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EUSPA EO and GNSS Market Report

EDITOR'S SPECIAL

Innovative Solutions for Health

European Union Agency for the Space Programme

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EUSPA EO and GNSS

Market Report

EUSPA
European Union Agency for the Space Programme

Environmental sustainability and economic viability drive the adoption of digital solutions in agriculture

GALILEO AND EGNOS

The European Global Navigation Satellite System (GNSS) allows users with compatible devices to determine their position, velocity and time by processing signals from satellites. It consists of two elements: Galileo; and the European Geostationary Navigation Overlay Service (EGNOS).

Galileo is the first global satellite navigation and positioning system designed specifically for civilian purposes, which can be used by a variety of public and private actors worldwide. It provides Europe with independence from the other GNSSs but remains interoperable with them, in order to facilitate GNSS combined use and offer better performance.

EGNOS is Europe's regional Satellite-Based Augmentation System (SBAS). It improves the quality of open signals from the US Global Positioning System (GPS) and (soon) Galileo.

GOVSATCOM[1]

The objective of the EU **GOVernmental SATellite COMmunication** (GOVSATCOM) initiative is to ensure the availability of reliable, secure and cost-effective satellite communication services for EU and national public authorities managing emergency and security-critical missions, operations and infrastructures.

GOVSATCOM aims to avoid duplication of efforts between European Union Member states and overcome the existing fragmentation of the secure SatCom market, targeting both civil and defence actors. The result will be wider coverage and better exploitation of existing assets.

COPERNICUS

Coordinated and managed by the European Commission, **Copernicus** is the European Union's Earth Observation (EO) and Monitoring programme.

Copernicus relies on its own set of satellites (Sentinels), as well as contributing missions (existing commercial and public satellites), and a variety of technologies and in-situ measurements systems at atmosphere, land and ocean. The accurate and reliable data generated is turned into value-added information by the Copernicus Services for different thematic domains: atmosphere monitoring; marine environment monitoring; land monitoring; climate change monitoring; and security and emergency management.

Most data generated by Copernicus are made available to anyone globally based on a Full, Free and Open (FFO) data policy. They are accessible through various services, including a set of cloud-based platforms called Data and Information Access Services (DIAS).

SPACE SITUATIONAL AWARENESS[2]

A strategic goal of the European Commission (EC) space strategy is to reinforce Europe's strategic autonomy in accessing and using space, and this in a secure and safe environment.

This goal is paving the way towards the development of Space Situational Awareness (SSA) capabilities at a European level, comprising a holistic approach toward supporting Europe's independent utilisation of and access to space. This is achieved through the provision of timely and accurate information and data regarding the space hazards and environment (e.g. space debris, space weather phenomena and Near Earth Objects) and both in-orbit and ground-level infrastructure.

[1] Since this report focuses on the EO and GNSS market, the market of GOVSATCOM is not presented in this report.

[2] Limited insights into SSA are provided in the market segment "Space" on page 178

Dear Reader,

I am delighted, for the first time for the European Union Agency for the Space Programme (EUSPA), to introduce the first published EUSPA Earth Observation (EO) and Global Navigation Satellite System (GNSS) Market Report.

2021 has been a year of accomplishments for the European Union in space. The first-ever integrated Space Programme, gathering the two satellite navigation systems, Galileo and EGNOS, the EU Earth Observation system, Copernicus, and GOVSATCOM, the upcoming system for secure governmental communications, is now in place. EUSPA has an extended mandate, including the provision of satellite-based services for Galileo and EGNOS and development of the GOVSATCOM Hub, enhanced security responsibilities, and the market uptake of Galileo, EGNOS, commercial utilization of Copernicus, and the development of GOVSATCOM users' phase, among others.

With the EU Space Programme now a reality, new horizons are opening up. The EU's downstream sector continues to thrive, and the future of our commercial space industry has never looked so promising. In 2021, global GNSS- and EO-enabled revenues crossed €200 billion, set to reach almost €500 billion over the next decade. In this context, it is more important than ever to keep abreast of developments and trends on the GNSS and EO markets, and this is exactly what the revamped EUSPA EO and GNSS Report offers.

Since its inception, the report has established itself as the most authoritative reference document for information on the global GNSS market. It is regularly referenced by policy-makers and business leaders around the world. For the first time it offers an analytical overview of key GNSS and EO market segment trends, future evolution forecasts as well as insightful charts and value chains. A total of seventeen market segments can be found inside, most of which are synergetic by nature (i.e. balanced use of both EO and GNSS).

In this issue, the Editor's special introduces the topic of health, where EO and GNSS are showing a growing potential and role to monitor, analyse and contribute toward the mitigation of global health challenges.

The report is the result of collaborative work between a team of 15 EUSPA experts from various fields and a consortium of market research companies supporting EUSPA, backed up by more than 50 external experts who helped to validate market trends and the data contained in almost 150 charts.

I am confident that the latest edition of the EUSPA EO and GNSS Market Report will enable you to keep your finger on the pulse of the space downstream industry and reap the maximum benefit from the opportunities offered by this rapidly developing market.

Rodrigo da Costa

Executive Director
European Union Agency for the Space Programme (EUSPA)
Prague, January 2022

How to read this report

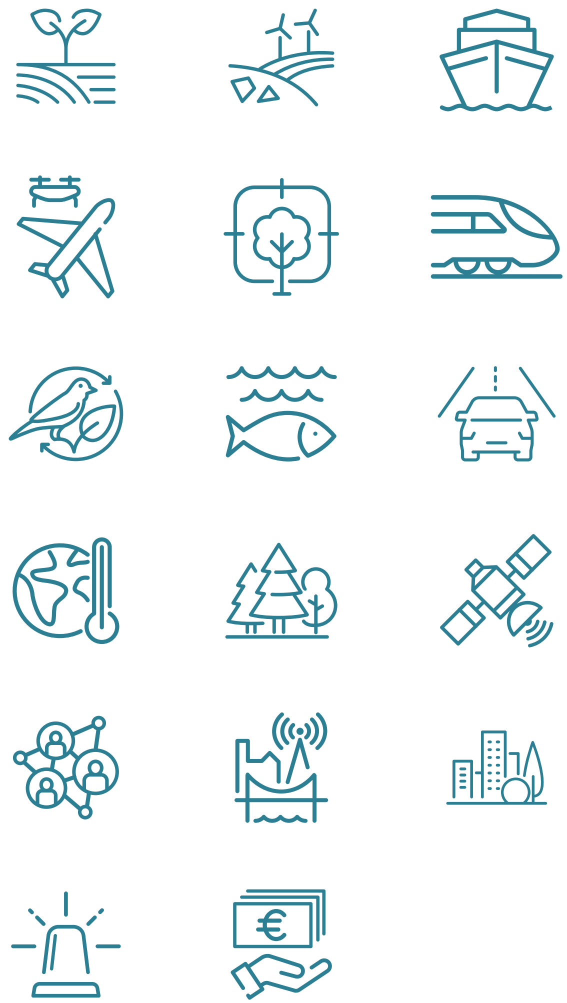
The European Union Agency for the Space Programme (EUSPA) and the European Commission (EC) welcome all readers to this first issue of the EUSPA EO and GNSS Market Report. Following two previous issues of the Copernicus Market Report by the EC and six previous issues of the EUSPA GNSS Market Report, this EO and GNSS Market Report combines the market and application insights of both into a single report that provides global coverage of the Earth Observation and Global Navigation Satellite System applications across multiple market segments.

For those readers that are new to the report, the EUSPA EO and GNSS Market Report is a continuously evolving publication that builds on a similar structure and format used in previous issues. With the merger of both EO and GNSS into a single report, no less than 17 market segments are featured.

The 17 market segments are the following: **Agriculture / Aviation and Drones / Biodiversity, Ecosystems and Natural Capital / Climate Services / Consumer Solutions, Tourism and Health / Emergency Management and Humanitarian Aid / Energy and Raw Materials / Environmental Monitoring / Fisheries and Aquaculture / Forestry / Infrastructure / Insurance and Finance / Maritime and Inland Waterways / Rail / Road and Automotive / Space / Urban Development and Cultural Heritage.**

The report is structured as follows:

- **General overview of the EO and GNSS market** presents an overview of the downstream space application market, main EO and GNSS trends, market size and revenues of both EO and GNSS (as well as shipments and installed base in the case of GNSS). It further presents a global industry overview and main trends, as well as a general description of what Copernicus and EGNSS encompass. Finally, it presents how EO and GNSS play a role across general policy and market trends.
- **The market segments** form the core of the report. All segments, regardless of length, follow the same structure:
  - ✓ To introduce the segment, an overview of the EO and GNSS applications is presented alongside a segment description;
  - ✓ **Key** market segment **trends** are illustrated with examples;
  - ✓ **User perspective** focuses on user needs and the utilisation of EO and GNSS in the segment from the users' point of view;
  - ✓ The **industry value chain(s)** provide a non-exhaustive list of key stakeholders;
  - ✓ **Recent developments** focus on historical data of shipments of GNSS devices and EO data and service revenues by application or region over the past decade, presenting initiatives and examples that have recently been implemented;
  - ✓ **Future market evolution** forecasts GNSS shipments or EO revenues over the next decade spanning 2021 to 2031. It presents ideas and concepts whose outputs will impact the market in the mid-term and highlights promising applications that might boost the future growth of the segment;
  - ✓ **European Systems and Projects** provides information on the current usage of Galileo, EGNOS and Copernicus services and associated relevant projects within the particular segment; and
  - ✓ **Reference charts** present a forecast of the installed base and revenues of the market segment by region and application.
- In this issue the **Editor's special** introduces the topic **'Innovative solutions for health'**, where EO and GNSS are showing a growing potential and role to monitor, analyse and contribute toward the mitigation of global health challenges.
- **Annexes** conclude the report with a description of the methodology behind the data presented (Annex 1), definition of key performance parameters (Annex 2), list of application descriptions (Annex 3), list of acronyms (Annex 4) and information about the authors (Annex 5).



Executive Summary

This first issue of the **EO and GNSS Market Report** provides insights into how EO and GNSS contribute to a plethora of applications across a total of **17 market segments**, followed by an additional **Editor's Special** focus on **Innovative Solutions for Health**.

GNSS- and EO-enabled revenues crossed €200 billion in 2021, set to reach almost €500 billion over the next decade

Facing **global challenges** such as the digital revolution, climate change and pandemics threatening the economy at a worldwide scale, society – more than ever – relies on **innovative solutions** to deal with the big data paradigm, respond to and mitigate natural and man-made disasters, curb the spread of deadly diseases and strengthen a global supply chain that underpins our daily lives. **EO and GNSS will play a vital role in contributing to these innovative solutions** through dozens of applications that are emerging or already in use by citizens, governments, international organisations, NGOs, industry, academia and researchers around the world.

By 2031, more than 10 billion GNSS devices will be in use across the world

Between 2021 and 2031, **annual shipments of GNSS receivers are forecasted to grow from 1.8 billion units to 2.5 billion units**. These shipments will be heavily dominated by the Consumer Solutions, Tourism and Health segment following the wave of global smartphone and wearable sales that contribute to roughly 92% of global shipments.

Consequently, the global installed base of GNSS devices in use is expected to reach over 10 billion units by 2031. Here again a **dominant role is set aside for the mass market segments of Consumer Solutions, Tourism and Health and Road and Automotive**, which will contribute the lion's share of 98% of all devices in use.

The **global GNSS downstream market revenues**, covering both device sales and service-related revenues, is **expected to grow at a CAGR of 9.2% over the next decade, reaching a total of €492 billion by 2031**. Over 82% of these revenues will be generated by value-added services (i.e. €405 billion in 2031). Besides the **dominance of the aforementioned mass market segments**, the professional markets of (i) **Agriculture**, (ii) **Urban Development and Cultural Heritage**, and (iii) **Infrastructure** will be the main contributors to the global GNSS revenue stream.

In terms of demand, the **Asia-Pacific region continues to dominate the GNSS revenues market** both for device and services revenues (i.e. 36% and 40% of the global share respectively in 2021). Whilst the region is expected to increase its share of the global services revenues, nearing 46% by 2031, Asia-Pacific will see a decline of its market share of device revenues (expected to drop to 28%). In this area, the region will be challenged by the upcoming markets of South America & Caribbean, Non-EU27 Europe and the Middle East & Africa regions.

North America dominates the EO demand market for both data and service revenues, with Asia-Pacific and EU27 being numbers 2 and 3 respectively

With revenues **set to double from roughly €2.8 billion to over €5.5 billion** over the next decade, the market for **Earth Observation applications is boosted by a large pool of value-added services (i.e. 85% of global revenue)**. These contribute across all segments, though especially in those of Climate Services, Urban Development and Cultural Heritage, Agriculture, Energy and Raw Materials and the Insurance and Finance segment.

When it comes to the sale of **EO data (worth €0.8 billion in 2031, 15% of global revenue)**, the top five of segments is made up of Urban Development and Cultural heritage, Agriculture, Insurance and Finance, Energy and Raw Materials as well as Consumer Solutions, Tourism and Health.

Despite a relatively small market share in 2021 (i.e. 5% or €145 million), the Insurance and Finance segment – boosted by the growing use of **parametric insurance products** in the context of disaster resilience frameworks by commercial entities in areas with high exposure to extreme events – will increase its uptake of EO data and value-added services over the decade, **pushing the Insurance and Finance segment to a forecasted €1 billion EO-enabled revenues by 2031** (constituting an 18% market share).

From a **supply** perspective, the **EO market is jointly led by the United States of America and Europe with market shares of 42% and 41% respectively. Europe plays a leading role in the market of Analysis, Insights and Decision Support** (the subset of value-added services closest to end-users) with a 50% market share covering all segments, contributing to its overall market share above. Although challenged by US companies in the mature Agriculture market and the growing Insurance and Finance segment, **European companies lead the market across almost all other segments**, excluding the Emergency Management and Humanitarian Aid segment (led by Asian companies with 52%) and the niche EO market of Road and Automotive (led by US companies with 77%).

The European EO industry is dominated by SMEs and start-ups

Based on the latest European Association of Remote Sensing Companies (EARSC) Industry Survey, SMEs and start-ups account for more than 93% of European EO companies, showcasing the **importance of small companies** for the European EO economy.

As presented throughout this report, **the flagship EU Space Programme** – driven in tandem by Galileo and EGNOS on one side and Copernicus on the other – **has become** a **major enabler in the downstream space application market**.

Across each and every market segment displayed in this report, the **added value and key differentiators of European GNSS and EO are showcased, both separately but also, more importantly, in synergy with each other**.

Introduction to the EO downstream space application market

WHAT IS EO?

Earth Observation (EO) refers to remote sensing and in-situ technologies used to capture the planet's physical, chemical, and biological systems and to monitor land, water (i.e. seas, rivers, lakes) and the atmosphere. Satellite-based EO by definition relies on the use of satellite-mounted payloads to gather data about Earth's characteristics. As a result, satellite-based platforms are suitable for monitoring and identifying changes and patterns for a range of physical, economic, and environmental applications globally. Once processed, EO data can be assimilated into complex models to produce information and intelligence (e.g. forecasts, behavioural analysis, climate projections, etc.), and complemented by in-situ measurements.

KEY EO PERFORMANCE PARAMETERS

Firstly, different types of sensors utilize different EO technologies:

- **Optical or thermal sensors** are payloads monitoring the energy received from the Earth due to the reflection and re-emission of the Sun's energy by the Earth's surface or atmosphere. They operate between the visible and infrared wavelengths of the electromagnetic spectrum.
- **Radar sensors** are payloads operating in the lower part of the spectrum (longer wavelengths). Most of these sensors send energy to Earth and measure the feedback from the Earth's surface or atmosphere, enabling day and night monitoring during all-weather conditions.

The second essential parameter in EO is the sensor resolution.

- **Spatial resolution** defines the size of the pixels analysed by the sensors. EO satellites can be distributed into three categories based on this parameter: Low and medium resolution, High resolution, and Very-High Resolution.
- **Temporal resolution** defines the frequency at which the data is acquired for a defined area. The needs can vary substantially for this parameter, with applications requiring images every day or every few hours, whilst others require updates only every few weeks.
- **Spectral resolution** is also considered in the case of optical sensors. This is defined by the width of the spectrum bands that can be distinguished by the payload, enabling some applications that require the ability to analyse specific wavelengths.

The last key parameters considered for remote sensing techniques is the **coverage**.

In-orbit infrastructures offer a global coverage with a single spacecraft, while aerial or in-situ sensor coverage is local. Orbital geometry however limits the frequency of fly-by over a same location (typically once per day to once every few days) while local monitoring allows a higher persistence, from a new acquisition every few hours down to near real time.

More details on EO performance parameters and requirements are provided in **Annex 2**.

EO MARKET

This Market Report considers the EO market to be defined as: *activities where satellite EO-based data and value-added services enable a variety of applications across multiple segments.*

The EO market presented in this report displays EO data and EO value-added service revenues separately, as well as combined into a single chart. This illustrates the different ways in which users in different segments access information based on satellite remote sensing. Data revenues arise from a financial transaction between an EO Data Provider and a user (this user can be either a service provider or an end-user with processing capabilities). Value-added service revenues are further along the value chain and arise from a transaction between an EO Products and Services, or Information Provider (that uses free and/or commercial input data) and an end-user*.

This report displays only the commercial EO market, meaning that the market quantification captures only activities based on commercial transactions. This means specifically that grant-funded activities in the EO domain are outside the scope of the content of this Market Report.

> Although EO data and services, combined with data from meteorological satellites, contribute to the generation of weather data and services, **Weather Services themselves are not included in this market report as an EO segment.** Dedicated weather services at segment level (e.g. Agriculture) are included since these are specific EO applications with a commercial business model behind them.

ON CHARTS AND METHODOLOGY

Data contained within the charts starting from the year 2020 are estimated, forecasted and subject to update in the next edition of the Market Report. Historical figures are actual numbers based on reliable sources. These will only change if the number of applications is expanded in future reports.

Terminology used in charts:

➜ **Revenue**: The revenue from data/services sales in a given year.

➜ **Regions**: EU27, Non-EU27 Europe, North America, Asia-Pacific, Middle East & Africa, and South America & Caribbean.

Revenues are presented under two distinct points of view. First, EO demand shows in which region revenues are generated, similarly to the shipment of GNSS devices (this is the majority of the chart material presented in the report). Alternatively, the market share analysis looks at the origin of supply – where the company offering the product is headquartered – as presented on the dedicated Industry and Market share pages. The difference between this market data and the industry and market share analysis data thus gives an indication of the trade balance between regions.

For methodology and information sources see **Annex 1** and for any abbreviation used within the report, please refer to **Annex 4**.

> Through the **Full, Free and Open (FFO) data policy** of the EU Earth Observation programme, the data coming from the Sentinel satellites and the added-value products coming from the Copernicus services are made available free-of-charge to users. Through the FFO, **valuable information and services have been delivered for free and have proven to form a solid baseline for the development of value-added products and have stimulated the commercial market of EO-based products and services**. The combination of freely available information and services with commercial offerings have enabled Earth Observation companies and users to generate the global revenues as presented in this market report.

* All transactions along the EO value chain (see p13) are considered within these revenue streams, without overlap or omission.

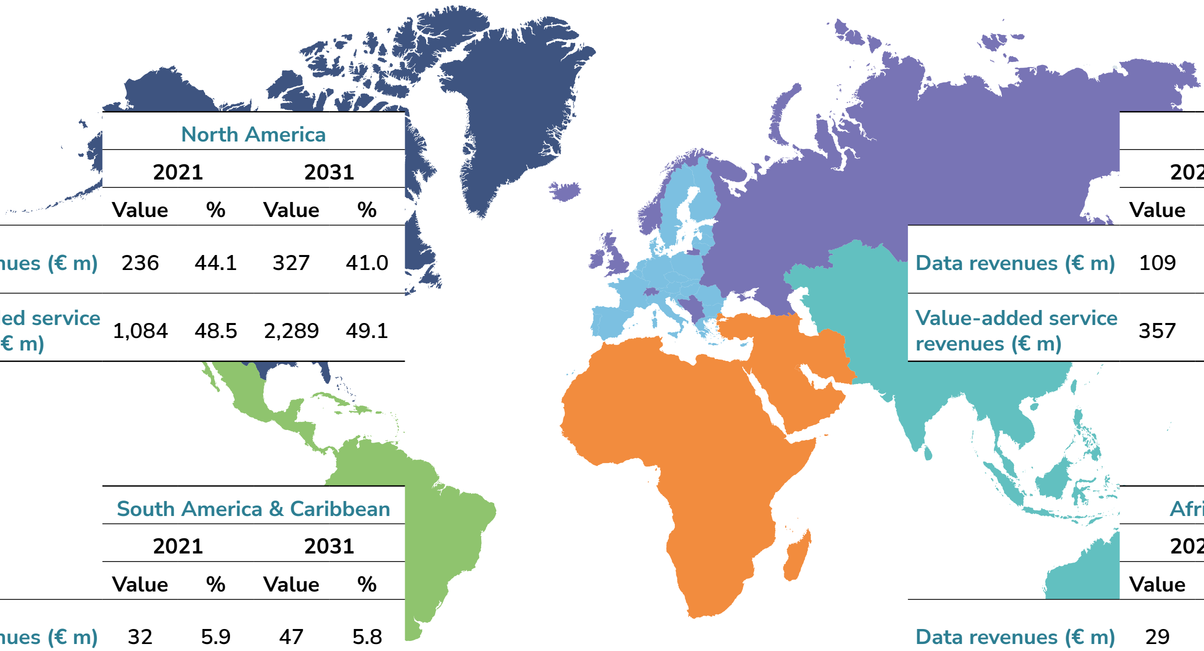
EO demand world map

	European Union (EU27)			
	2021		2031	
	Value	%	Value	%
Data revenues (€ m)	82	15.4	117	14.6
Value-added service revenues (€ m)	342	15.3	664	14.2

	Global	
	2021	2031
	Value	Value
Data revenues (€ m)	536	797
Value-added service revenues (€ m)	2,236	4,662

	Russia & Non-EU27 Europe (Non-EU27 Europe)			
	2021		2031	
	Value	%	Value	%
Data revenues (€ m)	47	8.8	65	8.2
Value-added service revenues (€ m)	161	7.2	327	7.0

	North America			
	2021		2031	
	Value	%	Value	%
Data revenues (€ m)	236	44.1	327	41.0
Value-added service revenues (€ m)	1,084	48.5	2,289	49.1



	Asia-Pacific			
	2021		2031	
	Value	%	Value	%
Data revenues (€ m)	109	20.4	192	24.0
Value-added service revenues (€ m)	357	16.0	769	16.5

	South America & Caribbean			
	2021		2031	
	Value	%	Value	%
Data revenues (€ m)	32	5.9	47	5.8
Value-added service revenues (€ m)	136	6.1	278	6.0

	Africa & Middle East			
	2021		2031	
	Value	%	Value	%
Data revenues (€ m)	29	5.5	51	6.4
Value-added service revenues (€ m)	156	7.0	334	7.2

Note: Due to rounding, numbers and percentages might not add up to the global figures provided.

Role and key trends of EO across the market segments

Of the 17 market segments presented in the first EO and GNSS Market Report, 16 have a strong or even dominant influence of EO applications. For each of these segments, a brief summary of the scope and key trends are presented below. More insights into segment-specific trends can be found on their respective 'Key Trends' page. The Space segment is the exception that does not cover any EO content.

Agriculture – Modern farming relies on EO data and information for sustainable nutrient management, restoring soil health and the preservation of biodiversity. A major trend in the field is the increased use of EO as an input for smart analytics for optimising agri-tech solutions.

Aviation and Drones – Traditionally, EO has enabled the monitoring of volcanic ash clouds and hazardous weather, as well as helping aviation identify preventative maintenance in response to particulate matter. In combination with GNSS it is expected to help accurately understand and reduce the impact aviation has on the environment.

Biodiversity, Ecosystems and Natural Capital – EO helps to progress our understanding of the health of ecosystems and existing and potential stressors therein, thus paving the way towards more concrete and effective measures against ecosystem and biodiversity loss. While most of biodiversity assessments are still done on-site, the use of EO in the field is growing.

Climate Services – The role of EO in climate services is well-established and contributes with invaluable data for climate modelling. The integration of EO with innovative technologies and the number of policies requiring close monitoring are set to further boost the market of EO applications related to climate resilience and adaptation.

Consumer Solutions, Tourism and Health – EO-enabled health apps focusing on air quality and UV monitoring are finding traction in the market. Sustainable and safer tourism is enabled by EO e.g. by providing insights about wave conditions and water quality.

Emergency Management and Humanitarian Aid – EO is providing a full picture needed for context-aware emergency responses, ranging from preparedness and early warning to rapid mapping and post-event analysis.

Energy and Raw Materials – EO related to renewable production is mainly linked with the planning and operation monitoring phases, while for raw materials, EO can have an important role in all stages of the mining cycle from exploration, discovery and development, to production and reclamation. EO data also has great potential to support novel energy solutions, such as power-to-x solutions in post-production phases, contributing to a greener future.

Environmental Monitoring – Various environmental parameters obtained by EO data contribute to an increasing number of international, regional, and local policies related to, or impacting, the environment. This is expected to drive the growing demand for EO data and applications in the sector.

Fisheries and Aquaculture – Dedicated EO services and products bring value-added in the fisheries and aquaculture segment providing insights in salinity, temperature, water quality etc., greatly improving fisheries and aquaculture outputs. As the importance of aquaculture grows, a major trend is the increasing use of EO products and services in the field.

Forestry – EO is becoming an extremely valuable tool in monitoring and maintaining the sustainability of forests. From carbon monitoring to battling deforestation and degradation, EO is contributing to conservation in this area. A key trend emerging in the forestry industry is the use of EO in monitoring carbon offsetting practices.

Infrastructure – EO supports the various stages of the infrastructure life cycle, from site selection to post-construction infrastructure health monitoring. Thanks to its capacity to deliver information on risk exposure and future impacts of climate change, EO should increasingly contribute to the design of more resilient and sustainable infrastructures.

Insurance and Finance – EO data is used to compute parametric products benefiting both finance and insurance stakeholders. Risk and claim assessments based on EO data brought increased granularity in risk selection and pricing for insurers.

Maritime and Inland Waterways – Thanks to EO, and in synergy with GNSS, applications such as ship route optimisation contribute to a more efficient means of maritime transport. This optimisation also leads to reduced emissions as well as safer means of navigation, leading to net benefits for the industry and society.

Rail – EO contributes to the overall safety of the railway network by providing railway infrastructure managers with information on risk exposure in relation to vegetation encroachment, landslides and floods. In the future, thanks to its capacity to detect millimetre-scale ground movements, EO should also play an increasing role in the monitoring of track deformation and infrastructure health along the track.

Road and Automotive – Whilst the use of EO is rather new and innovative, applications such as driving comfort have greatly benefited from global EO data, contributing to road safety.

Urban Development and Cultural Heritage – A key enabler for healthier cities, EO assists officials, developers and citizens with the monitoring of air quality, light pollution and mapping of green areas as well as the preparation of urban planning in general. EO will contribute to novel solutions related to smart and sustainable cities.

MARKET OVERVIEW

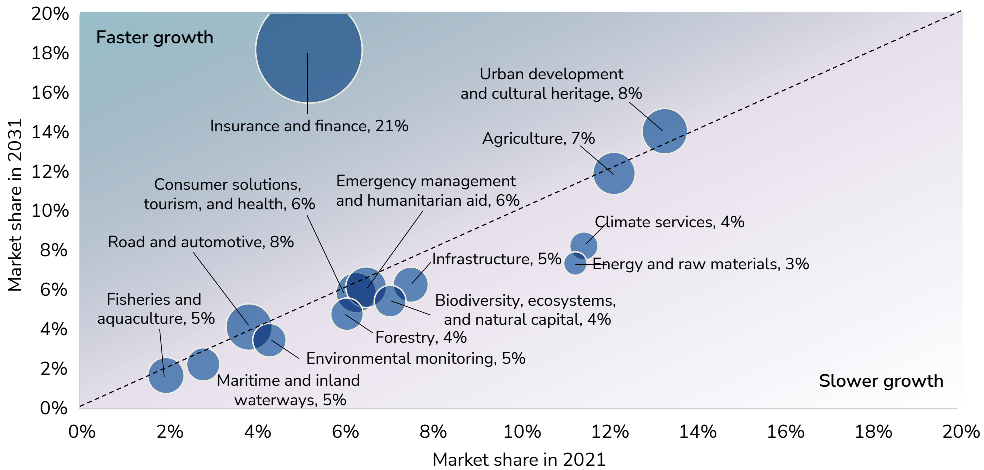
EO data and service revenues are set to double over the next decade

The global EO market of data and services, based on an analysis of over 100 applications, has been split across 16 segments (with Space being the sole segment unconnected with the EO market in this report). Despite having identified several EO applications across each segment, only **14 of these EO segments are currently quantified in terms of data and value-added service revenue streams** as no quantifiable data was available for the Aviation and Drones and Rail segments.

In 2021, the global turnover across EO data and value-added services amounts to €2.8 bn. Over half of these global revenues (i.e. 55%) are generated by the top five segments, namely Urban Development and Cultural Heritage, Agriculture, Climate Services, Energy and Raw Materials, and Infrastructure. **However, it is forecasted that the Insurance and Finance segment (i.e. €145 m and 5.2% in 2021) will realise substantial growth over the next decade and become the largest contributor to global EO revenues in 2031 (with €994 m and an 18.2% market share). By 2031, revenues of the global EO data and value-added services market will approach €5.5 bn.**

The forecasted growth of EO data and value-added service revenues within the Insurance and Finance segment can mainly be attributed to an expected rapid uptake of solutions that support parametric insurance[1].

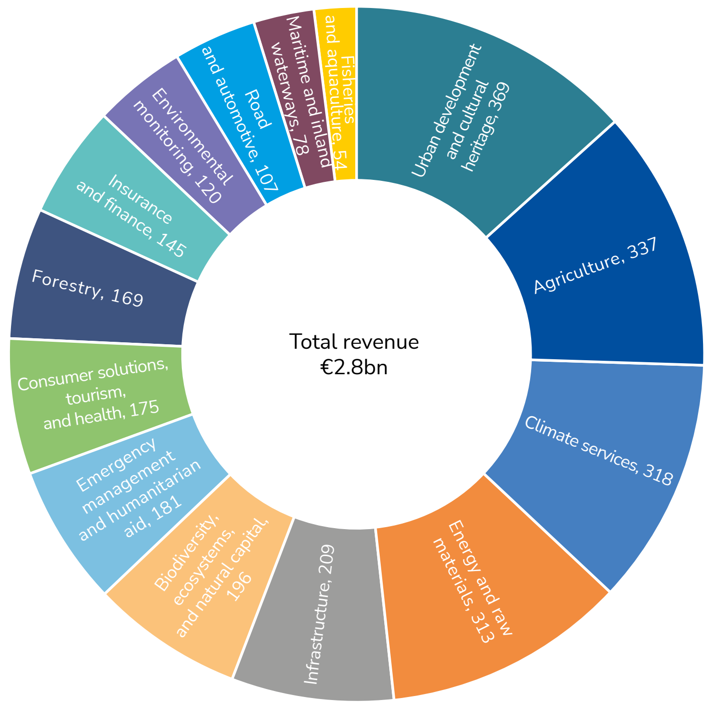
Segment's market share in 2021 and 2031



Note: The size of the bubbles represent the CAGR of each segment between 2021 and 2031.

[1] Parametric insurance or index-based insurance is an innovative insurance product that offers pay-outs following pre-defined parameters and specific perils (e.g. droughts, floods). See Annex 3 for more information on Index production.

Distribution of revenue by segments (€m, 2021)



As presented in the figure on the left, in which each segment's market share growth is illustrated over the 2021-2031 timeframe for both data and value-added service revenues, the **Insurance and Finance segment is expected to experience the fastest growth over the next decade**. Segments in the darker zone are those which are projected to grow faster than others, while those in the lighter zone will experience slower growth. This can be explained by the degree of maturity of the segment. More mature market segments will experience smaller year-on-year growth than emergent markets in which the customer base is not yet well established. For instance, a mature segments such as Energy and Raw Materials has a slow and constant growth rate. Conversely, Insurance and Finance is a rapidly increasing segment with high growth rate.

The total revenues for **EO data** in 2021 accumulate to **€536 m** across all segments. From 2021, the EO data market will see a CAGR of 3.5% by 2031, resulting in **€797 m** total revenues.

The EO value-added services market is considerably larger and accumulated globally a **total of €2.2 bn** in 2021 within the same scope of market segments. From 2021, the EO value-added services market will see a CAGR of 6.8%, resulting in **€4.7** bn total revenues by 2031.

EO industry overview

Revenue[1] generated from **EO data** and **value-added services** is concentrated **in the United States and Europe**[2]. This table presents the revenues under the supply lens, from where EO data and services are provided. It differs from the **EO demand world map showing which regions purchase** data and services (page 10).

Together US and European companies hold over 83% of the global market, each accountable for over 40%. The remaining market is distributed around the rest of the world. **Chinese**[3] companies accounts for 6% of the market, while **Canada** and **Japan** generate respectively 4% and 3% of global revenue.

Revenue generation in the EO industry by key domains (% split of revenues 2019)

Europe	41%	Canada	4%
US	42%	Japan	3%
China	6%	Others	4%

The downstream EO industry is defined as three categories: **Data acquisition and distribution, Data processing, Analysis, insights & decision support**. The top right table presents the top ten companies in each value chain category. The top companies tend to differ across the value chain. However, big companies such as Maxar, Airbus and Amazon have presence in more than one value chain category.

Top 10 companies across the value chain based on 2019 revenues

Data acquisition and distribution		Data processing		Analysis, insights & decision support		Users
Maxar	US	Maxar	US	Airbus	NL	Users of EO products and services across the different market segments
Airbus	NL	Airbus	NL	Leonardo	IT	
Thales	FR	Alphabet Inc. (Google)	US	Verisk	US	
Planet	US	Leonardo	IT	Trimble Inc.	US	
Leonardo	IT	Oracle Corp	US	NEC Corporation	JP	
Amazon	US	Amazon	US	CGI Inc.	CA	
Space Imaging Middle East	AE	CGI Inc.	CA	Maxar	US	
21AT	CN	ESRI	US	VITO	BE	
KSAT	NO	Trimble	US	21AT	CN	
Science and Technology Holding B.V.	NL	Cyient Limited	IN	Beijing Piesat	CN	

[1] A different methodology was used to calculate EO revenues compared to rest of the report as described in Annex 1. This methodology measures the size of EO industry from a supply perspective based on a bottom-up approach which quantifies revenues attributable to EO of more than 500 individual companies for which financial data are available (those with turnover greater than the threshold exempting small firms from financial reporting – this threshold is not universal so smaller companies may be included in some regions than in others). Companies are allocated to a single region based on the registered headquarters of the company (or its ultimate parent). In contrast, the methodology in the rest of the report attributes the size of the EO market to the region where data or services are sold and used. Specifically, this means that the 41% European share of the EO market presented in this table is a fundamentally different statistic to the 15.4% share of the market presented for EU27 in the map on page 10.

[2] Europe: EU27, Norway, Switzerland, UK.

[3] There may be vertical integration in the Chinese government that means activities, which in Europe are procured by government from industry on market terms, are delivered internally by the Chinese government. This means Chinese companies account for a relatively smaller share of the market than their share of activities. Such vertical integration does not represent a market but may explain the relatively small Chinese share.

The EO value chain

The EO value chain is presented at three levels. At the highest level (light blue), the market is split by EO data and EO value-added services. At the next level (green), industry players fit into three categories namely, Data acquisition and distribution, Data processing, and Analysis, insights & decision support. At the lowest level (dark blue), the detailed value chain includes:

- **Infrastructure providers**: providers of various types of computing infrastructure upon which EO data can be accessed, stored, distributed or manipulated.
- **Data providers**: providers of unprocessed or pre-processed EO data.
- **Platform providers**: providers of online platforms and/or digital services, through which users can utilise tools and capabilities to analyse EO data, develop algorithms and build applications.
- **EO products and service providers**: providers of products (e.g. land cover classifications) or services (e.g. ground motion monitoring) that make full use of EO data and processing capabilities offered by data and platform providers.
- **Information providers**: providers of sector-specific information that incorporates EO data along with non-EO data.
- **End Users:** the final users who benefit from the applications and services offered by information providers.

Example of a generic EO value chain

The European EO industry is a global leader when it comes to data analysis

European[1] EO Market Share

European companies account **for half of the global Analysis, Insights & Decision Support market in 2019**. Companies in this market make use of EO data to provide information and intelligence to their clients seeking to solve complex geospatial challenges.

The European industry is the market leader in most market segments within this value chain category. In **Maritime and Inland Waterways, Fisheries and Aquaculture**, and **Aviation and Drones**, the European industry makes up for over 80% of the global market. The only segments in which European companies have a market share far below the European average are Rail (35%), Emergency Management and Humanitarian Aid (17%), and Road and Automotive (12%).

Europe accounts for 42% of the global Data Acquisition and Distribution market and 34% of the global Data Processing market in 2019.

Data acquisition and distribution companies supply commercial raw, unprocessed or pre-processed data. They include satellite, online platforms and data catalogues.

Data processing companies provide services used to process, calibrate, and analyse data, develop algorithms and build specific applications. The processing of data leads to change detection, mapping trends and the quantification of desired indicators on the Earth's surface.

Europe's 2019 market share in Analysis, insights & decision support, by market segments

	Analysis, insights & decision support (Europe: 50%)						
	Europe	North America	Asia+Russia		Europe	North America	Asia+Russia
	64%	33%	3%		59%	31%	11%
	45%	44%	11%		93%	4%	1%
	60%	28%	12%		35%	16%	49%
	81%	8%	11%		45%	37%	18%
	89%	11%	0%		43%	28%	28%
	42%	31%	27%		17%	31%	52%
	47%	53%	0%		12%	77%	10%

Note: Segment share for Rest of the World is not shown in this table.

Focus on Europe – The EARSC Industry Survey 2021

The European Association of Remote Sensing Companies (EARSC) is a not-for-profit organisation which coordinates and promotes the activities of European companies engaged in delivering Earth Observation-derived geo-information services. Acting as a bridge between industry, decision makers and users and covering the full EO value chain (from data acquisition through processing, fusion, analysis and final geo-information products and services), the organisation's members span across 25 countries and include over 130 companies (including SMEs and start-ups).

Since 2013, EARSC has been conducting an industry survey to compile facts and figures concerning the state of the European EO industry. Based on outcomes from its sixth edition, the EO services sector comprised of 713 Companies (an increase of 24% compared to the previous year) across 32 countries (comprising EU and ESA member states). Companies offering services or supplying (selling) data or information using satellite data generated a total of €1.7bn revenues (driven by Copernicus data and information) in 2020.

The European EO industry is dominated by small companies. The 2021 Survey shows that 93% of the companies covered have less than 50 employees whereas 70% have less than 10 employees.

More information on: https://earsc.org/wp-content/uploads/2021/10/EARSC-Industry-survey-2021.pdf and EARSC website.

[1] In the market share analysis, Europe is defined as EU27 plus Norway, Switzerland, and the United Kingdom.

Copernicus delivers a wealth of environment and security-related data

Copernicus is the European Union's Earth Observation and Monitoring programme

Copernicus delivers accurate and reliable information in the field of environment and security and supports a wide range of Union policies in domains such as agriculture, environment, energy, health, civil protection, humanitarian aid and transport. Mainly tailored to the needs of public authorities, Copernicus also serves research, academic, commercial and other private users. The system consists of three main components: a **space component**, which delivers data from a fleet of dedicated observation satellites (the '**Sentinels**') and from contributing missions; an ***in-situ* component** which collects data acquired by a multitude of sensors at air-, sea- and ground-level; and a **service component** which transforms the wealth of satellite and in-situ data into timely and actionable information products.

The programme is managed by the European Commission and implemented in partnership with the Member States, European Space Agency (ESA), European Organisation for the Exploitation of Meteorological Satellites (EUMETSAT), European Centre for Medium-Range Weather Forecasts (ECMWF), EU Agencies and Mercator Ocean International.

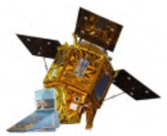
Eight Sentinels are already operational

The Sentinels are the Earth Observation satellites dedicated to the Copernicus programme and are designed to meet the needs of the Copernicus services and their users. Made-up of six families, they ensure an independent and autonomous Earth Observation capacity for Europe with global coverage. They deliver observations (including day and night, all-weather observations) which serve a wide range of user needs related to land and ocean surfaces, atmospheric measurements, air quality, emergency situations, and so on.

Sentinel-1A & -1B provide all-weather, day and night radar imagery for land and ocean services.

Sentinel-2A & -2B provide optical imagery for land and emergency services.

Sentinel-3A & -3B provide optical, radar and altimetry data for marine and land services.



Sentinel-5P provides atmospheric data, bridging the gap between Environmental Satellites (ENVISAT) and future Sentinel-5 data.

Sentinel-6 provides radar altimetry data to measure global sea-surface height, primarily for operational oceanography and for climate studies.

To be launched early 2024

Sentinel-4 & -5 are payloads to be respectively embarked aboard EUMETSAT MTG-S and Metop-SG satellites, in order to provide data for atmospheric composition monitoring.

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

The **Copernicus Atmosphere Monitoring Service (CAMS)** continuously monitors the composition of the Earth's atmosphere at global and regional scales and delivers accurate and reliable information related to air pollution and health, solar energy, greenhouse gases and climate forcing. ECMWF implements CAMS Under the Delegation Agreement with the European Commission.

The **Copernicus Marine Environment Monitoring Service (CMEMS)** provides regular and systematic reference information on the physical and biogeochemical state, variability and dynamics of the ocean and marine ecosystems for the global ocean and the European regional seas. Mercator Ocean International was selected by the European Commission to implement CMEMS.

The **Copernicus Land Monitoring Service (CLMS)** delivers geographical and environmental information on land cover which includes land cover characteristics and changes, land use, vegetation state, water cycle and earth surface energy variables. The CLMS has been jointly implemented by the European Commission and the European Environment Agency.

The **Copernicus Climate Change Service (C3S)** provides authoritative information about the past, present and future climate, as well as tools to enable climate change mitigation and adaptation strategies by policy makers and businesses. C3S is being implemented by the European Centre for Medium-range Weather Forecasts on behalf of the European Commission.

The **Copernicus Emergency Management Service (CEMS)** delivers on-demand geospatial information* for emergency situations that arise from natural or man-made disasters anywhere in the world, and provides early warning information for floods, wildfires and droughts. The CEMS has been implemented by the European Commission.

The **Copernicus Security Service* (CSS)** delivers information which helps the European Union to improve crisis prevention, preparedness and response and to face the security-related challenges in the areas of maritime surveillance, border surveillance and support to EU external action. The European Commission has entrusted European Maritime Safety Agency (EMSA), European Border and Coast Guard Agency (FRONTEX) and EU SatCen with the different components of the CSS.

FFO. Thanks to the Full, Free and Open (FFO) data policy of the EU Earth Observation and Monitoring programme, the data from the Sentinels satellites and most value-added products derived from the Copernicus services are made available free-of-charge to users and service providers.

* Serves registered Public users only

Copernicus data supports industry and policymakers

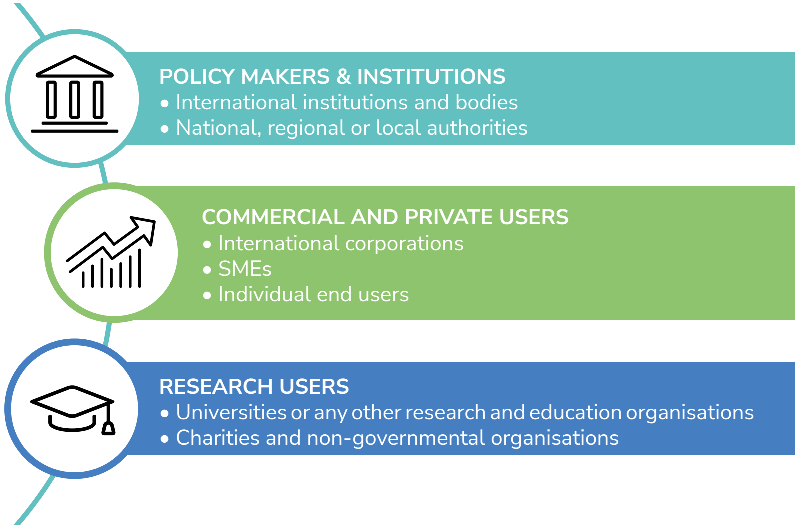
Copernicus is a user-driven programme

Since the early stages of the programme, users have been at the centre of the design and implementation of Copernicus and have particularly driven the implementation and validation of the service-related requirements.

The initial technical specifications have largely been based on the outcomes of workshops with the Member States, through 'implementation groups' (2007-2010) established by the European Commission, and of numerous European projects, among which have been the Sixth Framework Programme Global Monitoring for Environment and Security (FP6 GMES) integrated projects, the GMES Initial Operation projects and the ESA GMES Service Elements.

Following the Copernicus Regulation published in 2014, the Commission services have engaged in a continuous collection of user needs through questionnaires, interviews, workshops, studies (e.g. the 'NEXTSPACE' project, 'Copernicus for EC (C4EC)' study, etc.) and consultation with bodies such as the European Commission's Directorates General, Member States and Entrusted Entities.

The programme governance structure also witnesses the permanent involvement of users, with a specific 'User Forum' established to assist the programme Committee in identifying user requirements, verifying service compliance and coordinating public sector users. At the next User Consultation Platform (UCP), EO requirements of commercial users will be discussed and validated alongside GNSS requirements (see page 25).



Earth Observation data and services benefit a large base of users, including:

- **Core users:** International institutions and bodies and national, regional or local authorities entrusted with the definition, implementation, enforcement and monitoring of a public service or policy. EO informs the decision making of national governments tasked with, for example, setting up plans for disaster response, improving resilience against high-risk hazards, or adapting policy to the effects of extreme weather and climate change. Additional contributors are organisations such as the Intergovernmental Group on Earth Observations (GEO) which coordinates Earth Observation systems and facilitates data and information sharing at a global level.
- **Commercial and private users:** geospatial data and analysis tools not only help businesses address sustainability and climate risks but also optimise their use of resources (e.g. farmers, shipping companies, airlines, etc.). The use of EO by these communities is abundant – use cases and examples of applications can be found throughout this report, both in general and in each market segment.
- Last but not least, the availability of EO data in combination with technological developments (e.g. artificial intelligence, cloud computing and machine learning) enables **research communities** to generate a vast amount of insights – these include tracking and visualising forest and coral-reef loss or predicting disease outbreaks and glacier melts.

Access to Copernicus Data

The massive amount of data and information produced in the context of the Copernicus programme – representing tens of terabytes every day – are made freely available and accessible to any citizen and any organisation around the world.

Satellite data are in particular delivered to their users through a variety of online data access platforms, such as the ESA-managed **Sci Hub** and **Copernicus Space Component Data Access System (CSCDA)**, and the EUMETSAT-managed **EUMETCast** and the **Copernicus Online Data Access (CODA)** platforms. In addition to the above platforms, each **Copernicus Service** has developed its own online platform which provides users with access to information products, associated documentation and support services for their use (1000+ Copernicus products are available to users in total).

Considering the amount of data to be exploited, traditional processing chains have today reached their limits. To fully tap the potential of Copernicus data, in 2018 the European Commission launched the development of five cloud-based platforms: the **Copernicus Data and Information Access Services (DIAS)**. Each DIAS provides access in a virtual environment to all Copernicus data and information, as well as tools and utilities to process them without having to download massive amounts of data.

The Copernicus DIAS

Introduction to the GNSS downstream space application market

WHAT IS GNSS?

Radio Navigation Satellite Services (RNSS) is infrastructure that allows users with a compatible device to determine their position, velocity and time by processing signals from satellites. RNSS signals are provided by a variety of satellite positioning systems, including global and regional constellations and Satellite-Based Augmentation Systems:

➜ **Global constellations i.e. Global Navigation Satellite System (GNSS)**: GPS (USA), GLONASS (Russian Federation), Galileo (EU), BeiDou (PRC).

➜ **Regional constellations**: QZSS (Japan), NavIC (India), and BeiDou regional component (PRC).

➜ **Satellite-Based Augmentation Systems (SBAS):** WAAS (USA), EGNOS (EU), MSAS (Japan), GAGAN India), SDCM (Russian Federation) and SNAS (PRC).

KEY GNSS PERFORMANCE PARAMETERS

GNSS technology is used for many types of applications, covering the mass market, professional and safety-critical applications and critical infrastructures. Depending on user needs, important GNSS User Requirements are:

- **Availability:** The percentage of time the position, navigation or timing solution can be computed by the user. Values vary greatly according to the specific application and services used, but typically range from 95-99.9%.
- **Accuracy:** The difference between true and computed solution (position or time).
- **Continuity:** Ability to provide the required performances during an operation without interruption once the operation has started.
- **Integrity:** The measure of trust that can be placed in the correctness of the position or time estimate provided by the receiver.
- **Time To First Fix (TTFF):** A measure of a receiver's performance covering the time between activation and output of a position within the required accuracy bounds.
- **Robustness to jamming:** The ability of the system to mitigate radio frequency (RF) interference and continue operations within stated service performance limits.
- Robustness to spoofing: The ability of the system to prevent, detect, and mitigate spoofing attacks. Authentication relates to the system's ability to assure the users that they are utilising signals and/or data from a trustworthy source, and thus enhance its robustness level.

Parameters not directly related to GNSS performance are also important. Such parameters include **Power consumption, Resilience, Connectivity, Interoperability and Traceability.**

More details on GNSS performance parameters and requirements are provided in **Annex 2**.

GOVERNMENTAL GNSS MARKET

GNSS constellations may be used in very diverse types of applications. One of the first community to adopt GNSS were Governmental organisations, whose end users are either a governmental entity (e.g. police, fire brigades, customs, etc.) or a non-governmental organisation ensuring the operation of essential services. These GNSS governmental applications are not considered in this report.

GNSS MARKET

This Market Report considers the GNSS market defined as activities where GNSS-based positioning, navigation and/or timing is a significant enabler of functionality. The GNSS market presented in this report comprises device revenues, revenues derived from augmentation and added-value services, (which together form 'Services') attributable to GNSS.

Augmentation services include software products and content such as digital maps, as well as GNSS augmentation subscriptions. **Added-value** service revenues include data downloaded through cellular networks specifically to run location-based applications (such as navigation), as well as the GNSS-attributable revenues of smartphone apps (sales revenue, advertisements and in-app purchases), subscription revenues from fleet management services, drone service revenues across a range of industries, and so on. Both services are shown on the World Map (next page) together as 'Services'.

For multi-function devices such as smartphones, the revenues include only the value of GNSS functionality – not the full device price. Therefore, a case-specific correction factor is used:

- **GNSS-enabled smartphone**: Only the value of GNSS chipsets is counted.
- **Aviation**: The value of the GNSS receiver inside the Flight Management System is taken into account, in addition to the GNSS-specific revenues driven by the certification process.
- **Precision Agriculture system:** The retail value of the GNSS receivers, maps, and navigation software is counted.
- **Search and Rescue devices:** For Personal Locator Beacons and Emergency Locator Transmitters, only the price differential between GNSS and non-GNSS devices is included.

ON CHARTS AND METHODOLOGY

Data contained within the charts starting from the year 2020 are estimated, forecasted and subject to update in the next edition of the Market Report. Historical figures are actual numbers based on reliable sources. These will only change if the number of applications is expanded in future reports.

Terminology used in charts:

➜ **Shipments**: The number of devices sold in a given year.

➜ **Installed base**: The number of devices currently in use.

➜ **Revenue**: The revenue from device/service sales in a given year.

➜ **Regions:** EU27, Non-EU27 Europe, North America, Asia-Pacific, Middle East & Africa, and South America & Caribbean.

