is an independent start-up delivering geo-referenced data using EGNOS, Galileo and Copernicus data in complementarity with other sensors (IMU, UAV, etc.) to provide affordable solutions to farmers, as well as to city and land administrators, and other users.

Project portfolios range from determining flood areas and conducting preparatory studies for new infrastructure (highways, railways, etc.), in Eastern Europe, to 3D modelling for Western European city planners and building companies.

For more information: http://www.tehnogis.ro/index.php/ro/

Case study 24. An electric scooter sharing service for sustainable urban mobility

Vehicle sharing services benefit from GNSS information in order to track the vehicles, which are widely distributed across the city. In the case of "floating sharing", where vehicles are not parked in specific stations, GNSS is the main source of information for users to locate the vehicle. It also enhances security of the system by alerting about unexpected movements and tracking a vehicle in the event of theft.

G-MOTIT is a European-funded project that has developed an electric scooter sharing service in order to solve urban mobility problems potentially in major metropolitan areas in Europe. It allows users to reserve a scooter with their smartphone, receive a notification with the position of the assigned vehicle, drive it and drop it off wherever they want. The service aims to enhance vehicle positioning performance by developing and integrating EGNSS-based location technology, which is key for the success of the service.

For more information: http://gmotit.pildo.com/

Goal 12 – Responsible Consumption and Production

Ensure sustainable consumption and production patterns

Sustainable consumption and production is about promoting resource and energy efficiency, sustainable infrastructure, and providing access to basic services, green and decent jobs and a better quality of life for all. Its implementation helps to achieve overall development plans, reduce future economic, environmental and social costs, strengthen economic competitiveness and reduce poverty. Sustainable consumption and production aims *at "doing more and better with less*", increasing net welfare gains from economic activities by reducing resource use, degradation and pollution along the whole lifecycle, while increasing quality of life. It involves different stakeholders, including business, consumers, policy-makers, researchers, scientists, retailers, media, and development cooperation agencies. It also requires a systemic approach and cooperation among actors operating in the supply chain, from producer to final consumer. It involves, for example, engaging consumers through awareness-raising and education on sustainable consumption and lifestyles, providing consumers with adequate information through standards and labels and engaging in sustainable public procurement.

QUICK FACTS

- Each year, an estimated one third of all food produced—equivalent to 1.3 billion tons worth around $1 trillion—ends up rotting in the bins of consumers and retailers, or spoiling due to poor transportation and harvesting practices.
- Less than 3 per cent of the world's water is fresh (drinkable). Of this freshwater, around five sixths is frozen in Antarctica, the Arctic and glaciers.
- If people worldwide switched to energy-efficient lightbulbs the world would save $120 billion annually.
- Should the global population reach 9.6 billion by 2050, the equivalent of almost three Earths could be required to provide the natural resources needed to sustain current lifestyles.

EGNSS and Copernicus supporting Sustainable Development Goal 12

Satellite imagery can help to monitor the efficient use of natural resources in a consistent and repeatable manner across the Earth. Images are captured with the same sensor and the same area can be imaged several times a month. This repeatability is a unique feature of satellite data. Thanks to this, and to the open and free data policy of Copernicus, these images are available worldwide, so different teams can use the same image and compare results.

GNSS and EO are widely used within GIS, which represent a cost-efficient and powerful tool for resource analysis towards sustainable management of forests, open-air mines, water reservoirs, logging, fisheries, crops and many other resources.

The Sentinel satellites are equipped with sensors able to monitor these variables and produce services based on this monitoring. An example is the land-use monitoring carried out by Sentinel 2, which carries a multispectral instrument (MSI) that is able to detect different chemicals, depending on the light they reflect. The objective of this mission is to provide images to create land-cover maps, land-change detection maps and geophysical variables.

There is potential for GNSS to act in synergy with Copernicus to provide valuable data for traceability purposes, to monitor the food supply chain and build trust with consumers by providing additional information on the origin of ingredients and on production methods. It can be used to supply proof of the origin of processed products and their ingredients, which in turn is used by producers to potentially justify a higher price for the products. One of the key advantages provided by GNSS is the possibility to achieve a significant improvement in efficiency, security and safety of the supply chain. It is therefore contributing to a better monitoring of cargo from the consignee to the consignor. It also results in lower costs and increased transport safety (for example for dangerous goods transportation).

Among many other applications, both systems can be combined to support sustainable tourism, creating reliable maps of the best sightseeing opportunities and alerting tourists when they are in the vicinity of something worth seeing, so they can be guided to the right location, as referred in the target 12.b. The creation of AR tourist guides is a growing business that creates jobs and can help to revitalize local tourist markets by making them easier to access.

The targets under SDG 12 that receive the greatest contribution from EGNSS and Copernicus are as follows:

- 12.2 By 2030, achieve the sustainable management and efficient use of natural resources
- 12.b Develop and implement tools to monitor sustainable development impacts for sustainable tourism that creates jobs and promotes local culture and products

The degree of contribution is specified in table 11:

Table 11. Qualitative assessment of European Union space programmes' contribution to SDG 12 targets

Targets	EGNSS	Copernicus	Synergies
12.2	●●	●●	●●
12.b	◑●	●●	●●

Level of contribution in monitoring/achieving part of a target/indicator

◑◑ Limited contribution ●● Significant contribution

CASE STUDIES

Case study 25. An IoT application improves the measurement of key parameters in forest areas

Forest managers need to regularly assess a forest's status to efficiently manage and monitor the rapidly changing forest environment. Historically, this required significant manual effort and the associated costs made it more difficult to receive a high-quality assessment of a forest's status.

IoTrees is an IoT solution, currently under development by Treemetrics, which uses different sensors to regularly monitor forest areas without the need for human intervention. The proposed solution consists of a network of dendrometers featuring sensors, which communicate via a Low Power Wide Area Network (LPWAN) to a central gateway. Through this platform, users will be able to combine sensor data with EO datasets and alternative forest inventory data. GNSS is key to ensuring this aggregation of data by geo-referencing EO imagery and data taken in the field.

For more information: https://artes-apps.esa.int/projects/iotrees

Case study 26. GNSS track and trace system monitors the transport of dangerous goods

The transportation of dangerous goods is a key element of Intelligent Transport Systems (ITS) where solutions aim to prevent, as far as possible, accidents to persons or property and damage to the environment, the means of transport employed or to other goods.

Within the European Union-funded Scutum project, Eni (the Italian multinational oil and gas company) adopted an EGNOS-based solution to monitor its operational fleet transporting dangerous goods throughout Europe. About 300 trucks are presently equipped with GPS/EGNOS tracking and tracing devices. Location and cargo information is sent to the transport integrated platform to be visualized by the company's emergency management centre. The use of EGNOS enables a robust determination of vehicles' position.

For more information: http://www.scutumgnss.eu/

Goal 13 – Climate Action

*Take urgent action to combat climate change and its impacts**

Climate change is now affecting every country on every continent. It is disrupting national economies and affecting lives, costing people, communities and countries dearly today and even more tomorrow. People are experiencing the significant impacts of climate change, which include changing weather patterns, rising sea levels, and more extreme weather events. The greenhouse gas emissions from human activities are driving climate change and are continuing to rise. They are now at their highest levels in history. Without action, the world's average surface temperature is projected to rise over the twenty-first century and is likely to surpass 3°C this century—with some areas of the world expected to warm even more. The poorest and most vulnerable people are being affected the most. Affordable, scalable solutions are now available to enable countries to transition to cleaner, more resilient economies. The pace of change is quickening as more people are turning to renewable energy and a range of other measures that will reduce emissions and increase adaptation. But climate change is a global challenge that does not respect national borders. Emissions anywhere affect people everywhere. It is an issue that requires solutions that need to be coordinated at the international level and it requires international cooperation to help developing countries move towards a low-carbon economy.