The chart data is presented under two distinct points of view. First, GNSS demand shows in which region shipments are sold, devices are used, and revenues are generated (this is the majority of the chart material presented in the report). Alternatively, the market share analysis looks at the origin of supply – where the company's HQ offering the product is located – as presented on the dedicated Industry and Market share pages. The difference between this market data and the industry and market share analysis data thus gives an indication of the trade balance between regions.

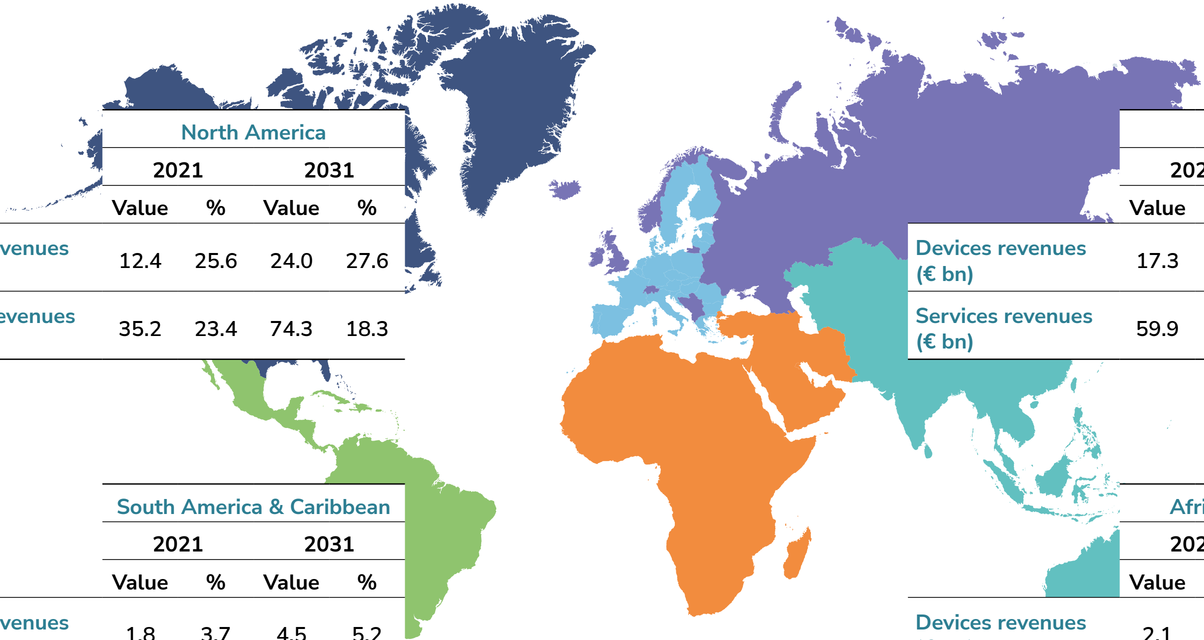
For methodology and information sources see **Annex 1** and for any abbreviation used within the report, please refer to **Annex 4**.

GNSS demand world map

European Union (EU27)	2021 Value	2021 %	2031 Value	2031 %
Devices revenues (€ bn)	12.1	25.0	21.6	24.8
Services revenues (€ bn)	27.4	18.2	53.7	13.3

Global	2021 Value	2031 Value
Devices revenues (€ bn)	48.4	87.0
Services revenues (€ bn)	150.5	405.2

Russia & Non-EU27 Europe (Non-EU27 Europe)	2021 Value	2021 %	2031 Value	2031 %
Devices revenues (€ bn)	2.7	5.6	7.6	8.7
Services revenues (€ bn)	7.4	4.9	20.7	5.1



North America	2021 Value	2021 %	2031 Value	2031 %
Devices revenues (€ bn)	12.4	25.6	24.0	27.6
Services revenues (€ bn)	35.2	23.4	74.3	18.3

Asia-Pacific	2021 Value	2021 %	2031 Value	2031 %
Devices revenues (€ bn)	17.3	35.7	24.0	27.6
Services revenues (€ bn)	59.9	39.8	185.3	45.7

South America & Caribbean	2021 Value	2021 %	2031 Value	2031 %
Devices revenues (€ bn)	1.8	3.7	4.5	5.2
Services revenues (€ bn)	7.9	5.2	22.1	5.5

Africa & Middle East	2021 Value	2021 %	2031 Value	2031 %
Devices revenues (€ bn)	2.1	4.3	5.3	6.1
Services revenues (€ bn)	12.7	8.4	49.1	12.1

Note: Due to rounding, numbers and percentages might not add up to the global figures provided.

Role and key trends of GNSS across the market segments

Of the 17 market segments presented in the first EO and GNSS Market Report, 16 segments have a strong or even dominant influence of GNSS applications. For each of these segments, a brief summary of the scope and key trends are presented below. More insights into segment-specific trends can be found on their respective 'Key Trends' page. The Environmental Monitoring segment is the exception that does not cover any GNSS content.

Agriculture – New technologies are pushing the Agriculture sector to new frontiers. GNSS is considered a key driver and enabler for these evolutions, ranging from traditional farming applications to Internet-of-Things, blockchain, Agri-fin tech and value chain management. GNSS-enabled livestock wearables are emerging as an exciting trend which is improving animal welfare.

Aviation and Drones – Global air traffic took a huge hit due to COVID-19 – airlines responded with consolidation of fleets, and older aircraft prioritised for retirement. Meanwhile, standards evolution in navigation and surveillance presses ahead, enhanced by growing demand from increasingly sophisticated drone operations.

Biodiversity, Ecosystems and Natural Capital – In the domain of biodiversity, ecosystems and natural capital, GNSS-beacons are used to geo-locate animals for the purposes of monitoring migrations, habitats, and behaviours. These are becoming more accurate and additional biodiversity applications are emerging (e.g. botanical mapping).

Climate Services – GNSS has limited but important application in the climate services domain. The technology supports a range of geodetic applications that measure properties of the earth (magnetic field, atmosphere) with direct impact on the Earth's climate. GNSS is expected to have an increasing role in the growing market of climate modelling.

Consumer Solutions, Tourism and Health – GNSS finds increasing use in facilitating our daily lives. From context-aware apps monitoring peak visit times to contactless deliveries and personal fitness apps (powered by wearable devices), navigation and positioning information plays a vital role.

Emergency Management and Humanitarian Aid – Estimated to save 2,000 lives a year, the new MEOSAR system of the GNSS-based COSPAS-SARSAT programme relies on the proper use of GNSS-enabled Search and Rescue beacons. On the field, GNSS is a valuable tool to coordinate emergency response and humanitarian aid.

Energy and Raw Materials – Monitoring and management of electricity utility grids heavily rely on GNSS timing and synchronisation, allowing the balance supply and demand and ensuring safe operations. In the domain of raw materials, the increased uptake of augmented GNSS supports site selection, planning and monitoring, as well as mining surveillance activities and mining machinery guidance.

Fisheries and Aquaculture – GNSS plays a vital role for the efficient and effective monitoring of fisheries activities through applications such as VMS and AIS. As the focus on the sustainability of these activities grows, agriculture lands diminish and food demand rises, GNSS applications are themselves seeing higher demand.

Forestry – GNSS is becoming an extremely valuable tool in monitoring and maintaining the sustainability of our forests. Besides precision forestry management, a key emerging trend is the use of GNSS-enabled UAVs and tracking devices help ensure the health of our trees and the efficiency of our timber supply chains.

Infrastructure – GNSS contributes to the proper functioning of Infrastructures operations. It allows a safe and on-time completion of construction work through the provision of high accuracy services and supports the synchronisation of telecommunication networks. With the transition towards 5G, the GNSS Timing & Synchronisation function is expected to play an increasingly critical role in telecommunication network operations.

Insurance and Finance – The financial world relies on GNSS timing and synchronisation for the accurate timestamping of financial transactions. Insurers, on the other hand, are turning towards GNSS-enabled UAVs for a more accurate and faster claim assessment.

Maritime and Inland Waterways – GNSS has shown its versatility providing data insights to monitor global shipping and port activities during the pandemic. Looking to the future, with automation and 5G expected to bring technological advancements in ports, GNSS will continue expanding its role beyond merely providing navigation information.

Rail – GNSS is becoming one of the cornerstones for non-safety related applications (e.g. asset management), whilst future adoption of GNSS for safety-related applications, including Enhanced Command & Control Systems, is expected to increase railway network capacity, decrease operational costs and foster new train operations. Thanks to GNSS taking part in digitalisation, Rail is becoming safer, more efficient and more attractive.

Road and Automotive – Despite the global slowdown of car production and sales, regulation for safer and autonomous vehicles is on track, with GNSS doubtless playing a key role. With In Vehicle Systems remaining the dominant source of Positioning, Navigation and Timing, it is moreover clear that public transport is increasingly adopting GNSS to improve its services.

Space – From using real-time GNSS data for absolute and relative spacecraft navigation, to deriving Earth Observation measurements from it, GNSS has also proven its worth for in-space applications. Driven by the NewSpace paradigm, the diversification and proliferation of space users leads to an increasing need for spaceborne GNSS-based solutions.

Urban Development and Cultural Heritage – In this field, GNSS-based solutions are used, in conjunction with EO, to accurately survey and map urban areas and to build advanced 3D models of the built environment. With more than 56% of the population already living in urban areas and this number expected to increase, digital solutions powered by GNSS will be needed more than ever support sustainable growth.

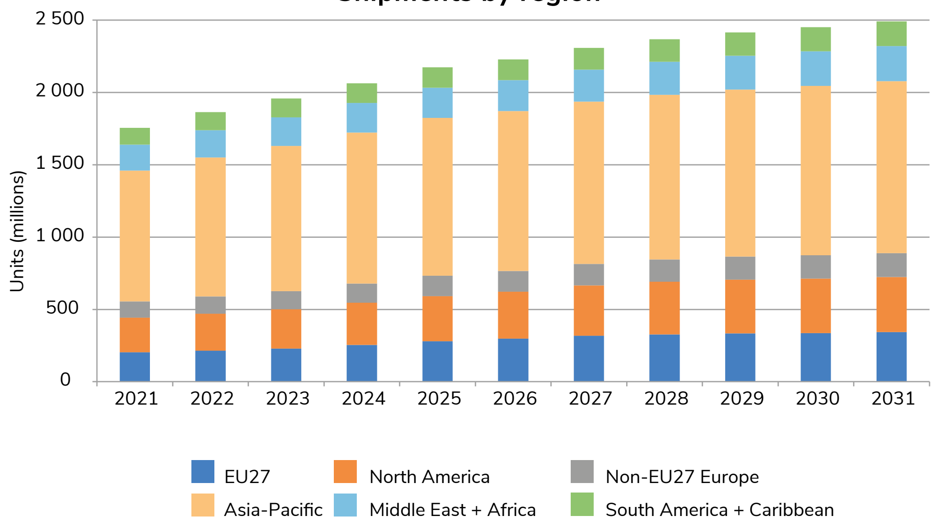
The GNSS market is set to grow steadily across the next decade

Global annual GNSS receiver shipments (graph below) will grow continuously across the next decade (from 1.8 bn units in 2021 to 2.5 bn units in 2031). The vast majority are associated with the **Consumer Solutions, Tourism and Health** segment which contributes **roughly 92% of all global annual shipments** thanks to the enormous numbers of smartphones and wearables being sold on an annual basis. From a regional point of view, it is clear that Asia-Pacific will continue its reign as the largest market.

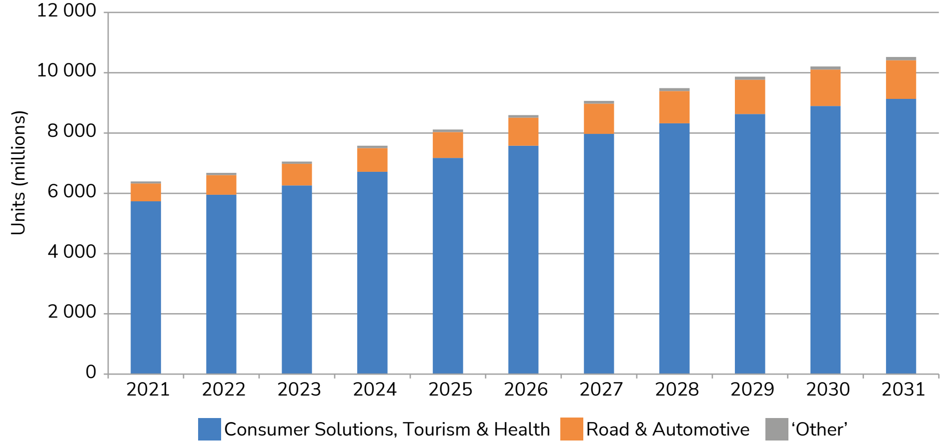
The **overall installed base (graph upper-right) will grow from 6.5 bn units in 2021 to 10.6 bn units in 2031**. Similar to global shipments, the lion's share of the installed base is dominated by the Consumer Solutions segment, accounting for 89% of global GNSS devices in use for 2021 and 86% in 2031. This drop of 3% in global share over the next decade is mainly influenced by the declining share of smartphones across all GNSS devices as there is a global trend towards extending the useful life of a smartphone, which in turn translates into a decrease in smartphone shipments. In parallel, the growing adoption and integration of In-vehicle Systems amongst new car shipments pushes the share of the Road and Automotive segment amongst the global installed base of GNSS devices from 9% in 2021 to 12% in 2031.

Looking at other segments (graphs in the bottom-right), **Aviation and Drones** is a significant market expected to grow from 42 m units in 2021 to 49 m in 2031. The **Maritime** segment is the second largest market in 2021, but sees it global share of 17% in 2021 (corresponding to 11 m units) drop to 16% (17 m in 2031), whilst **Agriculture** becomes the second largest market reaching a share of 18% in 2031 (roughly 20 m units in 2031, up from less than 5 m units in 2021).

Shipments by region

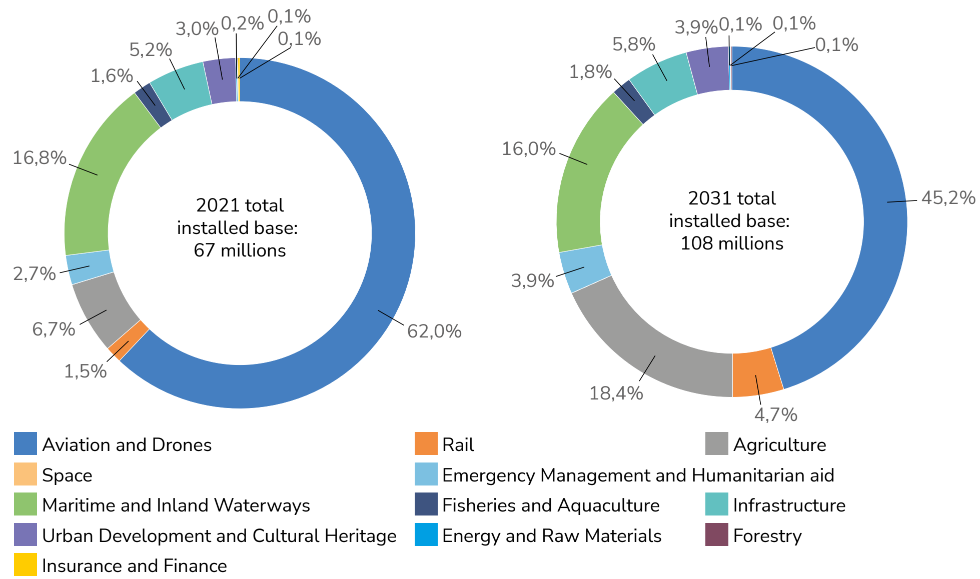


Installed base of GNSS devices by segment



Installed base of 'Other' by segment (2021)

Installed base of 'Other' by segment (2031)



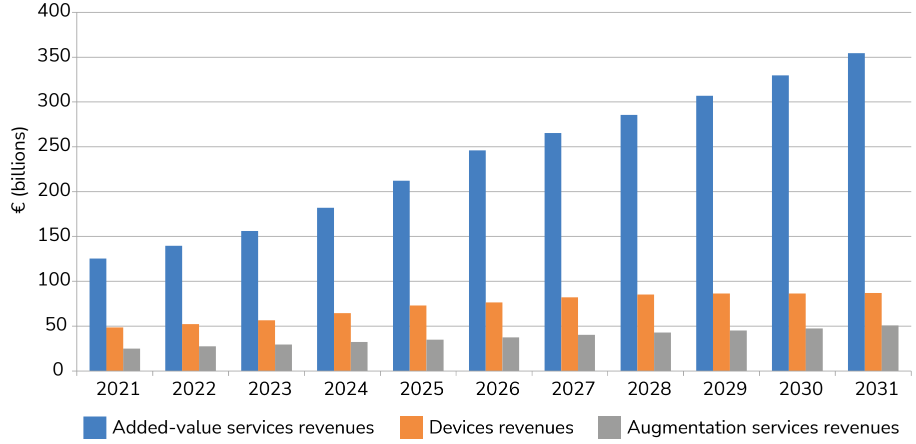
Added-value services account for 72% of the total GNSS revenues in 2031

The **global GNSS downstream market revenues from both devices and services will grow from €199 bn in 2021 to €492 bn in 2031** with a CAGR of 9.2%.

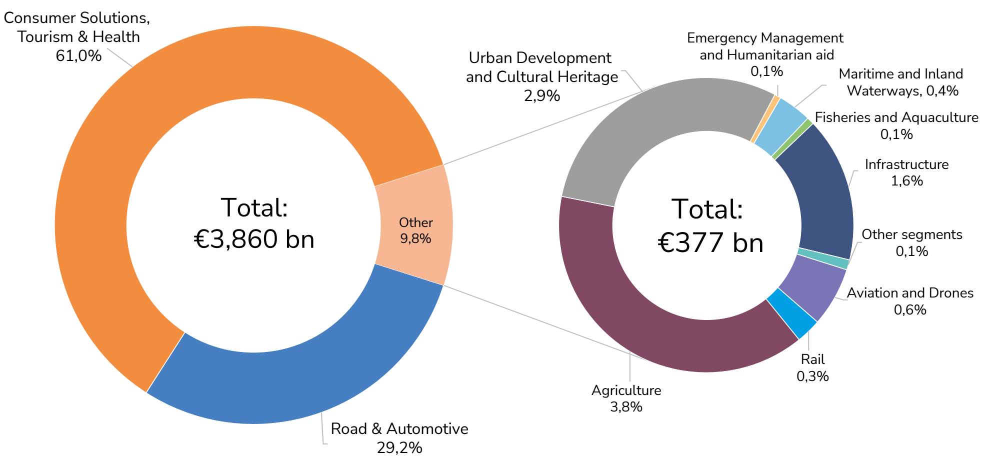
This growth is **mainly generated through the revenues from added-value services**. Over the next decade, these service revenues are expected to witness a skyrocketing growth of 11% per year reaching just over €354 bn in 2031 (compared to around €126 bn in 2021). The revenues from GNSS augmentation services are foreseen to grow annually by 7%, doubling their value from €25 bn in 2021 to nearly €51 bn in 2031.

Combined, **services revenues** (i.e. both added-value services and augmentation services) **will account for €405 bn in 2031, more than 82% of the total Global GNSS downstream market revenues.**

Revenue from GNSS devices sales and services



Cumulative revenue by segment 2021–2031



*Other segments includes Space, Forestry, Insurance and Finance, Energy and Raw Materials

Road and Consumer solutions dominate all other market segments in terms of cumulative revenue with a combined total of 90% for the forecasting period 2021-2031.

In the Road sector, most revenues are generated by devices used for navigation (In-Vehicle Systems (IVS)), emergency assistance, ADAS as well as fleet management applications (including insurance telematics), whereas Consumer Solutions revenues mainly come from the data revenues of smartphones and tablets using location-based services and applications.

Focusing on the remaining revenues, more than 70% of these will be generated by Agriculture (37%), Urban Development (26%) and Infrastructure (20%). Revenues in Agriculture are primarily generated from commercial augmentation services and automatic steering equipment, while the primary sources of revenue in Urban Development and Infrastructure are linked to Geomatics applications (mapping and surveying, construction operations, and site selection or monitoring).

GNSS industry overview

Revenue[1] generated from **GNSS components and receivers** and **added-value services** (including augmentation services) is concentrated in companies from **the United States and Europe**. The US holds the largest share (29%), while Europe is a close second (25%). Combined, **Japan, China and South Korea** account for 36% of the global market.

Revenue generation in the GNSS industry by key domains (% split of revenues 2019)

Europe[2]	25%	South Korea	5%
US	29%	Japan	18%
China	13%	Others	11%

The downstream GNSS industry is defined as three categories: **Components and receiver manufacturers, System integrators**, and **Added-Value Service providers**. The top right table presents the top ten companies in each value chain category. Top companies in **Components and receiver manufacturers** are dominated by US companies (six out of ten). **System integrators** are more geographically diverse but are dominated by automotive or smartphone companies. Tech giants such as Alphabet, Tencent, and Microsoft can be seen in the **Added-Value Service Providers** space alongside augmentation service providers like Trimble.

Top 10 companies across the value chain based on 2019 revenues

Components & Receivers Manufacturers		System integrators		Added-Value Service Providers		End users
Garmin Ltd.	US	Toyota	JP	Alphabet Inc. (Google)	US	Users of GNSS-based solutions across the different market segments
Qualcomm INC	US	China First Automobile Group Corporation	CN	Tencent	CN	
Trimble Navigation Ltd	US	Samsung Electronics	KR	Here International	NL	
Avago (Broadcom)	US	Ford	US	Hexagon AB	SE	
Bosch	DE	Volkswagen	DE	Trimble Navigation	US	
Mediatek	CN	General Motors	US	ESRI	US	
Hexagon	SE	Apple	US	Garmin	US	
VALEO SA	US	Huawei	CN	Denso	JP	
United Technologies Corporation	US	Honda	JP	Microsoft	US	
TomTom	NL	Nissan	JP	Pioneer Corporation	JP	

[1] A different methodology was used to calculate GNSS revenues compared to rest of the report as described in Annex 1. This methodology measures the size of GNSS industry from a supply perspective based on a bottom-up approach which quantifies revenues attributable to GNSS of more than 1,200 individual companies for which financial data are available (those with turnover greater than the threshold exempting small firms from financial reporting – this threshold is not universal so smaller companies may be included in some regions than in others). Companies are allocated to a single region based on the registered headquarters of the company (or its ultimate parent, if part of a corporate group). In contrast, the methodology in the rest of the report attributes the size of the GNSS market to the region where equipment and services are sold and used. Specifically, this means that the 25% European share of the GNSS market presented in this table is a fundamentally different statistic to the 19.9% share of the market presented for EU27 in the map on page 18.

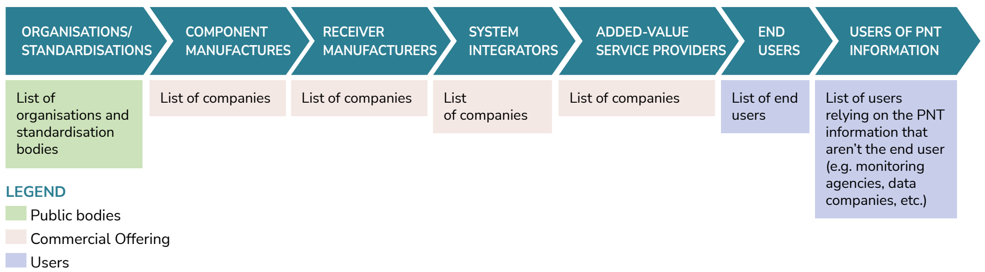
[2] Europe: EU27, Norway, Switzerland, UK.

The GNSS value chain

Across the different market segments, the core of the GNSS industry value chain is centred around the three categories as explained above. However, every market segment is somewhat unique in its value chain and therefore we strongly recommend you explore these per segment. In general, each value will contain the following categories of stakeholders:

- **(Inter)national organisations and standardisation bodies**: Regulated segments such as Maritime, Aviation etc. will present a first link in their value chain dedicated to bodies setting GNSS standards and requirements (not present in each segment).
- **Component manufacturers**: they underpin the industry by producing chips, antennas and other inputs for GNSS receivers.
- **Receiver manufacturers**: they develop the GNSS receiver taking into account specific user requirements for the different applications/market segments they are active in.
- **System integrators (and design consultancies)**: responsible for the technical implementation of the GNSS equipment into a complex system.
- **Added-value service providers**: these companies provide either added-value or augmentation services to end users (not present in each segment).
- **End users/users of positioning information**: the final users who benefit from the applications and services offered by system integrators.

Example of a generic GNSS value chain



The European GNSS industry is dominant in Road, Maritime and Space segments

European[1] GNSS Market Share

The adjacent table shows the regional market shares for Components and Receiver manufacturers in 2019 for each market segment. The data are created using the methodology described on the previous page. European companies account for a **quarter of the global GNSS Components and Receiver manufacturers market in 2019** (compared to 27% in 2017). The European industry's market share in this value chain category varies across market segments. While it has above average market shares in segments such as **Road (53%), Maritime (47%) and Space (65%)**, it has below average market shares in segments such as **Consumer Solutions (7%), Aviation (17%), Rail (14%), and Drones (10%)**.

Europe accounts for 24% in the System Integrators and 25% in Added-Value Service Providers in 2019.

Please note the market share analysis uses the same segmentation as was presented in GNSS Market Report issue 6. Assessments of the European market share in the expanded segmentation are provided on the segment pages. Changes in market share are driven by general market trends, mergers and acquisitions, and exchange rate fluctuations.

Europe's 2019 market share in Components & Receivers, by market segments

Europe's 2019 market share in Components & Receivers, by market segments

	Europe	North America	Asia +Russia		Europe	North America	Asia +Russia
Consumer Solutions	7%	45%	47%	Agriculture	20%	47%	33%
Road and Automotive	53%	25%	22%	Geomatics	35%	31%	33%
Manned Aviation	17%	81%	2%	Emergency Response	33%	39%	13%
Rail	14%	15%	71%	Drones	10%	42%	48%
Maritime	47%	27%	26%	Critical Infrastructures	36%	50%	12%
Space	65%	19%	17%				

Note: Segment share for Rest of the World is not shown in this table.

MUST READ: EUSPA's GNSS Technology Market Report

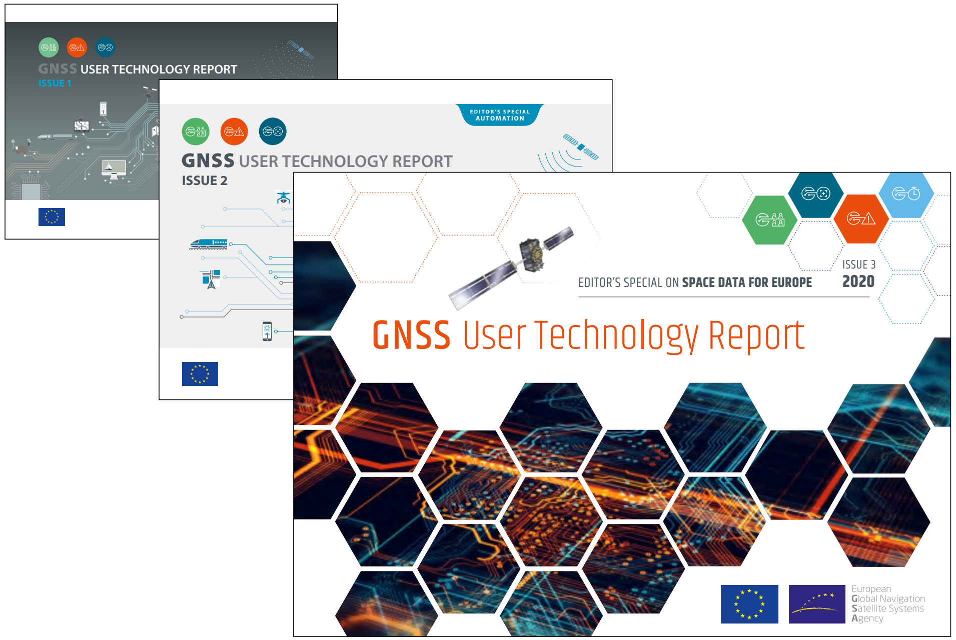
The 2020 GNSS User Technology Report Issue 3 is the go-to source for comprehensive knowledge and information on the dynamic, global GNSS user technology industry and its latest trends. It follows the second Issue that was published in 2018.

The GNSS User Technology Report takes an in-depth look at the latest state-of-the-art GNSS receiver technology, along with providing expert analysis on the evolutionary trends that are set to redefine the global GNSS landscape.

The 2020 report opening section provides an overview of recent development and future trends in GNSS user technology before deep-diving into four macrosegments presenting technology solutions and their use cases. The macrosegments are:

- High-volume devices;
- Safety- and liability-critical devices;
- High-accuracy devices;
- Timing devices.

The Report concludes with an Editor's Special on 'Space data for Europe' which describes the increasing role of space data and the associated challenges and opportunities, provides an overview of the EU space infrastructure and identifies a set of tools to support data management.



[1] In the market share analysis, Europe is defined as EU27 plus Norway, Switzerland, and the United Kingdom.

Galileo and EGNOS – the European satnav constellations

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

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

- **Open Service (OS)**: Galileo Full, Free and Open (FFO) service set up for positioning and timing services. The Galileo Open Service also provides Navigation Message Authentication **(OSNMA)**, allowing the computation of the user position using authenticated data extracted from the navigation message.
- **High Accuracy Service (HAS)**: A free access service complementing the OS by providing an additional navigation signal and added-value services in a different frequency band. HAS is intended to offer real-time user positioning performances with accuracy less than two decimetres in nominal conditions.
- **Public Regulated Service (PRS)**: Service restricted to government-authorised users, for sensitive applications that require a high level of service continuity.
- **Commercial Authentication Service (CAS)**: A service providing users with the capability to obtain an authenticated Galileo PVT solution.
- **Search and Rescue Service (SAR)**: Europe's contribution to COSPAS-SARSAT, an international satellite-based search and rescue distress alert detection system.

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

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

EGNOS delivers three core services:

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

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

Do you want to know whether your device supports Galileo?

To keep pace with the many new **Galileo-compatible devices and services** coming onto the market, the European Agency for the Space Programme (EUSPA) is operating an enhanced version of its popular UseGalileo.eu website to help users and developers keep track of Galileo-compatible devices and services for various needs as they become available.

The increase in the use of Galileo goes hand in hand with the wide range of Galileo-enabled devices and services that are continually appearing on the market. The range of applications for Galileo is enormous, covering both the public and private sectors and spanning many market segments and brings considerable benefits.

Besides Galileo, the website also provides an overview of **EGNOS-compatible receivers**, as well as insights to which airlines rely on EGNOS-enabled flight procedures.

EGNSS continues to create significant value as performances at user level improves

Galileo and EGNOS are user-driven programmes

While European independence is a principal objective of the programme, Galileo also gives Europe a seat at the rapidly expanding GNSS global table. The programme is designed to be compatible and interoperable with GPS, GLONASS and BeiDou. In this sense, Galileo is positioned to enhance the operational domain currently available through the other GNSS, providing a more seamless and accurate experience for multi-constellation users around the world. The European research and development and industrial sectors are able to leverage Galileo's increased accuracy in countless products and services, creating added value for the European economy and improving the lives of European citizens.

In sectors where accuracy and integrity are critical, EGNOS improves the accuracy and reliability of GNSS positioning information, while also providing a crucial integrity message regarding the continuity and availability of the signal. Today, EGNOS is benefiting numerous market segments, including Aviation and Drones, Road and Automotive, Maritime and Inland Waterways and Agriculture.

The 3rd edition of the User Consultation Platform (UCP) for the European Space Programme

The user consultation platform (UCP), organised by EUSPA, is a space where users from different market segments meet to discuss their needs for applications relying on location, navigation, timing, Earth observation and secure telecommunications. For the 2020 edition, the UCP included additional Copernicus and governmental satellite communications (GOVSATCOM) users, in addition European global navigation satellite system (EGNSS) users.

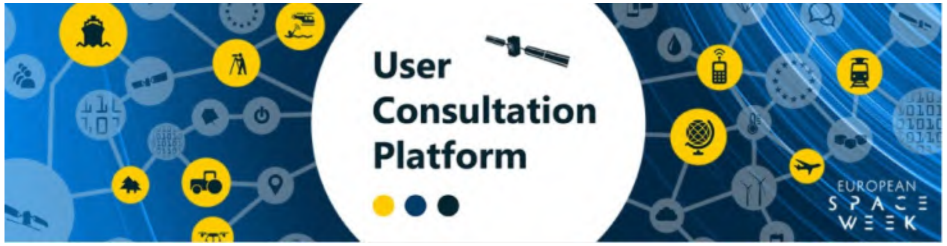
The UCP is engaging with user communities, industries, service providers and R&D, bringing together expertise and insights from different applications, sharing experiences, and strengthening an EU network of innovators by encouraging cooperation across broad disciplines.

UCP 2020 occurred in December, where twelve parallel panel sessions grouping users by market segments took place. During these sessions, many topics were addressed including an update on the user requirements, synergies with Copernicus, testing campaigns, main market trends, evolution of Galileo/EGNOS and R&D.

EGNSS for post-COVID recovery, need for high accuracy and robustness against spoofing were some of the main focuses during the plenary sessions.

The full results of the UCP 2020 are available via the following link: https://www.euspa.europa.eu/euspace-applications/euspace-users/user-consultation-platform-2020

Preparations for the UCP 2022 have just started and we kindly invite you to stay tuned for more information on the next edition of the UCP.



Outcomes of the UCP are used to compile and update a series of **Reports on User Needs and Requirements** per market segment. The objective of these documents is to constitute a reference for each market segment's user communities by collecting and analysing the most up-to-date GNSS user needs and requirements of the application domains. At the same time these reports themselves serve as a key input to the UCP so that main included outcomes can be validated and subsequently updated.

The latest User Requirements Documents are available via the following link: https://www.euspa.europa.eu/euspace-applications/euspace-users/user-needs-and-requirements

The European Green Deal and beyond

The European Green Deal - climate change as an opportunity to build a new economic model

The European Green Deal is a package of policies and initiatives presented by the EU in 2019 as a central part of the EU strategy to implement the United Nation's 2030 Agenda and its sustainable development goals. It aims to build **a new and green economic model which will transform Europe in the first climate-neutral continent by 2050**, by switching energy, industry and transport to clean tech. This ambitious roadmap towards a climate-resilient society comes in an age when some European economies are still heavily reliant on coal and thus the package is considered one of the most consequential legislative efforts in the history of the European Union; **comprehensive of every aspect of society and the economy and across all policy areas**.

Arguably the best-known objective of the European Green Deal consists of cutting carbon dioxide net emissions to zero by 2050, and already by 55% by 2030 (compared to 1990 levels). And while Europe has already cut a quarter of its emissions since the 1990s, this is hardly enough to reach the 2030 and the 2050 objectives. There is consequently still a long way to go and many other **ambitious and overarching key goals, policies and initiatives** concur to pave Europe's way to sustainability, notably:

- EU Emissions Trading System (EU ETS) to reduce greenhouse gas emissions from the power sector, industry and transport within the EU and national targets for sectors outside emissions trading, such as transport, buildings and agriculture;
- Ensuring European forests and land contribute to the fight against climate change;
- Boosting energy efficiency, renewable energy and governance of EU countries' energy and climate policies;
- Promoting innovative low-carbon technologies;
- Phasing down climate-warming fluorinated greenhouse gases;
- Protecting the ozone layer;
- Adapting to the impacts of climate change; and
- Funding climate action.

EU Space and Green Deal go hand in hand

The EU space ecosystem (Copernicus, Galileo and EGNOS) has been serving aims expressed by the Green Deal for much longer than the Green Deal itself has been around. The world's most advanced Earth observation system **Copernicus** has been monitoring the Earth's environment for some time, providing a unique combination of full, free and open data and services in six thematic areas (land, marine, atmosphere, climate change, emergency management, and security). **EGNOS and GNSS** contribute to the European Green Deal through positioning, navigation and timing used, for instance, in smart farming, as well as for reduction of road, maritime and aviation emissions through route optimisation. Moreover, both Copernicus and Galileo organise competitions and provide funding and support for entrepreneurs using their data, which predominantly results in financing 'green' applications, while stimulating the relevant EO/GNSS markets.

The recent consolidation of the EU Space Programme is aimed at better servicing policy objectives and more efficient development of EU commercial competitiveness. This will also allow exploration of new dynamics for supporting the EU Green Deal. Ongoing initiatives are intended to raise awareness of these contributions. A notable example is EUSPA's challenge 'Our green planet' within myEUspace competition, addressing three thematic areas of the EU Green Deal where space is a true enabler: 'Building a sustainable future', 'Safeguarding our ecosystems', 'Green and digital transformation'.

The full spectrum showcasing how GNSS and EO solutions help tackle the objectives of the European Green Deal is revealed to the reader in numerous instances throughout this Report.

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Green and sustainable investment at the core of our future

Public and private finance is tackling climate change through green and sustainable investments

Driven by growing concern and awareness of the climate crisis, governments, businesses, financial institutions and individuals have taken major actions to ensure a transition towards a more sustainable economy. A key element to guarantee this shift are green investments, focusing on companies or projects addressing environmental concerns.

Tools proposed by the **Organisation for Economic Co-operation and Development (OECD)** and its **Centre on Green Finance and Investment** (established 2016) have UN Sustainable Development Goals (SDGs) and the Paris Agreements at their core. At the European level, the main policy-driven green investment action is the **Sustainable Europe Investment Plan (SEIP)** targeted to support businesses and projects addressing European Green Deal goals. Furthermore, the **European Investment Bank (EIB)** is committing to align all financing activities with the Paris Agreement and doubling its green efforts to reach 50% of its annual financing by 2025.

Similar trends can be seen in the private sector. A green boom is already underway and is expected to increase in the upcoming years, with both small and big investors **raising demand for green funds** which often invest in renewable energy or research. In addition, there is a considerable rise **of investing focused on environmental, social and governance (ESG)** factors, marketed by the asset-management industry. Conventional funds are also 'greening' their portfolios, making green stock no longer a niche concern of some sustainable funds.

The main challenge that needs to be addressed within green investment is the growing **concern of greenwashing**. For public-led investment schemes the proposed solution is a clearly defined taxonomy stating what can or cannot be considered a 'green' investment. For private investors, the landscape is more complex. There is a clear need for more open disclosure of information which could allow for investors to assess the 'green' status of their investments. Fintech companies combining various data sources and AI-powered analysis for private funds could enable more **effective and quantifiable monitoring of green investments.** Similarly, businesses would also benefit from trustworthy ways to measure and display the impact of planned or implemented green corporate investments.

EO & GNSS contribute to compliance, monitoring and efficiency of green investments

As sustainable investing becomes mainstream, many companies must report to their stakeholders on Environmental, Social and Governmental (ESG) indicators. Information derived from space data is a key tool for assessing environmental impacts of business activities, providing quantitative impacts.

This information is available not only to companies but to investors, regulators and the general public, giving a more transparent and trustworthy measure than available from company internal reporting. This will help to differentiate real impacts from 'greenwashing'.

Among other factors relevant to a company's environmental performance, Earth Observation data is used to:

- **Monitor deforestation and biodiversity**, looking at the environmental impact of the commodities that go into a given product;
- **Track pollution**, either by periodically checking a given site for leakages, or by tracing observed spills back to their source.

As well as monitoring progress, EO and GNSS have a key role to play in helping businesses to meet these goals. Key examples include:

- Using precise timing from GNSS to support the use of **smart energy grids**;
- Using information derived from EO to **plan operations of energy generation** so as to optimise their performance;
- Using a combination of EO and observations from GNSS-powered drones to **monitor key infrastructure and optimise maintenance**;
- Using EO and GNSS in tandem to support **efficient supply chain management**.

Digital transformation: the backbone of policymaking

Clear vision heralds EU's transformation for the next decade

In March 2021, the Commission presented a vision for **Europe's digital transformation** by 2030. This vision for the **EU's digital decade** evolves around the four cardinal points within the digital compass: **a digitally skilled population and highly skilled digital professionals; secure and substantial digital infrastructures; digital transformation of businesses; and digitisation of public sectors**. The **EU digital specialisation** is focused on Artificial Intelligence (AI), Cybersecurity, Internet of Things, Big Data, High Performance Computing, 5G, and Software. In addition, **the Digital Europe Programme (DIGITAL)** has a global dimension, where the EU's work on digital policies focuses on various geographical areas. DIGITAL is leading the way in policy areas including digital trade, data sharing, and pushing global companies to behave responsibly online.

Data revolution supported by EO and GNSS

In this context, spatial information is profiling as an integrator, paving the way for a **common, open and innovative digital infrastructure**, rather than a simple point location enabler for applications. **AI-based big-data analysis** promises to also revolutionise the use of satellite data for purposes such as quantifying global urbanisation, supplying data on the nourishment of the world's population and improving the management of natural hazards. Conversion of data collected from space into knowledge is expected to help decision-makers on the ground to design sustainable cities worth living in, or to bring forest fires promptly under control.

Destination Earth

Another outcome of Europe's Digital transformation potentially pooling resources with the EU Space Programmes (and related national initiatives) is Destination Earth (DestinE), which aims to develop a high precision digital model of the Earth to monitor and simulate natural and human activity. Digital twins rely on the integration of continuous observation, modelling and high performance simulation, resulting in highly accurate predictions of future developments to continuously monitor the health of the planet. DestinE will therefore contribute to achieving the objectives of the twin transition, green and digital as well as reinforce Europe's industrial and technological capabilities in simulation, modelling, predictive data analytics, AI and High-Performance Computing (HPC).

DestinE will be developed through the following key milestones:

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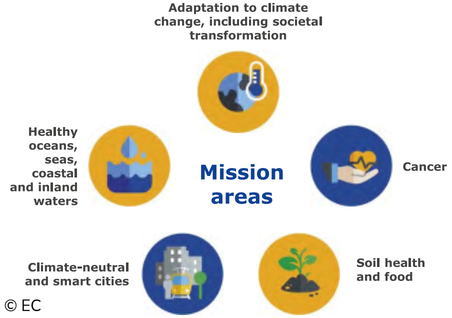
- By 2024: Development of the open core digital platform and the first two digital twins (extreme natural events and climate change adaptation);
- By 2027: Integration of additional digital twins (e.g. of the ocean) for sector specific use cases;
- By 2030: A 'full' digital replica of the Earth through the convergence of the digital twins.

Space programme is contributing to five missions areas defined by Horizon Europe

The EU's key funding programmes for research and innovation have the purpose to tackle climate change, help to achieve the United Nation's (UN) Sustainable Development Goals (SDGs), boost the EU's competitiveness and growth, facilitate collaboration and strengthen the impact of Research and Innovation (R&I) in developing, supporting and implementing EU policies while tackling global challenges.



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Five mission areas have been included in the Horizon Europe Regulation, namely:

1. Adaptation to Climate Change, including Societal Transformation;
2. Cancer;
3. Healthy Ocean, Seas, Coastal and Inland Waters;
4. Climate-Neutral and Smart Cities;
5. Soil Health and Food.

Copernicus, along with improved access to relevant climate science, data and information from other public and private sources and services (e.g. from regional climate projections and predictions, GEOSS and European Research Infrastructures (ERI)), will support regional and local authorities, citizens and other stakeholders to improve their understanding of climate risk.

Climate mitigation and adaptation actions that enhance the resilience of cities should be based on a sound understanding and quantification of the drivers of urban transformation and climate change (as well as policy objectives defined in the SDGs). Here, EO-derived intelligence integrating existing land, atmosphere, climate change and emergency management services can provide the tools necessary to meet the challenges facing European and global cities in the delivery of sustainable development and carbon neutral cities.

The third Horizon mission – to clean marine and fresh waters, restore degraded ecosystems and habitats and decarbonise the Blue Economy – is intended to be reached by 2030. To this end, the Ocean State Report is drawing on the marine monitoring capabilities of the Copernicus Marine Service (CMEMS), and already provides information on changes and variations in the ocean over the past decades with a focus on changes in the marine environment during the previous years. Similar to Ocean Health, Soil Moisture – which is recognized as an Essential Climate Variable (ECV) by the Global Climate Observing System (GCOS) – is being monitored through the Copernicus programme. Additional bio-geophysical products of global land surface such as monitoring of inland water levels and quality, are available through the Copernicus Global Land Service.

Digitalised and resilient supply chains and logistics to respond to more aware, demanding and modern consumers

Consumer patterns and awareness pushing changes along the value chain

The pandemic has changed the way people work, consume, travel and live. Currently, consumers have greater access to digital channels and are benefiting from new business models resultant of the adaptation to restrictions surrounding COVID-19. **Commerce is more than ever an 'on-demand' service accessible 'anytime and anywhere'.** On top of this, the pandemic has introduced the new delivery concept of **OTIFNENC – On Time, In Full, No Error, No Contact**.

With many aspects of our lives being re-evaluated, there is an increase in awareness and interest in **healthcare** and **wellbeing**, as well as focus on more **sustainable ways of consuming goods and food**, ultimately resulting in increased demand for **food traceability and transparent communication throughout agricultural and logistics value chains**. The increased demand for high-quality and local food is promoting shorter and environmentally-conscious value chains.

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Since 2020 the shift from physical shopping to eCommerce has accelerated by five years, according to the US Retail Index from IBM. This boom and the growing demand for same-day delivery will force online retailers to build more hubs and warehouses around the city. Closer warehouses lead to faster deliveries, less transit time and easier access to the e-commerce retailers' last-mile partners (delivering from transportation hub to the final delivery destination).

EO and GNSS supporting adaptation to the changes in value chains

In response to evolving consumption patterns, Earth Observation and GNSS-based location information **support the adaptation to changes in value chains** as explained by selected examples in the following paragraphs.

From the harvest/source location, **GNSS assists tracking food through all steps of the food chain**, including processing and distribution, to the final consumer. Smart technology incorporating GNSS – such as to track the movement of shipments in real time, or embedding sensors in packages (e.g. RFID) in order to monitor their temperature and humidity – **enables companies to provide their customers with the transparency and traceability they desire**. In addition, GNSS information continues to support an increasing number of daily digital operations with **location information used as a security mechanism**.

The rise of on-demand business models or **'uberisation of e-commerce'** consists of digital applications offering consumers services with immediacy and convenience enabled by GNSS location.

GNSS supports **supply chain resilience**. For real-time visibility platforms for shippers, logistics service providers and carriers, integration of **GNSS** results in a powerful tool for logistics companies and supply-chains to better manage delays in crossing borders (for instance those experienced by trucks at European border crossings, especially during the pandemic crisis).

Location information derived from **GNSS allows micromobility** companies (e.g. (e-)bike, scooter sharing scheme operators) **to better manage assets and improve user experience**, facilitating uptake of such services particularly in congested, urban areas. The increased adoption of lightweight, electric or man-powered vehicles (i.e. green transport) goes hand in hand with the **green transition and achieving sustainability related policy goals**.

New approaches are being implemented using spatial data and machine-learning techniques to connect **Earth Observation data** to conventional economic tools in order to help businesses and governments make **more sustainable economic decisions**. For instance, a tool for better science-based policy and informed decision making consists of combining global economic supply-chain data and models with high-resolution spatial datasets on human-driven environmental impacts. Examples include:

- Carbon Tracker and WattTime: both use artificial intelligence and machine learning in combination with high-resolution satellite data to estimate gridded activities and their impacts (global maps of real-time CO_2 emissions from fossil-fuel power plants).
- initiative led by SEI and Global Canopy, Trase: maps supply chains of tropical-forest risk commodities and their embedded deforestation with company-level detail.
- Commodity Risk Platforms, e.g. Global Canopy: screens investment portfolios based on supply-chain information to help banks avoid risk associated with financing deforestation-implicated companies.
- Global Fishing Watch: machine-learning-based systems are used to identify illegality and unsustainable resource-use patterns in the global fishing sector.

AGRICULTURE

Legend
EO application
GNSS application
Synergetic application (combined use of EO and GNSS)

Environmental monitoring
- Carbon capture & content assessment
- Environmental impact monitoring

Natural resources monitoring
- Biomass monitoring
- Crop yield forecasting
- Soil condition monitoring
- Vegetation monitoring

Operations management
- Asset monitoring
- Automatic steering
- CAP monitoring
- Farm machinery guidance
- Farm management systems
- Field definition
- Livestock wearables
- Pastureland management
- Precision irrigation
- Variable rate application

Weather services for agriculture
- Climate services for agriculture
- Weather forecasting for agriculture

Application descriptions can be found in Annex 3.

AGRICULTURE

The use of digital technologies in farm management and across the agricultural sector as a whole is helping to address several farm- and sector-level challenges for farmers, agricultural cooperatives, key decision makers and governments. This ultimately helps to improve farm profitability, address resource-use efficiency and contribute to our sustainability goals.

At the micro level, EO allows farmers to remotely monitor the performance of their crops and reduce their usage of inputs such as fertilizers. At the macro level, EO provides vast amounts of rich data which public authorities and economists can use to better inform their analysis and decision making.

GNSS delivers huge value to the sector by helping farmers precisely guide machinery and track their livestock, ensuring farm operations remain as efficient as possible.

Together, EO and GNSS allow stakeholders to better understand the sector, efficiently address its needs and help in guiding it towards a sustainable future.

What you can read in this chapter

- **Key trends:** Environmental sustainability and economic viability drive the adoption of digital solutions in agriculture.
- **User perspective:** There is significant progress in converging EO/GNSS value proposition to user needs.
- **Industry:** Agriculture Value Chains.
- **Recent developments:** Niche practices gain traction as the world strives to produce more food sustainably.
- **Future market evolution:** New paradigms drive the evolution of food production and land management.
- **Focus on European Systems:** The European space programme supports R&D activities in agriculture.
- **Reference charts:** Yearly evolution of installed base of GNSS devices and revenues as well as EO revenues by application and region.

Environmental sustainability and economic viability drive the adoption of digital solutions in agriculture

Key market trends

- Major investments into innovative agriculture solutions from venture capitalists and corporate giants will shape the market landscape going forward
- The EU Farm to Fork Strategy, a key component of the Green Deal, will be setting the pace for the adoption of sustainable management practices in Agriculture
- The sustainable management of soils and the preservation of biodiversity require advanced solutions powered by GNSS and EO

Copernicus and Galileo are at the heart of the EU Farm to Fork Strategy

The EU Farm to Fork Strategy sets the policy objectives that will govern the EU's efforts towards sustainable food production with a reduced environmental footprint. This is done in an effort to help the world reach its Sustainable Development Goals (SDGs), in particular **Zero Hunger** (SDG 2) and **Climate Action** (SDG 13). In the Strategy, Copernicus and EGNSS feature as invaluable tools for sustainable nutrient management, the protection of soils, the reduction of the use of fertilisers and pesticides, the monitoring of GHG emissions and the preservation of biodiversity. Innovation powered by the EU Space Programme will therefore be critical in achieving these objectives.

Sustainable management of soils

Restoring soil health is a critical challenge recognised by the EU as one of the main missions of Horizon Europe. Soil not only supplies the food we grow and eat, but also provides invaluable ecosystem services such as ensuring we have clean water, maintaining biodiversity and regulating the climate. The importance of maintaining these ecosystems and EO's applicability in this role is further explained in the Biodiversity, Ecosystems and Natural Capital segment.

Satellite-based EO in conjunction with ground measurements (e.g. from the Land Use/Cover Area frame Survey (LUCAS) soil monitoring system) are an essential tool for the monitoring, reporting and verification of soil condition and carbon capture potential – the latter is an area receiving increased attention from market players.

IoT for agriculture

The Internet of Things (IoT) is becoming an increasingly well-known term in day-to-day life. From smart home heating systems to driverless cars, IoT is fast becoming integrated in everyday life and is also increasingly used in precision agriculture. IoT technologies enable farmers to reduce waste and increase productivity through the utilisation of smart sensors and machines that can automate many farm tasks. To this end, Agricultural IoT can be harnessed in everything from precision irrigation systems to self-driving tractors, and even automated crop scouting drones.

HPC for agriculture

Increasing numbers of cutting-edge precision agriculture technologies are driven by the need for: 1) combining a vast plethora of data sources; 2) algorithms optimised for parallel execution; and 3) advanced infrastructural capabilities that can handle the **execution of these big data-enabled algorithms efficiently**. This emphasises the strong user need for High Performance Computing (HPC) infrastructure to tackle the extreme processing requirements. An illustrative example is climate simulation that requires fusion and analysis of satellite-derived earth observation time-series, together with climate forecasts, video streams, sensor information, plant genomics and other diverse data sources. HPC also aids in building the capacity required to make way for the new agricultural revolution known as 'Farming 5.0'. This will exploit artificial intelligence, machine learning, autonomous machinery and big data analytics to drive agricultural practices to higher efficiencies.

Blockchain, EO and GNSS support sustainable supply chain management

Blockchain/Distributed Ledger Technology (DLT) is considered to have huge potential in the agricultural sector. The flow of agriculture commodities has long been subject to controls, regulation and varying checks. Today, there is an **increasing need to track food from source to consumer**, primarily in order to ensure the safety and quality of the produce, but also to implement certain policy objectives (such as deforestation-free commodities, sustainable fisheries, fair trade, organic foods, carbon offsets, etc.). This is where blockchain, in conjunction with EO and GNSS, can ensure the traceability chain is immutable, immediately auditable and entirely digital.

There is significant progress in converging EO/GNSS value proposition to user needs

Key EO and GNSS user requirements

The key GNSS and EO user requirements for the different application groups within the Agriculture segment are, at EU level, collected using the following procedures:

- For GNSS, information is collected through extensive interactions with user groups, providers and experts in a continuous process culminating at the User Consultation Platforms (UCP). All relevant requirements are documented in detail and updated regularly within the Report on Agriculture user needs and requirements.
- User requirements for Copernicus services and products – as well as their evolution – are collected through an integrated process that involves different channels: (i) dedicated studies (e.g. "NEXTSPACE" project, "Copernicus for EC (C4EC)" study, Commission Staff Working Document on user needs), (ii) targeted consultations organised by the European Commission or the Entrusted entities with the relevant communities, (iii) regular and structured exchanges among representatives of the Copernicus governance structure and Member States through the Copernicus User Forum.

From the 2022 EUSPA`s UCP onward, EO user needs and requirements of commercial users will be validated and discussed with industry experts and user groups, mirroring the process implemented for GNSS.

Paying agencies gradually roll out EO/GNSS support for CAP monitoring

Since its adoption in 1962, the Common Agricultural Policy (CAP) has moulded how agriculture in the EU is managed, from keeping food production competitive and secure to ensuring farmers are supported and compensated fairly. The utilisation of EO and GNSS solutions in support of CAP monitoring can be considered as a **success story** regarding the meaningful convergence of user needs with technological capabilities. After years of R&D activities eventually triggered a direct provision for the use of Copernicus and EGNSS in CAP regulation, paying agencies across Europe are currently rolling out fully operational solutions for CAP monitoring powered by data from Copernicus and GNSS-enabled devices. A suite of fully digitised services is offered by innovative companies for a wide range of agricultural activities. These services help paying agencies to reduce the need for on-the-spot checks, whilst simultaneously ensuring that all fields are checked, all subsidy claims are properly processed and all subsidies are correctly distributed. Numerous initiatives exist that aim to drive forward the integration of EO and GNSS into CAP monitoring such as EGNSS4CAP, Sen4CAP and the FaST platform.

sen4cap common agricultural policy

The importance of having a common picture for all value chain actors

A new paradigm of transparency and empowerment is arising due to the value of Copernicus. This is achieved thanks to web applications that allow all actors in a given value chain (e.g. in the potato industry in Belgium) to have a common picture of the status of their crops, the potential effects of climate change, or labour shortages. This allows improved adaptation strategies and forward planning decisions, which in turn help to strengthen the overall output of a given sector, whilst also keeping track of its environmental footprint.

The explosion of venture and corporate-backed investment in Agtech

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Agtech startups have gained an unprecedented level of attention from venture capitalists and corporates who are investing in innovative solutions for sustainable food production. From vertical farming to more 'traditional' precision farming solutions, and from agri-fin-tech to agri-supply chain approaches, each of the last three years has seen a surge in investment.

Many of these companies are making use of EO and GNSS to develop advanced analytics and enable automation, both of which are achieving better reliability and opening new capabilities thanks to machine learning methods. This evolution is accompanied by changes in the business models deployed in the sector, with more companies seeking to provide underlying capabilities (e.g. analytics platforms using EO for vegetation monitoring, soil moisture, etc.) to other actors in the value chain using a white-label approach.

Agriculture Value Chains[1]

EARTH OBSERVATION

INFRASTRUCTURE PROVIDERS

- AWS
- CLOUDEO*
- COPERNICUS DIAS*
- GOOGLE CLOUD PLATFORM
- IBM CLOUD
- INTEL GEOSPATIAL
- MICROSOFT AZURE
- PENGUIN COMPUTING

- COPERNICUS COLLABORATIVE GROUND SEGMENT*

DATA PROVIDERS

- AIRBUS*
- BLACKSKY
- COPERNICUS DIAS*
- DESCARTES LABS
- E-GEOS*
- EARTH-I*
- ICEYE*
- MAXAR
- PLANET
- ZHUHAI ORBITA

- COPERNICUS SENTINELS*
- USGS/NASA LANDSAT
- RELEVANT IN-SITU NETWORKS

PLATFORM PROVIDERS

- ADAM*
- BEIJING PIESAT INFORMATION TECHNOLOGY COMPANY
- CLEOS*
- CLOUDEO*
- COPERNICUS DIAS*
- MAXAR
- NOR*
- PLANET EXPLORER
- SINERGISE* (SENTINEL HUB)
- TERRADUE*
- UP42*
- VITO*

- FAST*
- FOOD TEP*

EO PRODUCTS AND SERVICE PROVIDERS

- E-GEOS*
- EARTH DAILY
- FARMSTAR
- FIELDSENSE*
- GAF*
- GEOVILLE*
- GMV*
- KAPPAZETA*
- SATAGRO*
- SATELLIGENCE*
- SENCROP*
- SINERGISE*
- TALKINGFIELDS*
- VITO*
- VULTUS*

- COPERNICUS SERVICES*

INFORMATION PROVIDERS

FARM MANAGEMENT SERVICES:

- 365FARMNET*
- AGRIVI*
- AGWORLD
- CROPWISE
- FARMERP
- GRANULAR

SECTOR SPECIFIC SERVICES:

- GAMAYA* (SOY, SUGAR CANE)
- GEO4A* (POTATO)

END USERS

- AGRI-INSURERS
- AGRICULTURAL CONSULTANTS
- AGROCHEMICAL MANUFACTURERS
- AGRONOMISTS
- COOPERATIVES
- ENVIRONMENTAL AGENCIES
- FARMERS
- FOOD PROCESSORS
- INTERNATIONAL AGENCIES (E.G. FAO, WFP...)
- PAYING AGENCIES
- WINE PRODUCERS

LEGEND

- Commercial Offering
- Public Offering
- User segments

GNSS

AUGMENTATION SERVICE PROVIDERS

- DEERE & CO
- GEOFLEX*
- HEMISPHERE
- HEXAGON AB*
- TOPCON CORPORATION
- TRIMBLE NAVIGATION LTD

- NATIONAL AND REGIONAL RTK NETWORK PROVIDERS

COMPONENT AND RECEIVER MANUFACTURERS

- AGJUNCTION INC
- ARAG S.R.L*
- AVMAP S.R.L*
- BEIJING UNISTRONG SCIENCE & TECHNOLOGY
- CNH INDUSTRIAL N.V.*
- COMNAV TECHNOLOGY LTD
- DEERE & CO
- HARXON
- HEXAGON AB*
- RAVEN INDUSTRIES INC
- TOPCON CORPORATION
- TRIMBLE NAVIGATION LTD

SYSTEM INTEGRATORS

- AGCO CORP
- BERNARD KRONE HOLDING GMBH & CO*
- CLAAS CGAA MBH*
- CNH INDUSTRIAL N.V.*
- DEERE & CO
- J.C.B SERVICE*
- KUBOTA CORPORATION
- MAHINDRA & MAHINDRA LTD

END USERS

- AGRI-INSURERS
- AGRICULTURAL CONSULTANTS
- AGROCHEMICAL MANUFACTURERS
- AGRONOMISTS
- COOPERATIVES
- ENVIRONMENTAL AGENCIES
- FARMERS / CONTRACTORS
- FOOD PROCESSORS
- INTERNATIONAL AGENCIES (E.G. FAO, WFP...)
- PAYING AGENCIES
- WINE PRODUCERS

The European[2] EO and GNSS industry in the global arena

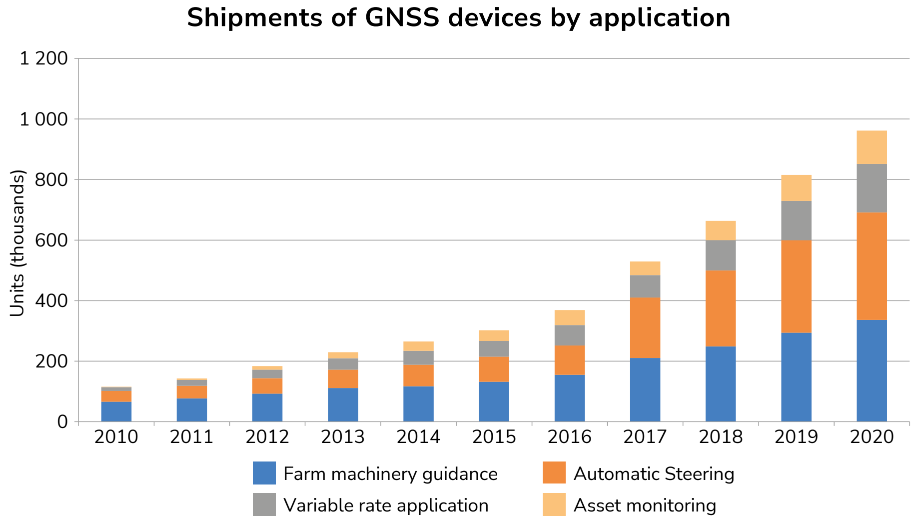
Whilst North America dominates the data processing and analysis, insights & decision support markets, European companies are close behind with 31% and 43% market shares respectively. The biggest European companies are Leondardo (parent company of e-GEOS) (IT), Airbus (NL), GMV (ES) and VITO (BE).

European companies such as Hexagon, CNH, Avmap and Arag hold a combined total of 22% of the total agriculture GNSS receiver market, the vast majority of which (19%) is held by Hexagon alone.

NOTES

[1] The value chain considers the key global and European companies involved in GNSS and EO downstream activities.
[2] In the market share analysis, Europe is defined as EU27 plus Norway, Switzerland and the UK.
* European-based companies. The region is defined with respect to the headquarters of the company, though the actual area of activity might be wider.

Niche practices gain traction as the world strives to produce more food sustainably



Overall, **shipments of GNSS receivers over the past decade have exhibited a very strong growth trend**, from 100,000 units shipped across all applications in 2010 to almost 1,000,000 units shipped annually just a decade later.

During the first half of the decade, **farm machinery guidance was the dominant application**. However, automatic steering has subsequently gained market share year on year as advanced steering systems have seen take-up among end users. In fact, in 2019 and 2020, automatic steering overtook farm machinery guidance as the most popular application, with around 350,000 units shipped worldwide in 2020.

The **increasing popularity of automatic steering** stems from the accuracy and real-world value that this application creates for end users, by improving machinery control and to use farming inputs such as fertilisers and pesticides more efficiently.

Finally, 2020 saw farm machinery guidance account for over 320,000 shipments, whilst variable rate application shipments accounted for just under 200,000 units. Shipments for asset management reached 100,000 units.

Organic farming benefits from EO and GNSS solutions

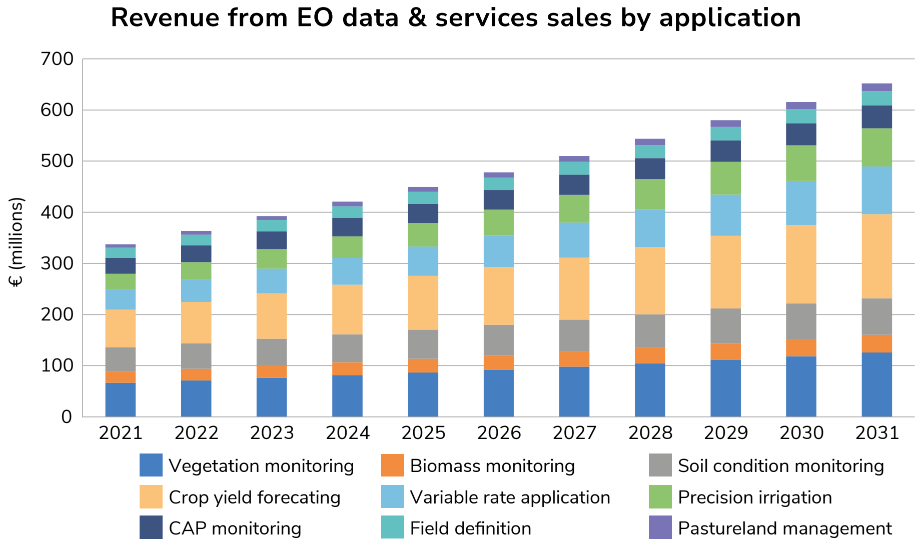
Organic agriculture must be certified in order to differentiate itself from conventional agriculture, and gain the confidence of consumers. Certification control is therefore a condition that organic farmers have to fulfil in order to benefit from economic support. Currently, certification controls are mainly based on the verification of farmers' accounting records. The reliability of accounting control becomes more questionable when a farmer practices both organic and conventional agriculture on their land. EO and GNSS technologies have the potential to enable efficient, cheap, rapid and accurate organic certification control.

ESA has been working with Ecocert, an organic certification organisation, to use satellite images to spot differences between conventional and organic farming in order to support the certification process. Multi- and hyperspectral satellite imagery are used to derive several indicators based on biophysical justification and crop management practices to differentiate between these methods. GNSS can complement EO technologies in defining boundaries and zoning organic produce.

The 'Internet of Animals' enabled by livestock wearables

Ear tags, collars, ankle and tail bracelets, belly belts – all these 'wearables' serve as the farmer's eyes, allowing them to continuously monitor and efficiently manage their livestock through smartphone apps. This technology is not just a trend enjoyed by tech-savvy farmers, but is increasingly becoming a necessity, given the global need for more food and the need to control the associated carbon footprint. To manage this, farmers make use of these wearables – which, thanks to GNSS, allow precise localisation of animals and the implementation of virtual fencing – whilst also monitoring the animals' welfare through a range of additional sensors. As a result, farmers can reduce labour costs, increase protein yield, keep their animals healthy and their land optimally used. This approach, while not new, has seen a significant boost in recent years thanks to advances in underlying technology (e.g. miniaturisation, power, connectivity, etc. through technologies such as Narrowband IoT). There are currently around 300 manufacturers of livestock wearables in the world -- while the highest percentage are in China, the USA (a close second) is also a major innovator. Over the coming decade, the number of manufacturers of livestock wearables is expected to rise to 500 as the market value increases more than 2.5 times. This translates into increased investments in and revenues for livestock wearable companies, and the clients they serve.

New paradigms drive the evolution of food production and land management



Revenues from EO data and service sales in agriculture are expected to steadily grow in the coming decade, from a combined total across all applications of €337 m in 2021 to €652 m in 2031.

The applications with the largest market share at present are crop yield forecasting, vegetation monitoring, soil condition monitoring, CAP monitoring, variable rate application, and precision irrigation. When combined, the operational applications of variable rate application of farming inputs and precision irrigation make up the second largest share of the market both now and in the future, accounting for over €70m in 2021 and almost €168 m in 2031.

Crop yield forecasting is expected to retain a substantial market share year on year, given the value it brings not only to farmers, but also to other actors in the agricultural value chain such as economists, financial traders and public authorities concerned with the maintenance of food security.

EO solutions in support of Carbon Farming

The current CO_2 storage imbalance between the atmosphere stock and the ground storage stock is an imminent and immediate threat to our economies and ways of life. Almost half of the EU's surface area is use for agriculture, and the surface layers of the farmlands store many times more carbon than the EU annually emits into the atmosphere. These carbon stocks must be maintained and increased. With the right farming practices, agricultural land can absorb more carbon from the atmosphere.

EO technologies are being used to monitor and maintain agricultural practices that increase carbon stocks, such as the maintenance of permanent grasslands. 'Carbon Farming' is a relatively new term that refers to the monitoring and management of increased CO_2 absorption in farm soil. This can be achieved in many ways, such as the use of carbon-rich fertilisers, reduced tillage or better crop rotation. Through the use of EO, large geographic areas can be constantly monitored, meaning Carbon Farming incentive schemes can operate much more efficiently, reducing inspection costs and helping to increase compliance. Developments in setting up carbon farming schemes are moving fast. For instance, in 2021 the European Commission published a comprehensive technical guidance handbook for implementing result-based carbon farming mechanisms. These included approaches to carbon credit trading schemes for farmers. Carbon farming is a promising candidate for helping to meet future greenhouse gas emission targets and will undoubtedly become more prevalent in the near term.

Farming in extreme environments requires frontier tech

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Intensified agricultural production (particularly if implemented with poor practices), climate change and deforestation is putting 20% of the world's arable land under the threat of desertification. As a result, new paradigms such as vertical farming have gained significant attention in recent years. This sees the production of food on vertically inclined surfaces in a controlled environment (e.g. indoors).

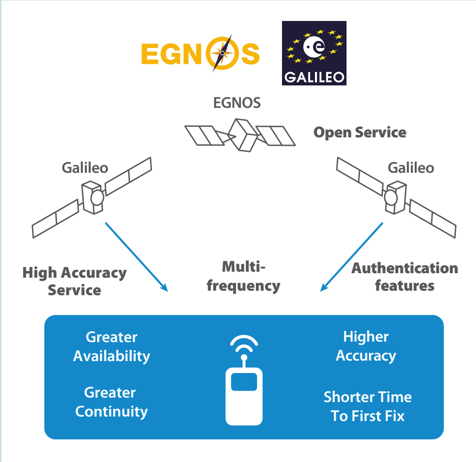
Whilst more energy-demanding than traditional farming, the fact that it can be deployed in unlikely settings (i.e. in cities) and that food is grown locally (which means low transportation costs) makes vertical farming particularly promising. This is why large investments have recently been made in vertical farming and in the technologies that can support it.

For these technologies, GNSS-aided robots may become commonplace in the future of vertical farming. Desert farming is another important trend on the rise. Whilst at a very early stage of development, solutions such as liquid nano clay and root zone irrigation may open up unprecedented opportunities to farm arid zones and desert areas.

The European space programme supports R&D activities in agriculture

Current usage of EGNSS

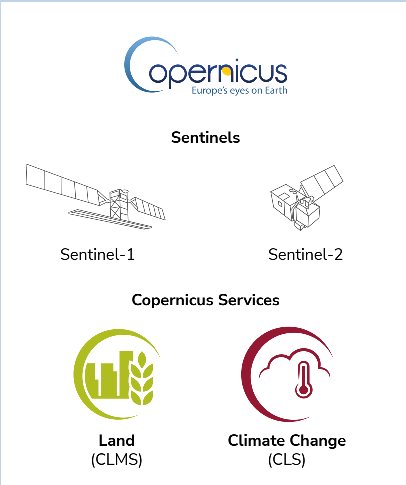
Farmers across the globe can strongly benefit from the added value enabled by Galileo. Its continuously increasing adoption in agriculture is reflected in the proliferation of Galileo-enabled receivers for machine guidance applications. Moreover, all major agricultural machinery manufacturers are 'Galileo-ready', while most augmentation service providers and device vendors are also incorporating Galileo in their offering. Galileo will also offer increased robustness to spoofing thanks to its Commercial Authentication Service (CAS) and the Open Service Navigation Message Authentication (OSNMA). As the use of robotics and autonomous vehicles is increasing in agriculture, so will the importance of this Galileo differentiator.



Current usage of Copernicus

Copernicus Sentinels 1 and 2 have brought about a revolution in the agricultural sector, providing world-class data in a free and open manner for multiple agricultural applications at an adequate resolution and appropriate revisit time. A host of innovative companies are making use of Sentinel data to provide farm management support, soil moisture measurements and agricultural supply chain insights.

Additional products from the Copernicus Land Monitoring Service (CLMS) (e.g. land use/land cover and various indices) as well as products from the Copernicus Climate Change Service (C3S) (e.g. temperature and precipitation) also contribute to agricultural activities.



HORIZON 2020

SCORPION

Automated precision spraying for crops

© SCORPION project

Agriculture faces the constant huge challenge of reducing phytopharmaceutical usage while maintaining crop yield, efficiency and value.

The SCORPION project's objective is to develop a safe and autonomous precision spraying tool integrated into a modular unmanned tractor (robotics platform) to increase spraying efficiency while reducing human and animal exposure to pesticides, and reducing water usage and labour costs. The project will primarily focus on steep-slope vineyards and other high-value permanent crops. SCORPION will fuse EGNSS receivers (triple frequency, PPP, OSNMA, HAS) with various other smart sensors. This fusion will increase the solution reliability, accuracy and safety in an effort to enable autonomous ultraviolet light treatments and high precision spraying in permanent crops.

More information available at: https://scorpion-h2020.eu/

HORIZON 2020

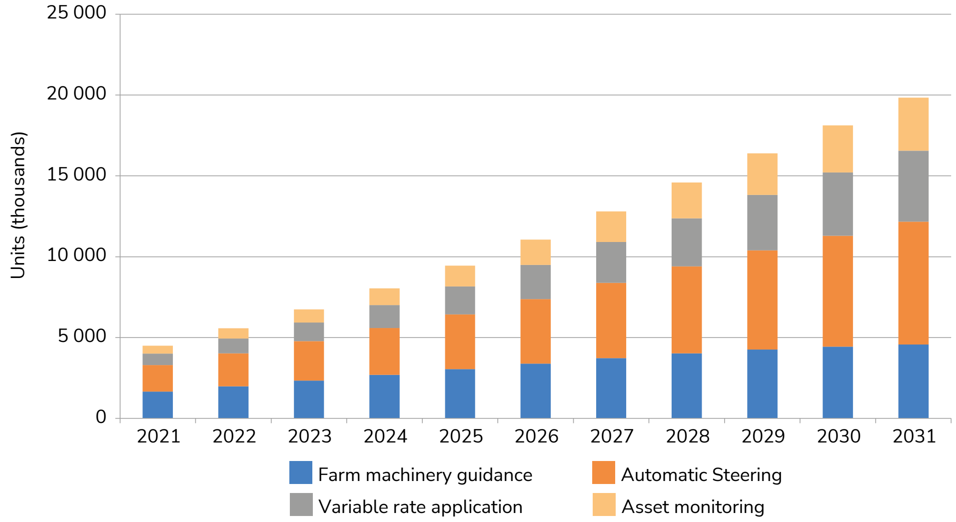
DIONE

EO powered tools to modernise CAP subsidy management

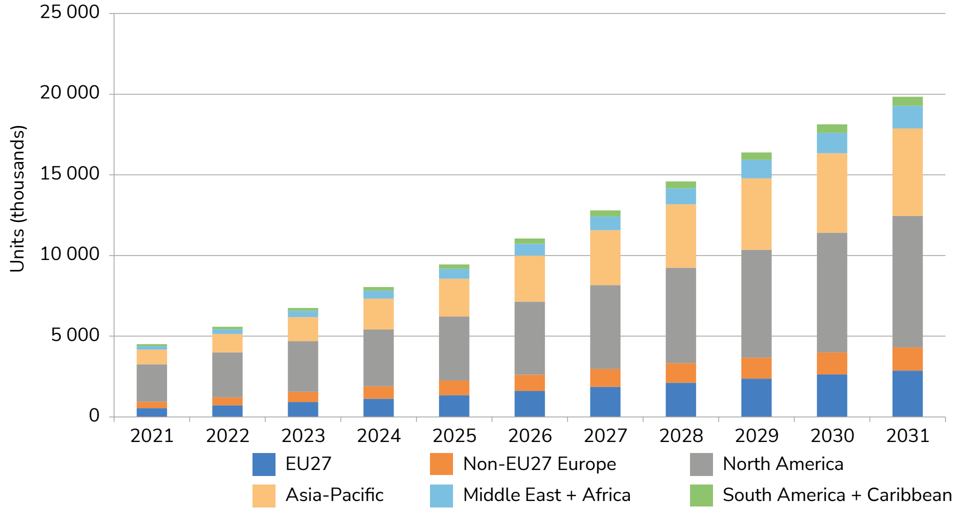
DIONE is a Horizon 2020 funded project that offers a unique fusion of innovative technologies that improves the workflow of agricultural monitoring. DIONE is developing a direct payment controlling EO-based toolbox for paying agencies to abide by the modernised CAP. As part of its ongoing move to simplify and modernise CAP, the European Commission has adopted new rules to allow a range of modern technologies to be used when carrying out checks for area-based CAP payments. For instance, new satellite technology will reduce the number of field inspections and the costs for administering controls and checks. Building on these advances, the DIONE project is developing a machine learning-based system that will evaluate current soil quality levels to form evidence-based conclusions regarding eventual environmental impacts across entire regions.

More information available at: https://dione-project.eu/

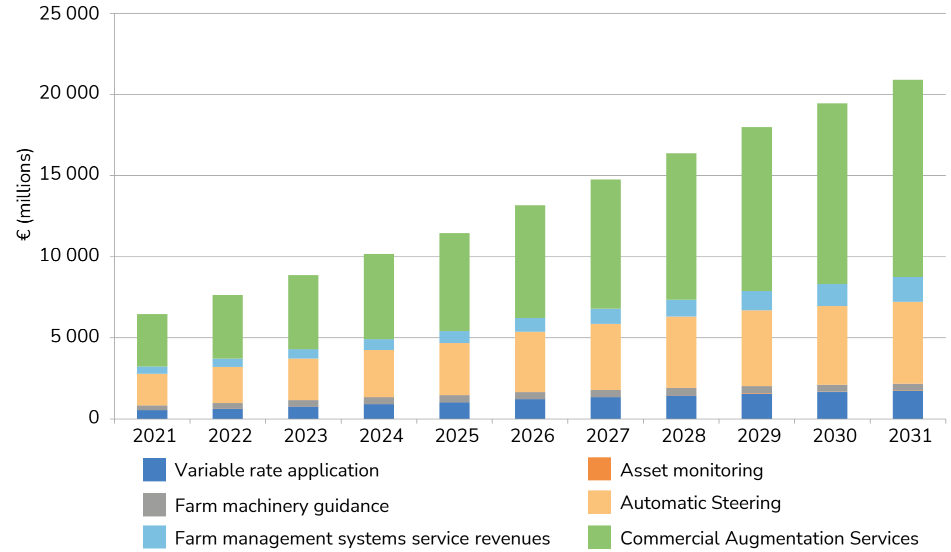
Installed base of GNSS devices by application



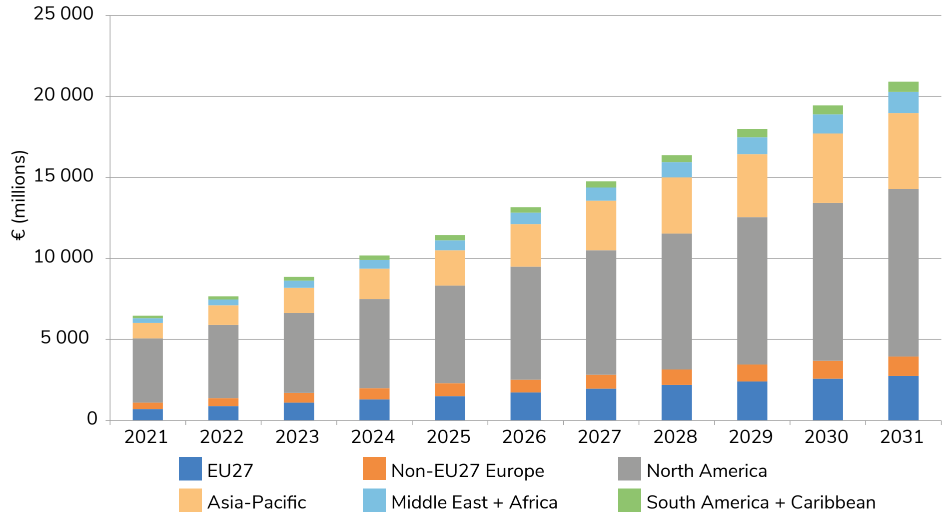
Installed base of GNSS devices by region



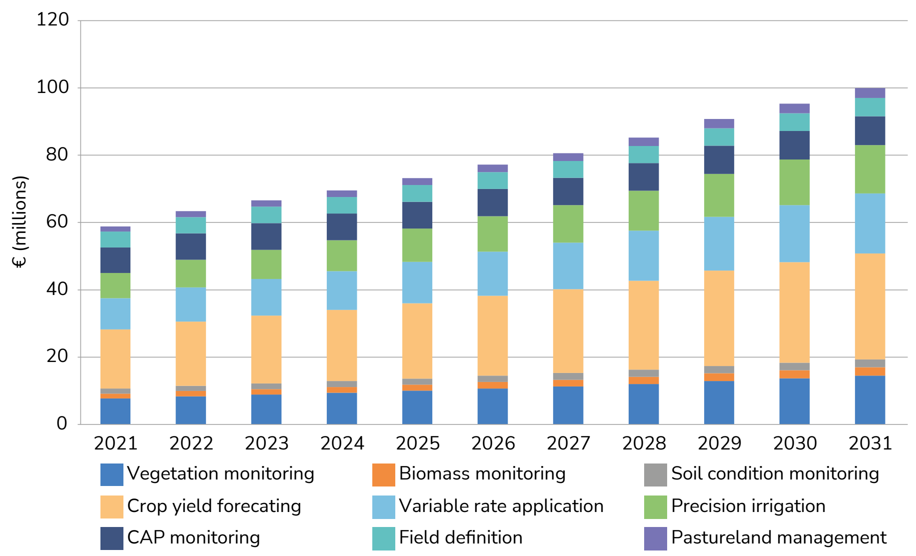
Revenue of GNSS device sales and services by application



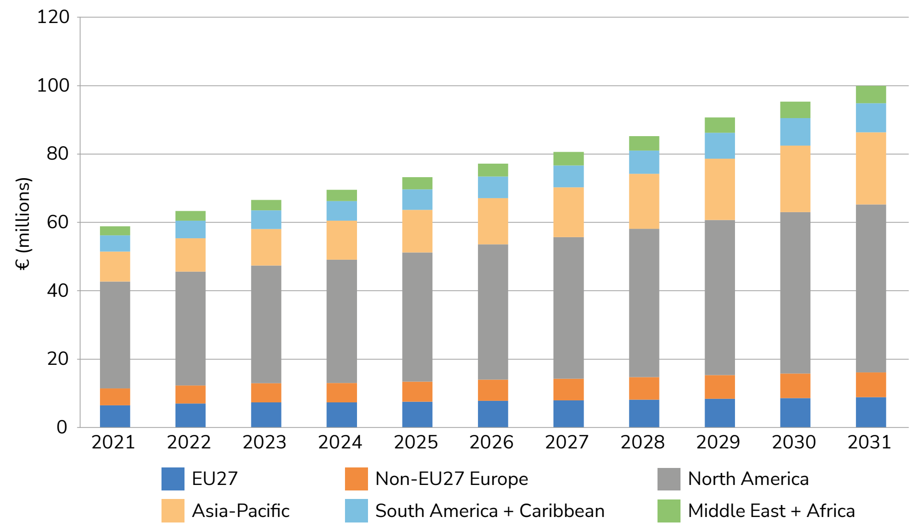
Revenue of GNSS device sales and services by region



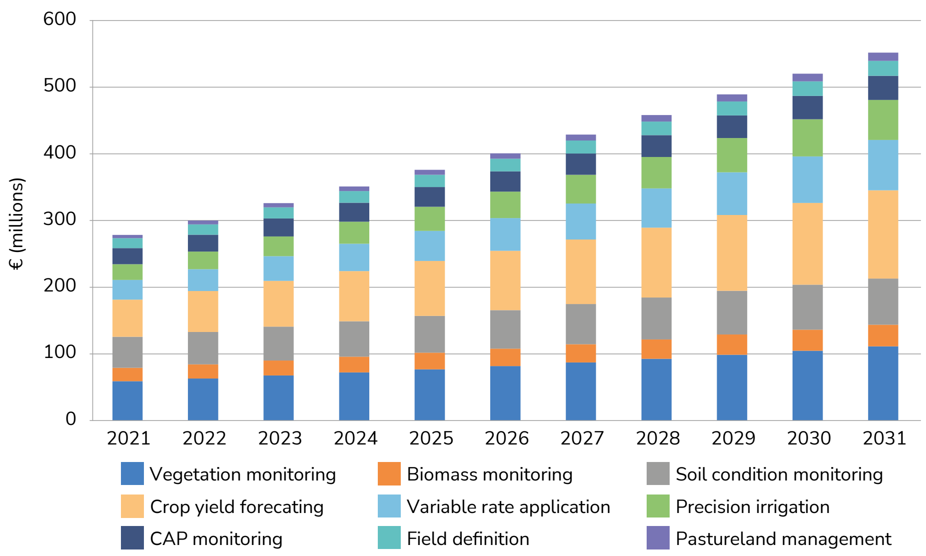
Revenue from EO data sales by application



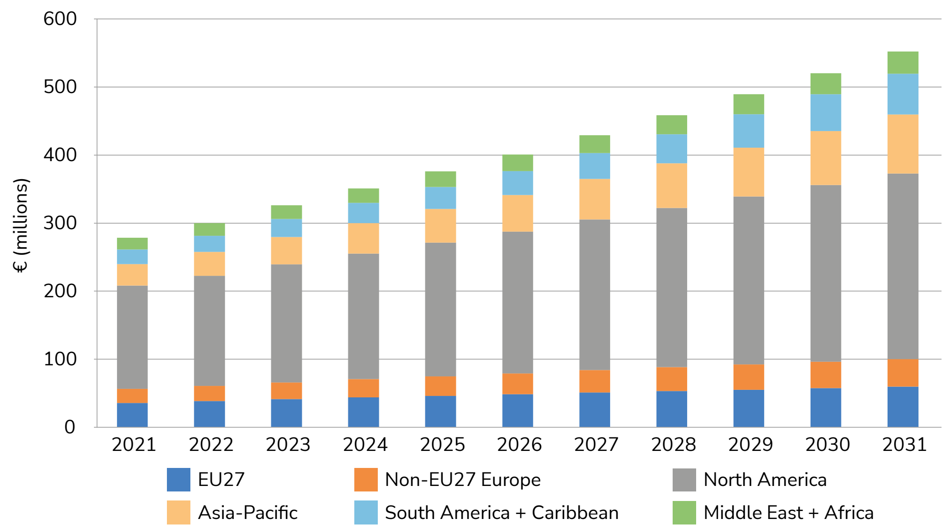
Revenue from EO data sales by region



Revenue from EO services sales by application



Revenue from EO services sales by region



AVIATION AND DRONES

Legend
EO application
GNSS application
Synergetic application
(combined use of EO and GNSS)

Communication
- ATM System Timing

Environmental Monitoring
- Aircraft Emission Measurement and Monitoring
- Particulate Matter Monitoring

Navigation
- Drone navigation
- Performance Based Navigation (PBN)
- VFR[1] complement

Operations Management
- Aircraft Maintenance and Operation Optimisation
- Airport Capacity and Safety
- Monitoring Terrain Obstacles near an Airport

Surveillance
- Electronic Conspicuity
- GADSS[2]
- Infrastructure Timing

Weather Services
- Hazardous Weather Identification

[1] Visual flight rules
[2] Global Aeronautical Distress & Safety System

Application descriptions can be found in Annex 3.

AVIATION AND DRONES

Aviation is one of the main drivers behind increasing global connectivity. In comparison, drones are a relatively recent technology which can put a payload anywhere it is needed. The aviation and drones segment encompasses services and products used by aviation and drone operators and industry. This includes airlines, pilots, helicopter operators, drone operators, airports and air navigation service providers.

Aviation uses GNSS extensively, with Satellite-Based Augmentation Systems (SBAS) providing better access to small and medium airports through Performance Based Navigation procedures, increasing safety and enabling business growth across Europe. GNSS is the primary source of navigation for aviation and drones, and meets the present-day performance requirements for all airspaces, from low-level to sub-space. GNSS supports advances in urban air mobility with evaluation of flight risk (e.g. geofencing, populated area avoidance, landing site optimisation), automation and tracking through position self-reporting (known as Electronic Conspicuity).

Combining GNSS and EO data advances emissions monitoring systems. EO itself enables the monitoring of volcanic ash clouds, emissions, terrain (supporting optimised routing), flight procedure development and flight planning. This benefits airlines, leisure pilots, drone operators, airports, air traffic control and public agencies serving global aviation communities.

What you can read in this chapter

- **Key trends:** COVID-19 indirectly accelerates GNSS capabilities.
- **User perspective:** : The dependency on GNSS and integration with EO is increasing.
- **Industry:** Aviation and Drones value chains.
- **Recent developments:** GNSS capabilities are growing to meet evolving requirements for navigation, surveillance and sustainability.
- **Future market evolution:** Aviation and particularly newly emerging drone sub-markets need advanced GNSS and new alternative Positioning, Navigation and Timing (PNT) solutions.
- **European Systems:** EGNSS and Copernicus current usage.
- **European Projects**: Latest EC and EUSPA project initiatives.
- **Reference charts:** Yearly evolution of installed base of GNSS devices and revenues by application and region.

COVID-19 indirectly accelerates GNSS capabilities

Key market trends

- GNSS and Performance-Based Navigation (PBN) implementation deployment significantly affected by COVID-19 impact on air traffic
- European push on drone regulations and unlocking Urban Air Mobility
- Drone use for delivery of medicines during COVID-19 crisis
- Assessment of COVID-19 pandemic: Monitoring European air traffic with EO

COVID-19 indirectly accelerates PBN modernisation

The recent COVID crisis has had a major impact on the volume of air traffic flying over Europe and globally. Reports from IATA, CANSO, A4E, AIRE, ERA and the Network Manager have all pointed to a significant air traffic **decline** of around **65% in 2020** relative to 2019. Although painful for the industry, this has also resulted in consolidation of PBN operations with changes in the utilised aircraft fleet, necessitated by the changing economics post-COVID. Several airlines accelerated the **retirement of older aircraft** with fewer GNSS capabilities. Others placed large orders for new aircraft with improved environmental efficiency and the avionic capabilities. These more modern fleets increased the proportion of flights flying with Localiser Performance with Vertical Guidance (LPV) capability within Europe from 14% prior to the pandemic to 24% post pandemic.

This has also provided an opportunity for work to continue on the deployment of PBN capabilities that will help to deliver capacity and environmental benefits when traffic returns to normal levels. Indeed, the actors above established a Continuous Descent Operations (CDO) / Continuous Climb Operations (CCO) **Task Force** to facilitate and encourage PBN solutions such as CDO/CCO and more direct routings, which reduce the environmental impact of aviation. These will help to **provide more efficient capacity** in the system for when air traffic volumes return to previous levels.

At the same time, PBN utilisation by rotorcraft and general aviation is gathering momentum. More operators are adopting PBN, for example enabling hospitals to support cloud break procedures based on GNSS, or through procedures for small aircraft to approach smaller airfields leveraging EGNOS. A shortage of guidance material, pilot cases and regulatory challenges constrain wider uptake which remains a focus to provide improved access, connectivity and resilience surrounding weather interruptions.

European regulations unlocking drones and Urban Air Mobility

In 2020 and 2021 major steps have been taken by the European Commission and the European Union Aviation Safety Agency (EASA) to further support the drone industry with the publication of clear regulations laying the foundation for approvals and new operations in the future.

The adoption of the **first regulatory framework for U-space** (Commission Implementing Regulation (EU) 2021/664, 2021/665 and 2021/666) sets out provisions for Unmanned Aircraft Systems (UAS) operators, U-Space Service providers (USSP) and providers of common information services (CIS). **Registration** of UAS operators and certified drones also became **mandatory** in Europe **from July 2020** (Regulation (EU) 2019/947). Registration is part of U1 services on the U-space blueprint from Single European Sky ATM Research (SESAR), which also includes geofencing facilitated by Drone navigation and guidance. U2 services include tracking (facilitated by Electronic Conspicuity) and flight planning (which would further benefit from the Hazardous Weather Identification).

Trials are being undertaken in several locations to demonstrate the feasibility and benefits of drone operations and Urban Air Mobility (UAM). The trials' results will help with the next steps on standardisation and awareness of the issues needed to enable further integration with traditional aviation. The COVID-19 pandemic and the necessity for social distancing has accelerated implementation of measures widening the use of drones in civil, commercial and social applications, especially in the **delivery of medicines** for medical home care. Drones have also been utilised in aerial spraying of public areas for precautionary disinfection. These applications will likely expand in the context of the new regulatory framework.

Growing utilisation of earth observation in aviation

Mapping data is of paramount importance to support the implementation of PBN procedures. From a **sustainability** perspective, the ability to utilise **EO data** has expanded from monitoring terrain and obstacles to **supporting environmental impact assessment**. Meteorological observations, including from EO, support compliance with planning requirements for new runways and airports (e.g. runway orientation and assessment of cloud base / visibility in combination with the wind direction to determine availability). The use of EO for monitoring upper atmosphere meteorological conditions is also important to support effective and safe flight planning – especially for phenomena that are not detectable with onboard equipment.

Practical recent demonstrations of the use of EO in the COVID-19 pandemic included the **monitoring of air traffic in Europe** using imagery from EO satellites integrated with 'Rapid Action on COVID-19 and EO' (RACE), which provides an economic indicator to track the number of parked aircraft compared to the baseline. Resulting data showed a 90% reduction in movements.

The dependency on GNSS and integration with EO is increasing

Key EO and GNSS user requirements

The key GNSS and EO user requirements for the different application groups within the Aviation and Drones segment are, at EU level, collected using the following procedures:

- For GNSS, information is collected through extensive interactions with user groups, providers and experts in a continuous process culminating at the User Consultation Platforms (UCP). All relevant requirements are documented in detail and updated regularly within the Report on Aviation user needs and requirements.
- User requirements for Copernicus services and products – as well as their evolution – are collected through an integrated process that involves different channels: (i) dedicated studies (e.g. “NEXTSPACE” project, “Copernicus for EC (C4EC)” study, Commission Staff Working Document on user needs), (ii) targeted consultations organised by the European Commission or the Entrusted entities with the relevant communities, (iii) regular and structured exchanges among representatives of the Copernicus governance structure and Member States through the Copernicus User Forum.

From the 2022 EUSPA`s UCP onward, EO user needs and requirements of commercial users will be validated and discussed with industry experts and user groups, mirroring the process implemented for GNSS.

A focus on deployment of U-Space

In the context of the new European regulations[1] on drones, there has also been a push toward supporting systems that are able to help monitor the positions of drones and to provide a service that supports **access to airspace** without relying on **temporary segregation techniques** that can inconvenience other airspace users. This depends on the deployment of GNSS as the only ubiquitous Position Velocity Time (PVT) solution available in drones due to size and power constraints - and is also the case for certified drones, although they may also depend on traditional terrestrial based aviation solutions.

These applications enabling drone traffic management are also underpinned by GNSS positioning on smartphones and within the drones themselves. This supports the planning and execution of missions. These operate similar to the ‘moving map’ applications used today by manned aviation and are designed to help users understand and avoid temporary and permanent airspace restrictions.

The planning and execution of missions also needs to account for operation risk based on location, such as obstacles to aviation in the vicinity, risks from overflight, and proximity to people and property. This relies on **accurate, up-to-date** information which itself can be dependent on frequency of **satellite-based mapping** and identification of specific features.

Earth Observation data supports GNSS based applications

All aviation depends on **reliable positioning information**, both in terms of current location and direction of travel. GNSS has made this information more intuitive across the whole industry, especially with the introduction of moving map displays. At International Civil Aviation Organisation (ICAO) level the requirements for terrain and obstacle data to be available electronically have started to shift focus **toward utilising satellites for data acquisition**. Today, this satellite-derived topographical data enables all flight procedure analysis, particularly with regard to safety in relation to any proximate terrain or obstacles.

Further benefits have been realised in the aftermath of volcanic eruptions, showing the value of utilising satellite data to **avoid ash clouds**, protecting aircraft engines from possible inflight failure. GNSS proves equally relevant and beneficial in the industry from an environmental perspective, supporting assessment of aviation emissions and sustainability and local aerodrome impacts such as land and flooding risks, airfield air pollution and environmental planning.

The use of EO coupled with GNSS-derived data by drones supports **collision** and **population risk assessments** and is more important in the more dynamic environment in which drones may operate compared to traditional aviation. More frequently updated datasets, derived for aviation purposes, are essential to allow planning of aviation infrastructure, development of databases for map-based systems (e.g. moving maps, Unmanned Aircraft System Traffic Management (UTM) and terrain avoidance systems) coupled with GNSS data for positioning in relation to maps, flight procedure design and surveillance infrastructure. Procedure design and placement of surveillance infrastructure such as radars, terrain and obstacles (trees, buildings, etc.) are essential information that is used in pre-implementation assessments.

[1] https://www.easa.europa.eu/document-library/easy-access-rules/easy-access-rules-unmanned-aircraft-systems-regulation-eu

Aviation and Drones GNSS Value Chain[1]

COMPONENT AND RECEIVER MANUFACTURERS

DRONES
GNSS CHIPSETS
- HEXAGON AB*
- NOVATEL
- QUALCOMM
- SEPTENTRIO*
- U-BLOX*
- INFINEON *
- TRIMBLE
- DJI BAIWANG
- VECTORNAV

AVIATION
- AVIDYNE CORP
- AZIMUT
- BEIJING BDSTAR NAVIGATION
- COBHAM *
- GARMIN
- HONEYWELL
- LEONARDO FINMECANICA *
- NORTHROP GRUMMAN CORPORATION
- OROLIA *
- SAFRAN *
- SBG SYSTEMS *
- SENSOR SYSTEMS
- TECHTEST *
- THALES AVIONICS*
- TRIG AVIONICS*
- UNIVERSAL AVIONICS

AIRCRAFT & DRONE MANUFACTURERS

DRONES
FIXED WING
AIRBUS*, ALTAVISION*, DELAIR*, MARQUES AVIATION*
MULTI-ROTOR
3D ROBOTICS, DJI, EUPHORIX*, PARROT*, YUNEEC
SINGLE ROTOR
BABCOCK*
VTOL FIXED WING
AEROVINCI*, AITI, ATMOS UAV*

AIRLINE MANUFACTURERS
- AIRBUS*
- ATR*
- BOEING
- COMAC
- BOMBARDIER
- EMBRAER

BUSINESS, ROTORCRAFT AND GENERAL AVIATION MANUFACTURES

URBAN AIR MOBILITY
- LILIUM
- UBER
- VOLOCOPTER

DRONE OPERATORS & AIRLINERS / AIRCRAFT OWNERS

DRONE OPERATORS
- CYBERHAWK
- HEMAV*
- MANNA*
- NASA
- SKYFUTURES*
- WING

MAIN AIRLINES ALLIANCES
- ONEWORLD
- SKYTEAM
- STAR ALLIANCE

USER GROUP ASSOCIATIONS
- AIRCRAFT OWNERS AND PILOTS ASSOCIATION (AOPA)
- AIRLINES FOR EUROPE (A4E)
- EUROPEAN AIR SPORTS
- EUROPEAN BUSINESS AVIATION ASSOCIATION (EBAA)
- EUROPEAN HELICOPTER ASSOCIATION (EHA)
- EUROPEAN REGIONS AIRLINE ASSOCIATION (ERA)
- INTERNATIONAL AIR TRANSPORT ASSOCIATION (IATA)
- INTERNATIONAL AIR CARRIER ASSOCIATION (IACA)
- PPL/IR

UTM SERVICE PROVIDERS & ATM DATA SERVICE PROVIDERS & AIR NAVIGATION SERVICE PROVIDERS

MAIN ORGANISATIONS
- GLOBAL UTM ASSOCIATION
- INTERNATIONAL CIVIL AVIATION ORGANISATION (ICAO)

MAIN ORGANISATIONS
- CIVIL AIR NAVIGATION SERVICES ORGANISATION (CANSO)
- INTERNATIONAL CIVIL AVIATION ORGANISATION (ICAO)

AERODROMES & INFRASTRUCTURE OPERATORS

DRONE INFRASTRUCTURE PROVIDERS
- AIRBUS*
- SKYPORTS*

INTERNATIONAL AIRPORTS
PRIVATE AIRPORTS
REGIONAL AIRPORTS
ASSOCIATIONS
- AIRPORTS COUNCIL INTERNATIONAL (ACI)

European[2] GNSS industry in the global arena

Within the aviation segment, European and North American organisations continue to dominate manufacturing of GNSS receivers for aviation (>95% of the market) in 2019 with North American receiver suppliers supplying 85% and European suppliers 14%.

The picture is more mixed when it comes to drones, with shares depending on the sophistication of the drone platform. Overall the Asian share is 47% with the European share at 10%.

* European-based companies. The region is defined with respect to the headquarters of the company, though the actual area of activity might be wider.

[1] The value chain considers the key global and European companies involved in GNSS downstream activities.

[2] In the market share analysis, Europe is defined as EU27 plus Norway and Switzerland.

Aviation and Drones EO Value Chain[1]

INFRASTRUCTURE PROVIDERS	DATA PROVIDERS	PLATFORM PROVIDERS	EO PRODUCTS AND SERVICES PROVIDERS	INFORMATION PROVIDERS	END USERS
• AWS • COPERNICUS DIAS* • GOOGLE CLOUD • IBM SPECTRUM COMPUTING • INTEL GEOSPATIAL • MICROSOFT AZURE • PENGUIN COMPUTING	• AIRBUS • BLACKSKY • CEYE • COPERNICUS DIAS* • DESCARTES LABS • EARTH-I • E-GEOS • MAXAR • PLANET	• BOHANNAN HUSTON • COPERNICUS DIAS* • CREOTECH INSTRUMENTS • DARES TECHNOLOGY • EISAT IMAGENS DE SATELITE • FLYCOM HOLDINGS • LEONARDO • RHEA SYSTEM • SATELLITE EARTHSTAR GEOGRAPHICS • SATELLITE IMAGING • SKYMAP GLOBAL	• BOHANNAN HUSTON • DARES TECHNOLOGY • EISAT IMAGENS DE SATELITE • FLYCOM HOLDINGS • L3HARRIS TECHNOLOGIES • LEONARDO • RHEA SYSTEM • SATELLITE IMAGING • SKYMAP GLOBAL • SNC-LAVALIN	• BOHANNAN HUSTON • DARES TECHNOLOGY • EISAT IMAGENS DE SATELITE • FLYCOM HOLDINGS • L3HARRIS TECHNOLOGIES • LEONARDO • RHEA SYSTEM • SATELLITE IMAGING • SKYMAP GLOBAL • SNC-LAVALIN	• AIR NAVIGATION SERVICE PROVIDERS • AIRPORT PLANNERS • AIRPORTS • FLIGHT PLANNERS • INSTRUMENT FLIGHT PROCEDURE DESIGNERS
• COPERNICUS COLLABORATIVE GROUND SEGMENT*	• COPERNICUS SENTINELS* • USGS/NASA LANDSAT • RELEVANT IN-SITU NETWORKS		• COPERNICUS SERVICES*		

Europe[2] is a major player in EO for Aviation

The value of Earth Observation for Aviation is growing. Currently there are more than 70 companies tracked globally with a share in the Aviation EO market. Europe leads the contribution with a >70% share.

The value of the EO products and services within aviation is estimated at **€55m in 2019** and expected to increase as the contribution to supporting and assessing sustainable aviation gathers pace.