EGNSS and Copernicus supporting Sustainable Development Goal 13

EO data has made possible an unprecedented knowledge of planet Earth and, thanks to this, climate change and the variables contributing to it are much better understood. The Global Climate Observing System (GCOS) introduced the "Essential Climate Variables" (ECVs) in its Second Adequacy Report in 2003. The ECVs are either specific variables or groups of closely related variables that provide reliable, traceable, observation-based

*Acknowledging that the United Nations Framework Convention on Climate Change is the primary international, intergovernmental forum for negotiating the global response to climate change.

QUICK FACTS

- Five hundred million small farms worldwide provide up to 80 per cent of food consumed in a large part of the developing world.
- Global emissions of carbon dioxide (CO_2) have increased by almost 50 per cent since 1990.
- Given current concentrations and ongoing emissions of greenhouse gases, it is likely that by the end of this century the increase in global temperature will exceed 1.5°C compared to 1850 to 1900.
- From 1880 to 2012, the average global temperature increased by 0.85°C. To put this into perspective, for each 1 degree of temperature increase, grain yields decline by about 5 per cent.

evidence for a range of applications, including monitoring, mitigating, adapting to, and attributing changes in climatic conditions, as well as understanding past, current, and possible future climate variability. The Copernicus Climate Change Services (C3S) will cover up to 30 ECVs out of 50 by 2030, using Copernicus. C3S can help monitor the implementation of climate change measures across the globe. The service will provide access to several climate indicators (for example temperature increase, sea level rise, ice sheet melting, warming up of the ocean) and climate indices (for example based on records of temperature, precipitation, drought event) for both the identified climate drivers and the expected climate impacts. Not only is C3S gathering information on ECVs, the Copernicus Global Land Service is also gathering ECVs to complete the picture, gathering information to understand Earth's climate.

Climate change is likely to exaggerate the number of extreme weather events and associated natural disasters. The use of satellite-based information is critical for the disaster management cycle, as explained in previous sections; EGNSS and Copernicus play a crucial role in SAR operations, as explained in the section on SDG 1. By integrating accurate GNSS position information into distress beacon signals, GNSS is also revolutionizing SAR operations. By 2020, all Cospas-Sarsat Emergency Personal Location Beacons (registered personal devices that can be used in any remote location or situation where people may require rescue) are expected to be using precise GNSS positioning, helping to reduce response times and save lives. In Galileo-enabled beacons, the Galileo return link service will reassure the navigator that the signal has been received and that help is on its way. EGNSS data is also used within specialized smartphone applications for disaster management, integrating crowdsourcing data from users and from other systems such as EO (for example Copernicus) and/or weather stations, allowing civil protection services and policy-makers to effectively prevent and/or react to natural disasters (for example the European-funded projects iReact and Floodis).

Climate change and air pollution are closely linked, as they influence each other through complex interactions in the atmosphere. Increasing levels of greenhouse gases, including CO_2, alter the energy balance between the atmosphere and the Earth's surface, ultimately leading to changes in temperature. Direct emissions of air pollutants can also influence this energy balance. The use of GNSS reduces the fuel consumed on roads, at sea, in the skies and in fields, which reduces CO_2 emissions and therefore alleviates some of the effects of climate change.

- GNSS navigation provides road vehicles with a planning tool that supports route optimization, leading to a reduction in fuel used and CO2 emitted.
- GNSS use in aviation enables landings in adverse weather conditions which implies a reduction in delays and diversions, thus resulting in less fuel used.
- GNSS enables precision agriculture, which allows farmers to optimize the application of pesticides and fertilizer, targeting only the sections of a field where it is needed. Additionally, it reduces the pass-to-pass overlap, allowing farmers to work the fields using fewer passes and therefore fewer pollutants such as fuel, pesticides, herbicides and fertilizers.

The contribution of EGNSS and Copernicus to this SDG is mainly to the following targets:

13.1 Strengthen resilience and adaptive capacity to climate-related hazards and natural disasters in all countries

13.2 Integrate climate change measures into national policies, strategies and planning

13.b Promote mechanisms for raising capacity for effective climate change-related planning and management in least developed countries and small island developing States, including focusing on women, youth and local and marginalized communities

The degree of contribution is summarized in table 12.

Table 12. Qualitative assessment of European Union space programmes' contribution to SDG 13 targets

13 CLIMATE ACTION

Targets	EGNSS	Copernicus	Synergies
13.1	●●	●●	●●
13.2	●●	●●	●●
13.b*	●●	●●	●●

*Thanks to the MoU between the UNOOSA and the European GNSS Agency, it is possible to collaborate on training and workshops for developing countries.

Level of contribution in monitoring/achieving part of a target/indicator

◐◐ Limited contribution ●● Significant contribution

CASE STUDY

Case study 27. Monitoring of Norway's glaciers with Copernicus

Fluctuations in the Earth's glaciers are directly linked to the history of climate change. Glacier monitoring delivers fundamental baseline information for climatological, hydrological, and hazard assessments which can be used by governments to make long-range plans to better cope with the economic impacts of climate change.

The Copernicus Glacier Service ("Copernicus bretjeneste" in Norwegian) is a cooperative project between the Norwegian water resources and energy directorate (NVE), the Norwegian Polar Institute and the Department of Geosciences, University of Oslo, with the objective of developing a national service for glaciers in mainland Norway and Svalbard. The project will mainly use EO optical imagery from Sentinel-2, but also from Landsat-8 and other sensors, when relevant, to gather information on:

- Glacier outline, area and calving front
- Glacier surface type and snow line
- Ice velocity
- Glacier crevasses and surge
- Glacier lakes

For more information: https://www.nve.no/hydrology/glaciers/copernicus-glacier-service/

Goal 14 – Life below Water

Conserve and sustainably use the oceans, seas and marine resources for sustainable development

The world's oceans—their temperature, chemistry, currents and life—drive global systems that make the Earth habitable for humankind. Our rainwater, drinking water, weather, climate, coastlines, much of our food, and even the oxygen in the air we breathe, are all ultimately provided and regulated by the sea. Throughout history, oceans and seas have been vital conduits for trade and transportation. Careful management of this essential global resource is a key feature of a sustainable future.

Oceans, along with coastal and marine resources, play an essential role in human well-being and social and economic development worldwide. They are particularly crucial for people living in coastal communities, who represented 37 per cent of the global population in 2010. Oceans provide livelihoods and tourism benefits, as well as subsistence and income. They also help regulate the global ecosystem by absorbing heat and carbon dioxide from the atmosphere and protecting coastal areas from flooding and erosion. In fact, coastal and marine resources contribute an estimated $28 trillion to the global economy each year through ecosystem services. However, these resources are extremely vulnerable to environmental degradation, overfishing, climate change and pollution. The sustainable use and preservation of marine and coastal ecosystems and their biological diversity is essential to achieving the 2030 Agenda, in particular for small island developing States.

EGNSS and Copernicus supporting Sustainable Development Goal 14

The monitoring and evaluation of marine resources, due to the large areas involved, cannot be achieved without the contribution of satellite data. Galileo and Copernicus are critical for mapping and monitoring of natural and protected areas.

Copernicus' marine environment monitoring service (CMEMS) provides information to protect and manage living marine resources. The service monitors sea-surface temperature and ocean colours, which are indicative of specific fish species. The top-down view of remotely sensed data can be communicated to local fisherman, who can use this information to save time and fuel in real time. This information can be used in synergy with GNSS to improve the productivity of fishing activities. In fact, a recent GPS jamming incident off the South Korean coast saw more than 20 per cent of fishing vessels return to port. GNSS is also used to monitor compliance with fishery regulations and the effect of protection policies (such as fishery or navigation limitations) on the marine environment. Focusing on improved productivity, Copernicus' CMEMS collects data on different parameters so as to identify the most productive areas, allowing for more effective catches. As regards detection of illegal fishing, Copernicus services can be used to detect, with a higher level of accuracy, illegal fishing activities through synthetic aperture radar imagery. These data can be correlated with a GNSS-enabled Vessel Monitoring System (VMS), providing data to the fishing authorities on the location, speed and course of fishing vessels operating in Europe, allowing authorities to detect and track movement and activity in restricted fishing grounds. Within VMS, the authentication feature of Galileo is expected to contribute by certifying the communicated vessel position, ensuring more reliable services and therefore more safety and better enforcement capabilities.