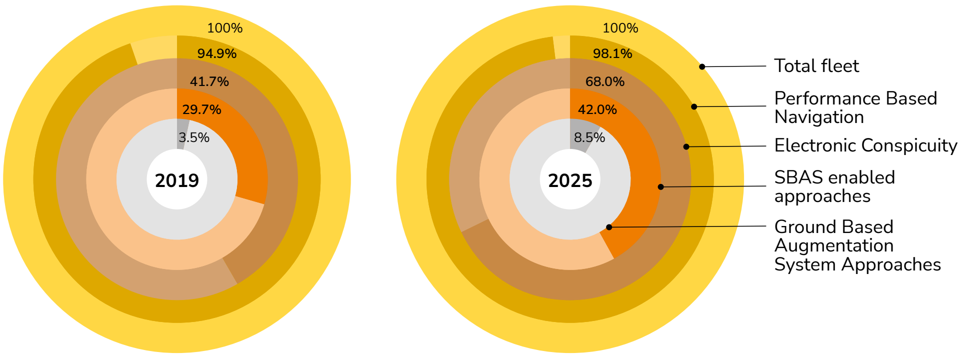
LEGEND
- Commercial Offering
- Public Offering
- User segments

NOTES

[1] The value chain considers the key global and European companies involved in EO downstream activities.
[2] In the market share analysis, Europe is defined as EU27 plus Norway, Switzerland and the UK.
* European-based companies. The region is defined with respect to the headquarters of the company, though the actual area of activity might be wider.

GNSS capabilities are growing to meet evolving requirements for navigation, surveillance and sustainability

GNSS capabilities as a proportion of total civil aviation fleet



Due to the COVID-19 pandemic, air traffic dropped by more than 65% compared to 2019 and worldwide the aircraft fleet is expected to have shrunk by 15% in 2021 compared to 2020. Some aircraft have been switched to transporting cargo in a desperate attempt to avoid bankruptcy by their operators. This impact is expected to last for some years with the net effect that there may be fewer shipments but an increase in GNSS capabilities within the fleet as older, non-upgraded aircraft will be retired to save costs. Due to the pandemic, major key players in the GNSS Chips & Modules market are witnessing fluctuation in demand, which is altering market trends, potential opportunities and consumer preferences. The figure above illustrates how this change is expected to impact fleet capabilities, especially in relation to Localiser Performance with Vertical Guidance (LPV) and SBAS which see a significant increase over the period in response to COVID-19.

GNSS is essential in aviation, and the technical developments are targeted to support specific problems. However, as the ubiquity of GNSS in aviation across Communication, Navigation and Surveillance (CNS) increases, so too does the requirement to improve across all areas. This section presents some of the more recent developments and focus areas from a CNS perspective.

Dual Frequency Multi-Constellation progress in navigation

The GBAS Approach Service Type D (GAST D), which allows Cat-III precision approaches to less than 100ft height, is fully standardised and validated for GPS L1 signals. Furthermore, a dedicated ICAO ad-hoc group is defining the future DFMC GBAS concept, which takes benefit from dual-frequency signals and multiple constellations such as GPS and Galileo, in order to enhance the robustness of GBAS approach service and even explore new GBAS services. The ICAO DFMC GBAS Concept Paper is expected by the end of 2022.

As of today, it is expected that the GNSS Manual (Doc 9849) will update to accommodate GAST-F in 2024 and that ICAO Standards And Recommended Practices for GBAS GAST F would be written around 2030.

GBAS GAST F or GBAS DFMC is seen as the future of GBAS and will enable greater robustness against ionosphere disturbances as well as against Radio Frequency Interference (RFI), as it will work with two frequencies and offer reversion modes.

The ICAO Navigation System Panel (NSP) approved new Standards and Recommended Practices for the use of EGNOS and Galileo in November 2020. This is an important milestone in **SBAS DFMC Standardisation** for EGNOS and Galileo but also for European aviation. Indeed, DFMC SBAS opens up new possibilities for air transportation but also more resilience for users against RFI.

In the **U-Space** and **UAM** area EUSPA has supported numerous trials of drones equipped with EGNOS as well as Galileo through its EGNSS4RPAS project. Manned aircraft are expected to be outnumbered by all kinds of drones, employed for everything from weather and environmental monitoring to personalised delivery services. The traditional person-based air traffic control model will need to evolve to accommodate such a shift, based on automated monitoring, traffic management and collision avoidance. In Europe, this highly automated version of air traffic control is termed U-Space.

GNSS performance requirements supporting drone operations are being developed globally. Eurocae WG-105 within Europe is developing minimum operational performance specifications (MOPS) for Detect and Avoid (DAA) in Very Low Level (VLL) airspace.

SBAS's safety-of-life service is essential to making this happen, moving from today's situation — where drones are limited to specific air corridors and line-of-sight operations — to let them roam freely but safely in busy airspace and built-up areas.

Electronic Conspicuity has an important role in surveillance

Electronic Conspicuity is an umbrella term for technologies that provide **self-reporting of position** from an aircraft to other aviation actors. Electronic Conspicuity can be considered in two groups: **Certified** (used in controlled airspace by users such as commercial aviation and certified category drones) and **Uncertified** (used outside controlled airspace typically by General Aviation). It is also an essential enabler for U-Space as the means to provide the ability to 'detect' other aircraft. **No solution** has yet been agreed to enable **interoperability** between U-Space and manned aviation, but GNSS positioning reporting is enabled through the established ADS-B and a mix of proprietary solutions gaining traction with some users. There are several solutions including Automatic Dependent Surveillance Broadcast (ADS-B) (1090MHz and UAT), Flight Alarm (FLARM), LTE/5G and 802.11 raising questions on interoperability.

ADS-B implementation, both airborne equipage and ground infrastructure, continues toward full integration in the ATM environment. Since December 2020, **new aircraft** are required to be **ADS-B equipped** with a transition period till June 2023 for retro-fit. At European level, users would like to improve cost-efficiency through rationalisation of the surveillance infrastructure, including the decommissioning of CNS facilities and to improve the aviation spectrum efficiency. GNSS will become more critical as this step progresses.

Increased focus on environmental impacts demanding more from GNSS and EO

Increased focus on monitoring aviation emissions

There is an increasing push for aviation to become more environmentally friendly. Whilst particular complaints in the vicinity of aerodromes might focus on noise, it is the **emissions** and the level of **fuel burn** that are predominantly being addressed, particularly at European level where commercial airlines are subject to the emissions **charging scheme**. Airport expansion plans in recent years have also been subject to restrictions on movement or night curfews as pressure builds on limiting the impacts of aviation.

Drones are one area where there is significant development and interest due to the electrification of flight and the consequent 'zero' emissions in comparison to traditional aviation.

In this context, EO has a great role to play for the aviation sector. EO services can be used at a global level for airport planning and development, such as monitoring wind, precipitation and temperature to influence the determination of runway size and layout. These services can additionally be used at local level with development plans assessing the existing emissions and helping, through modelling, to gauge the impacts that the expansion will have on the local area. EO can provide a monitoring source for the effects of aircraft emissions at different flight levels, or in areas in which air pollution is at or approaching legal limits.

Indeed, Copernicus Atmosphere Monitoring Service (CAMS) provides continuous data and information on atmospheric composition. Notably, CAMS could be used to help the Volcanic Ash Advisory Centres (VAAC) forecast volcanic ash clouds dispersion trajectories. This would **enhance flight safety** in case an aircraft flies in the **vicinity** of **volcanic ash**. In addition, the CAMS products include analyses/re-analyses of greenhouse gases (carbon dioxide, methane, and nitrous oxide), having the ability to monitor these compositions in a number of layers at different altitudes. Therefore, the European Commission has already completed some studies[1,2] into the **feasibility** of the **CAMS** system being used to **monitor air pollution** at different altitudes. This would be of great interest to better understand the impact of aviation on the environment.

The Copernicus Land Monitoring Service might also enable the monitoring of precise localisation and the size of terrain and obstacles that surround an airport. This is of particular relevance to procedure designers when designing and publishing specific procedures for the airport, and to the general integrity and safety of the airport. Both these factors are essential enablers for PBN and the exploitation of GNSS for navigation purposes.

Given the long lifecycle of airport development projects in general, the use of EO data would allow easy access to reliable, up-to-date information throughout a project lifecycle thanks to high-frequency revisits.

[1] https://publications.jrc.ec.europa.eu/repository/handle/JRC111789

[2] https://publications.jrc.ec.europa.eu/repository/handle/JRC112816

Sustainable and smart mobility - Green airports

Mobility within Aviation targets the application of innovative digital and **satellite-based** solutions, including new tools and **traffic optimisation** mechanisms for multimodal access, **passenger and freight flows** into, out of and between airports, facilitating airport access and reducing traffic to/from cities or other nodes.

As transport systems become more integrated, aviation is expected to increasingly interface with other public transport links. Llinks with GNSS and EO are expected to become more critical. This is not just through the ambitions of the Green Deal, but also linked to the exploitation of increased automation and PBN procedures to improve the efficiency of aircraft operations arriving and departing at each aerodrome. Optimising flows with the better sharing of information between airports and airspace users is a focus of R&D within SESAR.

The importance of timing on optimising operations

The exploitation of **GNSS timing** as a reference source for timing and synchronisation processes is fundamental for critical infrastructure like telecommunication networks, energy distribution grids, financial markets and commercial aviation systems and networks.

In the case of aviation, **optimising the traffic flows** also comes down to timing, as does synchronisation of information about flights. This information can be shared between users to cut down on flight times and reduce delays, diminishing the environmental impact. GNSS time is used for:

- positioning and timing for on-board navigation purposes;
- timing and synchronisation for datalink communications (on-board to ground and vice-versa); and
- timing and synchronisation for ground systems used for Air Traffic Control (ATC), communication networks, airspace surveillance, and airport logistics coordination.

Updated Aviation and Drones applications

Previous market reports provided data broken down by airspace user group. In this edition, data is presented by GNSS **application**. These applications are used by different airspace user groups in **both** manned aviation and drones. Definitions of each application are provided in Annex 3. Not all applications appear in the charts:

- ATM systems timing and Infrastructure timing are not yet quantified.
- GADSS Aircraft Tracking uses either the Performance Based Navigation system and on-board satellite communications, or can be collected by satellites that detect the aircraft or certified drone's Electronic Conspicuity transmissions.
- Earth Observation applications are not yet quantified.

Aviation needs advanced GNSS and new alternative PNT solutions

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Push for new Alternative PNT

PBN is the foundation for enabling aircraft trajectories in the future that are optimised for the efficiency and environmental impact, with GNSS the key enabler. The evolution of navigation and surveillance applications, which will enable interoperability between manned aircraft and drones, is required. Future applications are therefore likely to lead to **increased dependence on GNSS**.

In aviation, the GNSS landscape is evolving and moving steadily towards more precise operations using Dual Frequency Multi-Constellation (DFMC), while aviation surveillance infrastructure increasingly utilises integrated GNSS, particularly for timing. From a GNSS standardisation perspective, this is well advanced, although not finalised, for manned aviation.

Traditional aviation has always operated with alternative technologies, particularly ground-based navigation aides, in addition to GNSS. Whilst these technologies cannot deliver the performance equivalent to GNSS, particularly with DFMC, they do provide **resilience**.

With interoperability, new airspace users expect a continued push for **rationalisation** of historical alternative technologies in the future, there will be a need to maintain a **spectrum** and **cost-efficient** solution accessible to all, drones and manned aviation alike. Technologies such as the L-band Digital Aeronautical Communications System (LDACS) and 5G offer integrated positioning services, yet there is no clear solution that can meet the key performance requirements that GNSS delivers.

Advanced GNSS Operations for Helicopters and General Aviation

On 18th November 2020, EUSPA and EHA (the European Helicopter Association) hosted a workshop on the GNSS/EGNOS benefits for Helicopter Emergency Medical Services (HEMS) operations. This builds on the increasing **importance of GNSS** to support helicopter operations operating in **hostile** environments, such as close to mountains or in valleys with poor connectivity to traditional infrastructure. GNSS provides HEMS operations with capabilities that improve the safety of the operations and enable an expedited rescue for the most suitable hospital for patients. Workshops such as this have helped the HEMS community become more aware of the operational benefits and technical requirements of GNSS.

In addition, the use of GNSS-based altitude can provide specific benefits for helicopter operations under particular conditions:

- GNSS-based altitude can be used instead of barometric altitude to improve altitude information reliability in low-level operations in areas where the local settings for barometric altitude (QNH) are not available or not reliable.
- Terrain Awareness Warning Systems (TAWS) and Synthetic Vision Systems (SVS) data is based on GNSS altitude. If the altitude displayed in the helicopter cockpit were GNSS-based instead of barometric, then all data would have the same reference and be coherent.
- At low speeds, the rotor flow can impact barometric sensors, which can lead to some bias on barometric altitude determination. On some helicopters, a hybridization of GNSS-based altitude with barometric altitude is already made to reduce noise and bias in the altitude value.

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New drone uses continue to emerge

Overall drone market evolution by 2025

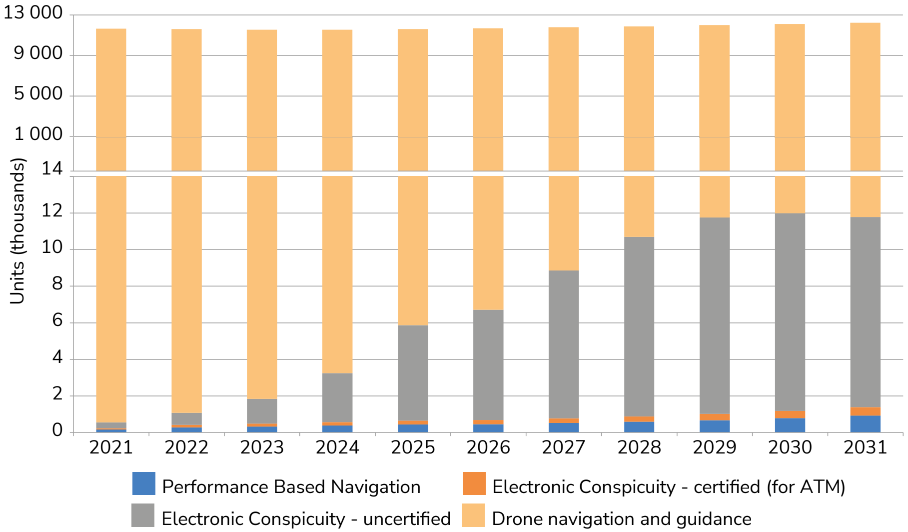
The global drone market will grow from €19.4 bn in 2020 to over €36.9 bn in 2025 at a CAGR of **13.8%[1]**. This huge growth will drive shipments of **GNSS-capable drones** to exceed **10 million units** per year for most of this decade, as shown in the chart below. The proportion of drone service revenue attributed to GNSS is shown in the adjacent chart.

Nearly all drone use cases will continue to be operated outside of controlled airspace by **Open** or **Specific** category drones. Certified Electronic Conspicuity and Performance Based Navigation devices will be used for high-value applications, but by a relatively small population (compared to the overall drone market) of **Certified** drones.

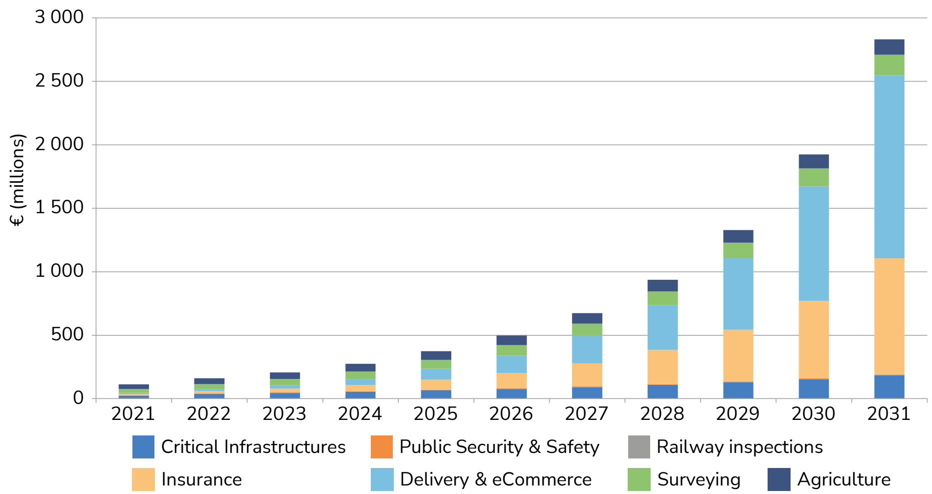
Applications such as critical infrastructure inspection and drone Delivery & eCommerce – which is predicted to be the largest market area by 2030 – are developing rapidly. These applications increase demand for **Beyond Visual Line of Sight (BVLOS)** missions classified as medium risk, which will fall under the **Specific** category. Such missions require a proportionate approach to safety and will require a design verification report. The designs will almost certainly include Electronic Conspicuity devices (uncertified as they will be outside of controlled airspace) to ensure awareness of other airspace users, and support U-space tracking by UTM systems.

[1] According to the Drone Market Report 2020

Shipments of GNSS devices by application (Drones only)



EU27 dependant service revenue by service area



Urban Air Mobility

Urban Air Mobility (UAM) is a concept looking for ways to quickly and efficiently move people within cities in a safe and environmentally friendly manner. UAM transport networks will offer an alternative to congested city transport systems and will develop strong interfaces between city/region, drone, transport and urban planning communities. UAM is expected to debut in the coming years in big cities such as Paris and Singapore, according to Volocopter and Lilium, two European leaders in this market. UAM is not expected to emerge as a significant market until the **2030s**.

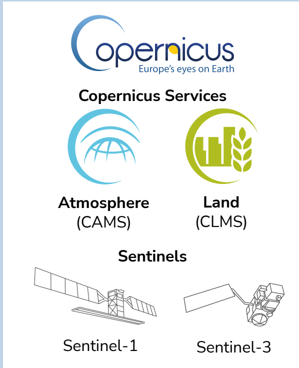
As in most transportation modes, UAM strongly benefits from the GNSS services for positioning, but also from other services that are specifically tailored to drones applications: geo-fencing and geo-caging; e-identification (Drone navigation and guidance); and tracking (facilitated via Electronic Conspicuity). Maps that integrate EO data will provide up-to-date information about the distribution of dwellings and approximate population. This will help planning routes for UAM traffic to avoid densely populated areas and for developers to strategically plan infrastructure.

The Solution for EGNSS U-Space Service (SUGUS) project, funded by the European Commission, organised a survey last year, whose results can be used as a valuable input to tailor the EGNSS Service Provision layer to specific drone missions' needs, allowing better mitigation of risks in complex operations like UAM, increasing safety and security.

EGNSS and Copernicus current usage

Current usage of Copernicus

COPERNICUS USE FOR MANNED AVIATION

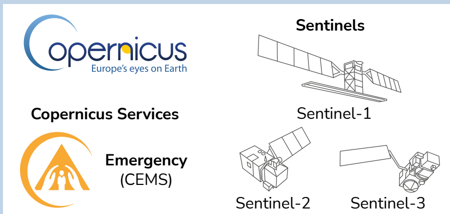


In **manned aviation**, a new project called **AsSISt** - Aircraft Support & Maintenance Services – is using atmospheric data to bring accurate information about atmospheric conditions that affect aviation to the aircraft maintenance market. The Aircraft Support and Maintenance Services use atmospheric datasets obtained from CAMS (Copernicus Atmosphere Monitoring Service). The datasets contain everything needed to compute three key indicators of atmospheric conditions: abrasion, clogging, and corrosion. By using CAMS data, AsSISt provides indicators to help airlines and manufacturers to save costs, thanks to precise monitoring of aeroplanes' exposure to harmful particles, thereby allowing airlines to build their maintenance plans around the expected damage.

Copernicus use of the land and atmosphere monitoring services supports both the evaluation of a greener aviation and the safety of developments within the aerodrome environment. Specifically, it can provide an effective way for the aerodrome to monitor construction within the aerodrome vicinity and support compliance with ICAO Standards And Recommended Practices for aeronautical information and aerodrome mapping.

Other obligations for the aerodrome include a requirement to focus on the environment and to manage water runoff and other pollutants such as de-icing or related aircraft chemicals that could find their way into the water system.

COPERNICUS USE FOR DRONES



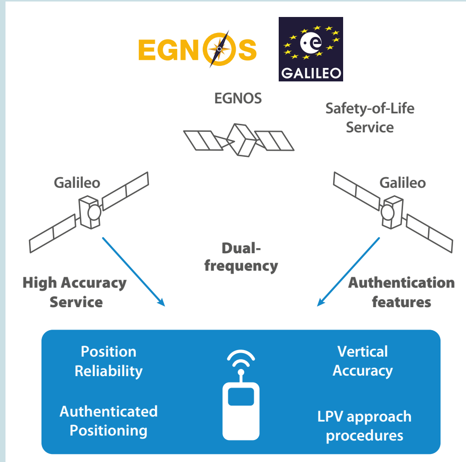
Myriad is an Internet-of-Things (IoT) system that triggers autonomous Unmanned Aerial Vehicle (UAV) surveys based on changes detected over Copernicus imagery. Monitoring large industrial areas using traditional on-site methods is usually costly. Important changes in the landscape can go unnoticed, which may lead to a loss of money, environmental and security issues, or a loss of a commercial opportunity. Myriad aims to solve this problem using Artificial Intelligence (AI) to detect changes over Copernicus datasets from Sentinels 1, 2 and 3, sending those changes to the UAV that will then automatically fly over it.

These applications are already under development. For example, some start-ups are evaluating the potential to provide all drone users with up-to-date satellite imagery from the Copernicus Emergency Management Service. The purpose is to integrate up to date drone images and video as layers on top of post-disaster satellite imagery.

Terminology used on this page is explained in Annex 2 for both GNSS and EO performance parameters.

Current usage of EGNSS

GALILEO USE FOR MANNED AVIATION



Galileo SAR Performance exceeding the commitments

The Galileo Return Link Service has been exceeding performance levels committed to in the SAR/Galileo Service Definition Document. The continuous monitoring of Galileo SAR and the Return Link Service (RLS) confirmed that the Service has been available 99.99% of the time, and that the Galileo RLS system took an average of 0.61 minutes (37 seconds) to deliver the automatic acknowledgement to the activated beacons, as observed by the Galileo Reference Beacons.

Both performance parameters are significantly better than their target values of 95% and 15 minutes respectively. Following the declaration of Initial Services in December 2016, the Galileo Initial Open Service (OS) and the Galileo Search and Rescue (SAR) Service Public Performance Reports are published quarterly, to provide the public with information about the Galileo OS and the Galileo SAR Service measured performance statistics.

GALILEO USE FOR DRONES

Based on useGalileo.eu data, Galileo is already present in over 30% of receiver models used for drone applications. High performance positioning system for drones are being developed in the frame of current European projects, within the U-Space framework focusing on VLL (Very Low Level) and UAS (Unmanned Aircraft System) operations.

Galileo OSNMA test underway

The Galileo Open Service Navigation Message Authentication (OSNMA) is an authentication mechanism that allows GNSS receivers to verify the authenticity of GNSS information, making sure that the data they receive is indeed from Galileo and has not been modified in any way. Galileo has started testing OSNMA in the signal-in-space, allowing the first-ever OSNMA-protected position fix to be successfully computed[1]. Testing will continue over the next months, ahead of a public observation phase. This is the first ever transmission of authentication features in open GNSS signals in a global navigation system. During the User Consultation Platform 2020, the European drone community expressed interest in the potential use of Galileo OSNMA to support operations.

[1] https://www.gsc-europa.eu/news/tests-of-galileo-osnma-underway

Latest EC and EUSPA project initiatives

MyGalileo Drone Competition

Following the Galileo initial service declaration in 2016, the increasing availability of Galileo–enabled receivers and the fast-growing market of drone-based applications and services, the EU Agency for the Space Programme (EUSPA) market activities have focused on Galileo 'Good Use' by increasing awareness and stimulating its use by entrepreneurs and general public.

The aim of the contest was to design, develop, test and prepare the commercial launch of a drone-based application and/or service able to provide a position and/or time fix by using a Galileo-enabled receiver.

The contest stimulated drone application developers and service providers to learn about Galileo's potential and create new tools that could also be exploited in future projects. From the point of view of final users, the contest encouraged innovative applications and services based on drones and powered by Galileo, and showcased Galileo performance and benefits, fostering its introduction into this new market.

Link to the website: https://www.euspa.europa.eu/mygalileodrone

ARAIM Prototype Receiver for Dual Constellations - GLAD

© GLAD Project

Global the Advanced Receiver Autonomous Integrity Monitoring (ARAIM) for Dual-Constellation Project (together, GLAD), co-funded by the EU Agency for the Space Programme (EUSPA), is developing the ARAIM prototype receiver under the Fundamental Elements programme.

The Consortium is made up by AIRBUS, NATS, GMV, Pildo Labs and led by Collins Aerospace. The purpose of GLAD Project is to implement the ARAIM algorithm developed by GNSS subject matter experts on a Collins' Dual Frequency Multi-Constellation (DFMC) Multi-Mode Receiver (MMR) baseline.

The ARAIM algorithm should support three possible architectures enabling different levels of performance, leveraging the use of Integrity Support Messages (ISMs). ARAIM is a targeted solution to ensure navigation integrity for en-route flight, terminal and approach operations supporting lateral and vertical guidance operations down to 200 feet decision height.

A Webinar was organised in June 2020 explaining the purpose of GLAD project as well as its main outcomes: the overall design; development; and experimentation.

Link to the website: https://www.euspa.europa.eu/newsroom/news/global-araim-dual-constellation-webinar-took-place-24-june-2020

Drones and EGNSS for Low airspace urban mobility - DELOREAN

The DELOREAN (Drones and EGNSS for Low Airspace Urban mobility) H2020 project was awarded by EUSPA within the framework program 'EGNOS Adoption in Aviation'. Its main objective is to develop innovative EGNOS-based solutions that respond to increased mobility needs of people and goods, enabling efficient, sustainable, affordable and effective air services in challenging urban scenarios.

The consortium working behind this project is formed by CATEC, GeoNumerics, Airbus, Correos, Bauhaus Luftfahrt, Eurocontrol, UPV (Universitat Politècnica de València) and PildoLabs. Together they intend to test, evaluate and quantify how distinguishing features of EGNOS and Galileo can contribute to the positioning and integrity requirements of such air services.

© Delorean project

Along with the introduction of EGNSS in future standards and regulations to ensure the safe navigation of UAM and UAD drones, an important goal of DELOREAN is contributing to the definition of EGNSS requirements and standards that can be used as Acceptable Means of Compliance (AMC) in the new European drone regulation. This particularly applies to the Specific drone category, as a result of the application of the Specific Operations Risk Assessment (SORA) method.

Link to the website: https://sites.google.com/pildo.com/delorean

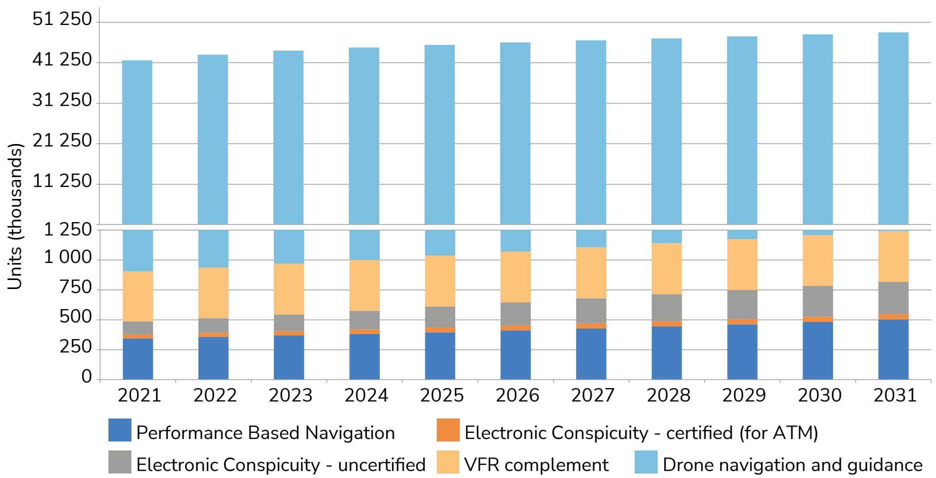
Scandinavian Air Ambulance – BSAA-REACH

The BSAA-REACH project is progressing with the implementation of Point in Space (PinS) approach and departure procedures and Low Level Route (LLR) in three health regions in Sweden, connecting a pair of helipads in each region, resulting in a total of six locations.

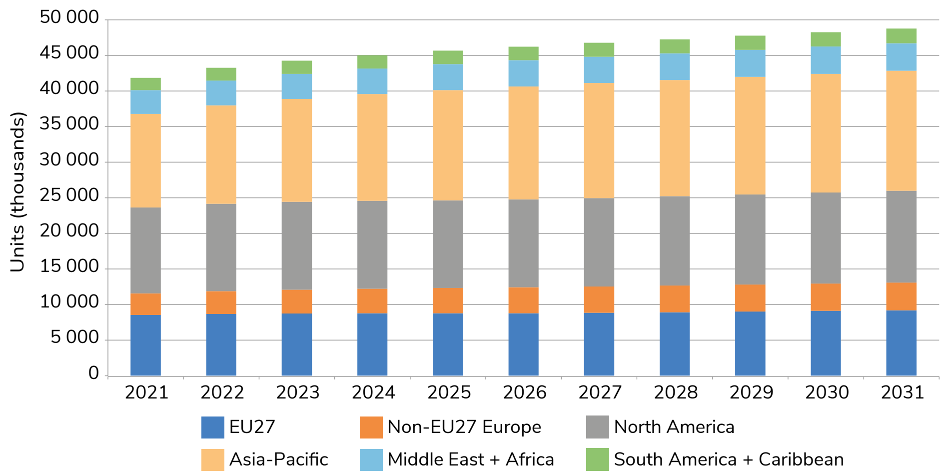
The project's objectives are to:

- implement 6 PinS procedures at 6 different sites in Sweden: Stockholm/Karolinska, Visby, Gallivare, Lulea/Sunderby, Östersund/Göviken HEMS base and Are Health Clinic, one of the first operational implementations of Helicopter EGNOS-based procedures in Sweden;
- develop the necessary enablers for the provision of a flight validation service on the basis of existing and proved in region technical solutions;
- enable Helicopter IFR operations in areas where no Air Traffic Service is available.

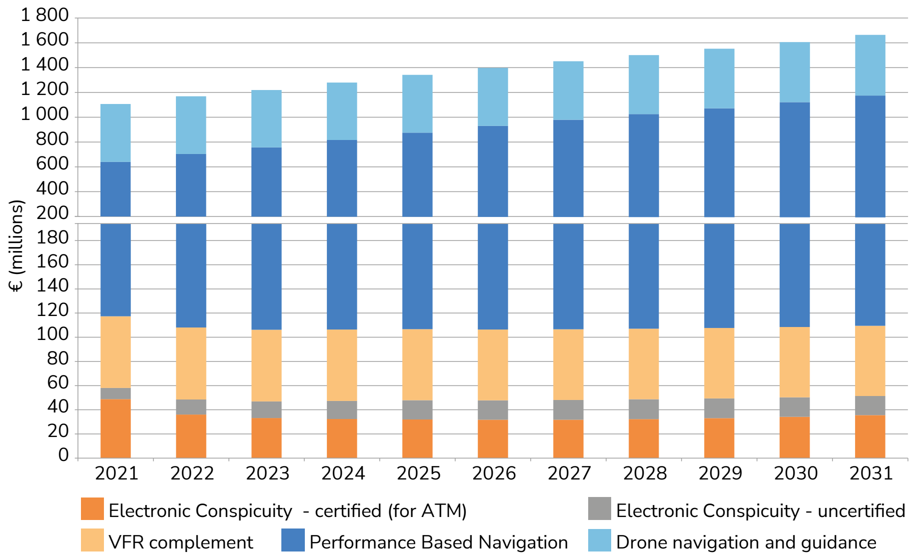
Installed base of GNSS devices by application



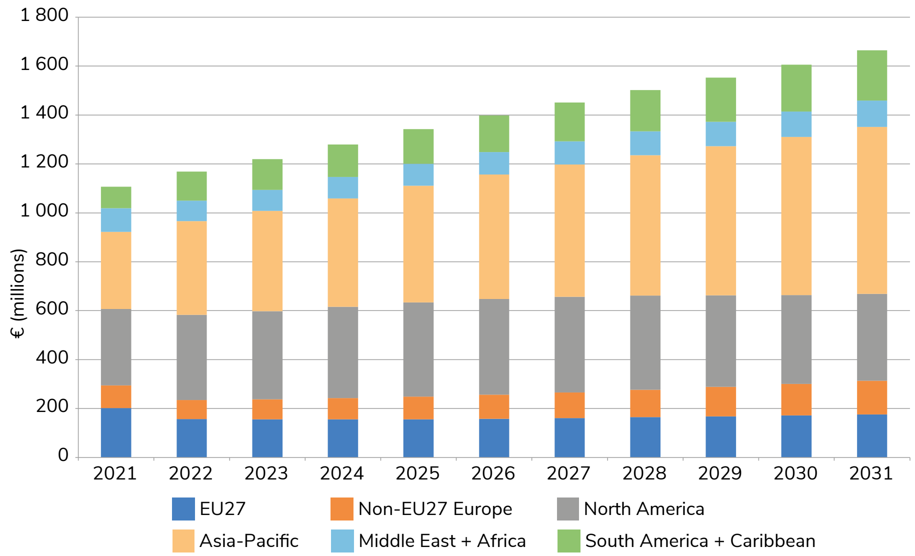
Installed base of GNSS devices by region



Revenue of GNSS device sales by application

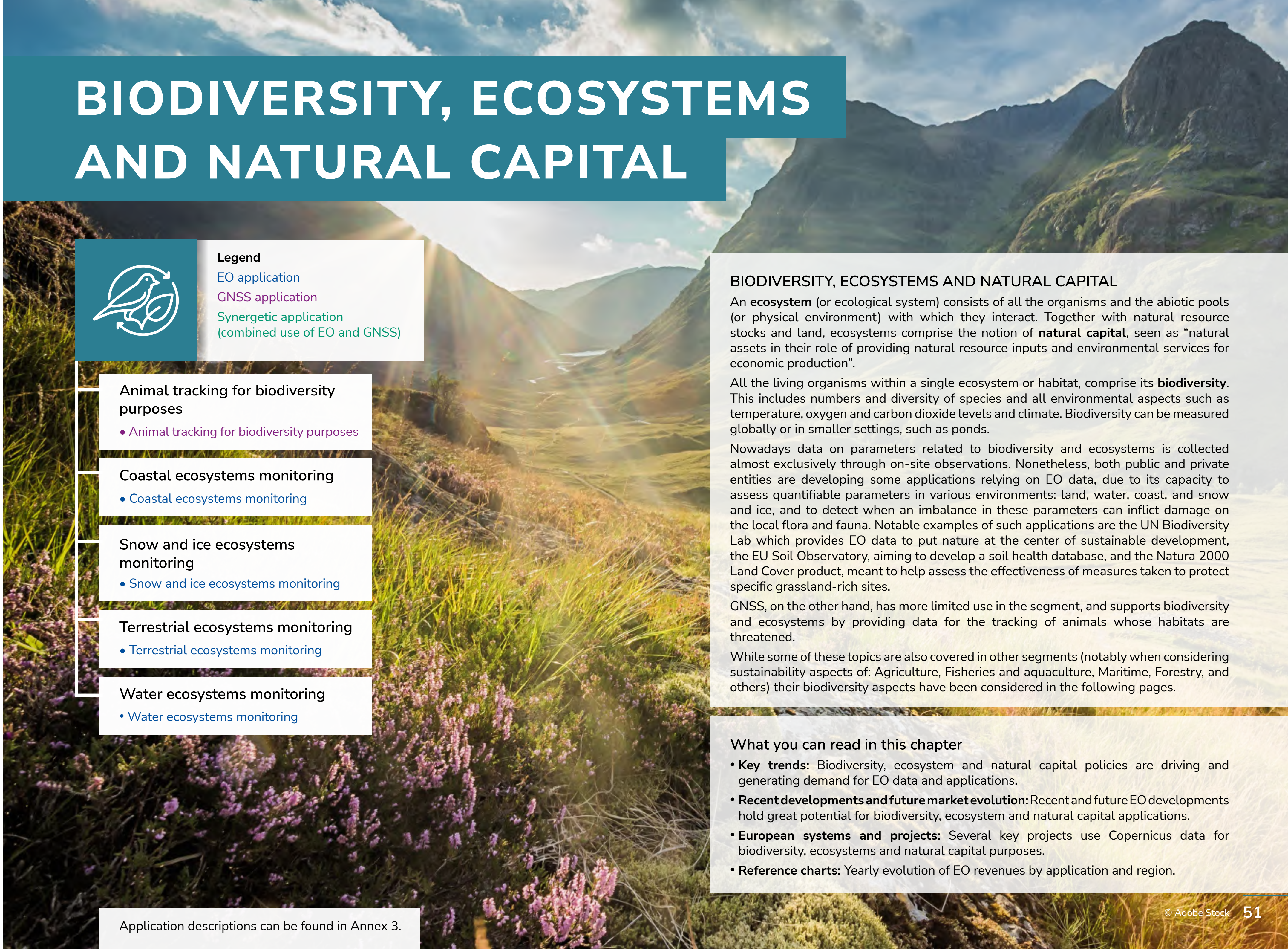


Revenue of GNSS device sales by region



Certified Electronic Conspicuity devices relying on the aircraft's integrated GNSS receiver are included within the PBN application.
GADSS Aircraft Tracking will either use the GNSS receiver quantified under Performance Based Navigation ,or Electronic Conspicuity – certified.
Earth Observation applications, and ATM systems timing and Infrastructure timing, are not yet quantified and are therefore not presented in this edition of the Market Report.

BIODIVERSITY, ECOSYSTEMS AND NATURAL CAPITAL



Legend

EO application

GNSS application

Synergetic application (combined use of EO and GNSS)

Animal tracking for biodiversity purposes

- Animal tracking for biodiversity purposes

Coastal ecosystems monitoring

- Coastal ecosystems monitoring

Snow and ice ecosystems monitoring

- Snow and ice ecosystems monitoring

Terrestrial ecosystems monitoring

- Terrestrial ecosystems monitoring

Water ecosystems monitoring

- Water ecosystems monitoring

Application descriptions can be found in Annex 3.

BIODIVERSITY, ECOSYSTEMS AND NATURAL CAPITAL

An **ecosystem** (or ecological system) consists of all the organisms and the abiotic pools (or physical environment) with which they interact. Together with natural resource stocks and land, ecosystems comprise the notion of **natural capital**, seen as “natural assets in their role of providing natural resource inputs and environmental services for economic production”.

All the living organisms within a single ecosystem or habitat, comprise its **biodiversity**. This includes numbers and diversity of species and all environmental aspects such as temperature, oxygen and carbon dioxide levels and climate. Biodiversity can be measured globally or in smaller settings, such as ponds.

Nowadays data on parameters related to biodiversity and ecosystems is collected almost exclusively through on-site observations. Nonetheless, both public and private entities are developing some applications relying on EO data, due to its capacity to assess quantifiable parameters in various environments: land, water, coast, and snow and ice, and to detect when an imbalance in these parameters can inflict damage on the local flora and fauna. Notable examples of such applications are the UN Biodiversity Lab which provides EO data to put nature at the center of sustainable development, the EU Soil Observatory, aiming to develop a soil health database, and the Natura 2000 Land Cover product, meant to help assess the effectiveness of measures taken to protect specific grassland-rich sites.

GNSS, on the other hand, has more limited use in the segment, and supports biodiversity and ecosystems by providing data for the tracking of animals whose habitats are threatened.

While some of these topics are also covered in other segments (notably when considering sustainability aspects of: Agriculture, Fisheries and aquaculture, Maritime, Forestry, and others) their biodiversity aspects have been considered in the following pages.

What you can read in this chapter

- **Key trends:** Biodiversity, ecosystem and natural capital policies are driving and generating demand for EO data and applications.
- **Recent developments and future market evolution:** Recent and future EO developments hold great potential for biodiversity, ecosystem and natural capital applications.
- **European systems and projects:** Several key projects use Copernicus data for biodiversity, ecosystems and natural capital purposes.
- **Reference charts:** Yearly evolution of EO revenues by application and region.

Biodiversity, ecosystem and natural capital policies are driving and generating demand for EO data and applications

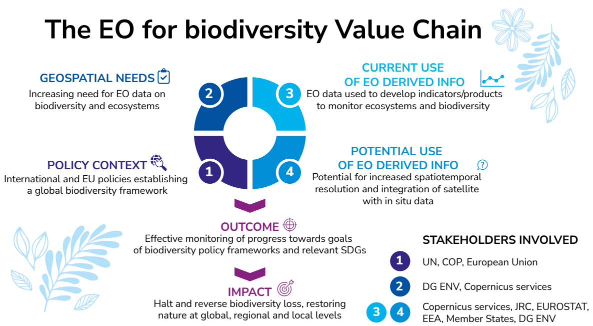
Key market trends

- Policy commitments drive ecosystem monitoring developments on the global stage; in Europe these are spearheaded by the new Biodiversity Strategy
- Natural capital and ecosystem accounting efforts benefit from Earth Observation services including those offered by Copernicus
- The intensification of efforts to understand and protect soil health and ocean health is paramount for food security and carbon sequestration

Use of EO for the implementation of biodiversity policies

Geospatial data supports biodiversity monitoring and decision making in numerous ways. This support is being bolstered through recent initiatives implemented by international and regional actors. In 2018 the UN launched the **UN Biodiversity Lab**. This interactive mapping program contains spatial data on protected areas, endangered species, climate and carbon variables, land cover, marine areas, human impacts on natural systems and socio-economic data. It is aimed at decision-makers, particularly from countries who do not have the technical capabilities and/or access to their own geospatial data.

In Europe, the **EU's Biodiversity strategy for 2030** could also make extensive use of EO data. Indeed, **EO data is already used in policies** such as the monitoring of Natura 2000 sites, an initiative for preserving and protecting breeding and resting sites for rare and threatened species, and specific natural habitat types, covering over 18% of the terrestrial and 8% of the marine territory of the EU. Through this, specific Copernicus products have been developed such as the Copernicus Land Monitoring Service's Natura 2000 Land Cover product.



© EC

Copernicus in support of natural capital & ecosystem accounting

Earth's stock of natural resources – its geology, soils, air, water and all living organisms – forms its natural capital. Some of these assets directly contribute to humanity's wellbeing by providing so-called **ecosystem services** which underpin our economy and society, making human life possible (e.g., clean water, fertile soil, waste decomposition, crop pollination, climate regulation, etc.). To help mainstream ecosystem services in policies and in business decision making, the **Earth Observation for Ecosystem Accounting (EO4EA)** and the **ARIES initiatives** are seeking to identify and link the data needs of ecosystem accounting producers to key earth observation data sources. Preliminary studies have shown that the Copernicus products are well-suited for providing data on some simple physical, structural and functional characteristics of ecosystems; although, in most cases, the Copernicus products for ecosystem condition variables are likely to require further processing to make them suitable for ecosystem accounting. As **new policies place increased attention on ecosystem accounting**, improvements on the EO-based solutions supporting it can be expected.

GNSS technologies for wildlife tracking

GNSS technologies also provide support to biodiversity. GNSS beacons in devices such as collars, harnesses, or directly attached to the animal, can be deployed on a targeted sample size of an endangered species and used for tracking. Two types of devices are used; those that allow downloading of data once the animal/device has been retrieved, and a more advanced type where data is transmitted remotely, sometimes in real time. The signals help scientists and conservationists map behaviour, population demographics and inter-species interactions, including with the predatory environment. Such devices already provide knowledge on how far, and where exactly, birds travel to migrate, or how water temperature influences fish migration.

In sanctuaries the use of GNSS trackers has specific purposes; for instance, showing if an endangered animal is injured, sick, trapped by poachers or has escaped from a reserve.

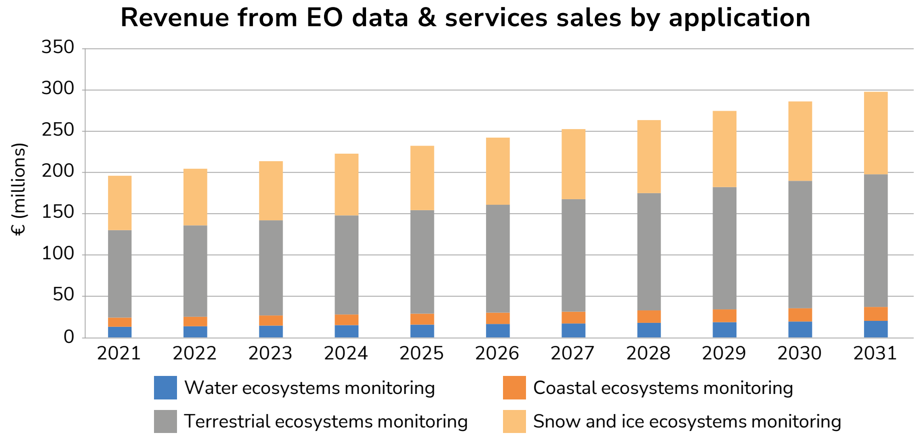
Initiatives exploiting Earth Observation in soil health monitoring

A quarter of all known species live in the soil, and life above ground depends on the soil and its countless inhabitants. Yet global strategies to protect biodiversity have so far paid little attention to this habitat. Suffering considerable stress because of intensive cultivation with heavy machinery, fertilisers and pesticides, compaction, coverage with buildings and exposure to wind and water erosion, soil health is declining – according to the Joint Research Centre, 970 million tonnes of soil are lost every year in Europe. **Improving soil health** is relevant not only for promoting food security, but, perhaps more importantly, **for fighting climate change** – achieving just a 0.4% increase in the amount of carbon in soil could greatly reduce the amount of CO_2 in the atmosphere. In Europe, the recently launched **EU Soil Observatory** merges Copernicus EO data with field assessments from the European Soil Centre to create a soil health database. Worldwide, initiatives such as **NASA Harvest and Soil BON** seek to determine which regions of the world need protection and which protective measures are most appropriate. Although satellites can only currently observe the surface, technology is fast progressing. Shortly, imaging spectrometers are expected to enable measurements of the carbon content of soil and some pollutants.

Recent and future EO developments hold great potential for biodiversity, ecosystem and natural capital applications

Decommissioned oil rig structures supporting thriving marine ecosystems

There are more than 12,000 offshore oil and gas platforms built on continental shelves worldwide, with thousands due for decommissioning in the coming decades. Constructed out of corrosion-resistant steel that withstands breakup, rigs have a large, open structure that allows easy circulation for fish whilst also providing hard substrate for barnacles, corals, sponges, clams, etc. Certain countries have reconsidered their decommissioning procedures as an opportunity to **convert oil rigs into artificial reefs**: more than 500 rigs are converted to date in the United States. With an emerging wind farm decommissioning market and oil and gas decommissioning ramping up, Earth observation could play a key role in these activities, providing a regional overview of the maritime environment and allowing operational data from teams in the field to be interrogated in real-time. To this end, through the 4EI project, ESA is investigating the feasibility of using space-based data to support the decommissioning of energy assets. It is seeking to provide accurate information relating to hazards such as sea and weather conditions, maritime traffic and environmental pollution. EO-based products which allow for the planning of rig decommissioning in advance could contribute to a decrease in the overall costs related to these activities and reduce the need for using vessels (thus ultimately reducing fuel usage and the related greenhouse gas (GHG) emissions).



In 2021 the annual revenue from EO data and services for Biodiversity, ecosystems and natural capital reached €196 m, expected to increase steadily to €297 m in 2031. The markets of the four applications will grow in parallel and will keep their relative shares: the biggest one being held by the market of **Snow and ice ecosystems monitoring** data and services, with **Terrestrial ecosystems monitoring** coming a close second. Much smaller parts of the market are (and will remain) held by **Water** and **Coastal ecosystems monitoring**.

Making the most of Earth Observation in coral reef mapping & monitoring

According to the US National Oceanic and Atmospheric Association (NOAA), between 2014 and 2017 more than 75% of the world's tropical coral reefs experienced heat-stress severe enough to trigger bleaching and acidification, and that 25% of the ocean's fish depend on healthy coral reefs. Consequently, significant research and monitoring activities are being undertaken to progress our scientific understanding of these complex environments. Given the vast size of such areas, Earth Observation is well positioned to support these efforts. Notably, Copernicus monitors monthly global ocean acidification, Sentinel-3 and NASA's Moderate Resolution Imaging Spectroradiometer (MODIS) data inform the 3D water quality model of the entire Great Barrier Reef whereas Sentinel-2 data has been used to develop algorithms for the mapping (habitat, bathymetry, and water quality) and detection of change for coral reef health assessment and monitoring.

Temperature stress maps are a useful tool in identifying areas of potential risk during bleaching events, while habitat maps can be used to: a) locate suitable sites for restoration programs at ecologically relevant spatial scales; b) identify resilient reefs with high coral cover that are a priority for conservation; c) model ecosystem services (e.g. wave attenuation, fish nurseries); and d) detect detrimental changes in reef environments.

Potential & challenges in using Earth Observation for coastal monitoring

Coastal areas are complex and abundant ecosystems, a direct result of the interaction of terrestrial, aquatic, atmospheric and human landscapes. With approximately 356,000 square kilometres of global coastline benefiting from this convergence of productive and dynamic natural systems, coasts provide a large range of ecosystem services. Understanding how to sustainably manage them is necessary and required by the Convention on Biological Diversity, the United Nations 2030 Agenda for Sustainable Development and other similar commitments at international level. It is also required by several European policies, such as the Marine Strategy Framework Directive and the Water Framework Directive. As such, endeavours are bound to require large amounts of different types of data from multiple sources. Incorporating 'big' **EO data** could make a difference as it would **ensure the spatiotemporal information** required for historical analysis and current status mapping whilst also **enabling global coverage**. EO data has proven useful for mapping natural resources along the coast, covering (but not limited to) fisheries, water quality and bathymetry and natural hazards (i.e., storm surges, coastal inundation, and rising sea levels). Regarding fisheries, although satellite imagery cannot be used to identify individual fish species, it can provide critical information on the environmental pressures that shape a species population's survival (e.g., the Sargassum Watch System). Water quality measurements are also complemented by data on agricultural land use in coastal zones and trophic status. These have the potential to inform actions promoting sustainable agricultural practices thus contributing to tackling biodiversity loss and an improved ecosystem health.

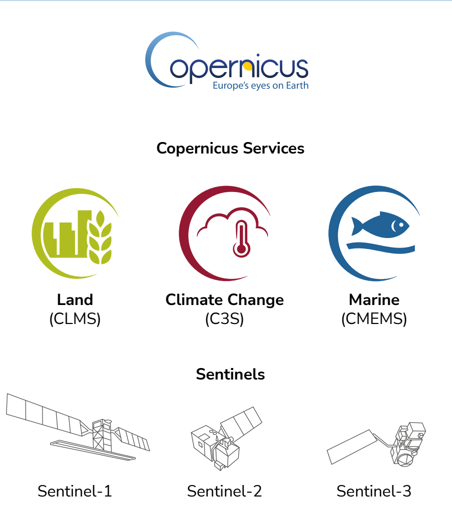
Several key projects use Copernicus data for biodiversity, ecosystems and natural capital purposes

Current usage of Copernicus

The Copernicus Climate Change Service (C3S) project **Sectoral Information System (SIS) for Global Biodiversity** is developing tailored climate information for the biodiversity sector to support the fight against biodiversity loss.

The climate-biodiversity indicators developed within the project can contribute to assessing the impact of temperature, rainfall, and other atmospheric, terrestrial or oceanic variables on: habitat suitability; species distribution; species fitness and reproduction; and ecosystem services.

The indicators will be suitable for biodiversity and ecosystem service assessments for both fauna and flora in both the terrestrial and the marine biosphere for different climatic zones around the globe. This will provide support for decision making, currently made difficult due to lack of relevant climate data.



HORIZON 2020 — EUROPABON

Europa Biodiversity Observation Network (EuropaBON): integrating data streams to support policy

The EuropaBON coordination and support project aims to develop a trans-national system for monitoring biodiversity and ecosystems in Europe and to track a range of so-called 'Essential Biodiversity Variables' that will provide a coherent overall picture of Europe, helping to form the basis for political decisions.

Copernicus and other remote-sensor data streams contribute to developing such novel monitoring systems and support the European habitats directive and restoration & climate policy.

More information available at: https://europabon.org/

HORIZON 2020 — CoastObs

Commercial service platform for user-relevant coastal water monitoring services based on Earth observation

CoastObs is an EU H2020 funded project that aims to use satellite remote sensing to monitor coastal water environments and to develop a user-relevant platform that can offer validated products to users. This will include biodiversity related products, such as monitoring of seagrass and macroalgae, phytoplankton size classes, primary production and harmful algae as well as higher level products such as indicators and integration with predictive models.

More information available at: https://coastobs.eu/

HORIZON 2020 — EOMonDis

Bringing Earth Observation Services for Monitoring Dynamic Forest Disturbances to the Users

EOMonDis service providers and research partners have worked together to overcome existing challenges in tropical forest monitoring by integrating dense time series from optical and radar sensor systems, especially from the Sentinels of the European Copernicus programme. EOMonDis developed user-tailored forest monitoring products such as forest cover and land use maps, near real-time forest disturbance maps and respective change products.

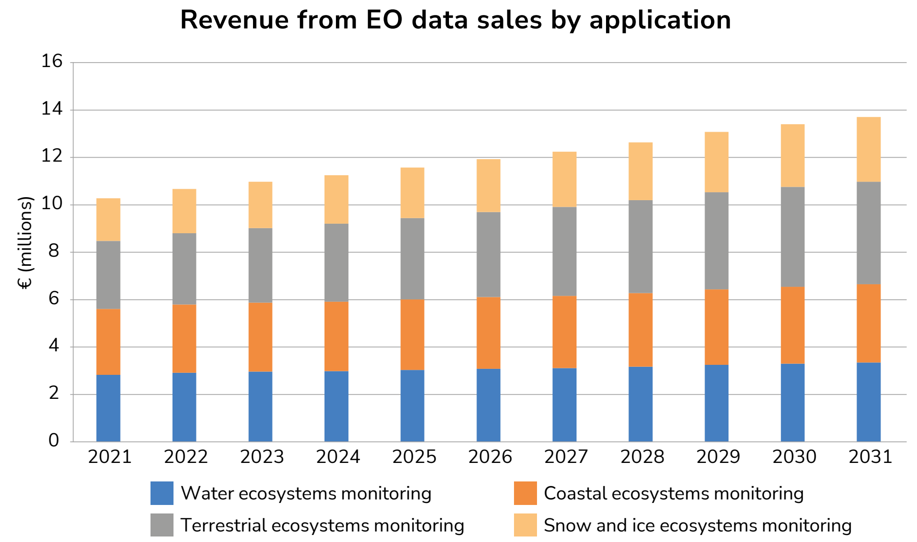
More information available at: https://eomondis.info/

HORIZON 2020 — EO4wildlife

Platform for wildlife monitoring integrating Copernicus and ARGOS data

The EO4wildlife project brought together a variety of multidisciplinary scientists in an effort to promote the use of EO in wildlife monitoring. The project-designed open cloud platform includes a toolbox of interoperable data processing services and features that connect to animal tracking databases, access large data collections from the Copernicus Marine core service, sample relevant environmental indicators, and run environmental models in a scalable processing environment.

More information available at: http://eo4wildlife.eu/


Revenue from EO data sales by application
€ (millions)
0
2
4
6
8
10
12
14
16
2021
2022
2023
2024
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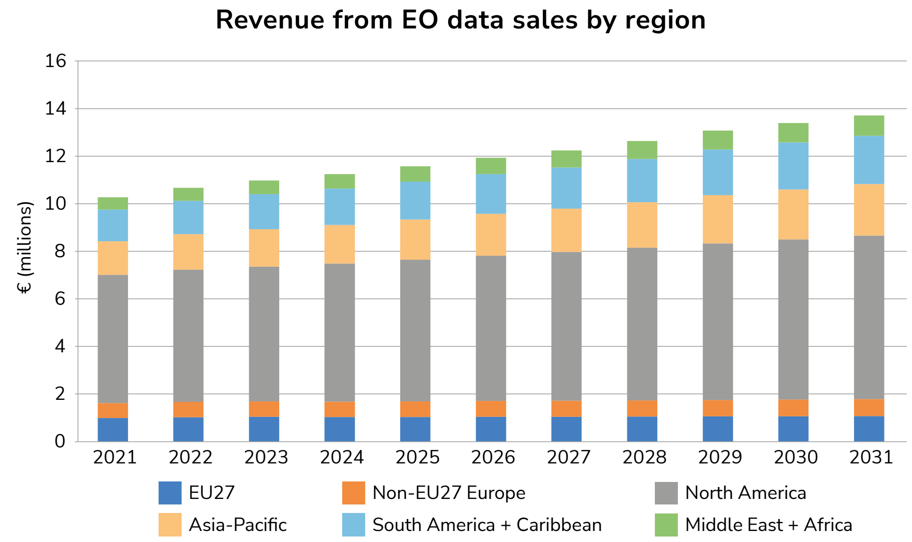
2030
2031
Water ecosystems monitoring
Coastal ecosystems monitoring
Terrestrial ecosystems monitoring
Snow and ice ecosystems monitoring


Revenue from EO data sales by region
€ (millions)
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2
4
6
8
10
12
14
16
2021
2022
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2024
2025
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2031
EU27
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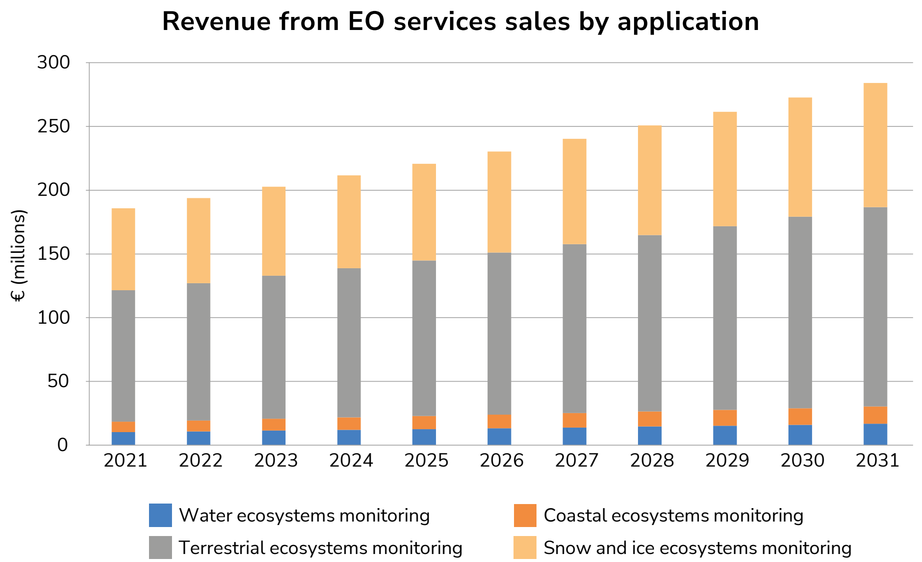
North America
Asia-Pacific
South America + Caribbean
Middle East + Africa


Revenue from EO services sales by application
€ (millions)
0
50
100
150
200
250
300
2021
2022
2023
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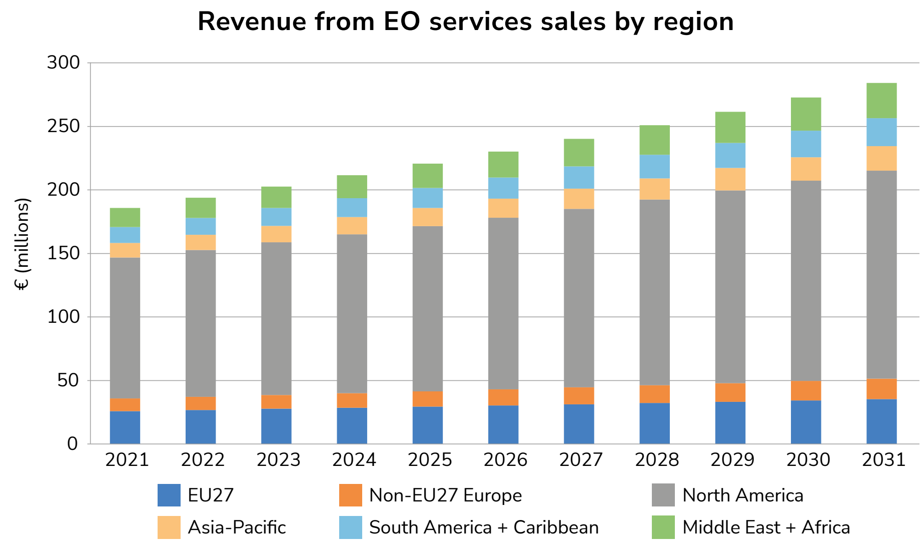
Water ecosystems monitoring
Coastal ecosystems monitoring
Terrestrial ecosystems monitoring
Snow and ice ecosystems monitoring


Revenue from EO services sales by region
€ (millions)
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2029
2030
2031
EU27
Non-EU27 Europe
North America
Asia-Pacific
South America + Caribbean
Middle East + Africa

CLIMATE SERVICES

Legend
EO application
GNSS application
Synergetic application (combined use of EO and GNSS)

Climate change mitigation and adaptation
- Climate change mitigation and adaptation

Climate modelling
- EO-based climate modelling
- GNSS-based climate modelling

Climate monitoring and forecasting
- Climate forecasting
- Climate monitoring

Application descriptions can be found in Annex 3.

CLIMATE SERVICES

The growing awareness of the climate crisis and the imminent need for informed adaptation and mitigation actions has driven up the demand for climate services. The main users are traditional actors in the climate domain such as national and international public bodies, notably policy makers and environmental agencies. Nonetheless, the popularity of climate services among non-governmental organisations, corporations and even the general public is also increasing.

Satellite data plays a major role as source of information for these services. EO and GNSS data are often used together with in-situ observations in **climate models**. These constitute an invaluable source of **climate monitoring and climate forecasting**, which provide the necessary awareness of the state of our climate and its evolution. In recent years, EO-based applications for **climate change mitigation and adaptation** have also emerged, in certain cases resulting in actual strategies.

For all of the above, EO enables the monitoring of the status of snow, ice caps and the permafrost, sea-level rises, the quantity of greenhouse gases in the atmosphere and on many other direct consequences of climate change.

GNSS has limited applicability within the climate domain. Nonetheless, there are a number of techniques such as GNSS radio occultation sounding and GNSS reflectometry used to measure phenomena such as vegetation and soil moisture, which support climate modelling.

What you can read in this chapter

- **Key trends:** Global climate and environment-related trends and policies are driving and generating demand for EO data and applications.
- **Industry:** Climate Services EO Value Chain.
- **Recent developments:** Recent and future developments in EO and GNSS have a strong impact on climate applications.
- **Future market evolution:** New launches, political will and technological convergence pave the way for a dynamic market for climate-related services and applications.
- **EU Systems & Projects:** Several key projects are developing climate services using Copernicus.
- **Reference charts:** Yearly evolution of EO revenues by application and region.

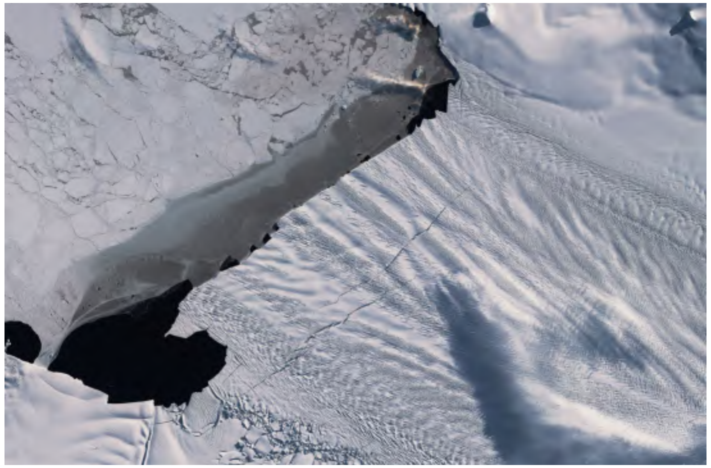
Global climate and environment-related trends and policies are driving and generating demand for EO data and applications

Key market trends

- Funding for applications and services linked to climate change is growing in tandem with increased political priority
- The role of EO in climate services is well-established and continues to grow, driven by synergy with other technologies
- Satellite-acquired data is increasingly exploited in carbon offset and monitoring products, which are expected to form a sizable and sustainable market for EO services and products

Funding and innovation support for climate applications is growing globally

Concurrent with the climate crisis and the political momentum around it, a multitude of funding streams have been unlocked to stimulate innovation and entrepreneurship on climate-related products, services and applications. Globally, international actors are experimenting in novel ways to engage with climate change mitigation and adaptation ventures, including projects and initiatives stimulating the demand for EO data and services. While this funding has traditionally been institutional – coming from the United Nations, the World Bank, Development Banks and other financial institutions, or from national or big regional players such as the European Union – private investment in this field is also steadily increasing, partially thanks to green financing incentives and schemes. The **Global Environment Facility** (GEF) is an independent financial organisation providing grants for projects related to environmental issues, including climate change. For three decades of operational activity, GEF has distributed over $20 billion through loans related to environmental problems. As attested by the 2020 report 'Earth Observation & The Global Environment Facility', **EO has proven to be an invaluable tool for achieving GEF objectives**. In 2020, a GEF project implemented by UNIDO (the United Nation Industrial Development Organization) was granted, aiming to combine financial modelling and climate projections (from the Copernicus Climate Change Service) in order to provide data to investors and decision-makers. These actors could then account for social, economic, and environmental parameters when making decisions related to nature-based large-scale infrastructure investments.



EO-based solutions are at centre-stage of major climate-related initiatives in the EU

Opportunities for EO data and services providers in Europe continue to emerge – this is unsurprising considering the European Union's Climate Fund will dispatch €10 billion over 2021-2030, and the European Commission's aim to mobilise at least €1 trillion of sustainable investment over this period. The Climate-Knowledge and Innovation Community (Climate-KIC) recently concluded a call for strategic partnerships aimed at building and developing investment capability to mobilise capital for climate innovation projects, while also in the process of launching a revamped accelerator programme and investor marketplace. **The goal is to invest €100 million (and leveraging over €1 billion) in innovation for climate action by 2022.** Another example, specifically focused on climate resilience is the EO4SD Climate Resilience initiative. The ESA-led project provides EO data and products for decision-makers through several pilot projects developed in cooperation between EO companies who provide the services and International Financing Institutions who, having the appropriate experience in climate financing, help define the user requirements.

Satellite data has a central role in climate change mitigation and adaptation

The use of satellites for climate monitoring is nothing new – 2022 marks the 50th anniversary from the launch of the first USGS Landsat satellite. Nonetheless, the technical capabilities of EO have been growing exponentially in the past years, as has the awareness of their benefits. A significant amount of credit can be attributed to the abundance of free and open data offered from Copernicus and other sources, which, in turn, have helped to incorporate satellite data in policy-making. a

In 2021 the World Economic Forum's Global Future Council on Space published the **'Space for Net Zero'** white paper. It examines the use of EO, and space technologies in general, for climate change adaptation and mitigation, particularly for greenhouse gas (GHG) reduction. It notes satellite data's primary role in quantifying essential climate variables, **more than 50% of which are measurable only from space..** The white paper highlights the need for a one-stop-shop for climate-related satellite data, expertise and capabilities[1].

The 'Space for Net Zero' white paper is only one instance of a series of reports praising the use of EO in climate change mitigation and adaptation, as well as advocating for its increased use. Another notable example is the 2021 IPCC Report identifying EO satellites as a critical tool to monitor the causes and effects of climate change.

[1] To some extent this is offered by Copernicus e.g. the Climate Adapt platform managed by the EEA is based mostly on C3S data as well as data coming from Copernicus DIAS.

Climate Services EO Value Chain[1]

INFRASTRUCTURE PROVIDERS

- AWS
- BARCELONA SUPERCOMPUTING CENTRE*
- CLOUDEO*
- CODE
- COLLAB GS
- COPERNICUS DIAS*
- GOOGLE CLOUD PLATFORM
- IBM CLOUD
- INTEL GEOSPATIAL
- MICROSOFT AZURE
- PENGUIN COMPUTING
- PEPS

- COPERNICUS COLLABORATIVE GROUND SEGMENT*

DATA PROVIDERS

- AIRBUS*
- BLACKSKY
- COPERNICUS DIAS*
- DESCARTES LABS
- E-GEOS*
- EARTH-I*
- ECMWF*
- EUMETSAT*
- ICEYE*
- MAXAR
- PLANET
- UP42*

- COPERNICUS SENTINELS*
- USGS/NASA LANDSAT
- RELEVANT IN-SITU NETWORKS
- ESA (CATE TOOLBOX)

PLATFORM PROVIDERS

- ADAM*
- CLEOS*
- CLOUDEO*
- COPERNICUS DIAS*
- MAXAR ARD
- PLANET EXPLORER
- SENTINEL HUB*
- TERRADUE*
- UP42*

- THEMATIC EXPLOITATION PLATFORM COASTAL, THEMATIC EXPLOITATION PLATFORM POLAR (ESA TEPS)

EO PRODUCTS AND SERVICE PROVIDERS

- 4 EARTH INTELLIGENCE*
- BERRING DATA COLLECTIVE*
- CONSTELLR*
- EOLAB*
- LOBELIA*
- MEEO*
- STRATOLLOON*

- COPERNICUS SERVICES*

INFORMATION PROVIDERS

- CLIMATE TRACE
- CLIMATE ANALYTICS
- DYNAMHEX
- JUPITER
- TOMORROW*

CLIMATE CHANGE MITIGATION:

- ACCLIMATISE*

END USERS

- POLICY MAKERS
- NGOS
- CORPORATES
- GENERAL PUBLIC
- ENVIRONMENTAL AGENCIES
- INTERNATIONAL AGENCIES (E.G. UN...)

LEGEND

- Commercial Offering
- Public Offering
- User segments

NOTES

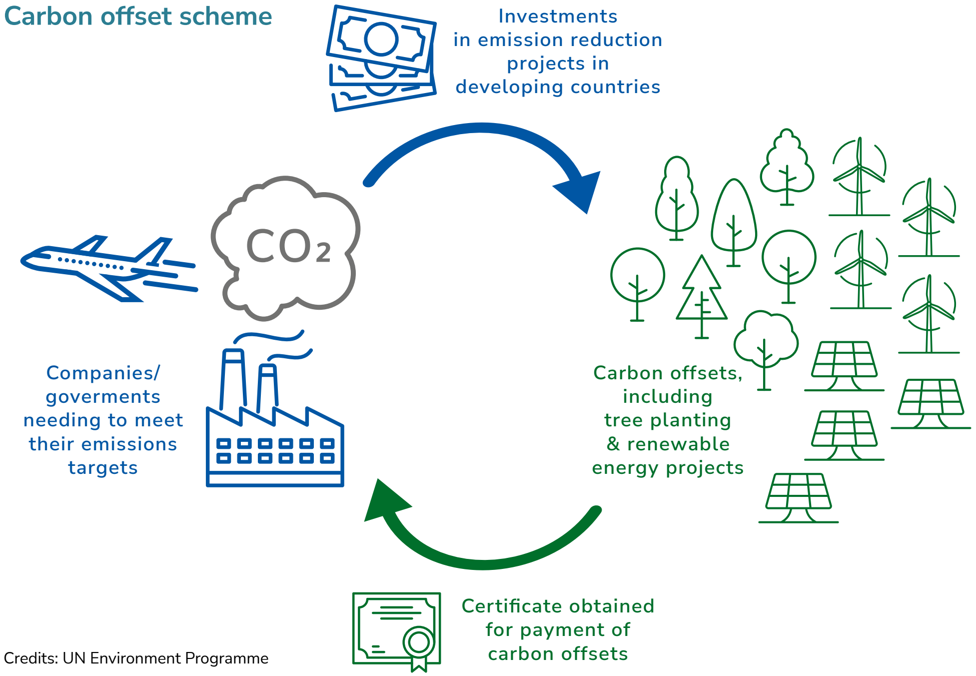
[1] The value chain considers the key global and European companies involved in EO downstream activities.
* European-based companies. The region is defined with respect to the headquarters of the company, though the actual area of activity might be wider.

Recent and future developments in EO have a strong impact on climate applications

An emerging role for Earth Observation in carbon offset markets

Satellites, artificial intelligence and big data are expected to increasingly contribute to the implementation of the Kyoto Protocol and the Paris Agreement. Driven by the need to provide regular and accurate monitoring, reporting and verification of greenhouse gas emissions as well as a need to offset some side effects of growing economies, EO solution developers are finding a source of new demand. For example, the Climate TRACE initiative seeks to track carbon emissions in real time. Concurrently, companies are using **machine learning and Earth Observation to monetise carbon offset opportunities**, either by allowing landowners to earn money for under-utilising their land or by connecting companies with carbon offset projects, thus slowly contributing to the development of a Forest Carbon Credit market.

Carbon offset scheme



Credits: UN Environment Programme

Increasing demand for EO data in climate modelling

Climate models are computer-simulated, dynamic projections of the Earth systems' behavior and used to investigate to what extent observed climate changes are due to human activities versus natural causes. Due to insufficient observations and an incomplete understanding of physical processes, climate models always contain some biases. Consequently, more accurate and reliable the data fed into the developed models can lead to more instructive outcomes. In this context **Earth Observation provides invaluable large-scale data which, combined with in-situ measurements, results in higher accuracy in reconstructing the historical, present and future states of the Earth's climate system.**

These models (created and used both by national meteorological offices and other institutions such as ECMWF, NOAA, etc.) support the forecasting of phenomena in the atmosphere, the oceans, and on land over seasonal, decadal and centennial time scales. Besides their vital support in informing policy (e.g. IPCC Reports, the Paris Agreement, Green Deal, etc.), climate models are also made available by the entities developing them for commercial purposes.

The ultimate sustainability project – Earth's Digital Twin and the Destination Earth initiative

To achieve climate neutrality by 2050 the European Union's 'Green Deal' and 'Digital Strategy' programmes make use of the 'Destination Earth' (DestinE) policy initiative. It is intended to progressively develop *'...a very high precision digital model of the Earth to monitor and simulate natural and human activity, and to develop and test scenarios that would enable more sustainable development and support European environmental policies'*. Based on the already existing weather and climate models and Copernicus data and models, DestinE – an initiative implemented by ECMWF, ESA, and EUMETSAT – will seek to make the most of technology by: (i) integrating AI across the numerical prediction chain; (ii) tailoring supercomputing to increasing processing needs; (iii) maximising Cloud capabilities; and (iv) advancing data-collection instruments besides 'onboarding' all Earth system science and Earth observation data and products onto the digital twin.

The DestinE digital twin for climate change adaptations and extreme events will give users access to high-quality information, services models, trustworthy and reliable scenarios and visualisations, while also enabling them to interact with the systems and to bring their own scenarios, thus potentially assisting the public sector in carrying out better informed decision-making processes.

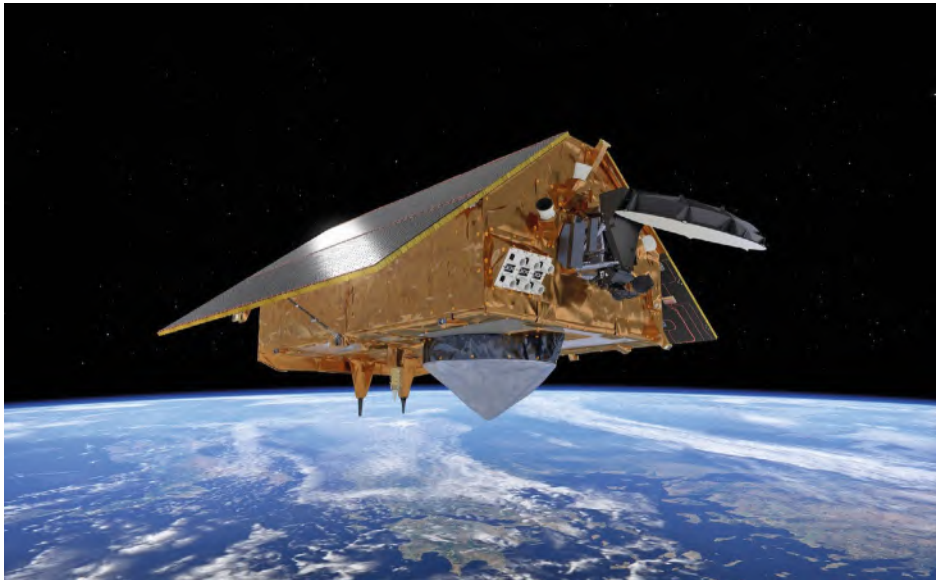
New launches, political will and technological convergence will drive the market of climate-related services and applications

New Sentinels, missions, and sensors providing enhanced scope for synergy

Sentinel-6 Michael Freilich makes an invaluable contribution to climate change adaptation and mitigation through its sea height measurements (similarly available through Sentinel-3). It provides continuity for such measurements, forming part of a chain going back almost three decades, and securing the future of the dataset until at least 2030. Sentinel-6 climate products will improve our understanding of climate change in the context of the Paris Agreement and will support adaptation policies in coastal areas and small-island states threatened by rising sea levels. Sentinel-6 also carries a GNSS Radio Occultation (GNSS-RO) instrument, which will collect highly accurate global temperature and humidity information.

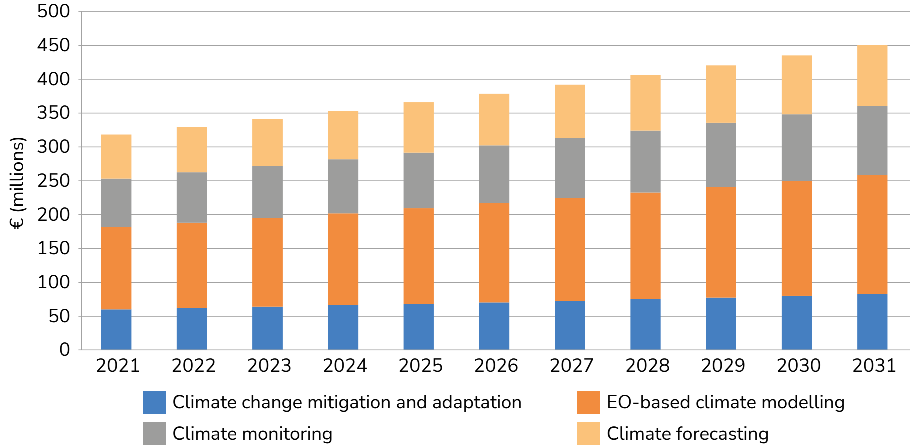
Moreover, the Copernicus programme is set to further extend its constellation of Sentinels with six high-priority candidate missions, several of which directly monitor climate-related variables and phenomena, such as polar ice and snow (Copernicus Polar Ice and Snow Topography Altimeter, CRISTAL), CO_2 (Copernicus Anthropogenic Carbon Dioxide Monitoring, CO2M) and the Copernicus Imaging Microwave Radiometer (CIMR) Mission.

In parallel, a number of private actors have launched, or are preparing to launch, missions which would complement the Sentinels by filling gaps in temporal resolution and in thematic content (through providing, for instance, VHR optical, radar, and hyperspectral data).



© ESA/ATG medialab

Revenue from EO data & services sales by application



The revenues from the sale of both EO data and services in the Climate services sector in 2021 amounted to €318 m, and will grow by almost 50% over the next decade to reach €451 m in 2031. The breakdown in terms of applications shows that **EO-based climate modelling** holds by far the largest market share in the segment, with the other applications (Climate monitoring, Climate forecasting, and Climate change mitigation and adaptation strategies) having similar market shares over the decade.

The integration of AI is increasing the quality of climate-related applications

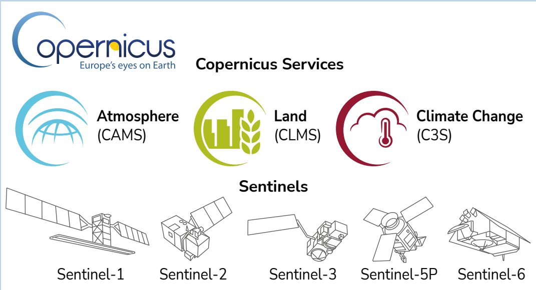
The Earth's climatic and environmental processes work in complex and non-linear ways. There is growing awareness and urgency to understand them better, underscored by the political momentum in response to climate change. More data than ever, including EO, have been gathered on climate, weather and the environment. This has opened an opportunity for artificial intelligence (AI), and particularly machine learning (ML) algorithms, which need vast quantities of relevant training data in order to produce accurate outputs (through classification, detection, indexing, prediction and data fusion).

AI is already in use within the Copernicus C3S and CAMS services for spotting changes in tree and land cover (which is very effective when in-situ monitoring is lacking), transposing air quality forecasts to city scale and processing imagery. The share of private companies applying AI/ML to environmental EO data is steadily and sustainably growing, resulting In a range of services in the environmental domain.

Several key projects are developing climate services using Copernicus

Current usage of Copernicus

The European Climate Adaptation Platform Climate-ADAPT is a partnership between the European Commission and the European Environment Agency (EEA). Climate-ADAPT is maintained by the EEA with the support of the European Topic Centre on Climate Change Impacts, Vulnerability and Adaptation (ETC/CCA). The platform uses **C3S data** and aims at supporting Europe in its adaption to climate change by helping users access and share data and information on topics such as expected climate change in Europe, current and future vulnerability of regions and sectors, national and transnational adaptation strategies and actions, adaptation case studies and potential adaptation options and tools that support adaptation planning.



Current usage of EGNSS

Although there is limited use of GNSS and thus EGNSS within the climate domain, there are a number of techniques such as **GNSS radio occultation sounding** and **GNSS Reflectometry** that support climate modelling. Both techniques can benefit from improved performances offered by Galileo and its services.

HORIZON 2020

Improving the reliability and usability of C3S information

The aim of CONFESS (Consistent Representation of Temporal Variations of Boundary Forcings in Reanalyses and Seasonal Forecasts) is to improve the reliability and usability of C3S information in the land-atmosphere coupled system by exploiting new and improved Earth Observations data records of land-use, vegetation states and surface-emitted aerosols delivered across different Copernicus Services.

More information available at:
https://cordis.europa.eu/project/id/101004156

HORIZON 2020

Accurate space geodesy and modelling to better understand the impact of climate change

This multidisciplinary fellowship within the GEOCLIME (Climate Change and Geodetic Deformation) project will improve understanding of the water cycle and the impact of climate change on Earth's shape via the study of loading effects using accurate space geodesy and modelling. Combining an innovative method and highly complementary data in terms of both spatial and temporal resolution – GNSS and space-borne gravity data (GRACE) – this fellowship will allow precise determination of loading effects and to invert for associated mass variations.

More information available at:
https://cordis.europa.eu/project/id/785919

HORIZON 2020

Multi-scale Earth observation indicator system for land degradation assessment of transitional Mediterranean climates

The evidence of geological field studies and that of Earth Observation sensors is vital to understanding how ecosystems cope with changes and loss of vegetation, representing a complex interaction. The PantEOn (a multi-scale Earth observation indicator system for land degradation assessment of transitional Mediterranean climates) project is working on a multi-scale framework that will link vegetation patterns with water resources and sediment formation, with a view to managing desertification.

More information available at:
https://cordis.europa.eu/project/id/845146

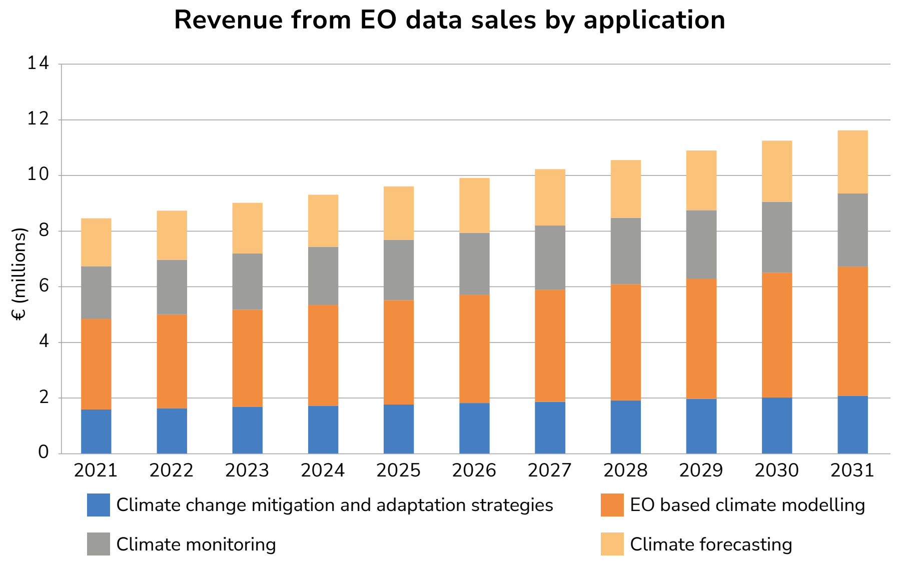
ClimSA

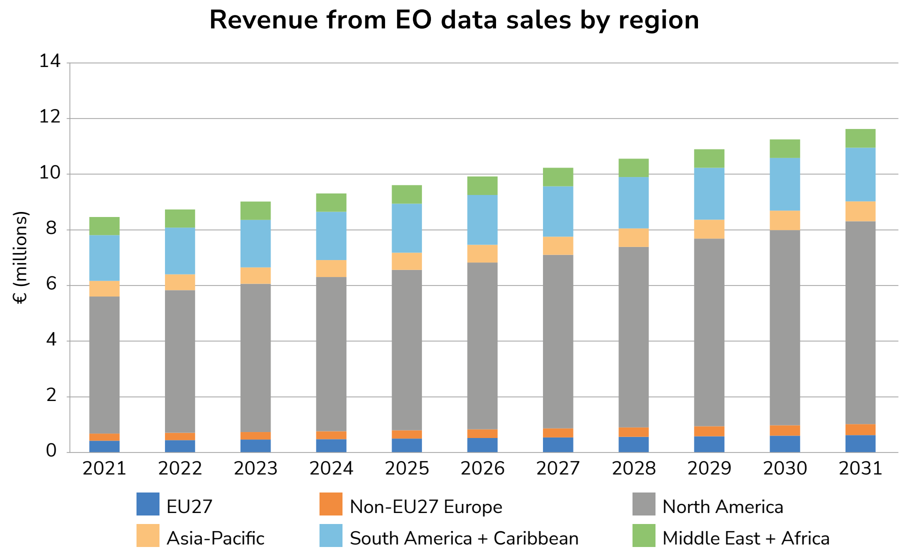
Improving the production, access to and use of climate information, services and applications for decision makers

The six-year Intra-ACP [African, Caribbean, Pacific Group of States] Climate Services and Related Applications (ClimSA) project – with €85 million in funding from the European Union – aims to improve the production, access to and use of climate information, services and applications for decision makers. The project will foster sustainable development through the prevention of desertification, preservation of ecological biodiversity and the implementation of sustainable water management in ACP countries.

More information available at: https://www.climsa.org/

Terminology used on this page is explained in Annex 2 for both GNSS and EO performance parameters.


Revenue from EO data sales by application
€ (millions)
0
2
4
6
8
10
12
14
2021
2022
2023
2024
2025
2026
2027
2028
2029
2030
2031
Climate change mitigation and adaptation strategies
EO based climate modelling
Climate monitoring
Climate forecasting


Revenue from EO data sales by region
€ (millions)
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2
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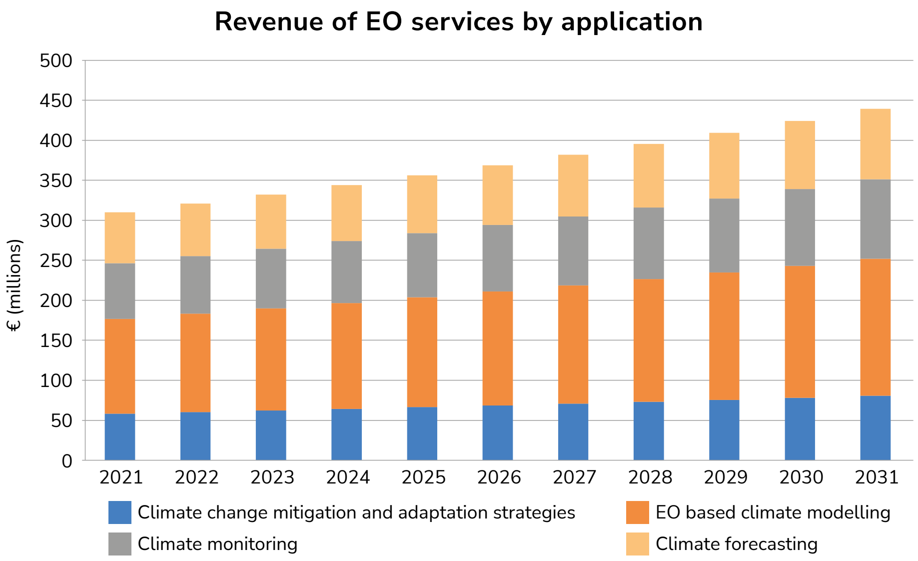
EU27
Non-EU27 Europe
North America
Asia-Pacific
South America + Caribbean
Middle East + Africa


Revenue of EO services by application
€ (millions)
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100
150
200
250
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350
400
450
500
2021
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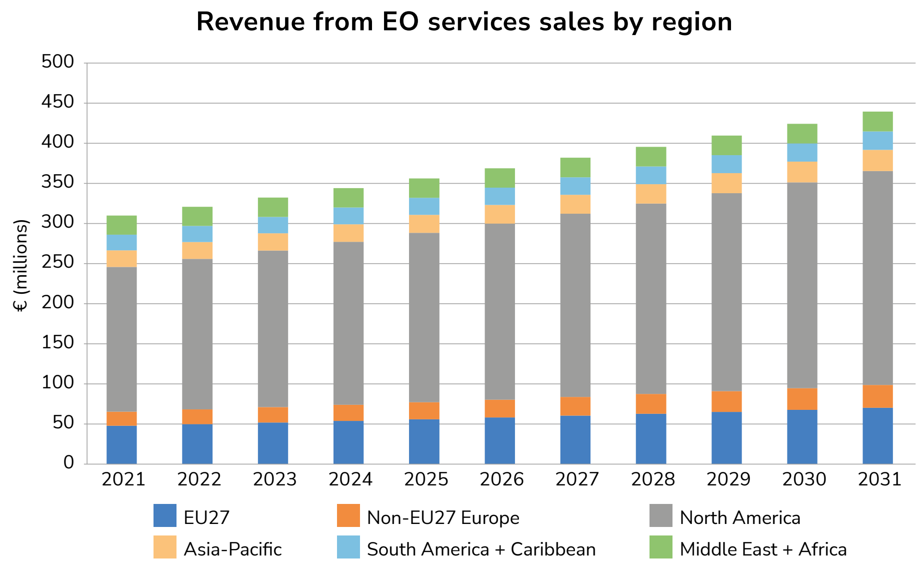
Climate change mitigation and adaptation strategies
EO based climate modelling
Climate monitoring
Climate forecasting


Revenue from EO services sales by region
€ (millions)
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500
2021
2022
2023
2024
2025
2026
2027
2028
2029
2030
2031
EU27
Non-EU27 Europe
North America
Asia-Pacific
South America + Caribbean
Middle East + Africa

CONSUMER SOLUTIONS, TOURISM AND HEALTH

Legend
EO application
GNSS application
Synergetic application (combined use of EO and GNSS)

Corporate
- Billing
- Geo-advertising
- Mapping and GIS
- Satcom users
- Workforce management

Health & Lifestyle
- Air quality monitoring
- Games
- Geo-tagging
- mHealth
- Safety and emergency
- Social networks
- Sport, fitness and wellness incl. specialist support tracking
- UV monitoring

Navigation & Tracking
- Navigation
- Personal & asset tracking
- Visually impaired support

Robotics
- Consumer robotics
- Enhanced human

Tourism
- Points of interest

Application descriptions can be found in Annex 3.

CONSUMER SOLUTIONS, TOURISM AND HEALTH

GNSS-enabled Consumer Solutions comprise a multitude of applications, tailor-made to satisfy different usage conditions and needs (e.g. lifestyle, tourism, health, etc.). These applications are supported by several categories of connected devices; mainly smartphones and tablets, but also specific equipment such as personal tracking devices, wearables, digital cameras and portable computers.

Nowadays, with a combination of technologies such as GNSS, 5G, Wi-Fi and Internet of Things (IoT), any physical device can become a connected device, enabling new applications to facilitate the end user's wellness and lifestyle. On top of this, Artificial Intelligence (AI) provides an additional layer to this connectivity enabling greater capabilities and sophistication to these devices.

Technological advances and substantial reductions in the costs associated with operation and supporting infrastructure (e.g. data storage) for satellites, have led to a dramatic rise in the availability of satellite imagery for civilian use in recent years. This significant amount of information on Earth's condition, often available on (at least) a daily basis, has enabled application developers to create service and information layers that enable dozens of apps for various purposes.

What you can read in this chapter

- **Key trends:** Now more than ever, GNSS solutions facilitate our ways of living.
- **User perspective:** Cutting-edge consumer applications require high-performance space data.
- **Industry:** Consumer Solutions, Tourism and Health Value Chain.
- **Recent developments:** Smartphone shipments continue to dominate the market as the industry experiences a slow down.
- **Future market evolution:** Despite maturing device markets, revenues are soaring thanks to EO and GNSS-enabled apps.
- **Focus on European Systems:** Start-ups and SMEs testify that EU space programme features are making a difference.
- **Reference charts:** Yearly evolution of installed base of GNSS devices and revenues as well as EO revenues by application and region.

Now more than ever, GNSS solutions facilitate our ways of living

Key market trends

- COVID-19 has heavily impacted day-to-day life, leading to increased adoption of context-aware apps to solve societal problems introduced by the virus
- A renewed focus on health, including public health, personal health and mental wellbeing is driving uptake of personal fitness mobile apps and wearables
- Online purchasing behaviour is causing changes in fraud patterns, with location data a key tool to fight digital fraud
- Consumer interest in sustainability is driving growth in repairable phones and longer replacement cycles

Context-aware apps in the spotlight to deal with COVID emergency

The importance of context-aware services has increased during the COVID-19 pandemic. New apps such as DiAry and Zostaň Zdravý, have taken the approach of using location data, shared in an anonymised format with public authorities, to help map and track the spread of the virus.

Context-aware apps have played an essential role in dealing with issues that have arisen in the era of social distancing. Filaindiana handles queue management at shops, FreMEn Adviser allows users to avoid crowds and peak visit times in public places such as parks, Coronamadrid helps people to access nearby medical services, UberEats allows contact-less deliveries and Swishd provides help with grocery deliveries for vulnerable people.

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These **context-aware apps are expected to stay post-COVID**, boosting re-integration and the returning of lives to 'normal', particularly for individuals from vulnerable groups.

Context-aware authentication used to fight rise in cyber fraud

The 'new normal' introduced by the COVID-19 pandemic has led to **an increased use of online financial services,** including mobile banking and online shopping. However, as mobile banking and eCommerce increases, digital fraud also rises. To combat the growth in digital fraud, fraud monitoring based on user **authentication has become a key role for online financial services.**

In today's complex world, anti-fraud strategies require a layered approach, where the user's true identity is verified using various contextual factors. GNSS positioning data plays a role as a layer of security against fraudulent purchases as purchases and money transfers from unusual locations can immediately be flagged as suspicious and require additional authentication. Many financial technology providers move beyond two-factor authentication and are now using geolocation data as part of a 'context-aware' authentication approach, including Venmo, Mastercard, Visa and Revolut. When unusual activity occurs, other attributes like time/date and the device used to make the purchase can be used to verify the user's identity.

Change in exercise patterns boost personal fitness apps and wearables

The COVID-19 pandemic and related social distancing requirements have changed patterns of exercise for sports enthusiasts. It has also renewed interest in personal health and wellbeing, encouraging more people to begin exercise routines. The result is an increased uptake of cycling, running, walking and other outdoor activities.

The increased popularity of outdoor exercise has aligned well with green initiatives of many regions and cities, with more than €1bn spent on cycling-related infrastructure worldwide since the pandemic began. The public health investment and personal health focus have been reflected in a boost in uptake of fitness tracking apps, with providers such as Strava reporting one million new users each month of the pandemic.

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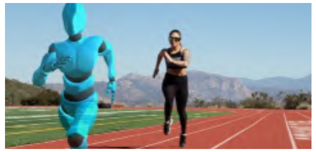

© Ghost Pacer

New to fitness apps and wearables are the improved functions offered through Augmented Reality (AR). Google Live AR Navigation combines GNSS localisation and visual mapping providing floating arrows on your camera feed, making it easier to follow directions or find a way out of unfamiliar areas whilst out on a run.

For sport enthusiasts looking for a stronger motivation and some competition with their former self, the AR glass manufacturer Ghost Pacer is introducing an AR holographic running partner for you to keep pace with.

Sustainability advancements in the smartphone market

Sustainable phones which ensure easy maintenance, either through long warranties which include all repairs (Teracube), and user-replaceable modules (Fairphone 3) are beginning to take off, although are still niche products in the smartphone market. With a consumer focus on sustainability, longer replacement cycles are demanded– phones designed to be long-lasting will bolster this trend. Premium phone prices continue to rise year on year, which ensures higher value for producers to offset longer device lifetimes.

© Fairphone

Cutting-edge consumer applications require high-performance space data

Increasing demand for sensor fusion and battery life

Applications such as augmented reality (AR) and robotics are pushing the boundaries of performance of positioning solutions in order to reach the next level of functionality, such as fully immersive augmented reality and operations in outdoor uncontrolled environments for robotics. The next generation of applications will require not just GNSS, but sensor fusion to reach the required performance. For example, to reach the full capabilities of immersive AR, the iPhone 12 now includes LiDAR sensors for better visual mapping.

In addition to more demanding positioning needs, there is a demand across all consumer applications for **longer battery lives**. At the 2020 GSA User Consultation Platform, 91% of users considered power consumption as crucial. The **size of the devices** (and their chips) is another critical requirement for consumer solutions. In the case of elite sport applications (e.g. tracking of rugby players) for example, the size, weight and shape of the device are very important criteria.


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Every improvement which can lead to the decrease of the power consumption and the size of the user device will open up new markets and new applications.

Current EU projects and the industry are working on tackling those challenges. An example is the Apollo project that aims at providing a Galileo-based geolocation solution for the IoT market by considerably decreasing the material bill of the GNSS function and reducing its power consumption by at least 95% via remote server storage.

Since the advent of the IoT era in the 2010s, great improvements have been realised in terms of cost and size reduction as well as the consumption of power. Whilst these improvements will boost the deployment of IoT in mass markets (e.g. vehicles, wearables, etc.) it also opens up the market for more niche applications and communities. Together with the democratisation of EO data in smartphones, low-powered IoT is revolutionising the way niche communities operate.

For instance, BeeLive is a beekeeper's decision making and social networking tool, based on GNSS-enabled devices and using EO satellite data to support the beekeepers' community to select location of desired vegetation (e.g. flowers, pine etc.), providing real-time notifications on weather conditions or events in the area. The BreezoMeter API relies, among other sources, on free and open data of the Copernicus Atmosphere Monitoring Service (CAMS) to provide personalised health recommendations based on air quality forecasts.


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Earth Observation enables many consumer applications

Many key consumer applications would not function without the information from EO data. For example, consumer applications which rely on mapping, such as smartphone navigational applications, require the accurate mapping of the Earth's surface by Earth Observation satellites. Tourists are using such data for identification of interest points and route planning.

Earth observation is also key to many other apps which help us live convenient and healthy lives. Air quality apps such as IQAir's AirVisual allows smartphone users to track air pollutants such as NO2 and facilitates pollen monitoring, providing quantitative information on air quality to users in their location. In addition, apps like Accuweather allow users to monitor the UV index level in their location, avoiding harmful UV exposure.


© ESA

Oostvadersplassen – a nature reserve in the Netherlands captured by Sentinel-2.

Key EO and GNSS user requirements

The key GNSS and EO user requirements for the different application groups within the **Consumer Solutions, Tourism and Health** segment are, at EU level, collected using the following procedures:

- For GNSS, information is collected through extensive interactions with user groups, providers and experts in a continuous process culminating at the User Consultation Platforms (UCP). All relevant requirements are documented in detail and updated regularly within the Report on Location-Based Services user needs and requirements.
- User requirements for Copernicus services and products – as well as their evolution – are collected through an integrated process that involves different channels: (i) dedicated studies (e.g. "NEXTSPACE" project, "Copernicus for EC (C4EC)" study, Commission Staff Working Document on user needs), (ii) targeted consultations organised by the European Commission or the Entrusted entities with the relevant communities, (iii) regular and structured exchanges among representatives of the Copernicus governance structure and Member States through the Copernicus User Forum.

From the 2022 EUSPA`s UCP onward, EO user needs and requirements of commercial users will be validated and discussed with industry experts and user groups, mirroring the process implemented for GNSS.

Consumer Solutions, Tourism and Health Value Chain[1]

COMPONENT AND RECEIVER MANUFACTURERS

- ANALOG DEVICES
- ALLYSTAR
- BROADCOM
- GLOBAL FOUNDRIES
- HISILICON
- INFINEON*
- INTEL
- MEDIATEK
- NIHON DEMPA KOGYO
- QUALCOMM
- SAMSUNG
- SEIKO EPSON
- SPREADTRUM COMMUNICATIONS
- SONY
- STMICROELECTRONICS*
- U-BLOX*

OPERATING SYSTEM DEVELOPERS

- APPLE (IOS)
- CANONICAL* (UBUNTU)
- GOOGLE (ANDROID)
- JOLLA* (SAILFISH)
- LINUX FOUNDATION (LINUX)
- MICROSOFT (WINDOWS)

DEVICE INTEGRATORS AND VENDORS

SMARTPHONE/ TABLETS:
APPLE, BLACKBERRY LIMITED, DORO, HTC, HUAWEI, LENOVO, LG, MALATA, MICROSOFT, NOKIA, ONEPLUS, OPPO, SAMSUNG, SONY, VIVO, XIAOMI, ZTE

WEARABLES: APPLE, AMER SPORTS*, CITIZEN, FITBIT, GARMIN, MICROSOFT, POLAR*, SAMSUNG, SUUNTO*, TIMEX*, XIAOMI

PEOPLE TRACKING DEVICE MANUFACTURERS

ORIGINAL DESIGN MANUFACTURERS

CAMERA MANUFACTURERS

PC MANUFACTURERS

SERVICE & CONTENT PROVIDERS

GNSS

MOBILE NETWORK OPERATORS AND ASSISTANCE DATA PROVIDERS:

- AT&T MOBILITY
- ORANGE*
- RXNETWORKS
- TELEFÓNICA*
- VERIZON WIRELESS
- VODAFONE*

EO MAP PROVIDERS
APPLE, GOOGLE, HERE, MAPQUEST, MICROSOFT, OPENSTREETMAP

EO DATA PROVIDERS
AIRBUS*, COPERNICUS DIAS*, MAXAR, PLANET*

- COPERNICUS SERVICES*

APP DEVELOPERS/ RETAILERS

GENERAL APP DEVELOPERS:
APPLE, FACEBOOK, FOURSQUARE, GOOGLE, IAC, MICROSOFT, NIANTIC, NOKIA, TRIPADVISOR, YELP, ZYNGA, and many small app developers

mCOMMERCE:
AMAZON, FOURSQUARE, GROUPON, PAYPAL, ZALANDO*

mHEALTH:
AZUMIO, EPOCRATES, FITBIT, FITNOW, IHEALTH, SANOFI*

RETAILERS: AIRLINES, BANKS, GENERAL RETAILERS, MEDIA COMPANIES, MOBILE NETWORK OPERATORS, TRANSPORT PROVIDERS, VEHICLE MANUFACTURERS

APP STORES

- 360 MOBILE ASSISTANT
- AMAZON APP STORE
- APPLE APP STORE
- BLACKBERRY WORLD
- GOOGLE PLAY
- TENCENT MYAPP
- WINDOWS PHONE STORE

USERS

- **CITIZENS**
- **ELDERLY AND VULNERABLE GROUPS**
- **TOURISTS**
- **SPORT ENTHUSIASTS**
- **WORKFORCE**

European[2] GNSS industry in the global arena

With STmicroelectronics, Infineon Technologies and U-Blox, Europe held three of the top 10 positions among GNSS Component and Receiver manufacturers in 2019. Europe had a share of turnover of 7%, behind North America (47%) and Asia (45%). European GNSS system integrators (e.g.. smartphone and wearable manufacturers) generated 3% of the turnover in 2019, trailing behind Asia (63%) and North America (34%)

LEGEND

- Commercial Offering
- Public Offering
- User segments

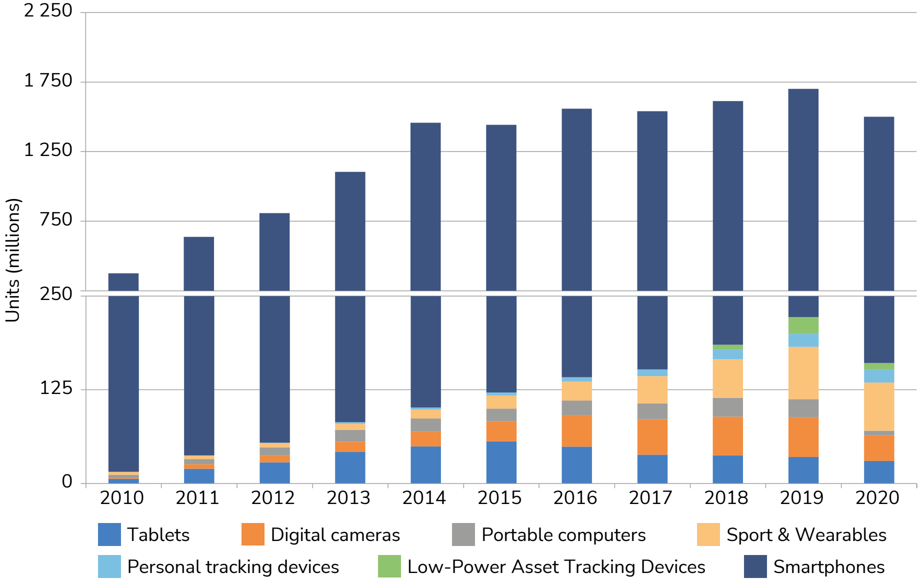
Green denotes EO-enabled services.