The contribution of EGNSS and Copernicus to SDG 14 is mainly to the following targets:

- 14.1 By 2025, prevent and significantly reduce marine pollution of all kinds, in particular from land-based activities, including marine debris and nutrient pollution
- 14.2 By 2020, sustainably manage and protect marine and coastal ecosystems to avoid significant adverse impacts, including by strengthening their resilience, and take action for their restoration in order to achieve healthy and productive oceans
- 14.3 Minimize and address the impacts of ocean acidification, including through enhanced scientific cooperation at all levels
- 14.4 By 2020, effectively regulate harvesting and end overfishing, illegal, unreported and unregulated fishing and destructive fishing practices and implement science-based management plans, in order to restore fish stocks in the shortest time feasible, at least to levels that can produce maximum sustainable yield as determined by their biological characteristics
- 14.5 By 2020, conserve at least 10 per cent of coastal and marine areas, consistent with national and international law and based on the best available scientific information

14.7 By 2030, increase the economic benefits to small island developing States and least developed countries from the sustainable use of marine resources, including through sustainable management of fisheries, aquaculture and tourism

14.c Enhance the conservation and sustainable use of oceans and their resources by implementing international law as reflected in the United Nations Convention on the Law of the Sea, which provides the legal framework for the conservation and sustainable use of oceans and their resources, as recalled in paragraph 158 of "The future we want"

The degree of contribution is specified in table 13.

Table 13. Qualitative assessment of European Union space programmes' contribution to SDG 14 targets

14 LIFE BELOW WATER

Targets	EGNSS	Copernicus	Synergies
14.1	◐●	●●	●●
14.2	●●	●●	●●
14.3	◐◐	◐◐	◐◐
14.4	●●	●●	●●
14.5	●●	●●	●●
14.7	◐◐	◐●	◐●
14.c	◐◐	●●	◐●

Level of contribution in monitoring/achieving part of a target/indicator

◐◐ Limited contribution ●● Significant contribution

CASE STUDIES

Case study 28. Fishery and living marine resource protection

Globally, illegal and unreported fishing accounts each year for up to 26 million tons of fish, worth up to €21 billion. This equates to more than 800 kg of wild-caught fish stolen from the seas every second.

The Pew Charitable Trusts, in partnership with the United Kingdom Satellite Applications Catapult, launched the project "Eyes on the Seas" in an attempt to reduce illegal or "pirate" fishing. The project combines EO satellite monitoring of the oceans with information from fishing-vessel databases and oceanographic data, providing detailed data reports that can alert officials to suspicious vessel movements in a very efficient way.

For more information: http://www.pewtrusts.org/en/about/news-room/press-releases/2015/01/21/pew-unveils-pioneering-technology-to-help-end-illegal-fishing

Case study 29. OceanPal

Oceanpal® is a low-cost and innovative instrument using GNSS signals. The instrument is tuned to use signals from the GPS, GALILEO, Beidou, IRNSS and GLONASS constellations. Using direct GNSS signals and their terrestrial reflection Oceanpal can measure water properties (level, wind and waves) and land parameters (soil moisture, vegetation or biomass) for a variety of applications.

The MISTRALE project, for monitoring soil moisture for agricultural applications, is building on this instrument.

For more information: http://spacetech.starlab.es/oceanpal/

Goal 15 – Life on Land

Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss

Preserving diverse forms of life on land requires targeted efforts to protect, restore and promote the conservation and sustainable use of terrestrial and other ecosystems. Goal 15 focuses specifically on managing forests sustainably, restoring degraded lands and successfully combating desertification, reducing degraded natural habitats and ending biodiversity loss.

The focus in Goal 15 on halting biodiversity loss comes at a critical time, since many species of amphibians, birds and mammals are sliding towards extinction. According to the International Union for Conservation of Nature's Red List Index, amphibians are declining most rapidly in Latin America and the Caribbean, primarily as a result of the chytrid fungus, one of numerous wildlife diseases on the rise worldwide. The greatest extinction risks for birds and mammals are found in South-Eastern Asia, mainly owing to the conversion of lowland forests. However, their decline is not inevitable, with extinction risks for vertebrate species having been reversed in five small island developing States (the Cook Islands, Fiji, Mauritius, Seychelles and Tonga) as a result of conservation actions over the past several decades.

Thirteen million hectares of forests are being lost every year, while the persistent degradation of drylands has led to the desertification of 3.6 billion hectares. Deforestation and desertification—caused by human activities and climate change—pose major challenges to sustainable development and have affected the lives and livelihoods of millions of people in the fight against poverty.

EGNSS and Copernicus supporting Sustainable Development Goal 15

Similarly to Goal 14, the monitoring of vast areas can only be accomplished in a reliable manner using satellite images. The *Copernicus Land Monitoring Service* is divided into four components: global, pan-European, local and reference data. Reference data is all the in situ information needed to ensure an efficient and effective use of space-borne data, allowing calibration and validation, and complementing the information that satellites can offer.

QUICK FACTS

- Around 1.6 billion people depend on forests for their livelihood. This includes some 70 million indigenous people.
- 2.6 billion people depend directly on agriculture, but 52 per cent of the land used for agriculture is moderately or severely affected by soil degradation.
- As of 2008, land degradation affected 1.5 billion people globally.
- Of the 8,300 animal species known, 8 per cent are extinct and 22 per cent are at risk of extinction.
- Of the over 80,000 tree species, less than 1 per cent have been studied for potential use.

The *Global Land Service* (GLS) provides a series of biogeophysical products on the status and evolution of the land surface on a global scale. It also provides, in a timely manner, a set of biophysical variables describing the state, the dynamism and the disturbances of terrestrial vegetation at mid and low spatial resolution. These products are used to monitor vegetation, the water cycle and energy budget. The GLS has been able to provide measurements on the fires in Australia in early January 2015, where 125 km2 were burned. The service is a success and makes a significant contribution to SDG 15. To give an idea of the level of its success, there are more than 1,600 users registered and 18.8 terabytes of data were downloaded in the first quarter of 2017 alone.

GLS provides physical variables of the canopy like the leaf area index, the fraction of vegetation cover, and the fraction of radiation absorbed for photosynthesis, to respectively quantify the density, the extent and the health of the vegetation. In addition, the dry matter productivity features the growth of standing biomass for specific agronomic applications. Finally, maps of burned areas delineate the zones of the globe affected by fire events. These biophysical products are useful for a wide range of thematic areas such as global crop monitoring and food security applications; forest, water, and natural resources management; land carbon modelling; and weather and climate forecasting.

GNSS is widely adopted for animal tracking. Understanding animal movement is vital for biodiversity research, predicting conservation hotspots, identifying human-animal conflict zones, rebuilding and sustaining productive fisheries and ecosystems and understanding the spread of pandemic disease and invasive species. As mentioned in SDG 12, GNSS is also an important component of GIS, a powerful tool for sustainable management of natural resources such as forests, parks and water reservoirs.