NOTES

[1] The value chain considers the key global and European companies involved in GNSS and EO downstream activities.
[2] In the market share analysis, Europe is defined as EU27 plus Norway, Switzerland and the UK.
* European-based companies. The region is defined with respect to the headquarters of the company, though the actual area of activity might be wider.

Smartphone shipments continue to dominate the market as the industry experiences a slow down

Shipments of GNSS devices by type



With roughly 90% of a 1.5 bn unit market, smartphones continued to greatly **outnumber other consumer devices** in terms of shipments. Nevertheless, the number of smartphones shipments has been decreasing significantly for the first time with the 2019-2020 year-on-year growth becoming negative (-9%). This can be explained by the increasing saturation of the market (mature EU, North American and China markets), the COVID-19 pandemic and consumer interest in sustainability which drives growth in repairable phones and longer replacement cycles (see Key Trends).

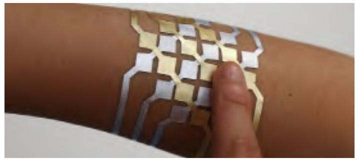
Other GNSS-enabled devices accounted altogether for around 161 m units in 2020. With 64 m units shipped that year, **sports & wearable devices** represented the second largest group of consumer solutions. Their shipments saw an annual increase of 30% between 2015 and 2020, with Chinese manufacturers dominating the smart wearables market. Driven by reducing device prices and growing consumer awareness, personal tracking devices continue to witness the highest growth rate across all Consumer Solution applications, with a CAGR of 79% between 2010 and 2020.

The remaining devices all saw their share shrink over the last couple of years. Shipments for personal and low-power asset tracking devices have been shrinking the most in 2020, mainly due to the slowdown in activities caused by the global pandemic. The declining shipments for tablets, digital cameras and portable computers are due to the maturity of these devices and their market as well as a general decline in the use of GNSS for said devices.

Endless possibilities for combining location data and Human Enhancement

Human enhancement refers to methods for altering the human body to enhance mental or physical performance. An example of well-developed technology in this area is the HoloLens 2 Industrial Edition, an untethered mixed reality device designed to support large variety of industrial environments. HoloLens 2 are used to build the Orion spacecraft and reduce tough manual labour e.g. an eight-hour shift was completed in just 45 minutes. Another more futuristic example is the brain-computer interfaces, which Facebook and Neuralink are looking to commercialise in the coming decades. Developments have also been made in digital tattoos – temporary tattoos that use the skin's reactivity and conductive metals to create a flexible computer chip, which can house sensors such as Near Field Communication (NFC) and haptics.

As the technology develops, the scope of its possible applications seems vast – GNSS position could be combined with optical feedback and 3D mapping to give users full situational awareness and the most accurate navigation. This is particularly interesting for emergency responders such as firefighters and paramedics.



© MIT

MIT Digital Skin Tatoo Touchpad

Robots that can roam wide and far

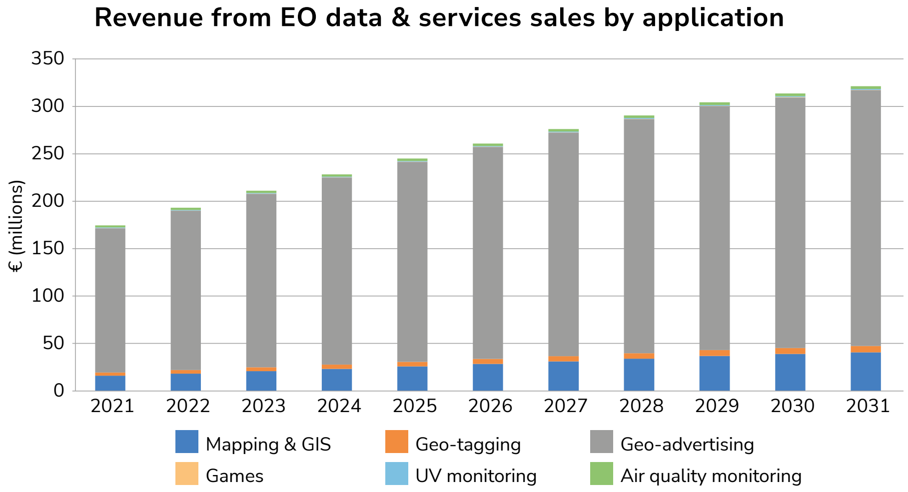
HThe 2020s are set to be the decade of robotics adoption. Since the start of 2020, we have seen an acceleration in the deployment of robots in outdoor environments to deal with the COVID-19 pandemic. CloudMinds robots have been used to deliver medicine and food to sick people in China, and the Boston Dynamics Spot robot has been used in Singapore to enforce social distancing in public parks. We have also seen advancements in consumer robotics for indoor environments, such as responsive pet robots like Qoobo and smart personal assistant robots like Samsung's Ballie. The market is open to many SMEs and start-ups. The European start-up 10Lines is developing autonomous parking lot robots to facilitate the creation of parking lots and increase efficiency in the sector, while Rover4RT provides a robotic alternative to chemical herbicides for the weed control in railway tracks.

Another example is the service provided by Unmanned Life, a platform for seamless orchestration of autonomous robotics. These examples are just the beginning, as the market for robotics is still in its infancy and there is plenty of room for growth foreseen in the upcoming years.

© Straits Times

Boston Dynamics Spot Robot enforcing social distancing in a Singapore park

Despite maturing device markets, revenues are soaring thanks to EO and GNSS-enabled apps



With an estimated CAGR of 6%, the global EO market of data and service revenues in consumer solutions, tourism and health will grow progressively from roughly €175 m in 2021 to almost €321 m in 2031.

The largest EO service in the consumer market belongs to **Geo-advertising**. The associated revenue will increase from €152 m in 2021 to €270 m in 2031. **Mapping & GIS** is foreseen to remain the second most important revenue-generator, with annual growth rates of around 10%, which is higher than the CAGR% of **geo-tagging** (7%).

With the lowest CAGR of 2% between 2021 and 2031, **UV monitoring** (from €764,000 in 2021 to €959,000 in 2031) and **air quality** (from €2 m in 2021 to almost €3 m in 2031) are the two applications expected to see the slowest growth over the next decade. However, this can be explained by looking at the nature of the applications which are clearly serving less a commercial role and more an informative one for the end users.

Finally, despite having the fastest growth forecasts of all EO applications (13% CAGR), **EO-enabled games** remain a niche amongst the mobile games. Whilst games themselves generate large revenues, the share associated to actual EO contributions is negligible compared to, for example, in-game purchases for in-game content.

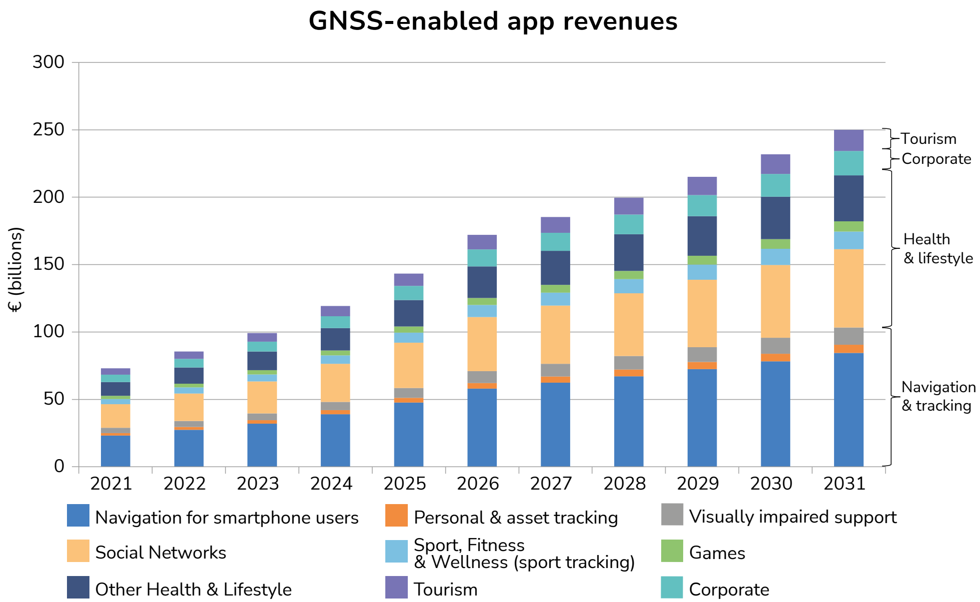
Whereas the market for GNSS-enabled devices has been maturing over the past decade (see previous page), **GNSS-enabled revenues generated by apps are expected to soar from roughly €73 bn in 2021 to €250.0 bn by 2031**, growing by a CAGR of 15%.

The chart on the right, focuses on the four biggest categories as well as the largest individual applications. **The largest group covers apps under 'Health & Lifestyle'** for a total market of €34 bn in 2021, of which the biggest ones are Social Networks (roughly €18 bn in 2021), Sport-related apps (almost €4 bn) and Games (over €2 bn). The remaining apps in this category (i.e. 'Other Health & Lifestyle' in the chart) add up to almost €10 bn.

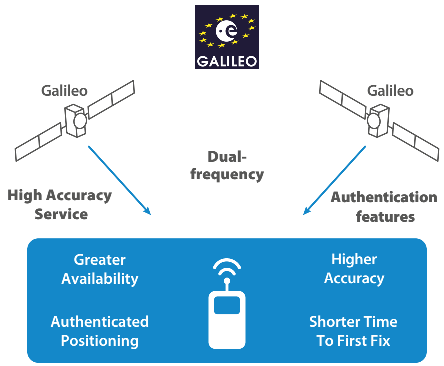
'Navigation & Tracking' apps combine for almost €29 bn in 2021, and the **Navigation apps themselves have global revenues worth €23 bn.** Albeit a niche category, the revenues of the Visually Impaired Support apps have an estimated revenue of almost €4 bn. Personal & Asset Tracking follow at almost €2 bn.

The remaining app categories, namely, **'Tourism' and 'Corporate', generate a combined €10 bn GNSS-enabled revenues in 2021.**

Over the next decade, it is forecasted that global GNSS-enabled revenues from apps in the 'Navigation & Tracking' category will reach €103 bn, remaining the second largest category behind 'Health & Lifestyle' which is expected to generate a total of €113 bn. Combined, these two app categories would dominate the global revenues with a share of 86% of the market.



Start-ups and SMEs testify that EU space programme features are making a difference

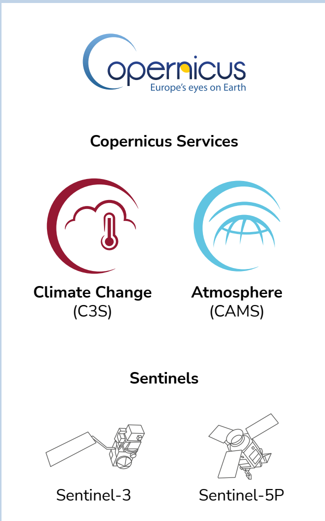


Current usage of EGNSS

More than 800 **different Galileo-compatible smartphone models** and over 130 different **Galileo-compatible wearable models** were available on the market by end of Q3 2021.

Current usage of Copernicus

The Copernicus Atmosphere Monitoring Service (CAMS) provides daily near-real-time analysis, reanalysis and four-day forecasts of European air quality, thus enabling a permanent assessment of the air we breathe. Applications such as real-time pollen and air quality trackers have already found their way into our Consumer devices such as Smartphones and Tablets.



EUSPA continues it's support to SMEs and start-ups through its competitions

In 2020 the GSA launched #MyGalileoSolution, a contest aimed at developing a location-based solution such as a mobile application, wearable-based solution, asset management, tracking solution or robotics, leveraging Galileo as a source of positioning, navigation and/or timing. Track 1 of the contest focused on the implementation of an idea into a prototype, whilst Track 2 focused on the development of a final product. **The winners were:** VisionAnchor (Track 1), with the world's first video anchor monitoring system for boats; and 10Lines (Track 2), with an autonomous parking lot marking solution.

Building up on #MyGalileoSolution experience, EUSPA launched in 2021 a new competition for innovators and entrepreneurs called MyEUspace. The competition, organised in two tracks and six innovation areas, challenges participants to develop and commercialise innovative solutions that leverage EU space data and services, including Galileo, Copernicus and their synergies as well as synergies with other technologies.

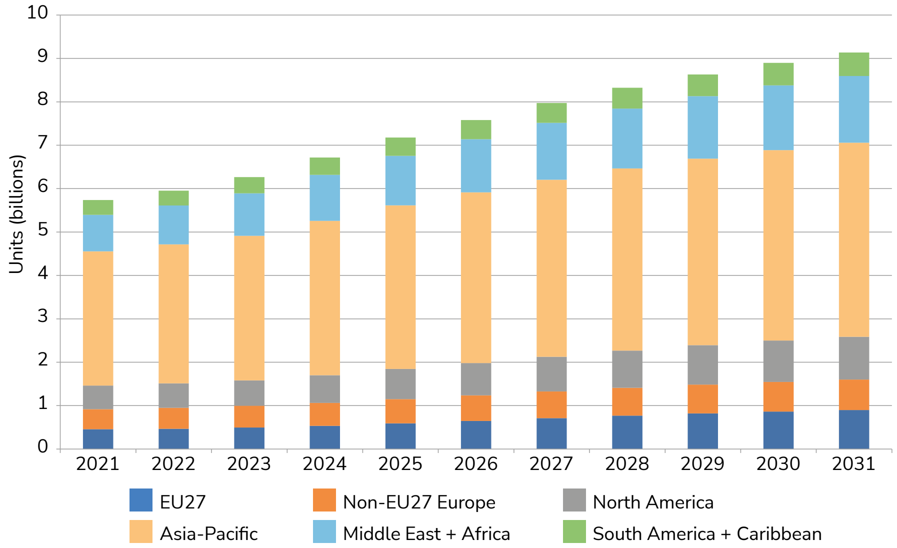
As a new initiative and additional stimulation for the space market uptake, the European Commission introduced the Cassini initiative to stimulate entrepreneurship in the area of space technology and applications building on space data. Its aim is to align the funding instruments better to the need of entrepreneurs, covering the whole life cycle of innovation from start-up to support during different stages of SME growth. Cassini will comprise mentoring and hackathons in at least 10 different locations.

Copernicus services contribute to safer water sports

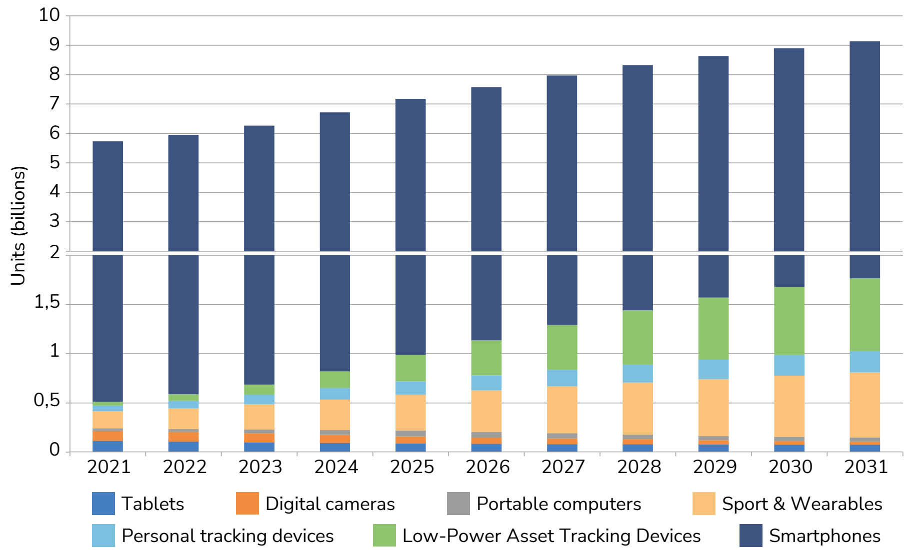
The surf industry amounts for over ten million surfers worldwide, increasing at 12%-16% per annum. Information about met-oceanic conditions is vital for their safety.

MeteoSurf is a free multi-source weather forecasting App designed to provide wind and wave conditions for the Mediterranean Sea. It is an application for smartphones and tablets, able to supply detailed and updated maps and data showing heights of sea waves. MeteoSurf shows data collected from three different forecasting system sources, amongst which is the **Copernicus Marine Service ocean forecast model**. Another project beneficial for the tourism sector is **iSWIM**. It is a Bathing Water Quality Monitoring in the Black Sea, web-based and mobile-friendly decision support system to enhance the management, monitoring and forecasting of the bathing water quality in the Black Sea. The app integrates numerical models downscaled from the Copernicus Marine Service Black Sea model with in-situ measured data and **Copernicus Marine Environment Monitoring Service (CMEMS)** remote sensing products. Finally, following a partnership agreement, over 800,000 users of the popular weather application **Windy** can now access global air quality information provided by **Copernicus Atmosphere Monitoring Service**, (CAMS). Three new layers using CAMS data can be seen via Windy's user-friendly interface: fire intensity; surface ozone; and total column sulphur dioxide (SO2).Windy already uses information from European Centre for Medium Range Weather Forecasting (ECMWF) to provide its users with a range of weather parameters including wind, rain, lightning and cloud types.

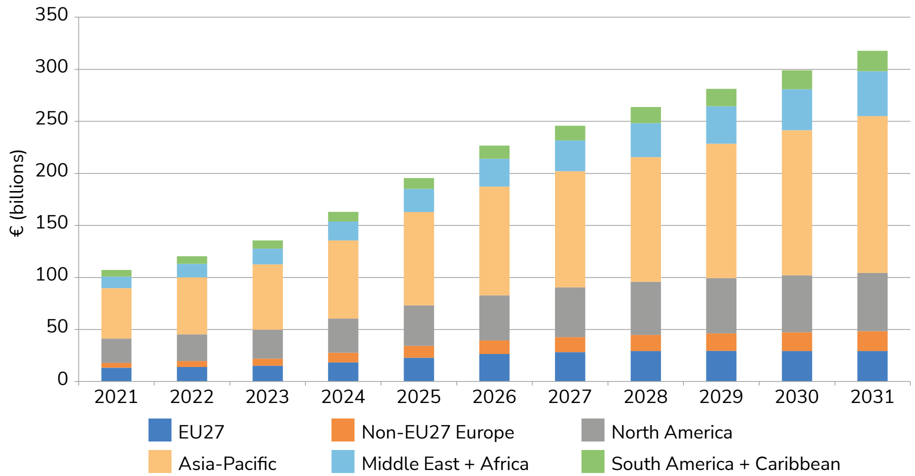
Installed base of GNSS devices by region



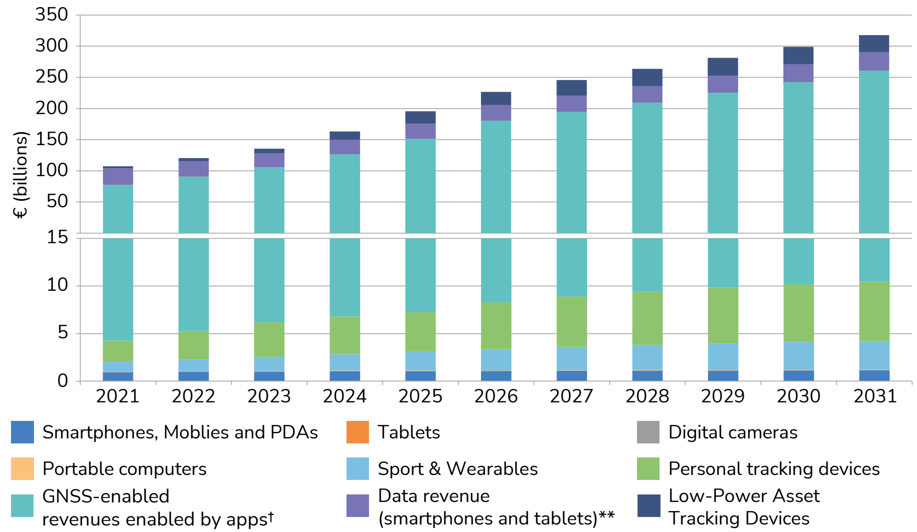
Installed base of GNSS devices by type



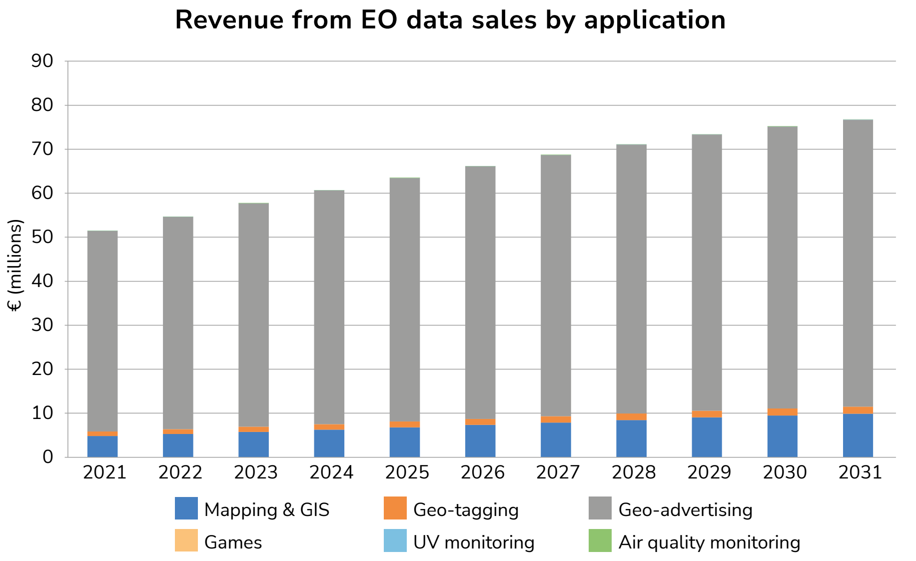
Revenue of GNSS device sales and services by region



Revenue of GNSS device sales and services by type



**: Only data revenue arising from the use of Location-based services considered;
†: Pay-to-download, In-app-purchases and adrevenue from health & lifestyle, navigation & trackings, tourism, and corporate apps


Revenue from EO data sales by application
€ (millions)
0
10
20
30
40
50
60
70
80
90
2021
2022
2023
2024
2025
2026
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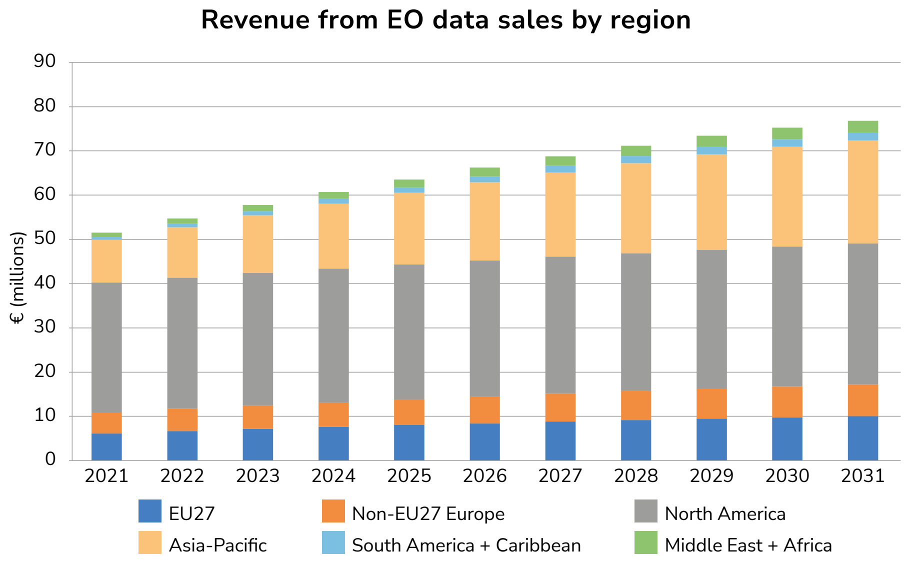
2029
2030
2031
Mapping & GIS
Geo-tagging
Geo-advertising
Games
UV monitoring
Air quality monitoring


Revenue from EO data sales by region
€ (millions)
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50
60
70
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90
2021
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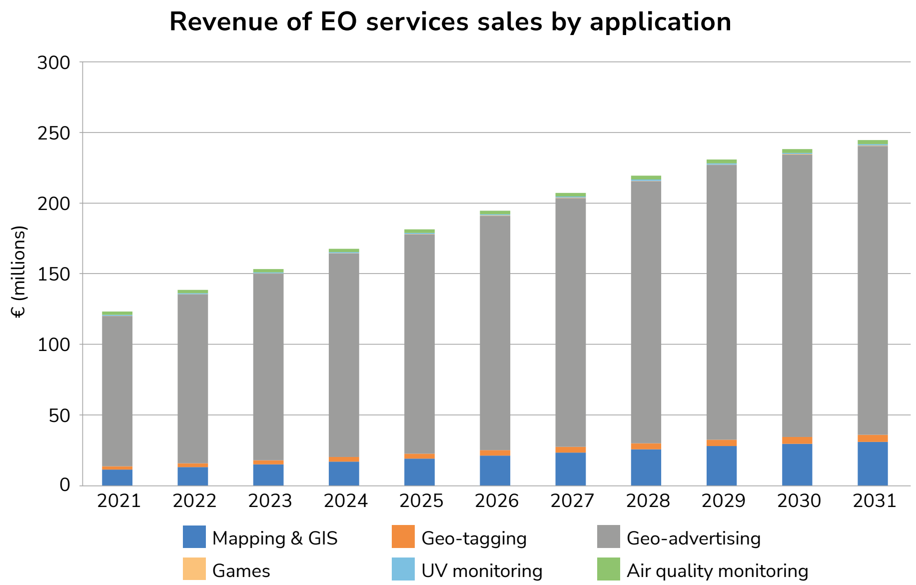
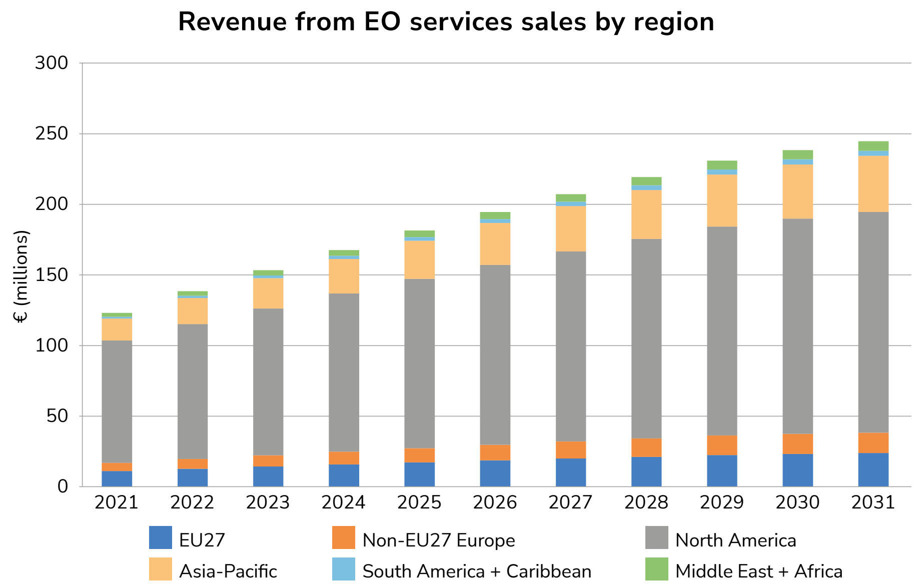
EU27
Non-EU27 Europe
North America
Asia-Pacific
South America + Caribbean
Middle East + Africa


Revenue of EO services sales by application
€ (millions)
0
50
100
150
200
250
300
2021
2022
2023
2024
2025
2026
2027
2028
2029
2030
2031
Mapping & GIS
Geo-tagging
Geo-advertising
Games
UV monitoring
Air quality monitoring


Revenue from EO services sales by region
€ (millions)
0
50
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200
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2021
2022
2023
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2026
2027
2028
2029
2030
2031
EU27
Non-EU27 Europe
North America
Asia-Pacific
South America + Caribbean
Middle East + Africa

EMERGENCY MANAGEMENT AND HUMANITARIAN AID

Legend
EO application
GNSS application
Synergetic application (combined use of EO and GNSS)

Early warning
- Early warning
- GNSS-enabled ocean monitoring buoys

Migration and settlement
- EO human displacement monitoring
- Management of refugee camps
- Population counting
- Telematics for Humanitarian Aid

Post-event analysis
- Post-event analysis

Preparedness
- Preparedness

Rapid mapping
- Rapid mapping

Search and Rescue
- Beacons for Aviation[1]
- Beacons for Land[2]
- Beacons for Maritime[3]
- Situational awareness supporting search and rescue

[1] Incl. Emergency locator transmitter (ELT), Emergency locator transmitter Distress Tracking (ELT-DT) and Personal Locator Beacons (PLBs)

[2] Incl. PLBs

[3] Incl. Emergency Position Indicating Radio Beacon (EPIRB), PLB, Automatic Identification System Search And Rescue Transponder (AIS-SART) and Automatic Identification System Man Overboard Beacon (AIS-MOB)

Application descriptions can be found in Annex 3.

EMERGENCY MANAGEMENT AND HUMANITARIAN AID

The domain of Emergency Management and Humanitarian Aid, although often seen as a market by and for public entities, relies on an array of commercial players for the provision of services, applications and devices. These products support actors both in the field and behind the desk at coordination centres across the world. Actors within this segment are national governments, international organisations, NGOs, dedicated agencies and private companies.

GNSS and EO capabilities are used in response to emergency management situations such as drought, earthquake, extreme temperatures, flood, landslide, mass movement, storm, volcanic activity, avalanches and tsunamis. Downstream applications of GNSS and EO are deployed in all phases of emergency management, from preparedness and early warning to rapid mapping and post-event analysis.

GNSS-enabled beacons have revolutionised Search and Rescue operations by transmitting positions of persons in distress over the 406MHz distress frequency band, which can be picked up by the international Search and Rescue Satellite Aided Tracking (COSPAS-SARSAT) programme. This programme acts as a distress detection and information distribution system that provides accurate, timely and reliable distress alert and location data for the use of search and rescue authorities. Such operations are now greatly improved by relying on EO-enabled situational awareness.

GNSS provides mapping and navigational assistance to international humanitarian surveyors in order to save lives and help people in need (e.g. the homeless, refugees, victims of natural disasters/wars/famines etc.). UN organisation Office for Coordination of Humanitarian Affairs (OCHA) uses Geographic Information Systems (GIS) as a communication tool to evaluate the humanitarian situation, whilst EO data and services provide the means to monitor displacement of refugees and internally displaced persons (IDPs), among other uses such as conducting population counting.

What you can read in this chapter

- **Key trends:** Developments in GNSS and EO help to save lives.
- **User perspective:** New technical capabilities are bringing better performance and new communications possibilities for emergency management operations.
- **Industry:** Emergency Management and Humanitarian Aid Value Chains.
- **Recent developments:** Better management of unpredictable natural and man-made disasters thanks to EO and GNSS capabilities.
- **Future market evolution:** New technologies for efficient emergency information platforms, supporting professional emergency rescue teams.
- **Focus on European Systems:** EGNSS and Copernicus contribute to more up-to-date Search and Rescue operations.
- **Reference charts:** Yearly evolution of installed base of GNSS devices and revenues as well as EO revenues by application and region.

Developments in GNSS and EO help to save lives

Key market trends

- EO and GNSS are increasingly combined to provide the full picture needed for context-aware emergency response
- MEOSAR is close to full operational capability – Galileo Search and Rescue ground facilities have upgraded for MEOSAR Full Operational Capacity (announced December 2020)
- Galileo Return Link Service has been declared operational and the first Return Link-enabled PLBs have hit the market in Europe
- Whereas the services covered under this segment are public services mainly used by first responders and governmental agencies, commercial businesses are often the ones implementing these emergency services, through governmental contracts and providing on-site support

EO and GNSS are contributing to all aspects of emergency management

Earth Observation provides information for emergency response and disaster risk management at each of the following stages:

- For **preparedness**, prevention, risk reduction and recovery phases, EO provides risk assessment and simulation models.
- For **early warning**, EO provides continuous observations and forecasts for many types of disasters such as flooding (e.g. hydrological modelling), earthquakes (e.g. surface deformation), landslides (e.g. terrain deformation), volcanic eruptions (e.g. atmospheric composition), tsunamis (e.g. wave height), wild fires (e.g. moisture conditions) and others. GNSS receivers also help to detect earthquakes and floods. This could bring an additional 10 to 30 seconds of warning to a city or nuclear reactor of an imminent quake, which could result in enormous social benefits.
- During a disaster, EO and GNSS provided **rapid mapping** (e.g. crowd-sourced mapping updates) allowing emergency responses to be coordinated as efficiently as possible.
- Finally, during **post-event analysis**, the comparison of recent and archival EO data assists relevant actors with an accurate damage assessment.

The components of Copernicus Emergency Management Service (CEMS) provide various ways to access or download the data through individual data access points. On top of this, open data sources such as GEOSS, OGC, Terralook, CEMS, Google Earth and other commercial services (e.g. 24/7 Emergency Service by Airbus) provide information to cover all kinds of natural and human-made disasters.

In all previously mentioned disaster examples, GNSS also plays a crucial role in search and rescue operations by providing locations of disasters and distressed persons (see topics adjacent).

MEOSAR to support Search and Rescue worldwide

The COSPAS-SARSAT programme is in the process of upgrading its satellite system to complement the existing Geostationary (GEOSAR) and Low (LEOSAR) systems with the **new Medium Earth Orbit Satellites Search and Rescue (MEOSAR) system**, which is close to full operational capability. MEOSAR is bringing together the benefits of GEOSAR (global coverage) and LEOSAR (which works without GNSS) and overcomes their limitations by providing **distress message transmission and independent beacon location** (in addition to GNSS beacon location for GNSS-enabled beacons) **with near real-time worldwide coverage**. MEOSAR provides improved availability, due to increased satellite redundancy and dependent GNSS localisation of the distress alert, 95% of the time. Galileo contributes to the MEOSAR system, which helps to save 2000 lives per year.

MEOSAR facilitates other enhancements such as a **return link transmission** to confirm to distressed parties that their distress signal has been received. Galileo is the first GNSS providing this service. It has to be noted that although not all produced Search and Rescue beacons are GNSS-enabled, there is an increasing trend towards GNSS uptake amongst these beacons.

Galileo Return Link Service PLBs enter the market

At the 12th European Space Conference in 2020, the Galileo Return Link Service was declared operational. The Return Link Service (RLS) allows persons in distress to receive automatic acknowledgement that their signal has been received. This service is the **first of its kind** and will contribute to increased rescue success, providing an important and critically-timed **psychological boost** and reduction in panic. In December 2020, the first Galileo return link-enabled beacon, the Fastfind ReturnLink PLB made by Orolia, hit the market with availability across 32 countries globally. This number is expected to increase over the following years when more countries update their beacon regulations.

The FastFind ReturnLink was developed in the frame of Horizon 2020 in close collaboration with EUSPA. Persons in distress – whether on land or at sea – will see a blue light blinking on their beacon, around 5 minutes after confirmation that the distress signal and the beacon's location has been detected.

New technical capabilities are bringing better performance and new communication possibilities for emergency management operations

Downstream space services shape emergency warning and Search and Rescue operations

As per the new Regulation 2021/696 from the Council of 28 April 20211, **Galileo will offer an emergency warning service (EWS),** free of charge for users. This will broadcast, through emitting signals, warnings regarding natural disasters and other emergencies in particular areas. The service will have global coverage and will be complementary to the Public Warning System which must be implemented by mobile networks before June 2022 as per the Directive (EU) 2018/1972, establishing the European Electronic Communications Code. The service can be accessed on any Galileo-enabled Receiver with this capability implemented.

Galileo will revolutionise the current Search and Rescue operations with the introduction of its unique feature: Return Link Service (RLS), operational since 2020, and with the first certificated beacon already on the market (FastFind ReturnLink Personal Locator Beacon). This feature will enable the additional service of **Remote Beacon Activation service (RBA).** RBA will give authorised users (from aviation and maritime backgrounds) the ability to remotely activate a beacon when a situation of distress is declared by relevant authorities, accelerating the localisation and organisation of targeted Search and Rescue operations.

© Orolia

Two-Way Communication service (TWC) and Beacon Distress Positioning Sharing service (BDPS) are two additional features which will contribute to a reduction of intervention times, improved detection of false alarms and better dimensioning of rescue means.

Key EO and GNSS user requirements

The key GNSS and EO user requirements for the different application groups within the **Emergency Management and Humanitarian Aid** segment are, at EU level, collected using the following procedures:

- For GNSS, information is collected through extensive interactions with user groups, providers and experts in a continuous process culminating at the User Consultation Platforms (UCP).
- User requirements for Copernicus services and products – as well as their evolution – are collected through an integrated process that involves different channels: (i) dedicated studies (e.g. "NEXTSPACE" project, "Copernicus for EC (C4EC)" study, Commission Staff Working Document on user needs), (ii) targeted consultations organised by the European Commission or the Entrusted entities with the relevant communities, (iii) regular and structured exchanges among representatives of the Copernicus governance structure and Member States through the Copernicus User Forum.

From the 2022 EUSPA`s UCP onward, EO user needs and requirements of commercial users will be validated and discussed with industry experts and user groups, mirroring the process implemented for GNSS.

Humanitarian aid uses EO to go from reactive to proactive actions

NGOs are increasingly looking to use data and **predictive analytics to forecast and mitigate emergencies**. Satellite imagery data allows researchers to build predictive models to help forecast the risk of disasters, enabling recommendations for proactive measures in order to mitigate the disaster – e.g. allowing proactive evacuation plans when a severe risk of a landslide, forest fire or other natural disaster is detected.

The Global Wildfire Information System (GWIS) is a joint initiative of the Geosynchronous Equatorial Orbit (GEO) and the Copernicus Work Programmes, which provides tools to support early operational wildfire management.

GWIS builds upon ongoing activities of the European Forest Fire Information System (EFFIS), the Global Terrestrial Observing System (GTOS), the Global Observation of Forest Cover - Global Observation of Land Dynamics (GOFC-GOLD) and the Fire Implementation Team (GOFC Fire IT).

Tsunami Early Warning Systems (TEWS) are a set of procedures used by national governments to ensure that warning messages are sent to all relevant officials for near-field warning in very short time frames. EO data can effectively reduce the warning time and improve its reliability.

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Emergency Management and Humanitarian Aid Value Chains[1]

EARTH OBSERVATION

INFRASTRUCTURE PROVIDERS
- AWS
- CODE-DE*
- COLLGS*
- GOOGLE CLOUD PLATFORM
- COPERNICUS DIAS*
- IBM SPECTRUM COMPUTING
- INTEL GEOSPATIAL
- MICROSOFT AZURE
- PENGUIN COMPUTING
- PEPS*

- COPERNICUS COLLABORATIVE GROUND SEGMENT*

DATA PROVIDERS
- AIRBUS*
- BLACKSKY
- COPERNICUS DIAS*
- DESCARTES LABS
- DMC INTERNATIONAL IMAGING
- EARTH-I
- E-GEOS*
- ICEYE*
- MAXAR
- NEC CORPORATION
- PLANET
- TWENTY FIRST CENTURY AEROSPACE TECHNOLOGY

- COPERNICUS SENTINELS*
- USGS/NASA LANDSAT
- RELEVANT IN-SITU NETWORKS

PLATFORM PROVIDERS
- 4EARTHINTELLIGENCE
- CLOUDEO*
- COPERNICUS DIAS*
- EO4GEO
- SERCO
- SPATIAL SERVICES GMBH
- UP42

- GEOHAZARDS, HYDROLOGY TEP*

EO PRODUCTS AND SERVICE PROVIDERS
- BEIJING PIESAT INFORMATION TECHNOLOGY
- DARES
- DEWBERRY LLC
- DHI GRAS A / S
- E-GEOS*
- GAF*
- GEOVILLE*
- INDRA SISTEMAS
- KAYRROS*
- KONGSBERG SATELLITE SERVICES AS*
- SKYGEO
- TRE ALTAMIRA (CLS GROUP)
- VERISK ANALYTICS

- COPERNICUS SERVICES*

INFORMATION PROVIDERS
E-GEOS*

EMERGENCY MANAGEMENT SERVICES:
PINKMATTER

HUMANITARIAN AID SERVICES:
GEOHUM

END USERS
- **CIVIL PROTECTIONS, SMALL PUBLIC SPACE AGENCIES**
- **INTERNATIONAL BODIES** (GROUP ON EARTH OBSERVATIONS (GEO))
- **NATIONAL GOVERNMENTS**
- **NGOS** (UNHCR, RED CROSS, MEDICINS SANS FRONTIERES (MSF))
- **REGIONAL AUTHORITIES**

GNSS

COMPONENT AND RECEIVER MANUFACTURERS
- H R SMITH*
- OROLIA*
- QUECTEL
- STMICROELECTRONICS*
- SYRLINKS*
- U-BLOX AG*

SAR BEACON MANUFACTURERS
EPIRB & PLB
ACR ELECTRONICS, H R SMITH*, JOTRON AS*, MOBIT TELECOM, OCEAN SIGNAL*, OROLIA*, SYRLINKS*, WÄRTSILÄ*

AIS-SART & AIS-MOB
ACR ELECTRONICS, JOTRON AS*, KONGSBERG MARITIME*, OCEAN SIGNAL*, OROLIA*, WÄRTSILÄ*

ELT
ACR ELECTRONICS, ASTRONICS CORPORATION, ELTA, ECA GROUP, H R SMITH*, OROLIA*, SAMYUNG ENC, SYRLINKS*

SEARCH AND RESCUE BEACON USERS
- **AIRPLANES AND HELICOPTERS PILOTS**
- **HIKERS**
- **FISHING BOAT OPERATORS**
- **MOUNTAINEERS**
- **OFF-SHORE OPERATORS**
- **RECREATIONAL BOATERS**
- **SHIP OPERATORS**
- **SOLE MARINERS**

USERS OF POSITIONING INFORMATION
SEARCH AND RESCUE RESPONSE
- COAST GUARDS
- COSPAS-SARSAT
- DISASTER MANAGEMENT TEAMS
- JOINT COORDINATION CENTRES

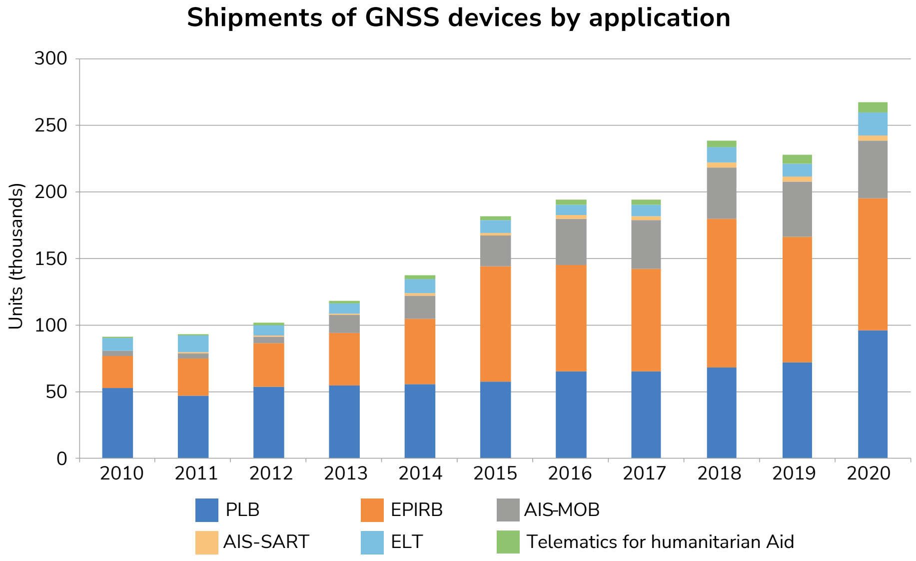
European[2] GNSS and EO industry in the global arena

Europe held several top positions among GNSS Component and Receiver manufacturers in 2019, with Orolia in second ahead of U-Blox, H R Smith and Syrlinks. Overall, European companies held a share of 33% behind only North America with 43%. In EO, the market is mainly divided between North America (36%) and Asia-Pacific (34%), followed by the EU market (17%). THALES (e-Geos) and Indra Sistemas are the leading EU companies.

LEGEND
- Commercial Offering
- Public Offering
- User segments

NOTES
[1] The value chain considers the key global and European companies involved in GNSS and EO downstream activities.
[2] In the market share analysis, Europe is defined as EU27 plus Norway, Switzerland and the UK.
* European-based companies. The region is defined with respect to the headquarters of the company, though the actual area of activity might be wider.

Better management of unpredictable natural and man-made disasters thanks to EO and GNSS capabilities



With close to 100,000 units in 2020, Emergency Position Indicating Radio Beacons (EPIRBs), are by far the largest group of GNSS-enabled search and rescue beacons being sold each year. The second largest category sold in 2020 are Personal Locator Beacons (PLBs), reaching nearly 100,000 units.

Although AIS-SART (Automatic Identification System Search and Rescue Transmitters) shipments have been growing at the highest historical CAGR (25% since 2010), in 2020 the category is outnumbered tenfold by AIS-MOB (Man OverBoard) with over 41,000 units.

In 2020, the global installed base of search and rescue beacons (see reference charts) was roughly 1.6m beacons, an almost fourfold increase compared to less than half a million units in use in 2010. PLBs contributed to around 43% of this global installed base and along with EPIRBs (36%) have been dominating the global installed base in absolute numbers. The installed base of AIS-MOBs, quite popular among recreational boaters and crews of smaller vessels has reached 225,000 units or roughly 14% of the market. The remaining 106,000 beacons, corresponding to 7% of the installed base worldwide in 2020, is made up by Emergency Locator Transmitters (ELTs) (6%) and AIS-SART beacons (1%).

GNSS telematics for dynamic and safe humanitarian management

GNSS-enabled telematics are used by humanitarian organizations working in crisis zones, where humanitarian aid reaches the most vulnerable populations. These telematics allow humanitarian response management teams to improve staff safety and security by locating and tracking personnel working in emergency response and delivery vehicles. GNSS telematics also improves fleet performance, leading to vehicle fleet optimisation up to 15% and allowing management teams to monitor vehicle health and create smart routing. This reduces the environmental footprint and the operational costs linked to fuel and maintenance.

Novacom CLS Services has partnered with HERE Technologies to provide a 'reverse-geolocation' service (or georeverse coding, the process of converting geographic coordinates into a readable address), where a vehicle's **geolocation can be combined with contextual factors such as nearby hazards**. This allows close monitoring of staff when driving near hazardous zones, and re-routing as dynamic threats are identified, such as in conflict zones or during an ongoing natural disaster.

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GNSS and EO deployed to support monitoring of COVID-19

The Copernicus Emergency Management Services (CEMS) has delivered rapid mapping services (high-resolution maps from geospatial information within hours or days of activation) to aid the response to the COVID-19 crisis. e-GEOS participated in this project, **providing satellite maps to support Civil Protection in enforcing lockdown measures by identifying areas of interest such as hospitals, outdoor markets and parks.** Correlating data on the location of hospitals and mobile facilities with population size and age allowed public authorities to mitigate hospital overcrowding, while details on outdoor markets and parks allowed authorities to manage safe access to these facilities.

The evolving field of GeoAI, which combines geospatial data with Artificial Intelligence, can also be used to **map the spread of COVID-19 based on the location of currently infected people.** For example, the Spanish application AsistenciaCovid-19 collects location data on an anonymised basis, feeding tools such as visualisation and geoanalytics to help authorities better track the spread of COVID 19. Other examples include TRACER (Cyprus) and 'Smittestopp app' (Norway).

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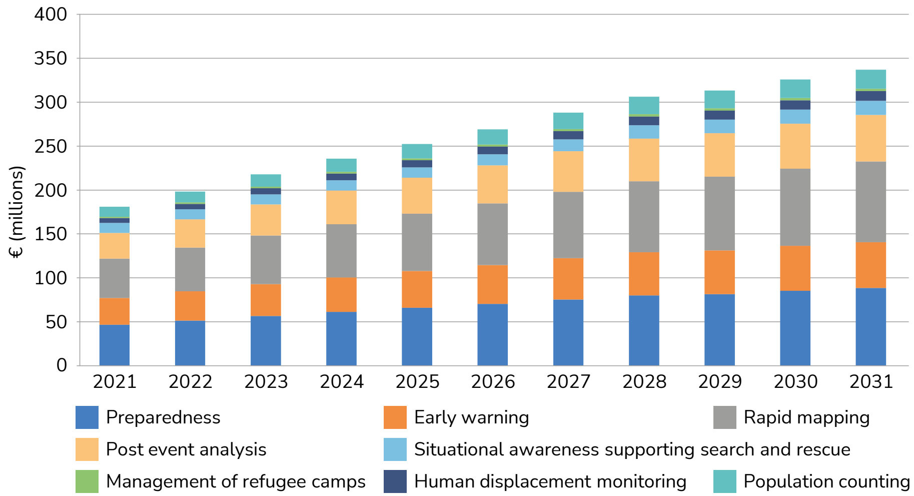
New technologies for efficient emergency information platforms, supporting professional emergency rescue teams

Revenue from EO data & services sales by application



Sales of EO data and services are foreseen to continue growing, reaching almost €340 m by 2031 and almost doubling revenues from 2021. In the long run, all services will grow progressively at a similar pace, with a CAGR between 6% and 7% (Search and Rescue is the exception, at 4%).