The targets where space can better contribute within SDG 15 are:

15.1 By 2020, ensure the conservation, restoration and sustainable use of terrestrial and inland freshwater ecosystems and their services, in particular forests, wetlands, mountains and drylands, in line with obligations under international agreements

15.2 By 2020, promote the implementation of sustainable management of all types of forests, halt deforestation, restore degraded forests and substantially increase afforestation and reforestation globally

15.3 By 2030, combat desertification, restore degraded land and soil, including land affected by desertification, drought and floods, and strive to achieve a land degradation-neutral world

15.5 Take urgent and significant action to reduce the degradation of natural habitats, halt the loss of biodiversity and, by 2020, protect and prevent the extinction of threatened species

15.7 Take urgent action to end poaching and trafficking of protected species of flora and fauna and address both demand and supply of illegal wildlife products

The degree of contribution is specified in table 14.

Table 14. Qualitative assessment of European Union space programmes' contribution to SDG 15 targets

15 LIFE ON LAND

Targets	EGNSS	Copernicus	Synergies
15.1	●●	●●	●●
15.2	●●	●●	●●
15.3	●●	●●	●●
15.5	●●	●●	●●
15.7	●●	●●	●●

Level of contribution in monitoring/achieving part of a target/indicator

◐◑ Limited contribution ●● Significant contribution

CASE STUDIES

Case study 30. EGNOS-enhanced tracking of animal movement and behaviour

A clear understanding of animals' movements provides essential insights to understand the functioning of an ecosystem. Ecologists are increasingly interested in monitoring wild animal behaviour in order to protect threatened species and prevent unwanted "interactions" such as traffic accidents, crop damage and/or the spreading of contagious diseases.

E-Track is a European Union-funded project developing a system for the measurement and analysis of movement, behaviour and interactions of wildlife. The project takes advantage of the latest developments in the miniaturization of GNSS receivers, in energy management and power supply, in data logging and transmission and in data analysis techniques. E-TRACK also employs EGNOS corrections to get reliable high-resolution location data on individual animals.

For more information: http://etrack-project.eu/

Case study 31 EGNSS and Copernicus for forest management

Monitoring of forest-covered areas is essential in order to track changes in the surface covered and its health status, as well as for environmental protection.

The GSA-funded H2020 project combines data related to biomass, from EO data (for example satellite imagery), regional data (for example airborne imagery and GNSS-based remote sensing data) and, when available, local data (in situ measurements) to improve current biomass estimation algorithms.

Galileo is a key enabler of the proposed concept, providing accurate positioning and supporting image georeferencing and remote sensing.

For more information: https://www.gsa.europa.eu/combined-positioning-reflectometry-galileo-code-receiver-forest-management; http://www.coregalproject.com/

17 PARTNERSHIPS FOR THE GOALS

Goal 17 – Partnership for the Goals

Strengthen the means of implementation and revitalize the Global Partnership for Sustainable Development

A successful sustainable development agenda requires partnerships between governments, the private sector and civil society. These inclusive partnerships, built upon principles and values, a shared vision, and shared goals that place people and the planet at the centre, are needed at the global, regional, national and local levels.

Urgent action is needed to mobilize, redirect and unlock the transformative power of trillions of dollars of private resources to deliver on sustainable development objectives. Long-term investments, including foreign direct investment, are needed in critical sectors, especially in developing countries. These include sustainable energy, infrastructure and transport, as well as information and communications technologies. The public sector will need to set a clear direction. Review and monitoring frameworks, regulations and incentive structures that enable such investments must be retooled to attract investments and reinforce sustainable development. National oversight mechanisms such as supreme audit institutions and oversight functions by legislatures should be strengthened.

QUICK FACTS

- Official development assistance stood at $135.2 billion in 2014, the highest level ever recorded.
- 79 per cent of imports from developing countries enter developed countries duty-free.
- The number of Internet users in Africa almost doubled in the past four years.
- 30 per cent of the world's youth are digital natives, active online for at least five years.
- But 4 billion people do not use the Internet, and 90 per cent of them are from the developing world.

EGNSS and Copernicus supporting Sustainable Development Goal 17

As satellite navigation systems expand globally, there is an increasing need for all systems to remain fully compatible and interoperable, and for this, international cooperation is crucial. EGNSS and

Copernicus are very powerful tools to support cooperation between the European Union and other regions. In particular, through the H2020 programme, scientific and technological cooperation is set up to strengthen R&D and encourage innovation with non-European Union countries. Moreover, the extension of EGNOS in the Middle East and Africa supports the development of applications in these regions. In this respect a Joint Programme Office in Dakar, staffed with African GNSS experts and engineers, is promoted by the European Commission in cooperation with the African Union, with the objective of leveraging EGNSS technologies across the continent.

Similarly, the European Union and Africa have engaged in a long-standing partnership (GMES and Africa) to foster the development of EO applications tailored to African needs, and to strengthen the capacity of African public and private institutions to use EO data and information for sustainable development purposes. GMES and Africa relies in particular on the expertise, technology, data and information offered by the Copernicus programme. Additionally, the GSA signed an MoU with UNOOSA establishing a partnership to cooperate on themes linked to satellite navigation, including pilot projects and educational activities. Examples of such activities are listed in the case study section.

The targets where EGNSS and Copernicus can better contribute within SDG 17 are:

17.6 Enhance North-South, South-South and triangular regional and international cooperation on and access to science, technology and innovation and enhance knowledge sharing on mutually agreed terms, including through improved coordination among existing mechanisms, in particular at the United Nations level, and through a global technology facilitation mechanism

17.7 Promote the development, transfer, dissemination and diffusion of environmentally sound technologies to developing countries on favourable terms, including on concessional and preferential terms, as mutually agreed

17.8 Fully operationalize the technology bank and science, technology and innovation capacity-building mechanism for least developed countries by 2017 and enhance the use of enabling technology, in particular information and communications technology

17.9 Enhance international support for implementing effective and targeted capacity-building in developing countries to support national plans to implement all the Sustainable Development Goals, including through North-South, South-South and triangular cooperation

17.18 By 2020, enhance capacity-building support to developing countries, including for least developed countries and small island developing States, to increase significantly the availability of high-quality, timely and reliable data disaggregated by income, gender, age, race, ethnicity, migratory status, disability, geographic location and other characteristics relevant in national contexts

The degree of contribution is specified in table 15.

Table 15. Qualitative assessment of European Union space programmes' contribution to SDG 17 targets

17 PARTNERSHIPS FOR THE GOALS

Targets	EGNSS	Copernicus	Synergies
17.6	◑●	●●	◑●
17.7	●●	●●	●●
17.8	●●	◑◑	◑●
17.9	●◑	●◑	●◑
17.18	●◑	●◑	◑◑

Level of contribution in monitoring/achieving part of a target/indicator

◑◑ Limited contribution ●● Significant contribution

CASE STUDY

Case study 32. European GNSS programmes rely on international cooperation

Regarding European GNSS, a number of initiatives have been put in place to facilitate international cooperation with other regions, including:

- The *H2020 GNSS.asia* project, dedicated to developing and implementing GNSS industrial cooperation between European and Asia-Pacific GNSS industries, with a focus on the downstream sector (applications and receivers).
- The *H2020 BELS* project, committed to bringing European GNSS companies to South-East Asia. The main objective of the project is to facilitate the breakthrough of EGNSS technology by conducting a set of coordinated activities for raising awareness and capacity-building.
- The *Euromed GNSS I and II* programmes tested real-life applications of EGNOS in civil aviation and multimodal transport, with a significant capacity-building effort for aviation and transport authorities across nine North African and Middle Eastern countries.
- The *H2020 MAGNIFIC* project is working to support awareness-raising and capacity-building in Africa on EGNSS applications and services. Specifically, the project helps European Union GNSS companies better anticipate African needs and, together with African partners, adapt solutions to these needs.
- Based in Brazil, the *Galileo Information Centre* is currently working to establish a network of associated centres across the region (including countries such as Argentina, Mexico and Chile) with the objective of disseminating information about EGNOS and Galileo.

Limited Contribution Tier

The remaining SDGs, characterized by a lower contribution of space technologies—and in particular EGNSS and Copernicus—to their fulfilment, are presented below with the corresponding level of contribution and relevant applications. The full description of how EGNSS and Copernicus contribute to each SDG in this tier as well as the relevant EGNSS and Copernicus cases studies are presented in annex.

Table 16. Limited Contribution Tier, high-level assessment of contribution of European Union space programmes

Global Goals for Sustainable Development	EGNSS	Copernicus	Synergies	Examples of applications
4 QUALITY EDUCATION	Monitoring: limited / Achieving: limited	Monitoring: limited / Achieving: limited	Monitoring: limited / Achieving: limited	Capacity-building initiatives
5 GENDER EQUALITY	Monitoring: significant / Achieving: significant	Monitoring: limited / Achieving: limited	Monitoring: limited / Achieving: limited	Prevention of human trafficking Sex offender tracking
10 REDUCED INEQUALITIES	Monitoring: limited / Achieving: limited	Monitoring: limited / Achieving: limited	Monitoring: limited / Achieving: limited	Enabling shared economy transactions Prevention of human trafficking
16 PEACE, JUSTICE AND STRONG INSTITUTIONS	Monitoring: significant / Achieving: limited	Monitoring: limited / Achieving: limited	Monitoring: limited / Achieving: limited	Surveillance Sex offender tracking Theft prevention

Level of contribution in monitoring/achieving part of a target/indicator

Limited contribution — Significant contribution

Annexes

Annex 1—Limited Contribution Tier SDGs

Goal 4 – Quality Education

Ensure inclusive and equitable quality education and promote lifelong learning opportunities for all

Despite progress, the world failed to meet the Millennium Development Goal of achieving universal primary education by 2015. In 2013, the latest year for which data are available, 59 million children of primary-school age were out of school. Estimates show that, among those 59 million children, 1 in 5 had dropped out and recent trends suggest that 2 in 5 out-of-school children will never set foot in a classroom. The SDGs clearly recognize that this gap must be closed, even as the international community more explicitly addresses the challenges of quality and equity in education.

At the end of primary school, children should be able to read and write and to understand and use basic concepts in mathematics. It is therefore very important to measure learning achievement, starting in the early grades, as it will help to identify where schools are failing to meet their commitments to children and to formulate appropriate remedial action. Acting at early stages in the educational process, by providing quality early education, gives children basic cognitive and language skills and fosters their emotional development.

QUICK FACTS

- In 2013, 59 million children of primary-school age were out of school.
- Worldwide, in 2013, two thirds of the 757 million adults (aged 15 and over) who were unable to read and write were women.
- Children from the poorest 20 per cent of households are nearly four times more likely to be out of school than their richest peers.
- To fulfil the promise of universal primary and secondary education, new primary school teachers are needed, with current estimates showing a need for nearly 26 million of them by 2030.

This Goal specifies that all girls and boys complete free primary and secondary schooling by 2030. It also aims to provide equal access to affordable vocational training, to eliminate gender and wealth disparities and achieve universal access to a quality higher education.

EGNSS and Copernicus supporting Sustainable Development Goal 4

The European GNSS Agency (GSA), signed an MoU with UNOOSA, to collaborate on educational events that could help build capacity in developing countries. In addition, other capacity-building initiatives are also in place or have been promoted in the past, including: the e-Knot project (to strengthen the interaction between education-research-industry in Europe), the BELS project (facilitating the breakthrough of EGNSS technology in South-East Asian industry), the SATSA project (offering training to the South African authorities on satellite navigation and augmentation systems) and the Space Expo exhibition (introducing space technology to the general public).

Among others, the following targets of SDG 4 are supported by EGNSS and Copernicus:

4.a Build and upgrade education facilities that are child, disability and gender sensitive and provide safe, non-violent, inclusive and effective learning environments for all

The degree of contribution is specified in table 17.

Table 17. Qualitative assessment of European Union space programmes' contribution to SDG 4 targets

4 QUALITY EDUCATION

Targets	EGNSS	Copernicus	Synergies
4.a	◑◑	◑◑	◑◑

Level of contribution in monitoring/achieving part of a target/indicator

◑◑ Limited contribution ●● Significant contribution

CASE STUDY

Case study 33. A GNSS-based platform helps assess education facilities in Nigeria

Facility assessments or surveys can provide governments with valuable information to improve service delivery or to better plan future infrastructure investments. Supporting this task, Information and Communication Technologies (ICT) offer unprecedented opportunities for using new types of complementary metrics and data.

The Nigerian government developed a scheme to assign grants to local authorities with the objective of reducing poverty and improving education and public health. Supporting this programme, a rigorous, geo-referenced baseline facility inventory of health and education facilities as well as water access points was performed across Nigeria over a period of two months. This was possible thanks to the use of a dedicated GNSS-based smartphone application which enabled fast, flexible and reliable mobile data collection.

For more information: http://qsel.columbia.edu/assets/uploads/blog/2014/04/NMIS.pdf

Goal 5 – Gender Equality

Achieve gender equality and empower all women and girls

Gender equality and women's empowerment have advanced in recent decades. Girls' access to education has improved; the rate of child marriage has fallen and progress has been made in the area of sexual and reproductive health and reproductive rights, including fewer maternal deaths. Nevertheless, gender equality remains a persistent challenge for countries worldwide and the lack of this equality is a major obstacle to sustainable development.

Deep legal and legislative changes are needed to ensure women's rights around the world. While a record 143 countries guaranteed equality between men and women in their Constitutions by 2014, another 52 had not taken this step. In many nations, gender discrimination is still woven through legal and social norms and gender inequalities are still deep-rooted in every society. Women suffer from lack of access to decent work and face occupational segregation and gender wage gaps. In many situations, they are denied access to basic education and health care and are victims of violence and discrimination. They are under-represented in political and economic decision-making processes.

QUICK FACTS

- Surveys conducted between 2005 and 2015 in 52 countries (including only one country from developed regions) indicate that 21 per cent of girls and women aged between 15 and 49 had experienced physical and/or sexual violence at the hands of an intimate partner in the previous 12 months.
- In 2016, the number of women speakers of national parliaments jumped from 43 to 49 (out of the 273 posts globally); women accounted for 18 per cent of all parliamentary speakers in January 2016.
- As of 2014, 143 countries guaranteed equality between men and women in their constitutions; another 52 countries have yet to make this important commitment. In 132 countries, the statutory legal age of marriage is equal for women and men, while in another 63 countries, the legal age of marriage is lower for women than for men.

Meanwhile, violence against women is a pandemic affecting all countries, even those that have made laudable progress in other areas. Worldwide, 35 per cent of women have experienced either physical and/or intimate partner sexual violence or non-partner sexual violence.

EGNSS and Copernicus supporting Sustainable Development Goal 5

Space can help combat gender inequality, particularly when it comes to violence and human trafficking. The use of remote sensing makes it possible to monitor borders or ocean routes used for human trafficking and smuggling, covering several thousand kilometres a day, and monitoring areas of 160,000 km2 with a single image, such as the Copernicus Sentinel-1 satellite, able to capture images of 400 km by 400 km, during day or night, regardless of cloud coverage.

Ankle monitors or emergency alert systems with GNSS receptors are a perfect example of what space can offer to avoid domestic violence offences or to track rapists, delivering alerts to the relevant authorities when the person wearing the device moves inside a geo-fenced area.

Moreover, gender equality is also considered at programme level. European institutions involved in the space industry, such as ESA, GSA, CNES, promote the role of women in the space sector through initiatives such as *"Space girls, space women"*, which promote the role of women in the space environment.

The contribution of EGNSS and Copernicus to this SDG is mainly to the following target:

5.2 Eliminate all forms of violence against all women and girls in the public and private spheres, including trafficking and sexual and other types of exploitation

The degree of contribution is specified in table 18.