EO data and services for **Preparedness** will grow from almost €47 m in 2021 to almost €89 m in 2031, **corresponding to over 26% of the total revenues.** By 2031, the market for EO data and services for Rapid Mapping is expected to become the largest one, totalling over €91 m or 27% of the total revenues. Post-event Analysis and Early Warning rank 3rd and 4th with 16% and 15% of total revenues respectively.

The smallest market share is attributed to EO services for Management of refugee camps. This market will grow from around €1.4 m in 2021 to roughly €2.7 m in 2031.

The service which is already **relatively mature**, and therefore will not grow much in the future is **Situational awareness supporting Search and Rescue**, with revenues going from around €11 m in 2021 up to €16 m in 2031.

HORIZON 2020

UAVs for Search and Rescue

UAVs have great potential for helping saving lives during Search and Rescue missions. UAVs can add critical situational awareness through video data and analytics. However, current limitations on drone flight time make the use of UAVs in such operations difficult.

Future-facing innovations will change this picture, unlocking the potential for UAVs in Search and Rescue.

An example of this is the H2020 SARA project funded by EC/EUSPA, which is building up a semi-automatic system using Earth Observation data to preliminarily detect suspect pontoons' trajectories (Surveillance) and support SAR operations based on a deployable RPAS (Remotely Piloted Aircraft System).

This technological contribution is supporting vessels to detect people lost at sea. Using thermal infrared sensors, the SARA solution increases situational awareness at night, which is currently a particularly challenging scenario for search and rescue operations.

© SARA Project

Use of 3D data to support better disaster risk reduction

Public authorities and NGOs can both benefit from EO data for disaster risk reduction and management. Future developments will see the incorporation of **3D data and modelling to provide additional layers of situational awareness to relevant authorities.**

Euro-Maps 3D DSM (digital surface model) is now also available via the Copernicus Data Access Portfolio. The model provides maps of homogeneous quality, suitable for large-scale, trans-national applications such as risk mapping. These 3D maps can improve planning and disaster risk management activities by providing better situational awareness.

PREDICT is a French start-up involved in the H2020 **Anywhere project** (EnhANCing emergencY management and response to extreme WeatHER and climate Events), helping local governments and enterprises to become more resilient against extreme meteorological events related to climate-change. Their risk management platform integrates various sources of data including satellite imagery from commercial and public providers.

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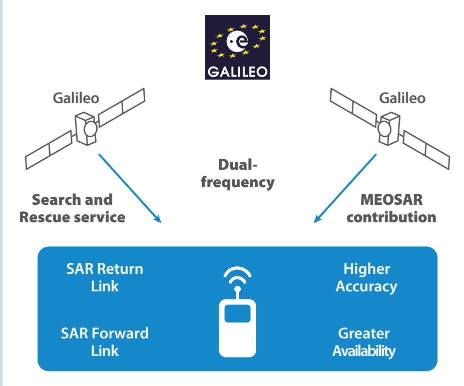
EGNSS and Copernicus contribute to more up-to-date Search and Rescue operations

Current usage of EGNSS

The Galileo Return Link Service (RLS) is a free-of-charge global service available to COSPAS-SARSAT RLS compatible beacons. The new functionality, currently offered only by Galileo, enables a communication link that relays Return Link Messages (RLM) back to the originating beacon, thus informing the user that the alert has been detected and localised. Via this new service, Galileo Search and Rescue is demonstrating how Europe is at the forefront of technological emergency management operations.



HORIZON 2020 SINSIN-GSA-PROJECT

SINSIN is paving the way to an effective terrestrial Search and Rescue service based on SAR/Galileo

The objectives of the SINSIN project are to develop an advanced Personal Locator Beacon (PLB) with an embedded EGNSS receiver and to enhance the latest Medium-Earth Orbit Local User Terminal (MEOLUT) by enabling localisation with only one or two satellites in view. This will result in improving the standard 'slow moving beacon' localization accuracy by a factor of ten. SINSIN is particularly effective in mountainous terrains, forests and jungles, where few satellites are in view. SINSIN technology could be implemented in MEOLUTs of specific regions where the tests have shown to increase the accuracy of localisation and thus reducing the final time to rescue.

Current usage of Copernicus

The Copernicus Emergency Management Service (CEMS) provides information for prevention, preparedness, response and recovery activities for different natural and man-made disasters and other humanitarian crises. The service includes an on-demand mapping component and an Early Warning component, compiled from the Forest Fire Information System (EFFIS), the Flood Awareness System (EFAS) and the Drought Observatory (EDO).

As part of the Copernicus Security Service, the Maritime Surveillance component is coping with challenges related navigation safety, fisheries control, combatting marine pollution and law enforcement at sea. The other two components of the Security Service, namely Border Control and Support to EU External Action, provide the European Union with means to contribute to the fight against cross-border crime as well as to promoting stable conditions for human and economic development.

HORIZON 2020 E2mC

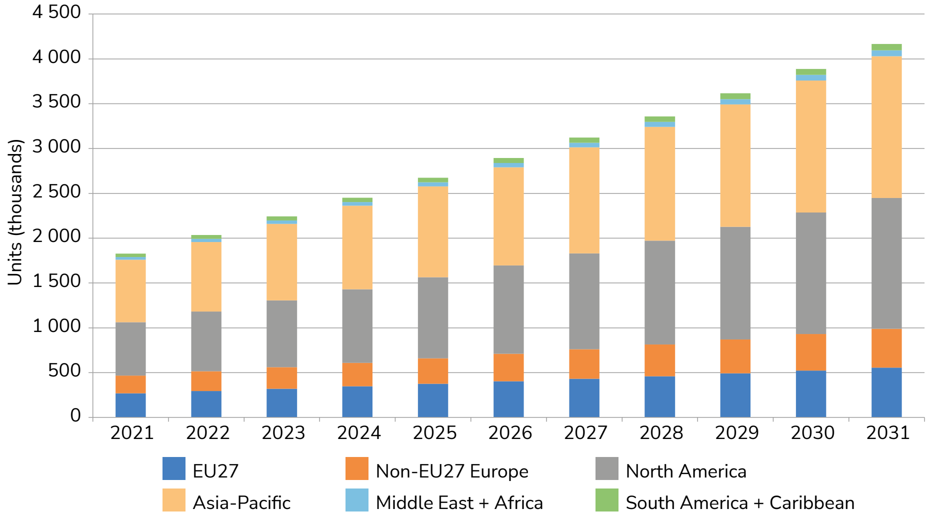
The E2mC project has developed a new Copernicus EMS component with crowdsourcing capabilities for early confirmation of a natural disaster

The project demonstrates the integration of social media analysis and crowdsourced information within both the Mapping and Early Warning Components of CEMS. The Project developed a prototype of a new CEMS Service Component, called **Copernicus Witness**, with the innovative and scalable Social&Crowd (S&C) Platform as the technological enabler. The purpose of the service is to improve the timeliness and accuracy of geo-spatial information provided to Civil Protection authorities during the overall crisis management cycle, especially in the first hours immediately after the event. The service is subject to the availability of mobile networks.

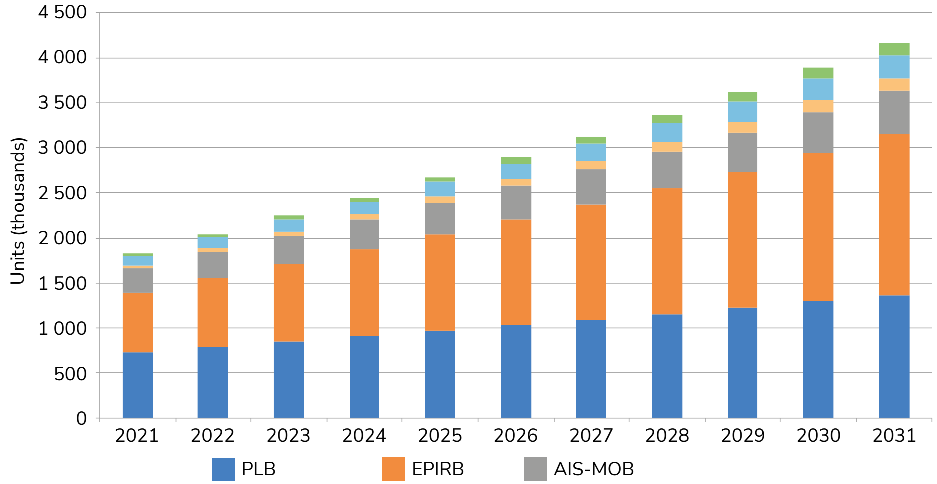
The incorporation of this component will result in an early confirmation of alerts from running Early Warning Systems, as well as a first rapid impact assessment from the field. The involvement of social media and crowdsourcing communities will thus foster the engagement of a large number of people in supporting crisis management.

Terminology used on this page is explained in Annex 2 for both GNSS and EO performance parameters.

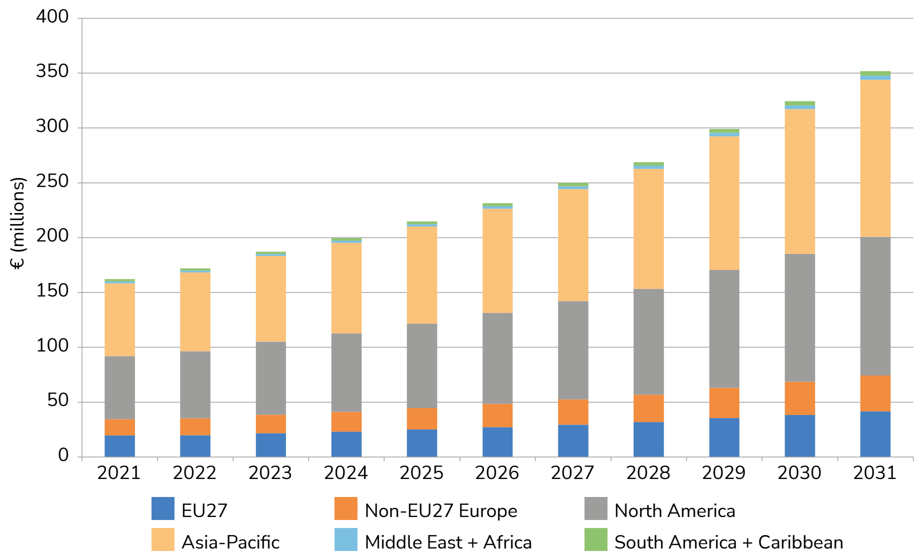
Installed base of GNSS devices by region



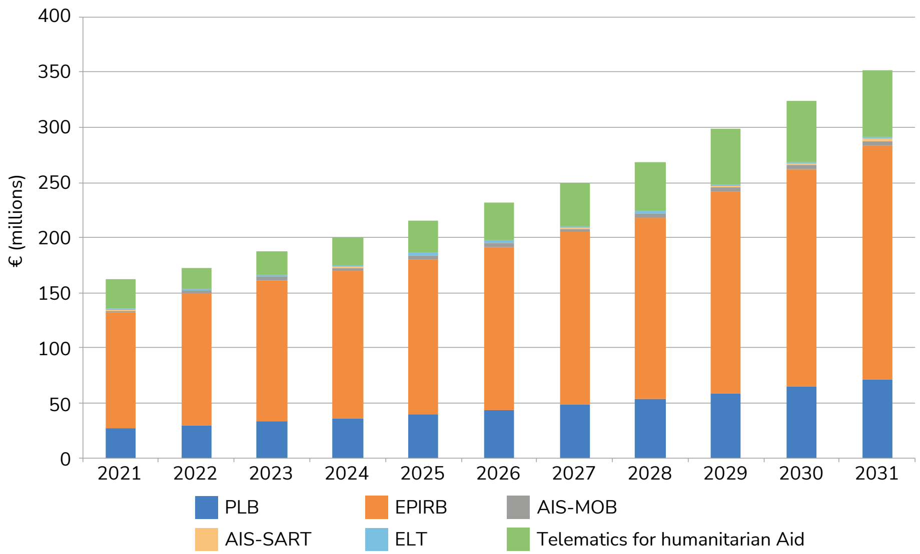
Installed base of GNSS devices by application

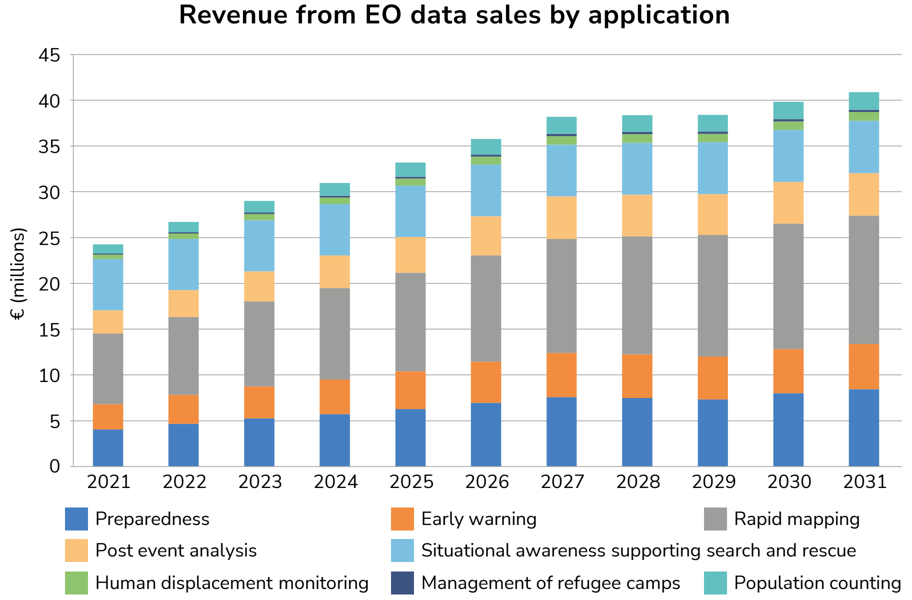


Revenue of GNSS device sales by region



Revenue of GNSS device sales by application




Revenue from EO data sales by application
€ (millions)
0
5
10
15
20
25
30
35
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45
2021
2022
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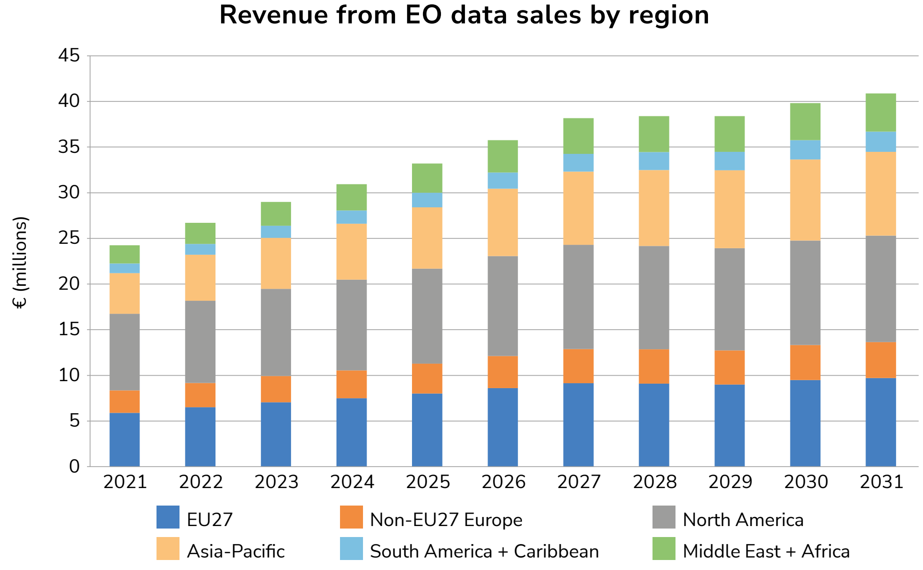
2024
2025
2026
2027
2028
2029
2030
2031
Preparedness
Early warning
Rapid mapping
Post event analysis
Situational awareness supporting search and rescue
Human displacement monitoring
Management of refugee camps
Population counting


Revenue from EO data sales by region
€ (millions)
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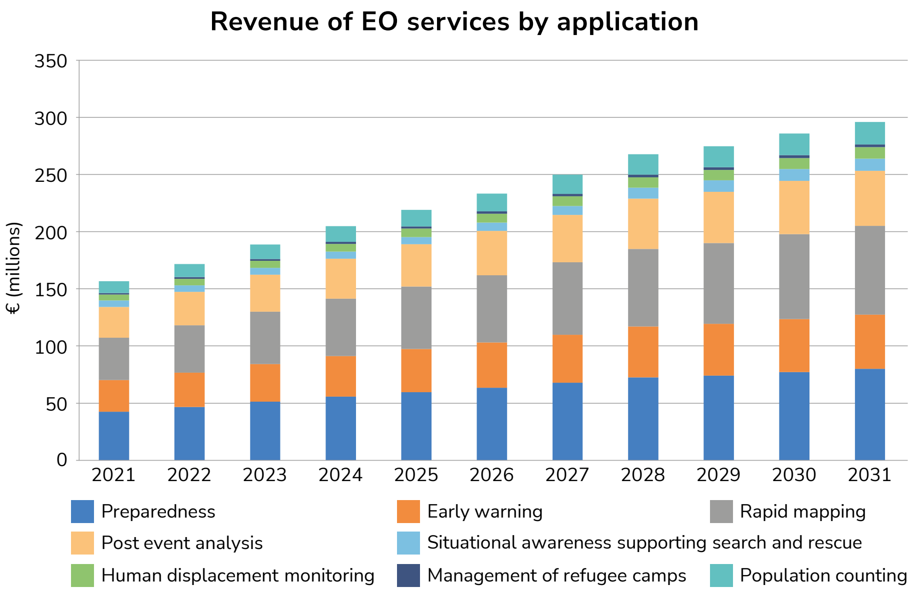
2031
EU27
Non-EU27 Europe
North America
Asia-Pacific
South America + Caribbean
Middle East + Africa


Revenue of EO services by application
€ (millions)
0
50
100
150
200
250
300
350
2021
2022
2023
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2025
2026
2027
2028
2029
2030
2031
Preparedness
Early warning
Rapid mapping
Post event analysis
Situational awareness supporting search and rescue
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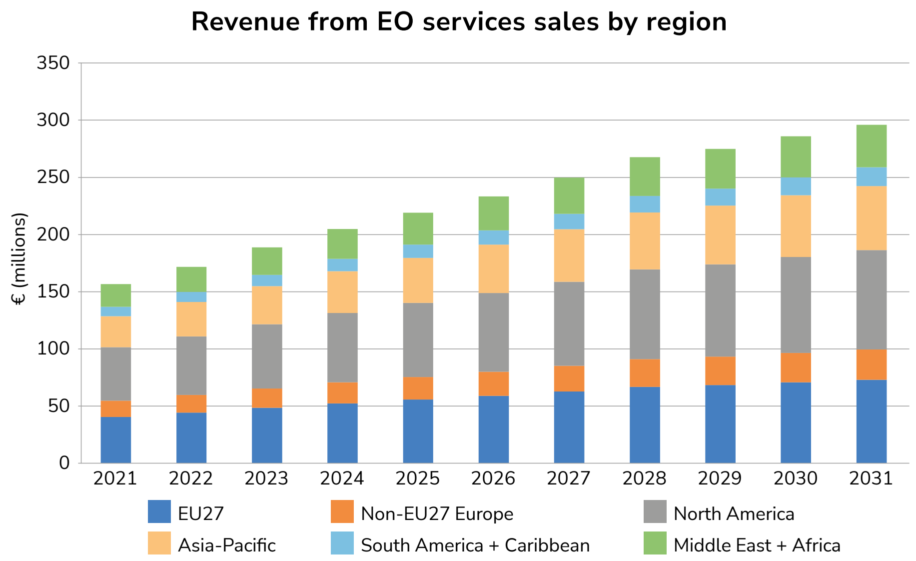
Population counting


Revenue from EO services sales by region
€ (millions)
0
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2027
2028
2029
2030
2031
EU27
Non-EU27 Europe
North America
Asia-Pacific
South America + Caribbean
Middle East + Africa

ENERGY AND RAW MATERIALS

Legend

EO application

GNSS application

Synergetic application (combined use of EO and GNSS)

Energy Network Fidelity

- Energy Network conditions monitoring
- Phasor Measurement Units (PMU)

Environmental Impact Monitoring

- Environmental impact assessment of energy and mineral resources plants

Market Intelligence

- Supply chain insights

Raw Materials

- Illegal mining monitoring
- Mining machinery guidance
- Mining Surveying
- Site selection, planning and monitoring for raw materials

Renewable Energy

- Renewable energy assessment potential and forecast
- Power plant design optimisation
- Risk assessment for energy assets
- Site selection, planning and monitoring for renewable energy

Application descriptions can be found in Annex 3.

ENERGY AND RAW MATERIALS

The complex field of energy and raw materials includes a long list of stakeholders such as governmental authorities, energy and utility companies, energy traders and supply chain managers and mining companies. For them, satellite technologies can provide invaluable data under the form of various EO and GNSS applications.

EO has multiple applications related to renewable energy and raw materials: for instance, helping select locations with optimal conditions (e.g. forecasting UV radiation or wind conditions for renewables and assessing abundancy of certain minerals for mining), or planning and monitoring the construction process. At the next stage, EO data is used to monitor a plant's operational life, its wider conditions and its environmental impact. For mining in particular, high-resolution EO data is used to monitor pit slopes and ground motion effects. Another upcoming raw materials application is the use of multispectral EO imagery in the field.

Similarly to EO, GNSS is also used for site selection, planning and operational activities for raw materials and renewables. Another use of GNSS in renewable resources relates to the synchronisation of energy networks and smart grids, particularly in helping to distribute produced energy.

In mining and raw materials, high-accuracy GNSS is used to survey sites and safely guide earth movers, bulldozers or other machinery – in recent years many of these are operated fully autonomously thanks to GNSS guidance. Moreover, satellite data (both EO and GNSS) is invaluable in the post-operational phase for the mining industry, especially in site clean-up, rehabilitation and waste management.

What you can read in this chapter

- **Key trends:** Post-COVID recovery and goals on climate-neutrality drive innovation in the energy and raw materials market.
- **User perspective:** Users across the full spectrum of energy and raw materials applications exploit services powered by EO and GNSS.
- **Industry:** Energy and Raw Materials Value Chains.
- **Recent developments:** The EU Space Programme is powering decisions and operations worth millions - Earth Observation provides inputs for the development of various energy and raw materials applications.
- **Future market evolution:** From mining operations to waste management, GNSS enables smart and sustainable activities – new satellite capabilities and more advanced AI-backed methods allow novel applications to emerge.
- **European Systems:** Current usage of Galileo and Copernicus in the energy and raw materials sector.
- **European projects:** EU projects cover a vast range of GNSS and EO applications for energy and raw materials.
- **Reference charts:** Yearly evolution of installed base of GNSS devices and revenues as well as EO revenues by application and region.

Post-COVID recovery and goals on climate-neutrality drive innovation in the energy and raw materials market

Key market trends

- Europe's post-COVID recovery, the European Green Deal and the EU energy package as an opportunity for the renewable energy and raw materials markets alike
- A greener future with EO supporting power-to-X solutions
- EU Space Programme will aid the European Raw Materials Alliance to provide innovation in the EU's raw materials supply chain
- New Time- and Synchronisation- as-a-service business models for the energy sector

Europe's post-COVID recovery as an opportunity for the renewable energy market

Many global and local initiatives aim for climate neutrality – however, it is Europe who are drafting the most ambitious policies in the sector. Before the rise of the pandemic the European Green Deal had already confirmed the essential role that renewable energy would have in Europe. The deal **aims to make Europe climate neutral by 2050** and establish an EU-wide target of 32% of power coming from renewable energy as early as 2030 (in 2018 this figure was 18.9%, with large differences between Member States). Moreover, the EU's post-COVID recovery plan, worth €750 billion, singles out renewables (particularly wind and solar) as one of the four strategic pillars of the EU's path towards a resilient, inclusive and green recovery and a low-carbon future.

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The achievement of these goals will heavily rely on information and services powered by the EU Space Programme as discussed within this report.

EO support for power-to-X solutions

Apart from using batteries as enabling technologies, electricity can be stored by being converted into hydrogen or heat. The process of converting the power generated from solar and wind sources to different types of energy carriers (gas, heat, nitrogen) for use across multiple sectors, or to be reconverted back into power, has the potential to greatly increase the flexibility of the power grid.

For instance, power-to-hydrogen involves using electrolysis to split water into hydrogen and oxygen using electricity. Hydrogen is a versatile, clean and safe energy carrier that can be used as a fuel for power or as a feedstock in industry. Power-to-gas is the process of converting renewable energy to gaseous energy carriers such as hydrogen.

While EO applications related to renewable energy production are more widely known and utilised in the planning and monitoring phase, when it comes to power-to-X solutions, EO data have the potential to support the post-transformation phase – for instance, by monitoring the storage and transporting infrastructure (important for energy network conditions monitoring). Nowadays, similar solutions are based on EO radar and optical data, and may go as far as offering mapping, prevention and emergency alerts to the infrastructure owners. However, the sensitivity to detectable hazards is largely dependent on resolution. The use of EO data in this these applications is expected to grow alongside the popularity of power-to-X solutions themselves.

Ambitions for sustainability of the EU's raw materials supply chain drive opportunities for innovation in the market

The COVID pandemic has highlighted vulnerabilities in the EU's raw material supply chains. At the same time, the strategic goal of building a greener future requires access to key raw materials. To address this, the EU has set up the **European Raw Materials Alliance** that will seek to bolster the creation of environmentally sustainable and socially equitable innovations and infrastructure for the European Raw Materials sector. This will enable the implementation of a circular economy of complex products like electric vehicles, clean tech and hydrogen-powered technology. All this will rely on capabilities enabled by the EU Space Programme for the identification of raw materials (e.g. using hyperspectral imaging satellites for detection of global-scale subterranean minerals), the safe operation of mining activities (e.g. guiding autonomous haulage systems in deep open pit mines) and the environmental monitoring of their footprint (e.g. monitoring waste leakages from tailing dams).

Innovative T&S service and new business models increasingly offered

The issue of GNSS vulnerability and complexities with installing traditional antenna-based GNSS timing infrastructure solutions have become a growing concern to Infrastructure operators and authorities. It led the industry to develop and offer **'Time-as-a-Service' (TaaS) and 'Synchronisation-as-a-Service' (SaaS) solutions** (together, T&S). A wealth of areas can benefit from these solutions such as IoT infrastructure, where high-volume data flows generated by IoT devices need to be synchronised precisely, or critical processes of datacenters, where time-stamping precision and accuracy is critical both across servers within a data center and between data centers in a network.

These TaaS and SaaS services can also offer their customer with a 'certified' time complying with Service Level Agreements in the order of microseconds allowing traceability and resilience of the timing function. **New business models** have also been put in place along with this new technology that aim to increase operational flexibility for the Infrastructure operators. The services are generally proposed on a subscription basis on top of hardware and installation costs.

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Users across the full spectrum of energy and raw materials applications exploit services powered by EO and GNSS

Earth Observation opens new horizons for solar cadastre

Three quarters of the global energy supply is consumed in the urban environment, and the percentage is expected to continue growing. The need for energy can be met more efficiently by renewable energy solutions such as solar energy systems, whereby production and consumption do not occur far from each other.

Using PVs (photovoltaics) in urban environments is nonetheless a challenging endeavour due to the shadow effect caused by buildings, roof superstructures and vegetation. To address this, there is a **growing market of 'solar cadastres':** companies identifying available spaces with strong solar potential and high efficiency for installation of PVs in the city, with a corresponding solar resource evaluation for each, taking into account the shadow effect and the local orientations of roofroofs. This relies on 3D models of buildings acquired through photogrammetric or LiDAR aerial surveys.

Earth observation data (e.g. data on solar irradiance, water vapour, aerosols, etc.) are used in **forecasting and nowcasting models.** This ultimately results in more precise data and helps electricity grid operators to adapt their production quickly and even stimulates other markets, such as energy-trading, specifically in relation to re-grouping portfolios of PV systems. EO data can also be used for mapping different zones of a city to understand better the amount, regularity and distribution of electricity needs (e.g. foreseeing daytime consumption in business areas).

Multiple user groups benefit from similar applications; from regulators and policy-makers, to energy providers who need to anticipate consumption, to private users who are interested in foreseeing the amount of energy to be produced by their installed PVs.

Synchronisation at the core of Energy Distribution Systems

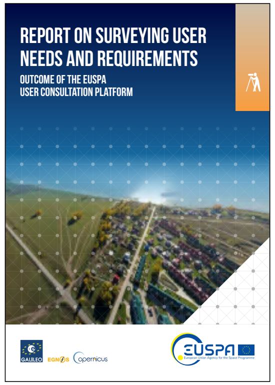
Energy efficiency is facing many challenges with rising electricity demand and the need to comply with sustainable development objectives. In this context, **new digital technologies are increasingly used to enable greater control and optimisation of grids** and contribute to making energy management systems more reliable. Energy operators are therefore increasingly integrating high-resolution synchronised measurements from Phasor Measurement Units (PMUs) to improve grid reliability, efficiency and stability. With cybersecurity of the synchrophasor measurements generated by PMUs becoming a growing concern, precise robust and resilient timing and synchronisation is needed. Moreover, smart gas grid and smart power grid interactions and integration of renewable energy and electric power generated by private power devices also need synchronization to ensure grid stability.

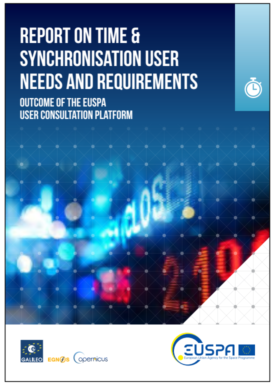
Key EO and GNSS user requirements

The key GNSS and EO user requirements for the different application groups within the **Energy and Raw Materials** segment are, at EU level, collected using the following procedures:

- For GNSS, information is collected through extensive interactions with user groups, providers and experts in a continuous process culminating at the User Consultation Platforms (UCP). In the case of **Energy and Raw Materials** the relevant requirements can be found in two separate documents. On the one hand, information on requirements for geomatic applications within the Energy and Raw Materials segment can be found in the Report on Surveying user needs and requirements. On the other hand, information on requirements for timing and synchronisation applications (i.e. PMUs) can be found in the Report on Time & Synchronisation User needs and requirements.
- User requirements for Copernicus services and products – as well as their evolution – are collected through an integrated process that involves different channels: (i) dedicated studies (e.g. "NEXTSPACE" project, "Copernicus for EC (C4EC)" study, Commission Staff Working Document on user needs), (ii) targeted consultations organised by the European Commission or the Entrusted entities with the relevant communities, (iii) regular and structured exchanges among representatives of the Copernicus governance structure and Member States through the Copernicus User Forum.

From the 2022 EUSPA`s UCP onward, EO user needs and requirements of commercial users will be validated and discussed with industry experts and user groups, mirroring the process implemented for GNSS.





Energy and Raw Materials GNSS Value Chain[1]

AUGMENTATION SERVICE PROVIDERS

- FUGRO*
- HEMISPHERE (ATLAS)
- HEXAGON*
- SAPCORDA*
- SWIFT
- TERIA*
- TOPCON
- TRIMBLE

- NATIONAL AND REGIONAL RTK NETWORK PROVIDERS

COMPONENT AND RECEIVER MANUFACTURERS

High Accuracy
- HEMISPHERE
- HEXAGON*
- NOVATEL
- SEPTENTRIO*
- TOPCON
- TRIMBLE

Timing & Synchronisation
- FURUNO
- MICROCHIP TECHNOLOGY INC
- SEPTENTRIO
- STMICROELECTRONICS*
- TRIMBLE
- U-BLOX*

DEVICE MANUFACTURERS

High Accuracy
- CHCNAV
- HEMISPHERE
- HEXAGON
- HI-TARGET
- STONEX*
- TOPCON
- TRIMBLE

Timing & Synchronisation
- ARBITER
- BRANDYWINE
- CHRONOS TECHNOLOGY*
- ELPROMA*
- ENDRUN
- GORGY TIMING*
- HOPF ELEKTRONIK*
- JACKSON LABS
- MASTERCLOCK
- MEINBERG*
- MICROSEMI
- OMICRON*
- OROLIA SPECTRACOM*
- OSCILLOQUARTZ*
- SEIKO
- SEL
- SEVEN SOLUTIONS*
- SYNERGY SYSTEMS
- TIMELINK*

SYSTEM INTEGRATORS DESIGN CONSULTANCIES TESTING & MAINTENANCE

High Accuracy
- CATERPILLAR
- DURA VERMEER*
- MODULAR MINING
- POSITION PARTNERS
- STONEX
- VOLVO*
- WENCO

Timing & Synchronisation
- ABB*
- ALSTOM*
- CHRONOS TECHNOLOGY*
- EATON*
- IBM
- JUNIPER

END USERS

- TRANSMISSION SYSTEM OPERATORS
- MINING COMPANIES
- REGULATORY AUTHORITIES
- ENVIRONMENTAL AGENCIES

European[2] GNSS industry in the global arena

GNSS receivers in Energy and Raw Materials are used for timing and synchronisation purposes and the industry supporting the segment overlaps with that serving both Infrastructure and Insurance and Finance. European companies such as Orolia, u-Blox, and Meinberg hold 36% of the timing and synchronisation market, withw a slightly higher intensity on Energy and Mineral Resources applications than their largest international competitors, yielding an estimated European share of 40% of the Energy and Mineral Resources market. GNSS also supports surveying and guidance operations for mining, whereby major European companies such as Hexagon compete well on the global stage.

LEGEND

- Commercial Offering
- Public Offering
- User segments

NOTES

[1] The value chain considers the key global and European companies involved in GNSS downstream activities.
[2] In the market share analysis, Europe is defined as EU27 plus Norway, Switzerland and the UK.
* European-based companies. The region is defined with respect to the headquarters of the company, though the actual area of activity might be wider.

Energy and Raw Materials EO Value Chain[1]

INFRASTRUCTURE PROVIDERS	DATA PROVIDERS	PLATFORM PROVIDERS	EO PRODUCTS AND SERVICE PROVIDERS	INFORMATION PROVIDERS	END USERS
• AWS • CLOUDEO* • COPERNICUS DIAS* • GOOGLE CLOUD PLATFORM • HEWLETT PACKARD ENT. • IBM CLOUD • INTEL GEOSPATIAL • MICROSOFT AZURE • PENGUIN COMPUTING	• 4EI* • AIRBUS* • COPERNICUS DIAS* • DEIMOS IMAGING* • E-GEOS* • EARTH-I* • ICEYE* • MAXAR • PLANET • UP42*	• ADAM* • CLEOS (E-GEOS)* • COPERNICUS DIAS* • MAXAR ARD • PLANET EXPLORER • UP42*	• BIRD.I* • BLUEFIELD* • CGG* • DARES* • DHI GRAS* • E-GEOS* • KAYRROS* • SINERGISE* • SKYGEO* • SOLEA* • TRANSVALOR* • TRE ALTAMIRA*	• 1SPATIAL* • BLUEFIELD* • ESRI • ICIS* • INSUNWETRUST* • KAYRROS* • S&P GLOBAL • THE SNIFFERS* • TSV ENERGY	• SUPPLY CHAIN MANAGERS • ENERGY TRADERS • GRID OPERATORS • ENERGY COMPANIES • MINING COMPANIES • UTILITY COMPANIES • GOVERNMENTAL AUTHORITIES
• COPERNICUS COLLABORATIVE GROUND SEGMENT*	• COPERNICUS SENTINELS* • USGS/NASA LANDSAT • RELEVANT IN-SITU NETWORKS	• THEMATIC EXPLOITATION PLATFORM ENERGY (ESA TEP)	• COPERNICUS SERVICES*		

European[2] EO industry in the global arena

In 2019, there were 162 active European EO companies in the Energy and raw materials segment. They held a market share of 35.1% (EU27) and 6.8% (Non-EU27 Europe) of the global market, which for that period, accounted to 320 million euros. Moreover, five of the world's top-10 EO companies in the sector are European.

LEGEND

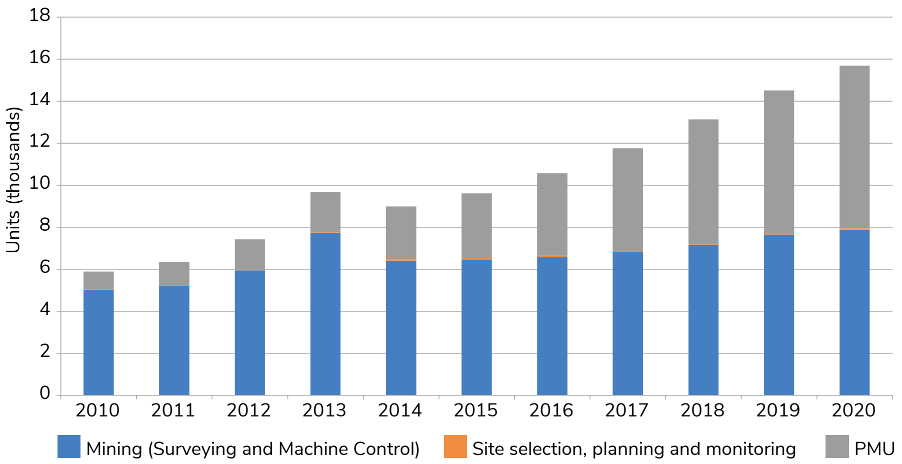
- Commercial Offering
- Public Offering
- User segments

NOTES

[1] The value chain considers the key global and European companies involved in EO downstream activities.
[2] In the market share analysis, Europe is defined as EU27 plus Norway, Switzerland and the UK.
* European-based companies. The region is defined with respect to the headquarters of the company, though the actual area of activity might be wider.

The EU Space Programme is powering decisions and operations worth millions

Shipments of GNSS devices by application



Modern energy facilities increasingly rely on GNSS

Frequent, synchronised and accurate time monitoring has been increasingly required in modern utility. Even if GNSS PMU remains a niche market compared to the other segments which rely on GNSS for T&S, the shift towards green energy and the modernisation of electricity substations has accelerated the deployment of PMU. **A solid CAGR of 25% was therefore observed for the PMU shipments over the 2010 – 2020 period** almost 8,000 units in 2020.

The use of GNSS-powered geomatics solutions for energy and raw materials has been steady over the past decade

Mining site operators have been early adopters of GNSS solutions for site selection, planning and monitoring but also for machine guidance. Thus, over the past decade the use of GNSS-based solutions in these domains has been steady, showing only marginal growth.

Supply chain analytics with the help of EO data and advanced AI techniques

The global energy supply chain is massive, globally distributed, dynamic, complex, and poorly understood. Traditional information sources are highly local, focusing on narrow parts of the energy supply chain, and can be biased and/or subjective. **EO data** has the potential to shed light on this complexity **by providing new, unique, and more timely intelligence enabling advanced analytics**. Thus, innovative EO service providers make use of advanced analytics to extract information from EO data and offer solutions supporting reservoir monitoring, heavy oil production mapping, underground gas storage and sophisticated methane-detection, to name a few examples.

The corresponding market is growing rapidly (16% CAGR), and so is the need by market analysts, traders, investors, energy operators and regulators, governments and international banking institutions to utilise such EO-based analytics solutions in their effort to better understand the new energy dynamics, shifting under the pressure of climate change.

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SCADA facility management solutions for energy operations

In the energy sector, SCADA (Supervisory Control and Data Acquisition) is a system of computer-aided tools used by operators of electric utility grids to monitor, control and optimise the performance of the generation and/or transmission system. According to GlobeNewswire, the global electrical SCADA Market was valued at $1,580 million in 2019 and is expected to reach over $2,880 million by 2026, growing at a CAGR of around 9% during the period.

SCADA is utilised for different operations within electricity production, transmission and distribution. These systems are also used to monitor and control pipeline networks that are used to transport natural gas at high pressure. GNSS provides a reference to UTC and ensures frequency synchronization between SCADA substations and components.

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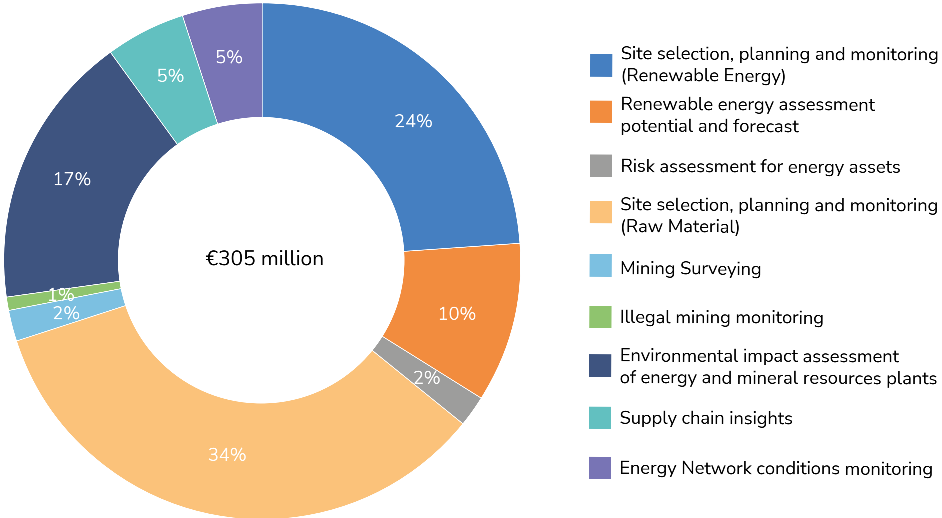
Earth observation provides inputs for the development of various energy and raw materials applications

Revenue from EO data & service sales by application in 2020



The revenues from the sale of both EO data and services to the energy and raw materials sector in 2020 amounted to €305 m. The breakdown in terms of application shows **three major market shares**: Site selection, planning and monitoring for Raw Materials; Site selection, planning and monitoring for Renewable Energy; and Environmental impact assessment of energy and mineral resources plants. These held 34%, 24% and 17% market share respectively.

The dominant market share held by the environmental impact assessment of energy and mineral resources plants application is a strong reflection of the **large focus on sustainability** in the sector. The energy and raw materials sector can sometimes hold a less than favourable reputation when it comes to GHG emissions or toxic waste. This large market share shows the focus this aspect of the sector and how valuable EO can help to monitor and reduce the sector's environmental footprint.

EO lends itself very well to site selection, planning and monitoring for both raw materials and renewable energy due to the fact that many sites are being developed in more and more isolated parts of the world. The substantial market shares for both are a reflection of the efficacy and efficiency of EO in remotely and cost-effectively enabling discovery, planning and management of sites.

The proliferation of wind farms relies on accurate insights from EO

The EU has been an early mover on renewable energy and is committed to becoming the global leader in renewables. While most of the wind energy (89%) continues to be produced onshore, **the EU currently holds 70% of the world's floating wind energy capacity** and investments in offshore are steadily growing.

The EO contribution to offshore wind data and atlases (mostly from space-borne scatterometers, Syntehtic Aperture Radar (SAR) and in-situ data, weather services and forecasts) are used in the planning phase to select an appropriate location for a windfarm. Moreover, site wind characteristics can also assist in the determination of the optimal location of each individual wind turbine, subsequently minimising energy production losses.

In the operational phase, EO-based services can support the establishment of optimal site maintenance needs, optimal weather windows for maintenance, and help foresee and monitor possible rain erosion effects on the blades.

While numerous feasibility studies are assessing the potential of EO applications in the sector and roadmaps are being created (e.g. under H2020 FIRE), commercial companies seek to make the most of EO data for windfarm operational insights.

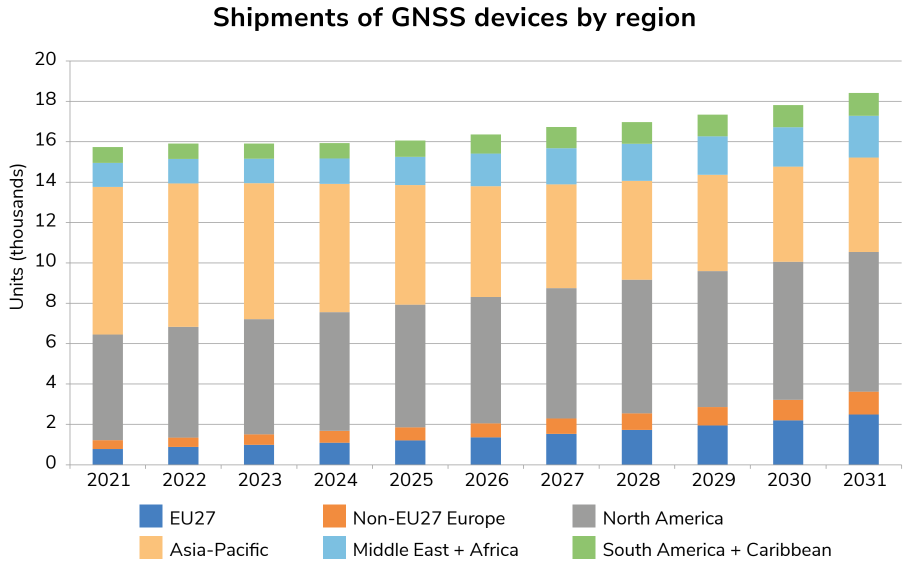
EO has become an essential tool for oil seepage mapping and monitoring

Thanks to its global coverage and to the high resolution and frequently updated images it offers, satellite-based remote sensing is a valuable and cost-effective tool for the detection and monitoring of natural oil seepage.

While on-the-ground seep detection mainly relies on optical data whose availability is weather-dependent, offshore detection relies on cloud penetrating radar imagery and therefore does not suffer the same limitation. Thus, satellites equipped with SAR capabilities enable a night and day systematic screening of offshore basins worldwide and the detection of any oil seepage on the sea surface. By doing so, they facilitate the identification of the areas to be more extensively explored by providing high-value insights on the existence and probable location of oil reserves and also support pollution monitoring in already exploited areas.

Due to the absence of weather-related limitations with SAR imagery and the emergence of new constellations of small satellites offering higher spatial resolution and more frequent revisits than current missions, SAR should favour future developments in the realm of offshore monitoring.

From mining operations to waste management GNSS enables smart and sustainable activities



Asia Pacific and North America are at the forefront of Energy infrastructure modernisation

Asia-Pacific is a leading region for PMU deployment with around 50% of shipment in 2021. In North America the old energy network is already under modernization with PMU deployment currently underway, leading to a limited growth of GNSS shipments (CAGR of 3% over the 2021 – 2031 period). EU27 is expected to have a stronger growth of 12% CAGR over the same period as the third region to engage with PMU rollout.

These regions are also driving shipments of GNSS receivers used in geomatics applications. This can be largely attributed to the deployment of multiple mega-sites of power plants and the steady modernisation of mining operations with environmental aspects in mind.

Guiding the largest vehicles and detecting the slightest ground movements make GNSS and EO invaluable tools for the mining industry

The mining sector has been a proficient user of augmented GNSS solutions for many years. Recently, however, as mining operations are moving to increased automation, GNSS has become a truly invaluable tool for the mining industry. Thus, from surveying mining sites to enabling fully autonomous operations of gigantic machinery, **GNSS is a key enabler for the management of mining operations**. This is supported by advanced connectivity features which enable seamless combination of GNSS with other technologies (e.g. LiDAR) to provide access to previously inaccessible areas.

Moreover, the **ingestion of different data streams from satellites, drones and in-situ sensors enables the construction of a high-resolution digital 'picture' of the entire mining area**. This is done with advanced machine learning algorithms and then projected through smart visualisation tools so that mining operation managers get actionable intelligence for safety, environmental monitoring and overall productivity throughout the full cycle of exploration, extraction and closure.

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GNSS to support water and wastewater system monitoring and control for sustainable and clean energy

Managing and efficiently using water resources for renewable, sustainable and clean energy is on all nations' agenda as safe drinking water is a prerequisite for protecting public health and all human activity (energy for water and water for energy). **Properly treated wastewater is indeed vital for preventing disease and protecting the environment.** Thus, ensuring the supply of drinking water and wastewater treatment and service is essential for the society and the economy.

According to Industry ARC, Water Treatment Systems Market size in 2019 is estimated to be $5.85 billion and is projected to grow at a CAGR of 7.6% during the 2020-2025 period. **GNSS receivers can be used to time stamp measurements** across a wide geographical area through SCADA systems. The purpose of such synchronisation is to augment water and wastewater system monitoring and to strengthen control and protection functions.

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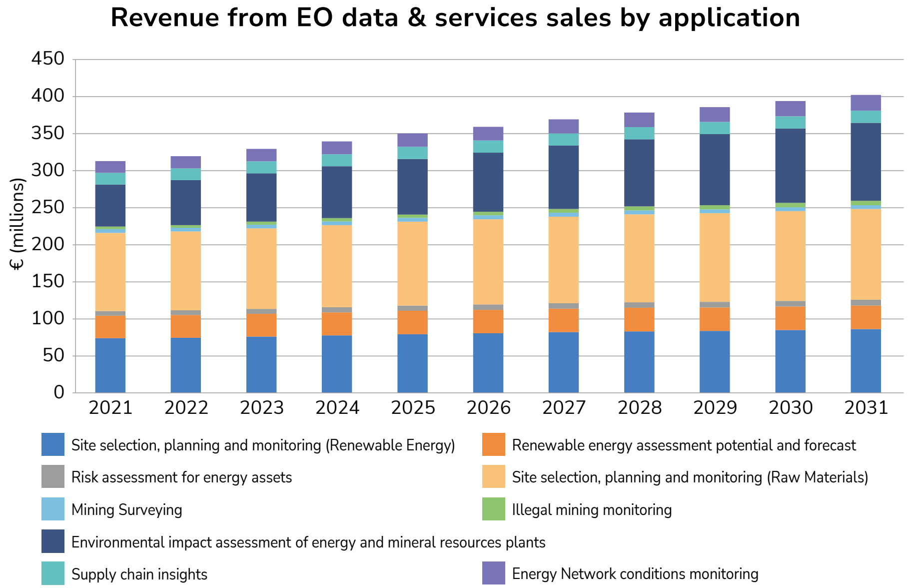
New satellite capabilities and more advanced AI-backed methods allow novel applications to emerge



For the energy and raw materials sector, the revenues from the sale of EO data and services in 2021 amount to €312 m and are expected to grow at a moderate rate year on year, reaching aggregate revenues of €402 m by 2031.

The application with the fastest growth is **environmental impact assessment of energy and mineral resource plants**, which is foreseen to double from €57 m in 2021 to €105 m in 2031. This could be **a reflection of strict regulations and monitoring requirements in many parts of the world** when it comes to the impact of the energy and mining sectors, as well as a result from the subsequent new and stronger focus on sustainability policies that multinational companies are adopting.

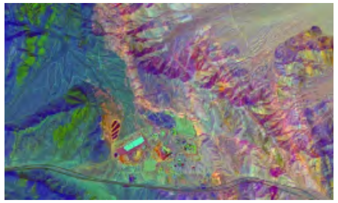
Site selection, planning and monitoring for the mining of raw materials holds the largest market share over the next decade, growing from €105 m to €122 m between 2021 and 2031. Again, as many raw materials become more difficult to find, the use of **EO opens up possibilities for efficiently scouting, selecting and monitoring mining sites and their operations** in remote locations.

Hyperspectral for raw materials detection

Hyperspectral imagery has the capability to analyse a vast portion of the electromagnetic spectrum by creating **unique 'fingerprints'** for the monitored objects. Known as spectral signatures, these 'fingerprints' enable the identification of the materials that make up the observed object and while hyperspectral technology cannot penetrate below ground or through vegetation or buildings, it can be combined with radar to obtain even better results.

While very few hyperspectral satellites are in orbit or planned, their impact on mineral exploration could be enormous: the technology be used to map vast amounts of land and narrow down the search area for valuable deposits of minerals. In some cases, hyperspectral imaging can be used to pinpoint the particular minerals of interest either directly or by locating indicator minerals i.e. minerals that suggest proximity of a valuable ore deposit.