Table 18. Qualitative assessment of European Union space programmes' contribution to SDG 5 targets

5 GENDER EQUALITY

Targets	EGNSS	Copernicus	Synergies
5.2	●●	◑◑	◑◑

Level of contribution in monitoring/achieving part of a target/indicator

◑◑ Limited contribution ●● Significant contribution

CASE STUDY

Case study 34. GNSS technology underpins emergency wearables for women

Global estimates published by the WHO indicate that 35 per cent of women worldwide have experienced either physical and/or sexual intimate partner violence or sexual violence by a non-partner at some point in their lives. GNSS-based wearable technology can offer peace of mind for recurrent victims.

A new generation of devices is being manufactured and sold as accessories, providing wearers with hidden emergency alert systems. The company Nimb produces a ring embedded with a bluetooth transmitter that can be paired with GNSS-enabled smartphones. When threatened, the user can send her location by pressing and holding a small button on the back of the ring. This will trigger a smartphone application to send an alarm message with basic information, a photo, and a map with the location, so she can receive assistance from other nearby users and/or from pre-set contacts.

For more information: https://nimb.com/

Goal 10 – Reduced Inequalities

Reduce inequality within and among countries

Goal 10 calls for reducing inequalities in income as well as those based on age, sex, disability, race, ethnicity, origin, religion or economic or other status within a country. The Goal also addresses inequalities among countries, including those related to representation, migration and development assistance.

The international community has made significant strides towards lifting people out of poverty. The most vulnerable nations—the least developed countries, the landlocked developing countries and the small island developing States—continue to make inroads into poverty reduction. However, inequality still persists and large disparities remain in access to health and education services and other assets. Additionally, while income inequality between countries may have been reduced, inequality within countries has risen. There is a growing consensus that economic growth is not sufficient to reduce poverty if it is not inclusive and if it does not involve the three dimensions of sustainable development: economic, social and environmental. To reduce inequality, policies should be universal in principle, paying attention to the needs of disadvantaged and marginalized populations.

QUICK FACTS

- On average—and taking into account population size—income inequality increased by 11 per cent in developing countries between 1990 and 2010.
- A significant majority of households in developing countries—more than 75 per cent of the population—are currently living in societies where income is more unequally distributed than it was in the 1990s.
- In 2014, total resource flows for development to the least developed countries totalled $55.2 billion.
- Evidence from developing countries shows that children in the poorest 20 per cent of the population are still up to three times more likely to die before their fifth birthday than children in the richest quintiles.

EGNSS and Copernicus supporting Sustainable Development Goal 10

The contribution to this Goal comes mainly from policies resulting in less inequality, such as the sharing economy, which refers to peer-to-peer sharing of access to goods and services. Consumers from lower income groups are beneficiaries of the peer-to-peer rental market generated through the sharing economy. In this scenario, GNSS location allows people to quickly make and respond to requests for goods and services (for example the Uber taxi service).

This Goal also calls for safe and responsible migration and mobility of people, which is where EGNSS and Copernicus can contribute to ensuring that migration is handled using the best available data, enabling stakeholders to take informed decisions.

The use of Copernicus, with its border and maritime surveillance service, and EGNSS can help monitor the flow of migrants who want to enter the European Union, helping also to reduce the death toll, and facilitating rescue activities at sea. The use of space data also helps to increase the internal security of the European Union as a whole by contributing to the prevention of cross-border crime and human trafficking, as well as managing piracy threats at the global level. The Copernicus mapping system makes it possible to survey and track marine borders in order to detect any accident or dangerous circumstance. In the surveillance of non-collaborative vessels, the EGNSS supports authorities' interventions, helping them to navigate towards their targets and find them.

The main target under SDG 10 to which Copernicus and EGNSS contribute is:

10.7 Facilitate orderly, safe, regular and responsible migration and mobility of people, including through the implementation of planned and well-managed migration policies

The degree of contribution is specified in table 19.

Table 19. Qualitative assessment of European Union space programmes' contribution to SDG 10 targets

10 REDUCED INEQUALITIES

Targets	EGNSS	Copernicus	Synergies
10.7	◐◐ (Limited contribution)	◐◐ (Limited contribution)	◐◐ (Limited contribution)

Level of contribution in monitoring/achieving part of a target/indicator

◐◐ Limited contribution ●● Significant contribution

CASE STUDIES

Case study 35. SCOMAR: An integrated border surveillance system using GNSS in complementarity with other technologies

The illegal traffic of goods and humans at sea creates challenges for law enforcement and border protection, and risks human lives.

SCOMAR is an operative surveillance system based on state-of-the-art technologies that ensure early detection, tracing, recognition and identification of ships involved in illegal traffic activities on the Black Sea. It uses GNSS for positioning/location/navigation of the patrol vessels as well as for timing for the network of SCOMAR sensor stations.

The Galileo PRS service could further reduce vulnerabilities in the system.

For more information: https://www.politiadefrontiera.ro/en/main/pg-scomar-106.html

Case study 36. Awareness in Africa: Disseminating knowledge on EGNOS and Galileo in Africa to foster local development

Capacity- and knowledge-building, with a special focus on technology and innovation, represents a sustainable way to reduce inequalities.

This GSA FP7 project targeted the creation of a practical link between the European Union and Africa regarding the GNSS and its applications. The main goals were to:

- promote and popularize scientific and technological aspects of GNSS with universities and research institutions
- find immediate applications for the GNSS (EGNOS and Galileo) within the context of development in Africa
- promote the use of GNSS technology among African SMEs/SMIs, chambers of commerce, and researchers
- educate African universities and institutions so they can conduct training in GNSS technology
- establish common interests between actors in the North and South for the development of a GNSS services market in sub-Saharan Africa.

For more information: https://www.gsa.europa.eu/awareness-africa-disseminating-knowledge-egnos-and-galileo-africa-foster-local-development, http://www.gnss4africa.eu

16 PEACE, JUSTICE AND STRONG INSTITUTIONS

Goal 16 – Peace, Justice and Strong Institutions

Promote peaceful and inclusive societies for sustainable development, provide access to justice for all and build effective, accountable and inclusive institutions at all levels

Peace, justice and effective, accountable and inclusive institutions are at the core of sustainable development. Several regions have enjoyed increased and sustained levels of peace and security in recent decades. But many countries still face protracted armed conflict and violence, and far too many people struggle as a result of weak institutions and the lack of access to justice, information and other fundamental freedoms.

Efforts are under way to make national and international institutions more effective, inclusive and transparent. Over the past 10 years, nearly two thirds of 144 countries with available data were able to plan their national budgets effectively (where final expenses remained within 10 per cent of original budgets). Voting rights assigned to various groups of countries in international institutions is one indication of inclusivity at the international level. For example, while developing countries account for 63 per cent of voting rights in the African Development Bank, this figure is only 35 per cent in the International Monetary Fund and 38 per cent in the International Bank for Reconstruction and Development of the World Bank Group.

EGNSS and Copernicus supporting Sustainable Development Goal 16

The Copernicus Security Service aims to support European Union policies by providing information to underpin the response to Europe's security challenges. It improves crisis prevention, preparedness and response in the areas of border and maritime surveillance and support to European Union External Action.

QUICK FACTS

- Globally, the share of girls and boys among victims of human trafficking (21 per cent and 13 per cent respectively) peaked in 2011. By 2014, the levels were twice those recorded for 2004.
- Corruption, bribery, theft and tax evasion cost developing countries some $1.26 trillion per year; this amount of money could be used to lift those who are living on less than $1.25 a day to above this level for at least six years.
- The rule of law and development are significantly interrelated and are mutually reinforcing, making the rule of law essential for sustainable development at the national and international level.

In the area of border surveillance, the main objectives are to reduce the number of illegal immigrants entering the European Union undetected, to reduce the death toll of illegal immigrants by rescuing more lives at sea, and to increase the internal security of the European Union as a whole by contributing to the prevention of cross-border crime and reducing violence at the borders of the European Union.

As regards maritime surveillance, the overall objective of the European Union is to support Europe's maritime security objectives and related activities in the maritime domain. The corresponding challenges mainly relate to safety of navigation, support to fisheries control, combating marine pollution and—of particular interest for this Goal—law enforcement, ensuring that infractions are detected and the prosecution process receives the necessary support.

As a global actor, Europe has a responsibility to promote stable conditions for human and economic development, human rights, democracy and fundamental freedoms. In this context, a main objective of the European Union is to assist third countries in a situation of crisis or emerging crisis and to prevent global and trans-regional threats from having a destabilizing effect. In particular, the Support to External Action (SEA) component will assist the European Union in its operations outside European Union territory, providing decision-makers with geo-information on remote, difficult to access areas where security is at stake. It targets mainly European users but it can also be activated by key international stakeholders, under the appropriate European Union international cooperation agreements.

EGNSS is an important component, providing position, navigation and time information. Furthermore, the use of the Public Regulated Service, which is open to institutional users, is an important asset supporting European Union Member States' institutions. In fact GNSS, enabling RPAS navigation, can be used for law enforcement by police in surveillance and pursuit activities. Finally, GNSS tracking capabilities are used to reduce violence against women through the use of electronic tracking devices; to ensure the safety of children through the use of dedicated wearables; and to prevent theft by monitoring assets.

The targets to which EGNSS and Copernicus can best contribute within SDG 16 are:

16.1 Significantly reduce all forms of violence and related death rates everywhere

16.2 End abuse, exploitation, trafficking and all forms of violence against and torture of children

The degree of contribution is specified in table 20.

Table 20. Qualitative assessment of European Union space programmes' contribution to SDG 16 targets

16 PEACE, JUSTICE AND STRONG INSTITUTIONS

Targets	EGNSS	Copernicus	Synergies
16.1	● ◑	● ◑	● ◑
16.2	◑ ◑	◑ ◑	◑ ◑

Level of contribution in monitoring/achieving part of a target/indicator

◑ ◑ Limited contribution ● ● Significant contribution

CASE STUDIES

Case study 37. Electronic offender tracking and monitoring by Galileo/EGNOS and EO

After conviction and/or release from prison, offenders may be tracked in order to ensure that they stay away from their victims and/or to monitor their whereabouts.

The system provides a complete electronic monitoring solution comprising hardware (GNSS ankle monitor, home-station, mobile charger), as well as a monitoring platform, including a component that displays the location of the offender and various alarms on a map. The monitor includes state-of-the-art satellite-based augmentation systems (EGNOS) and GNSS (Galileo, GLONASS) to improve the localization capabilities of the device (availability, precision, and integrity/security). The monitoring platform uses enhanced cartography and imagery obtained though EO.

For more information: https://artes-apps.esa.int/projects/electronic-offender-monitoring

Case study 38. ULTRA: Galileo PRS receivers for governmental users, including armed forces

The Galileo Public Regulated Service (PRS) is a secure positioning, navigation and timing service. It is an encrypted service only available to government-approved users with high demand for continuous services (such as armed forces and law enforcement units). The major benefit of PRS is its robustness, which protects it against accidental or malicious interference (for example jamming or spoofing). The drawback of PRS is that it imposes stringent security constraints on receivers, which also result in higher costs.

The focus of the GSA-funded ULTRA project is to develop an ultra-low-cost PRS receiver capable of addressing low-end applications (which represent 80 per cent of the PRS market).

The ULTRA project is an accelerator to stimulate support for and uptake of PRS across a range of users and applications. This will be achieved by developing and integrating key technologies that result in a significant reduction in the cost of PRS receivers, making them affordable to a larger customer base with an interest in PRS for low-end applications, while maintaining security and performance.

For more information: https://www.gsa.europa.eu/ultra-low-cost-prs-receiver

Annex 2

Copernicus missions and data

Mission	Instrument/ Data type	Resolution/ Pixel size/ Positioning accuracy	Coverage/ Swath width	Revisiting time/ Latency	Services and main applications:
Sentinel-1: The SAR Imaging Constellation for Land and Ocean Services, providing continuous radar mapping with interferometry capability. S1A from 03/04/2014 S1B from 25/04/2016	C-band synthetic aperture radar at 5.405 GHz	Pixel size: from 5x5 m to 20x40 m, depending on radar operating mode; vertical resolution in interferometric mode: mm-level	Global Swath from 80 km up to 400 km wide, depending on radar operating mode	**Revisit**: 6 days @ equator with 2 SVs. (12 days for 1 SV, 2nd SV at 180°) **Latency**: <24 hours after observation; approx. 1 hour for NRT (near-real-time)	**Marine services**: Monitoring sea ice and Arctic environment, oil spills, marine winds, waves and currents. **Land services**: Land-use change, land deformation (monitoring land surface motion risks) Mapping of land surfaces: forest, water and soil, agriculture **Emergency services**: Mapping in support of humanitarian aid in crisis situations, such as floods and earthquakes **Security services:** Maritime and borders surveillance
Sentinel-2: The Optical Imaging Mission for Land Services, providing wide-swath, high-resolution, multispectral imaging. S2A from 23/06/2015 S2B from 07/03/2017	Multispectral imager (MSI) covering 13 spectral bands (443 nm–2190 nm)	10 m (4 visible and near-infrared bands), 20 m (6 red-edge / shortwave-infrared bands) 60 m (3 atmospheric and correction bands) Data geolocation <20 m without Ground Control Points	Land and coastal areas between 84°N and 56°S. Swath width of 290 km	**Revisit**: 5 days @ equator with 2 SVs. (10 days for 1 SV, 2nd SV at 180°) **Latency**: <3 hours after observation level 1c product, <6 hours to retrieve archive	**Land Services:** Generic land-cover, land-use and change detection maps (for example CORINE land-cover maps update, soil sealing maps, forest area maps). Monitoring agriculture, forests, land-use change, land-cover change; mapping biophysical variables such as leaf chlorophyll content, leaf water content, leaf area index; monitoring coastal and inland waters. **Emergency Services:** Risk mapping and disaster mapping **Security services:** Frequently updated background reference map

KEY

Current/ Imminent | Planned

Source: GSA analysis, 2017

Sentinel-3: Global Sea/Land Monitoring Mission including Altimetry; providing high-accuracy optical, radar and altimetry data for marine and land services S3A from 15/02/2016 S3B launch in 2018 S3C in 2020 TBC	Multiple instruments: optical, radar, altimetry **Topography:** Dual frequency SAR Radar Altimeter (SRAL) and Microwave Radiometer (MWR)) **Optical**: Ocean and Land Colour (OLCI) (spectrometer) and Sea and Land Surface Temperature Radiometer (SLSTR). **Orbitography:** DORIS + GNSS + LRR	Resolution (pixel size) 300 to 1200 m, depending on instrument. Accuracy 0.3°K Accuracy of altimetry products dependant on orbit accuracy: Real-time <3 m 3 hours <8 cm 3 days <3 cm 1 month <2 cm	Global OCLI Swath 1,270 km	**Revisit**: 27 days (1 SV, geometric) **Observation**: 1 to 4 days, depending on instrument (different swath): SLSTR ~1 day, OLCI ~2 days, Altimetry (SRAL) ~27 days All cases using two-satellite constellation at the equator	**Marine Services:** Topography observations: altimeter height measurements primarily over oceans and inland water, sea-ice thickness. Optical observations: temperature and colour measurements over land and ocean. These measurements will be used, for example, to monitor changes in sea level, marine pollution and biological productivity. **Land Services:** Monitoring vegetation and agriculture at worldwide level. Water quality and water level of main rivers and lakes are also measured and followed. **Atmosphere Services:** Aerosol particulate matter and fire monitoring **Emergency Services:** Wildfires monitoring
Sentinel-4: Atmospheric composition monitoring mission - GEO Component; monitoring key air quality trace gases and aerosols over Europe at high spatial and temporal resolution ***Payload*** on EUMETSAT's Meteosat Third Generation (MTG) MTG-S1 planned in 2021 MTG-S2 in 2027 TBC	AUVN (ultraviolet-visible-near-infrared) spectrometer on MTG (MeteoSat Third Generation)* + data from EUMETSAT's Infrared Sounder (IRS), the Visible Infrared Imager (VII) and the Multi-viewing Multichannel Multi-polarization Imager (3MI)	8.9 km N/S, 11.7 km E/W at 45° N	Europe + part of Atlantic + part of Sahara, FOV = 4° N/S, 11°-14° E/W	**Revisit**: NA (GEO) **Observation**: 1 hour (scans Europe in the east-west direction with a repeat cycle of 60 minutes.)	**Atmosphere Services:** Continuous monitoring from a geostationary orbit of the atmospheric chemistry in order to support air quality, stratospheric ozone and solar radiation monitoring and forecast over the skies of Europe The main data products will be O_3 (Ozone), NO_2 (Nitrogen dioxide), SO_2 (Sulphur dioxide), HCHO (Formaldehyde) and aerosol optical depth. **Climate Services:** Climate monitoring, composition-climate interaction

Copernicus missions and data (*continued*)

Mission	Instrument/ Data type	Resolution/ Pixel size/ Positioning accuracy	Coverage/ Swath width	Revisiting time/ Latency	Services and main applications:
Sentinel-5: Atmospheric composition monitoring mission - LEO Component; monitoring trace gas concentrations for atmospheric chemistry and climate applications ***Payload*** on EUMETSAT's MetOp-SG (second generation) satellites MetOp-SG A: 2021 MetOp-SG B: 2022	Single instrument named UVNS: (ultra-violet / visible / near-infrared / SWIR) Spectrometer on MetOp-SG + data from EUMETSAT's IRS, the Visible Infrared Imager (VII) and the Multi-viewing Multi-channel Multi-polarization Imager (3MI).	50 x 50 km² (UV1), 7.5 x 7.5 km² (all other channels)	Global Swath width: 2,670 km	**Revisit**: 29 days **Observation**: 1 day	**Atmosphere Services:** Continuous monitoring of the atmospheric chemistry at high temporal and spatial resolution from a low-Earth orbit, supporting air quality, stratospheric ozone and solar radiation monitoring. The main data products include vertical column amounts of ozone O_3 (stratospheric and tropospheric), nitrogen dioxide NO_2, sulphur dioxide SO_2, carbon monoxide CO, methane CH_4, formaldehyde CH_2O, and aerosol optical depth. **Climate Services:** Climate monitoring, composition-climate interaction
Sentinel-5P: (Precursor-Atmospheric Monitoring Mission); providing data delivery (maintaining the continuity of science data) for atmospheric services between 2015 (EOL for ESA's Envisat and NASA's Aura missions) and 2020 (Sentinel 4-5). S5-P: September 2017	TROPOMI (Tropospheric Monitoring Instrument), a UV-VIS-NIR-SWIR sun back-scatter hyper-spectral imaging spectrometer. +data from VIIRS (Visible/ Infrared Imager and Radiometer Suite), embarked on the Suomi NPP satellite of NASA/NOAA	From 7 x 1.8 km² (NIR2) to 21 x 28 km² (UV1). All other bands: 7 x 7 km²	Global Swath width: 2,600 km	**Revisit**: 17 days (227 orbits). **Observation**: 1 day	**Atmosphere Services:** Monitoring changes in the atmospheric composition (for example ozone (O_3), nitrogen dioxide (NO_2), sulphur dioxide (SO_2), carbon monoxide (CO), methane (CH_4), formaldehyde (CH_2O)), and the properties of aerosols and clouds at sufficiently high spatio-temporal resolution to quantify anthropogenic and natural emissions Monitoring troposphere variability **Climate Services:** Monitoring of aerosol particles, which impact on air quality and climate forcing from the regional to the global scale

Sentinel-6/Jason-CS (Jason Continuity of Service): High-precision altimetry mission providing sea-surface topography Jason-CS A and B are planned for 2020 and 2026	**Topography:** Radar altimeter dual band (Poseidon-4) with Low-Res (Pulse) and Hi-Res (SAR) capability; and Microwave radiometer (AMR-C) **Orbitography:** DORIS + GNSS + LRA (Laser Retroreflector Array) **GNSS Radio Occultation** instrument as a secondary payload	Pixel approx. 7 x 7 km² Precision on sea-surface altitude approx. 3 cm	Global Because of the 315 km spacing at the equator, Jason-CS cannot satisfy the sampling requirements for mesoscale oceanography. Thus, the Sentinel-6 mission is coordinated with other altimeter missions, chiefly the Sentinel-3 mission.	**Revisit**: 9 days and 22 hours **Latency:** **Near-Real-Time (NRT)**: Altimetry and Radio Occultation: <3 hours after sensing. **Short-Time-Critical** (STC): Altimetry <36 hours after sensing, Radio Occultation NA **Non-Time-Critical** (NTC): Altimetry and Radio Occultation: <60 days after sensing	**Marine Services:** Operational oceanography and seasonal forecasts in Europe and beyond. It will provide measurements of sea-surface height, significant wave height, and wind speed. Marine meteorology and sea-level-rise monitoring. **Climate Services:** Sea-level-rise monitoring GNSS RO information on atmospheric pressure, temperature and water vapour and ionospheric data

Sentinel-6/Jason-CS (Jason Continuity of Service): High-precision altimetry mission providing sea-surface topography Jason-CS A and B are planned for 2020 and 2026	**Topography:** Radar altimeter dual band (Poseidon-4) with Low-Res (Pulse) and Hi-Res (SAR) capability; and Microwave radiometer (AMR-C) **Orbitography:** DORIS + GNSS + LRA (Laser Retroreflector Array) **GNSS Radio Occultation** instrument as a secondary payload	Pixel approx. 7 x 7 km^2 Precision on sea-surface altitude approx. 3 cm	Global Because of the 315 km spacing at the equator, Jason-CS cannot satisfy the sampling requirements for mesoscale oceanography. Thus, the Sentinel-6 mission is coordinated with other altimeter missions, chiefly the Sentinel-3 mission.	**Revisit**: 9 days and 22 hours **Latency:** **Near-Real-Time (NRT)**: Altimetry and Radio Occultation: <3 hours after sensing. **Short-Time-Critical** (STC): Altimetry <36 hours after sensing, Radio Occultation NA **Non-Time-Critical** (NTC): Altimetry and Radio Occultation: <60 days after sensing	**Marine Services:** Operational oceanography and seasonal forecasts in Europe and beyond. It will provide measurements of sea-surface height, significant wave height, and wind speed. Marine meteorology and sea-level-rise monitoring. **Climate Services:** Sea-level-rise monitoring GNSS RO information on atmospheric pressure, temperature and water vapour and ionospheric data

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The United Nations Office for Outer Space Affairs (UNOOSA) works to bring the benefits of space to all humankind by being a capacity-builder, a global facilitator, and the gateway to space in the United Nations. The Office is responsible for implementing the United Nations programme on the peaceful uses of outer space, and helps United Nations Member States, particularly developing countries, to use space science, technology and applications for sustainable development, as well as disaster recovery and risk reduction.

European Global Navigation Satellite Systems Agency

The European GNSS Agency (GSA), headquartered in Prague, manages the operations, security and commercialization of European GNSS Systems EGNOS and Galileo. In order to design and provide location and timing services that best respond to user needs, the GSA is engaging with a broad range of stakeholders, industries and user communities, and constantly monitoring the global GNSS market and technology trends with its two flagship publications: GNSS Market Report and GNSS Technology Report. For more information please visit www.gsa.europa.eu.

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