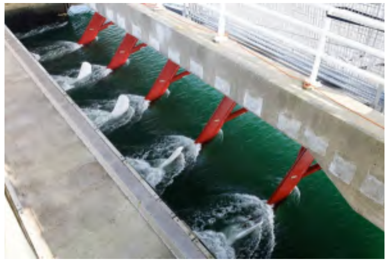
Common minerals like kaolinite and arsenic, which are products of standard geological processes, are clearly visible with hyperspectral imaging in open landscapes. Another example are kimberlite pipes, the most important source of mined diamonds today, which can be easily analysed with hyperspectral imagery.



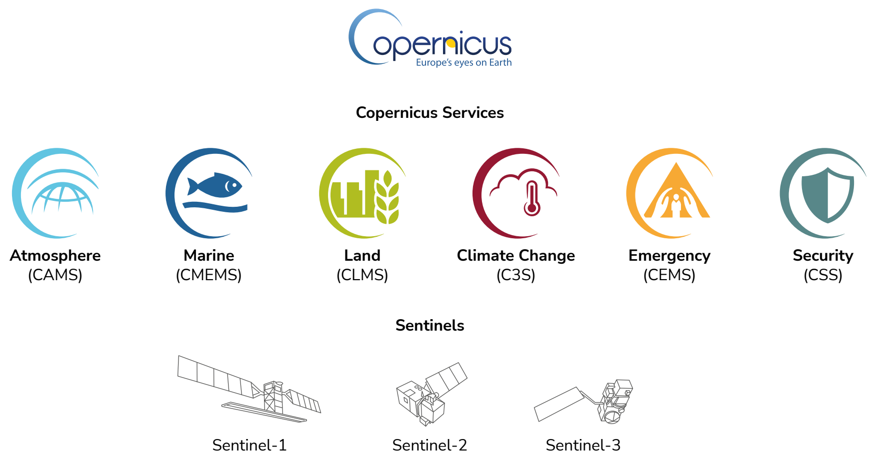
Offshore renewable energy unfolding its potential

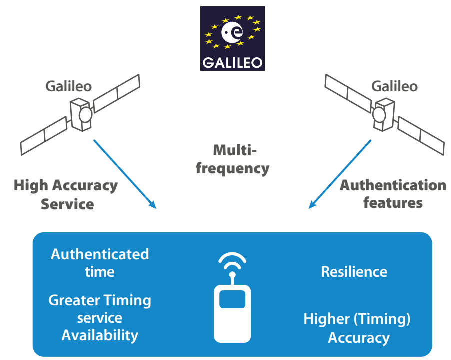
Oceans represent an enormous potential resource of clean and renewable energy. According to Ocean Energy Europe, by 2050 10% of Europe's electricity (100 GW) is expected to come from marine energy. Established offshore solutions such as wind and solar, as well as technologies currently piloted for harnessing the energy of the ocean - such as wave and tidal, can benefit from information provided by Earth Observation. For instance, through the provision of weather, ocean and sea status forecasts, EO helps in planning and optimising operations during the construction and maintenance phases.

Moreover, the measurement of ocean parameters such as temperature, wave height, salinity and speed of ocean currents contributes to better energy forecasting and consequently better forecasting of profitability. Finally, Earth Observation helps to monitor the environmental impact of ocean energy installations by comparing the surroundings before and after deployment.



Current usage of Galileo and Copernicus in the energy and raw materials sector





Current usage of Copernicus

The Copernicus Land Monitoring Service (CLMS) provides data on albedo and land cover (useful for raw materials and onshore energy production), the Copernicus Marine Environment Monitoring Service (CMEMS) provides data related to surface temperature, water conditions and water level (useful for onshore energy installations, marine and tidal energy) and the Copernicus Atmosphere Monitoring Service (CAMS) provides solar radiation data important for planning and operating solar installations. The Copernicus Climate Service (C3S) also contributes to the energy sector, notably through the C3S Energy operational service. Moreover, Sentinel-1 enables InSAR services for ground motion monitoring, including the upcoming European Ground Motion Service (EGMS). Such services, often working in conjunction with GNSS, are essential for mining.

The CLMS provides a wide range of biophysical parameters (land surface temperature, land cover, imperviousness, etc.) which support site selection and monitoring in this sector. The C3S Energy operational service delivers key information for climate-related indicators relevant to the European energy sector. This includes data of electricity demand and the production of power from wind, solar and hydro sources. The tools developed within C3S Energy are principally derived from the work of the two C3S Proof-of-Concepts (POCs) – CLIM4ENERGY (C4E) and the European Climate Energy Mixes (ECEM) – with additional elements from the work of other relevant services. The CAMS solar radiation services provide historical values (2004 to present) of Global, Direct, and Diffuse Solar Irradiance, as well as of Direct Normal Irradiance. These support European and national policy makers and help the development of commercial downstream services (e.g. for the integration of solar energy systems into the energy supply grid).

Current usage of EGNSS

Implementing Galileo in multi-constellation products offers more reliability and accuracy of the Timing solution with quantified integrity, multiple source comparison and versatile adaptive approach in mixing constellations and satellites. Galileo Open Service already provides UTC Time dissemination better than 30ns [95%] and a Frequency dissemination better than 3*10-13 [95%].

Similarly to most segments, T&S device manufacturers integrate GNSS chipsets that are often Galileo-ready. Galileo is also extensively used in mining operations as part of a multi-constellation paradigm that improves the outputs of augmented GNSS solutions. Galileo is also greatly used in the positioning systems of autonomous mining vehicles, which ultimately improves the safety of mining operations.

EGNSS services and features to be explored

The Galileo High Accuracy Service (HAS) provides a multitude of new business opportunities in mining operations. Combined with anti-spoofing services – such as the Galileo Open Service, Navigation Message Authentication (OSNMA) and Galileo Commercial Authentication Service (CAS) – the high accuracy service provides precise and secure tools for the autonomous machinery employed in the mining sector. Moreover, the increased robustness against GNSS spoofing offered by OSNMA and CAS will improve the T&S resilience of the energy networks.

EGNOS contributes to improved time accuracy and stability. Trustability is also enhanced via the provision of an independent time source, the EGNOS Network Time, and built-in integrity that could be used to provide a certified Time service in the future.

Terminology used on this page is explained in Annex 2 for both GNSS and EO performance parameters.

EU projects cover a vast range of GNSS and EO applications for energy and raw materials

HORIZON 2020 e-shape

EO supporting the smart solar energy planning and real-time management

The **e-shape** (EuroGEOSS Showcases: Applications Powered by Europe) project constitutes the largest coordinated effort to highlight operational services in the field of EO research in Europe. Articulated around 27 cloud-based pilot applications under seven thematic areas, it aims to develop operational EO services and demonstrate the benefits of EO at national and international scales. The **nextSENSE** pilot project falls under the umbrella of the 'Energy' showcase, actively supporting the smart solar energy planning and real-time management. Exploiting the synergy of EO data and radiative transfer modelling with image processing, optical flow technologies, machine learning and high-performance computing architectures, it addresses the need for improved solar energy potential monitoring solutions. Thes are key enablers for an increasing integration of solar farms into electricity grids and load exchanges, as well as efficient electricity distribution. Relying on existing and new EO techniques dealing with accurate, nowcast, short-term and long-term forecast estimations of solar energy, the nextSENSE interface allows users to navigate, zoom and click at any pixel of the 1.5 million matrix retrieving solar energy potential information for three hours either side of real time at 15-min intervals.

More information on: https://e-shape.eu/index.php/showcases/

HORIZON 2020 h2020AMPERE

Asset Mapping Platform for Emerging countRies Electrification

The **AMPERE** (Asset Mapping Platform for Emerging countRies Electrification) project aims to provide a dedicated solution for electrical power network information gathering. AMPERE will support decision making actors (e.g. institutions and public/ private companies in charge of managing electrical networks) to collect all needed information to plan electrical network maintenance and upgrades. In particular, a similar need is present in emerging countries where the access to electricity is still far from being achieved in a reliable way.

The challenge facing such communities goes beyond the lack of infrastructure assets. What is needed is a mapping of already deployed infrastructure in order to perform holistic assessments of the energy demand and its expected growth over time. In such a context, Galileo is a key enabler, especially considering its free-of-charge 'High Accuracy Service' (HAS) and its highly precise E5 AltBOC code measurements as core components to map electric utilities, optimise the decision-making process and therefore increase time and cost efficiency.

More information on: https://h2020-ampere.eu/

eit RawMaterials Connecting matters | Co-funded by the European Union | RawMatCop Europe's eye on raw materials

Building skills and Earth observation related expertise through Copernicus

The RawMatCop Programme aims to develop skills, expertise and applications of Copernicus data for the raw materials sector. It is funded in major part by a series of grants from the European Commission (DG DEFIS). Copernicus, the European Union's Earth Observation Programme, offers information services based on satellite Earth Observation and in-situ (non-space) data free of charge.

The RawMatCop Programme demonstrates, disseminates, educates and develops new skills and applications of Copernicus and other Earth Observation data through the following activities:

- Post-doctoral research projects developing innovative new skills, expertise and applications of Copernicus data and services for the raw materials sector.
- Placements for academic researchers in industry, companies and public authorities to facilitate the technological transfer of Copernicus skills to end-users.
- Orgainisng the RawMatCop Academy, which offers a hands-on approach and shows how to unlock the power of Copernicus for companies, organisations and research institutions along the entire life cycle of raw materials.

More information on: https://eitrawmaterials.eu/eit-rm-academy/rawmatcop/

HORIZON 2020 GOLDENEYE

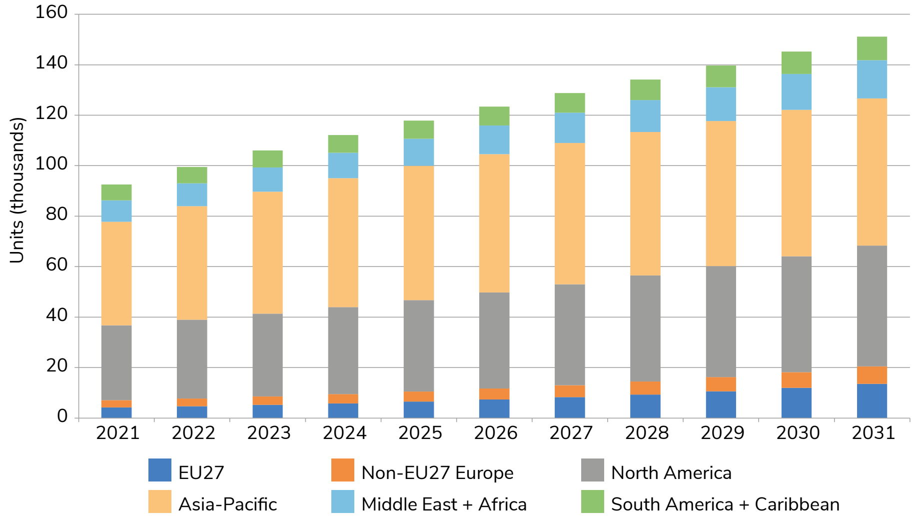
InnovativeGNSS technologies for safe mining operations

The **GOLDENEYE** project is seeking to demonstrate how improved use of Earth Observation and GNSS data systems can offer additional exploitation and environmental control and increase the productivity of mines. To that end, GOLDENEYE is developing a platform to allow satellites, drones and in-situ sensors to collect high-resolution data from an entire mine. These data, after processing, will be converted into actionable intelligence to be used for safety, environmental observation, more efficient exploitation and increased extraction.

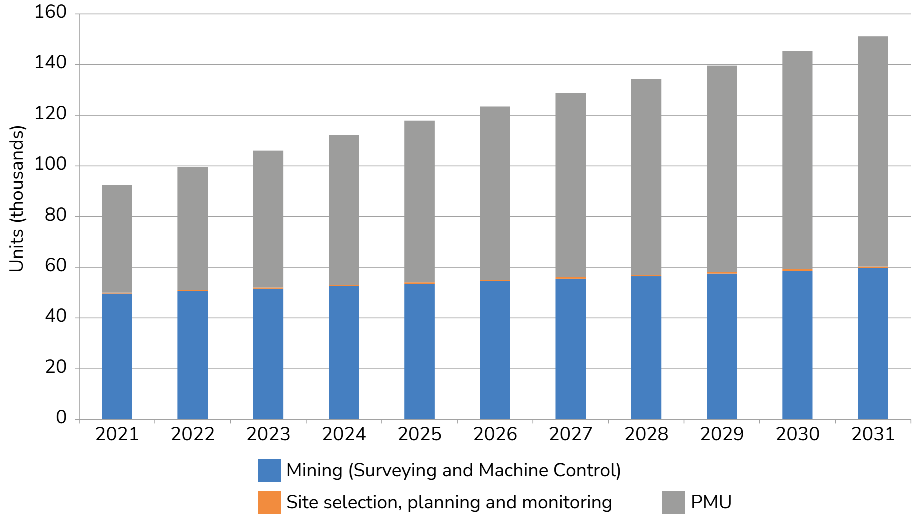
The project combines remote sensing and positioning technologies to take advantage of Earth Observation and GNSS data together with data fusion and processing powered by data analytics and machine learning algorithms.

More information on: https://cordis.europa.eu/project/id/869398

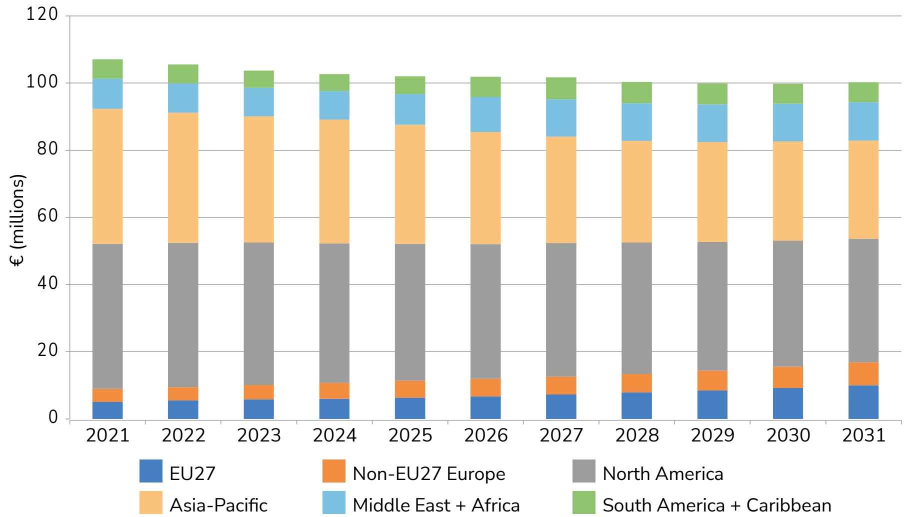
Installed base of GNSS devices by region



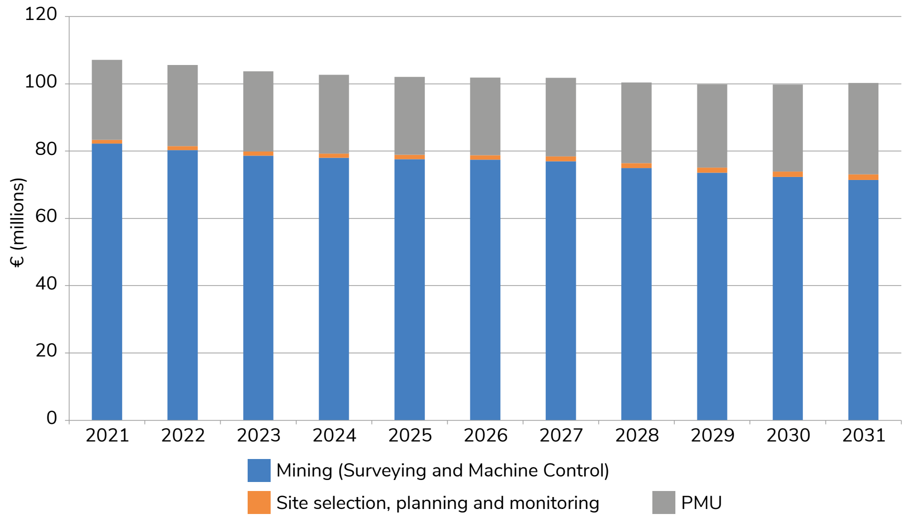
Installed base of GNSS devices by application

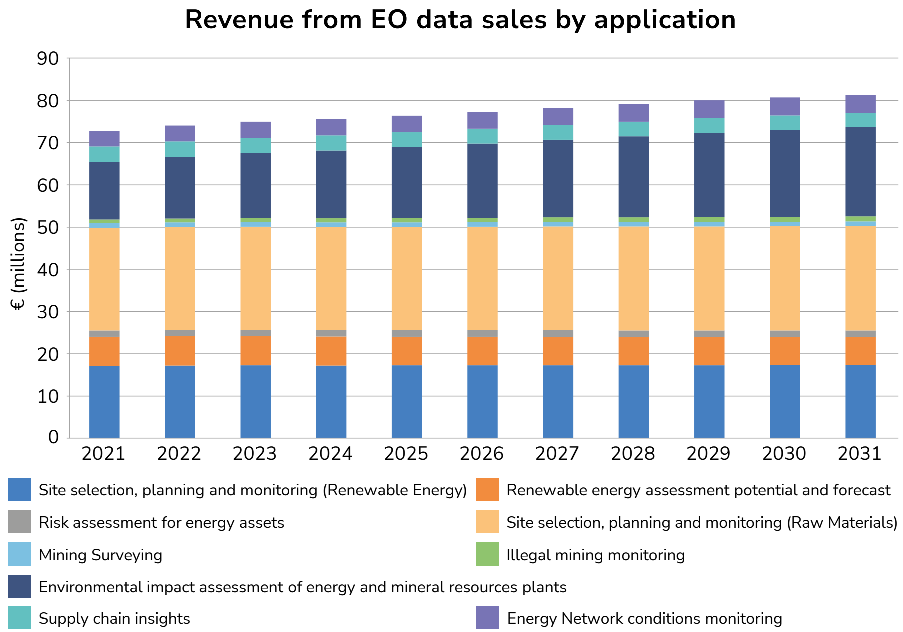


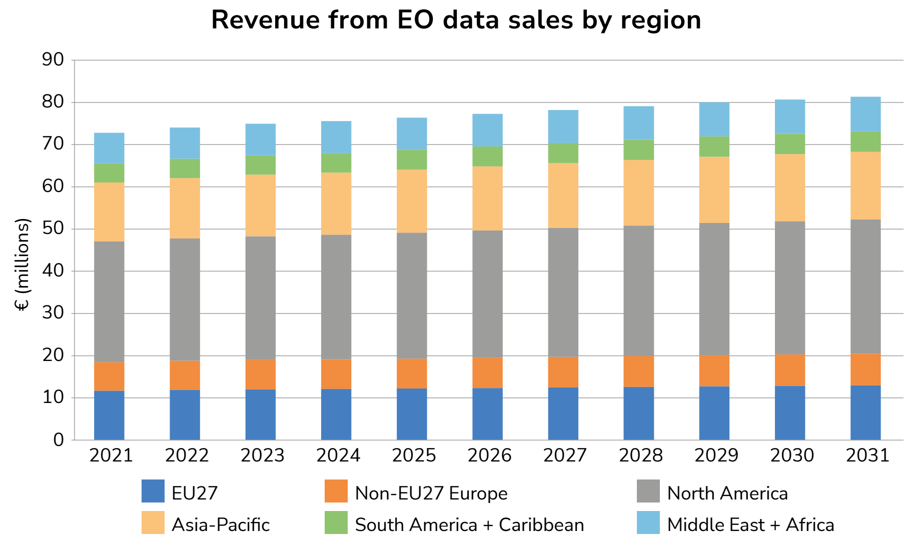
Revenue of GNSS device sales by region



Revenue of GNSS device sales by application




Revenue from EO data sales by application
€ (millions)
90
80
70
60
50
40
30
20
10
0
2021
2022
2023
2024
2025
2026
2027
2028
2029
2030
2031
Site selection, planning and monitoring (Renewable Energy)
Renewable energy assessment potential and forecast
Risk assessment for energy assets
Site selection, planning and monitoring (Raw Materials)
Mining Surveying
Illegal mining monitoring
Environmental impact assessment of energy and mineral resources plants
Supply chain insights
Energy Network conditions monitoring


Revenue from EO data sales by region
€ (millions)
90
80
70
60
50
40
30
20
10
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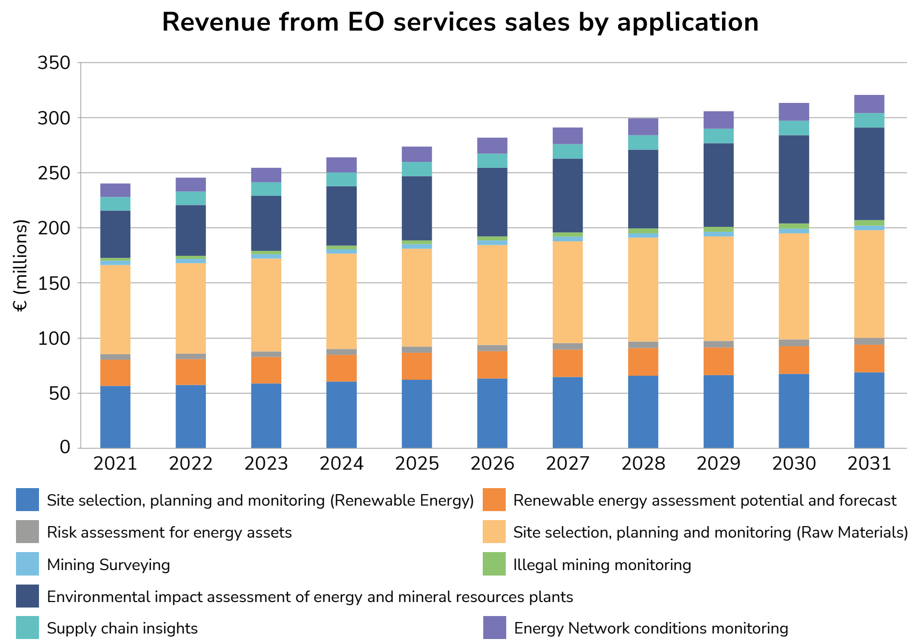
2021
2022
2023
2024
2025
2026
2027
2028
2029
2030
2031
EU27
Non-EU27 Europe
North America
Asia-Pacific
South America + Caribbean
Middle East + Africa


Revenue from EO services sales by application
€ (millions)
350
300
250
200
150
100
50
0
2021
2022
2023
2024
2025
2026
2027
2028
2029
2030
2031
Site selection, planning and monitoring (Renewable Energy)
Renewable energy assessment potential and forecast
Risk assessment for energy assets
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Mining Surveying
Illegal mining monitoring
Environmental impact assessment of energy and mineral resources plants
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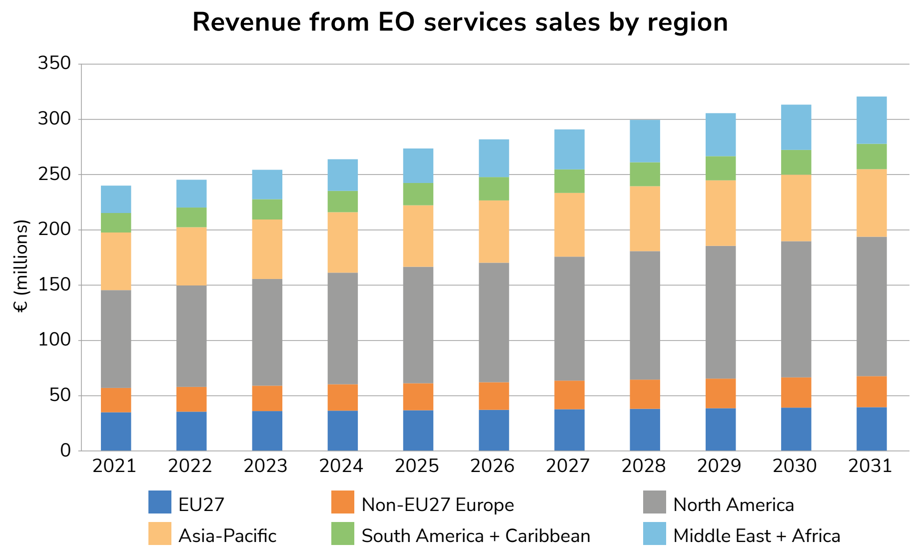
Revenue from EO services sales by region
€ (millions)
350
300
250
200
150
100
50
0
2021
2022
2023
2024
2025
2026
2027
2028
2029
2030
2031
EU27
Non-EU27 Europe
North America
Asia-Pacific
South America + Caribbean
Middle East + Africa

ENVIRONMENTAL MONITORING

Legend
EO application
GNSS application
Synergetic application
(combined use of EO and GNSS)

Environmental Auditing
- Environmental auditing[1]

Environmental Resources Management
- Environmental resources management[1]

Impact studies and ESG
- Impact studies and ESG[1]

[1] All three applications are applied across the same four different environmental systems being Atmosphere, Coasts, Land, and Water & Oceans.

Application descriptions can be found in Annex 3.

ENVIRONMENTAL MONITORING

National and international public bodies (and related agencies and institutions) are the main actors in charge of monitoring and protecting the environment, and the main user of relevant data and services.

Satellite data – EO in particular – have decades-long history of contributing to environmental monitoring. These are largely used for **environmental resources management** of multiple resources in various environments (e.g. water and oceans, coasts, atmosphere and land). Environmental data for these domains could also be used for more specific purposes, such as **environment auditing** and thus providing data on the human impact on the environment.

Due to the increase in public investments, and to the resulting technical innovation, private companies have also developed keen interest in using EO data and services for the purposes of **impact studies and ESG (Environmental, Social, and Corporate Governance)**, to mostly assess the impact of their activities or show compliance to applicable policies.

What you can read in this chapterv

- **Key trends:** The policies behind Environmental Compliance (Assurance) at EU level will drive the demand for EO data and applications.
- **Industry:** Environmental Monitoring EO Value Chain.
- **Recent developments:** The major market shares are already claimed by a few specific EO applications, while innovative projects and niche capabilities are finding their way.
- **Future market evolution:** Public authorities through public-private partnerships, flexible procurement schemes, and further regulation and standardisation, will open new market opportunities.
- **European systems and projects:** Current usage of Copernicus in the environmental monitoring segment
- **Reference charts:** Yearly evolution of EO revenues by application and region.

The policies behind Environmental Compliance (Assurance) at EU level will drive the demand for EO data and applications

Key market trends

- Environmental compliance assurance has just been defined as a self-standing concept in EU policy
- Environmental compliance requirements create opportunities for emerging EO markets
- Broadly, global climate policies are driving demand for data and services

Global climate policies are driving demand for environmental services

The influence of climate-related policies on the demand for data and services enabled by Earth Observation is increasing thanks to the political momentum engendered by the Paris **Agreement and the Sustainable Development Goals**. The European Union's Green Deal policy package positions Copernicus as a key complementary source of policy monitoring information for the European Climate Law and the Circular Economy Action Plan.

The **Regulation on the European Space Programme** (Art. 50) extends the scope of the Copernicus Services to include compliance assurance services. The Communication and Action Plan on improving compliance assurance and governance cites satellite imagery as one of nine forms of support for ensuring environmental compliance. Furthermore, the use of geo-spatial intelligence is included in the Work Programme 2020-2022 by the Environmental Compliance and Governance Forum. Last but not least, the 2030 Agenda for Sustainable Development opens up opportunities for the increased use of Earth Observation in the context of reporting on the Sustainable Development Goals. **All this drives demand for EO-based solutions in the market.**

Environmental compliance assurance: a regulatory perspective in Europe

Environmental compliance assurance (ECA) is an overarching concept throughout the environmental policies of the EU. It aims at creating *'...smart and collaborative culture of compliance with EU environmental rules on activities such as industrial production, waste disposal and agriculture...'* through *'...prohibitions, general binding rules, permits and other measures put in place to protect the environment, public health and society's long-term resource needs'.*

As Earth Observation in Europe plays a central role in environmental monitoring and compliance, within the framework of *'the endorsed work programme 2020-2022 to improve environmental compliance',* geo-intelligence (Copernicus in particular) is seen as an essential tool for the realization of ECA objectives across the three branches of ECA activities: compliance promotion; compliance monitoring; and follow-up and enforcement. This is due to the programme's operational capacity to provide data on multiple parameters, such as land cover/land cover change information, emission databases, monitored gas emissions in the atmosphere and oil spills or other pollution into water.

The regulatory cycle divided in sequential phases. In this context the possible uses of EO are explored. Credits: IMPEL

EO companies assisting Environmental compliance assurance

Environmental compliance assurance comes from international, EU and national policies and involves practitioners and duty holders both in the creation phase and implementation of policies. Nonetheless, the efforts to use EO best practices and capabilities would have limited effects if it were not for the full, free and open Copernicus data, and the ability of innovative EO companies to combine it with data from commercial satellites in their provision of value-added services.

Thus, **private EO actors provide expertise to support aspects of environmental compliance** in relation to regional and local norms (e.g., impact assessment, risk assessment, legal audit, damage evidence, law enforcement, etc.) and related products, such as alerts and reports. The exact type of expertise required may include, other than technical and EO expertise, some legal knowledge of the applicable regulations. The **potential and actual user base is broad** and includes governments, NGOs, law enforcement agencies and law firms.

So far, the number and the role of private companies in the ECA ecosystem has been limited due to factors such as the novelty of the concept, the lack of EO as a reference method across policies, an overall missing link between EO data and policy implementation and a lack of awareness, presence of reluctancy or legal impediments of public institutions to make use of it. This is expected to change as the legal framework on ECA becomes more elaborate. An example of this elaboration process is through the EU's biannual work programmes and the implementation of actions contained therein, which will in turn help ECA to affirm itself as an autonomous concept and to streamline policies and delineate market niches.

Environmental monitoring EO Value Chain[1]

INFRASTRUCTURE PROVIDERS	DATA PROVIDERS	PLATFORM PROVIDERS	EO PRODUCTS AND SERVICE PROVIDERS	INFORMATION PROVIDERS	END USERS
• AWS • BARCELONA SUPERCOMPUTING CENTRE* • CLOUDEO* • CODE • COLLAB GS • COPERNICUS DIAS* • GOOGLE CLOUD PLATFORM • IBM CLOUD • INTEL GEOSPATIAL • MICROSOFT AZURE • PENGUIN COMPUTING • PEPS	• AIRBUS* • BLACKSKY • COPERNICUS DIAS* • DESCARTES LABS • E-GEOS* • EARTH-I* • ECMWF • EUMETSAT • GHGSAT • ICEYE* • MAXAR • PLANET • UP42*	• ADAM* • CLEOS* • CLOUDEO* • COPERNICUS DIAS* • MAXAR ARD • NOR • PLANET EXPLORER • SENTINEL HUB* • TERRADUE* • UP42*	• BLUE LATITUDES • CYBELE* • ECOMETRICA* • EOMAP* • GEOVILLE* • OVERSTORY* • PLANETEK* • SATELLIGENCE* • WATER INSIGHT*	**AIR QUALITY:** • AIRQAST* • BREEZE TECHNOLOGIES* • EARTHSENSE* • WORLD FROM SPACE* **CARBON CREDITS:** • PACHAMA • SINGLE.EARTH* **EMMISSIONS:** • BLUEFIELD* (METHANE) • KAYRROS* (GREENHOUSE GAS) **FORESTS:** • C.O.D.E. COMPANY* • FÖRA* **WATER:** • DELTARES*	• POLICY MAKERS • DUTY HOLDERS • LEGAL PRACTITIONERS • JUDICIARY • NGOS • CORPORATES • GENERAL PUBLIC • ENVIRONMENTAL AGENCIES • INTERNATIONAL AGENCIES (E.G. UN...)
• COPERNICUS COLLABORATIVE GROUND SEGMENT*	• COPERNICUS SENTINELS* • USGS/NASA LANDSAT • RELEVANT IN-SITU NETWORKS	• ESA THEMATIC EXPLOITATION PLATFORMS	• COPERNICUS SERVICES*		

LEGEND

- Commercial Offering
- Public Offering
- User segments

NOTES

[1] The value chain considers the key global and European companies involved in GNSS and EO downstream activities.
* European-based companies. The region is defined with respect to the headquarters of the company, though the actual area of activity might be wider.

The major market shares are already claimed by a few specific EO applications, while innovative projects and niche capabilities are finding their way

Private sector actors entering the greenhouse gas monitoring market

Despite the strong scientific and institutional character of the greenhouse gases (GHG) monitoring sector, several private-sector firms are also active in this field. Methane, carbon and other trace gas emissions are being monitored via satellite remote sensing, in combination with ground-based sensor measurements, generally in the context of Environmental, Social, and Governance (ESG) data provision. Companies are also monitoring emissions at power-plant level and selling access to their datasets. As an example, Climate TRACE is a global coalition of non-profit and private sector actors working together to monitor nearly all human-caused GHG emissions worldwide, independently and in real time.

Although monitoring of GHGs from space remains largely an institutional and scientific endeavour, there is a clear need for such information, both for policy-level support and for operational applications.

The wide gap in technology adoption means that there is a niche for commercial actors to fill in this area. This is what also drives increased investment in companies that build EO constellations with specific focus on GHG monitoring.

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More and more companies are moving toward an environmental, social, and governance (ESG) culture

Be it driven by 'sustainable' financing opportunities, sector-specific environmental regulations, or the company's vision as upheld by its pool of customers, the corporate world is steadily moving towards an ESG culture. In practice, this means that **increasing numbers of companies** are becoming aware of and demonstrating an interest in the impact their resource (energy included) and waste chains have on the community and society overall, leading them to **take conscious steps towards improving their social impact and governance**. In this context, thanks to its broad spatiotemporal availability and standardised nature, **Earth Observation** is well positioned to support such efforts as it **enables consistent and comparative analyses at a continental scale**. For example, dedicated methane analytics and reporting are enabled by a number of EO-based businesses which are using Artificial Intelligence and Machine Learning to support asset managers and stakeholders responsible for ESG factors to understand investment risk and growth opportunity. Similarly, big corporations are using EO-enabled solutions to certify deforestation-free production of commodities (e.g. palm oil, cocoa, etc.). With major investors also implementing ESG-aware decisions, this recent trend can be expected to grow offering plenty of opportunity for EO-based solutions across multiple sectors.

Use of EO for harmful algae bloom (HABs) monitoring and reporting under the Water Framework Directive

The Water Framework Directive (WFD) bounds the Member States to **regular monitoring** and to **periodical reporting** on parameters relevant for determining the ecological and chemical status of water bodies. These parameters include, macrophytes and chlorophyll-a, transparency and salinity. Chlorophyll-a levels are a prime indicator for detecting harmful algae blooms in the observed water body, which are detrimental towater flora and fauna, and with possible repercussions on recreation, tourism and human health.

The monitoring activities of Member States related to the WFD are **traditionally dependent on in-situ measurements**. For some parameters, such as the chlorophyll-a, the **use of Earth observation data and numerical modelling could** (often in combination with in-situ) **lead to more precise results**, reduction of manual measurements and possibly even the saving of some costs related to traditional in-situ-only monitoring. This would benefit both public authorities in charge of monitoring and reporting under the WFD (i.e., environmental ministries, agencies and similar bodies) and the interested private sector (e.g., tourism and fisheries associations).

Data from the Copernicus programme (e.g., Sentinel-2 Multispectral Instrument) can be used for the purpose, as well as value added products and services offered by commercial providers.

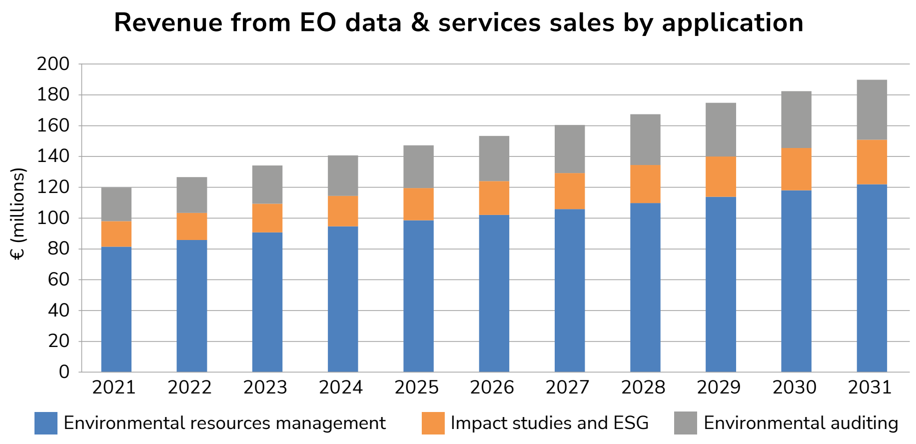
Use of EO to fight against environmental crime in the domain of waste disposal

Over the years, the European Union has gradually adopted a complete set of environmental legislation but still faces a number of implementation challenges. With 15% of waste placed on sites which do not meet the EU standards, waste disposal is part of these challenges.

During the last decades, the **production of waste has significantly increased, thus requiring more sophisticated and costly waste management systems**. Difficulties in treating waste have opened the door to illegal activities which cause significant harm to the environment and human health, resulting in losses of income representing several billion euros at a global scale for public authorities and private businesses.

Already largely used for environmental monitoring purposes, **satellite imagery can also play a crucial role in environmental law enforcement** and help public authorities in fighting against 'waste crime'. For instance, automated change detection routines applied to multitemporal radar data can detect the presence and monitor the evolution of illegal landfill sites, over large areas and at a reasonable cost. They can also be used to monitor legal landfills to ensure they remain within authorised boundaries. In this context, very high resolution optical data (mostly commercially available) can be an invaluable source of information, to potentially trigger on-site inspections and to constitute evidence files for use in a court of law.

Public authorities through public-private partnerships, flexible procurement schemes, and further regulation and standardisation, will open new market opportunities



The revenues from the sale of both EO data and services in the environmental monitoring sector in 2021 amount to €120 m, and will grow to reach €190 m in 2031. The breakdown in terms of applications shows the three major market shares ranked as follows: Environmental resources management; Environmental auditing; and Impact studies and ESG.

The dominant market share held by the Environmental resources management represents – and will continue to represent – over half of the revenue in the entire Environmental monitoring market. This is a reflection of the large focus on environmental monitoring across sectors, both vstrongoluntary and pursuant to compliance required by sectoral or overarching requirements. Similar are the factors driving the increasing demand in the field of Impact studies and ESG.

Long way to go: use of Earth observation imagery as evidence in environment-related court proceedings

Prosecuting environmental crime is arguably the most obvious instance or use of EO imagery in the courtroom. Determining if air, water or soil emission standards have been breached are only a few of the concrete applications where satellite data could be indispensable. However, the operational use of EO data in similar circumstances is still limited. This is due to procedural and technical barriers. Procedural barriers vary among jurisdictions, as do the conditions for data to be considered evidence and used in court. Technical barriers common among jurisdictions include a lack of awareness of satellite capabilities and limited ability in interpreting satellite data. In recent years significant efforts have been undertaken to overcome such barriers by entities such as the European Union Network for the Implementation and Enforcement of Environmental Law (IMPEL) who have been working actively to raise awareness of the possibilities of EO among environmental legal professionals. As for the question of interpretation and authentication of the satellite data, it is necessary that standardization efforts ramp up so that imagery or measurements can unequivocally be used in court.

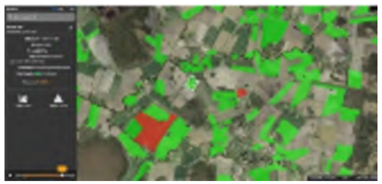
Each of these two developments will eventually open new opportunities for EO companies as providers, interpreters and potentially authenticators of data and value-added services.

Public-private partnerships and novel procurement schemes

The increased involvement of private actors within Environmental Compliance-related services seems imminent. There is a push from public authorities for this involvement, notably under the form of public-private partnerships (PPPs) where EO companies provide the EO data (or the value-added-service based on it) to the authority in charge of policy implementation/monitoring. For instance, this is the case for many EU Member States where the Common Agricultural Policy stimulates environmentally friendly practices through subsidies. When it comes to the maintenance of permanent grassland, farmers are entitled to subsidies as long as they mow the grasslands periodically. While in the past this was verified by the personnel of the Paying Agencies through on-site inspections, the responsible authorities are now partnering with local or international EO companies to automate the process.

The result is openly accessible online platforms where Copernicus data (and machine learning algorithms) are used to display the status of grassland mowing obligations at field level, allowing the responsible authority to objectively, automatically and remotely manage compliance checks and therefore distribute subsidy payments fairly. This improves the policy implementation process and potentially reduces costs of personnel inspections and from subsidising uncompliant claimants, while contributing to the principles of transparency and public accountability.

Further steps in using cutting edge technologies such as EO in the policy cycles of environmental compliance assurance will inevitably require more flexible procurement practices under the form of pre-commercial procurement, such as those already implemented by H2020 projects for specific EO sectors (e.g., the Marine EO project) as well for GNSS (e.g., the BroadGNSS project).



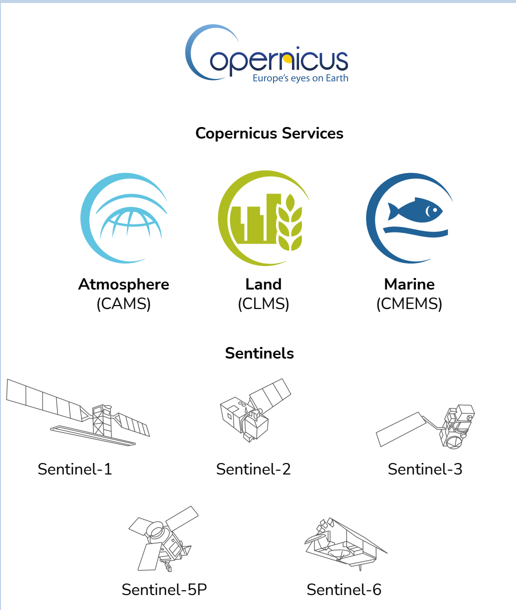
Mowing detection map showing compliant and non-compliant fields. Credits: © KappaZeta

Current usage of Copernicus in the environmental monitoring segment

Current usage of Copernicus

Extensive usage of Copernicus data and services is made by environment and climate applications. For the purposes of environmental monitoring, a vast range of data is used or can be used, depending on the subject of the environmental regulation or law at hand (e.g., air quality, waste management, atmospheric emissions, etc.). Data can also be provided to support Member states and bodies in reporting under directives.

This is the case of the **Joint Copernicus Marine - EMODnet catalogue**, released in June 2021 and soon to be extended to all European seas. The catalogue is aimed at supporting Member States in the implementation of the Marine Safety Framework Directive and its descriptors. The underlying free and open data is a combination of satellite and modelling (from CMEMS) and in-situ data (from EMODnet).



HORIZON 2020 enviroLENS

Supporting Environmental Law Enforcement with Earth Observation

At present, satellite-derived information is not used on a regular basis as primary evidence in environmental law enforcement.

The 'Copernicus for environmental law enforcement support' project aims to bridge the gap for the utilisation of capacities provided by Copernicus for environmental law enforcement and related cross-cutting sectors. To these ends, the project's objective is to deliver EO-based services providing evidence on environmental incidences and legal violations in order to support the evidence-gathering process and to foster data-driven decision-making.

More information on: https://envirolens.eu

HORIZON 2020 Water - ForCE

Defining the future of inland water services for Copernicus

The availability of free Copernicus data has started transforming approaches to the assessment, monitoring and sustainable management of aquatic environments. However, the water-related products are delivered through several different Copernicus services.

This project aims to develop a roadmap for a centralised provision of Copernicus water-related services, addressing (amongst other things) the quality of inland and coastal waters. This roadmap will support user uptake as well as the implementation of relevant policies.

More information on: https://waterforce.eu

HORIZON 2020 VERIFY

Observation-based system for monitoring and verification of greenhouse gas fluxes

As the negative impacts of global warming become increasingly evident, public authorities and private stakeholders are enhancing efforts to curve down the emissions of greenhouse gases (GHG).

This project is developing a system to estimate greenhouse gas emissions, based on land, ocean and atmospheric observations, to support countries' emissions reporting to the UN Climate Change Convention Secretariat. It focuses on the three major greenhouse gases responsible for global warming: carbon dioxide (CO_2); methane (CH_4); and nitrous oxide (N_2O).

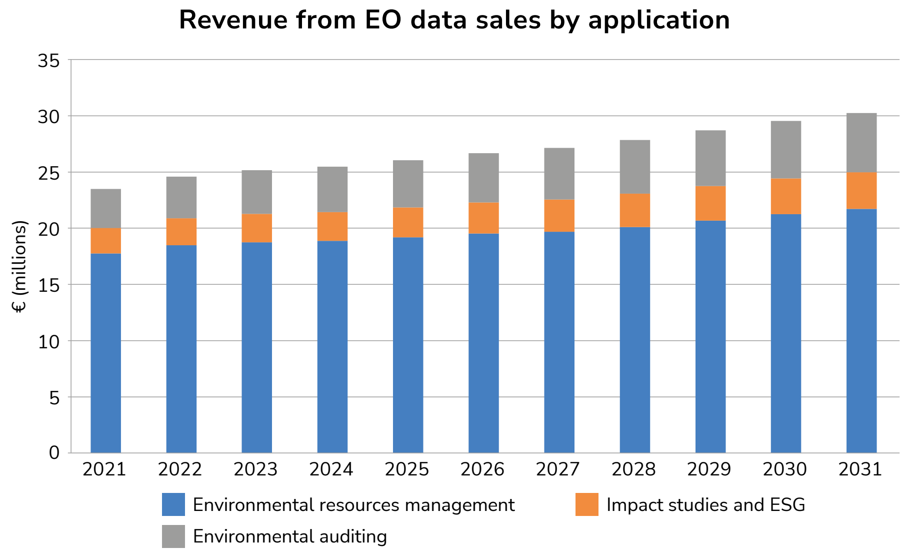
More information on: http://verify.lsce.ipsl.fr

HORIZON 2020 CoCO2 Prototype system for a Copernicus CO_2 service

Prototype system for a Copernicus CO_2 service

The $CoCO_2$ project is a continuation of the CO_2 Human Emissions (CHE) project, and builds on some of the work initiated in the Verifying Greenhouse Gas Emissions (VERIFY) project. Its objective is to design and build the prototype systems for a European Monitoring and Verification Support capacity for anthropogenic CO_2 emissions (CO2MVS), bringing together existing capacities and innovative ideas from a wide range of European and international players. The prototypes will link to as much of the already existing Copernicus infrastructure as possible, and will ensure that all the components needed for the attribution of CO_2 emissions are designed and developed (e.g. Earth system models, data assimilation techniques, prior emission estimation, etc.).

More information on: https://coco2-project.eu


Revenue from EO data sales by application
€ (millions)
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15
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25
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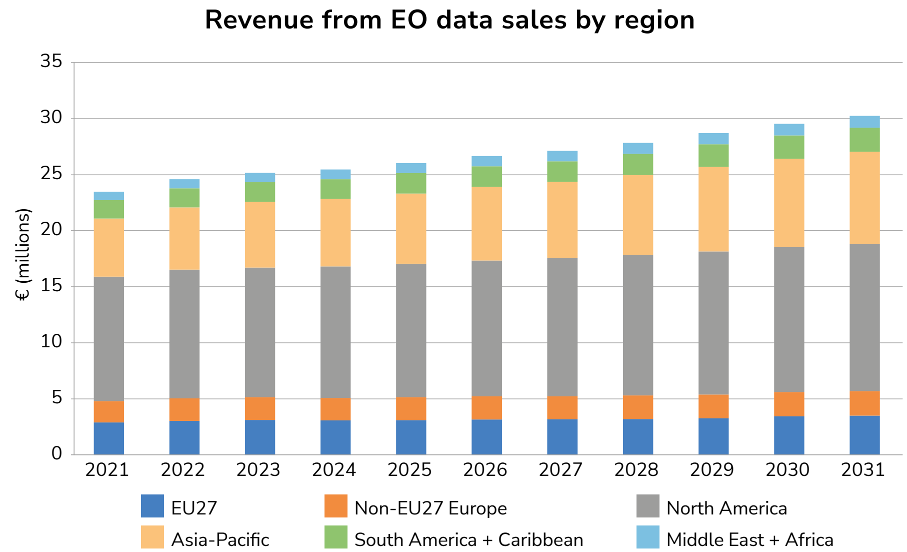
Environmental resources management
Impact studies and ESG
Environmental auditing


Revenue from EO data sales by region
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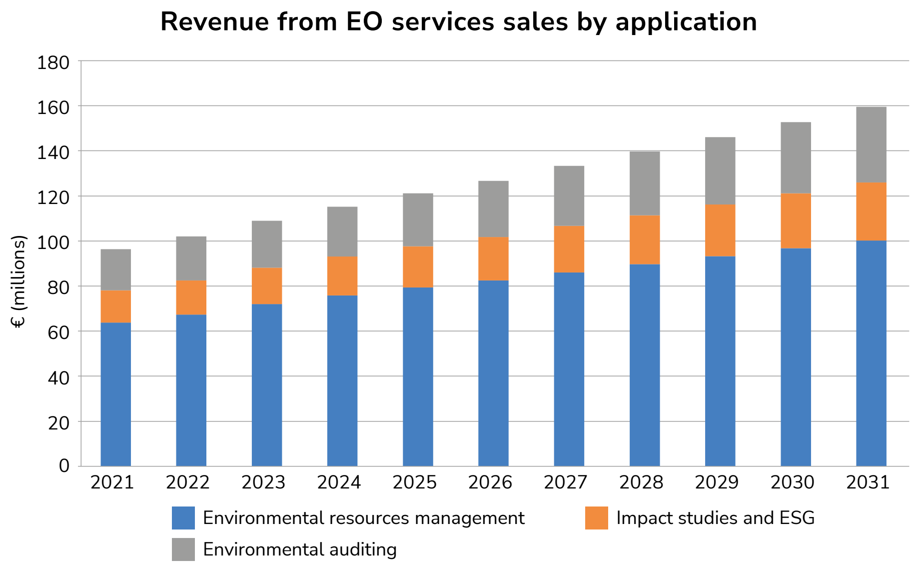
Asia-Pacific
South America + Caribbean
Middle East + Africa


Revenue from EO services sales by application
€ (millions)
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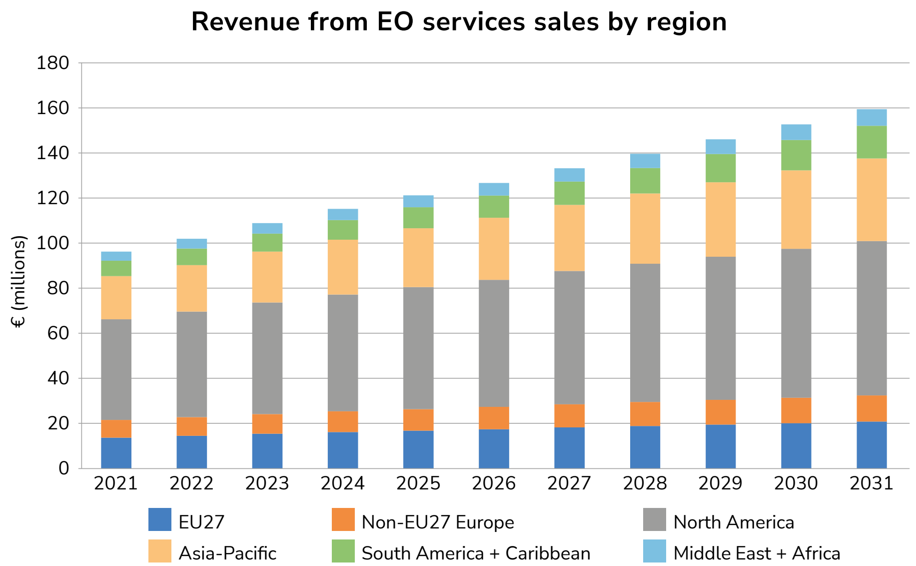
Environmental resources management
Impact studies and ESG
Environmental auditing


Revenue from EO services sales by region
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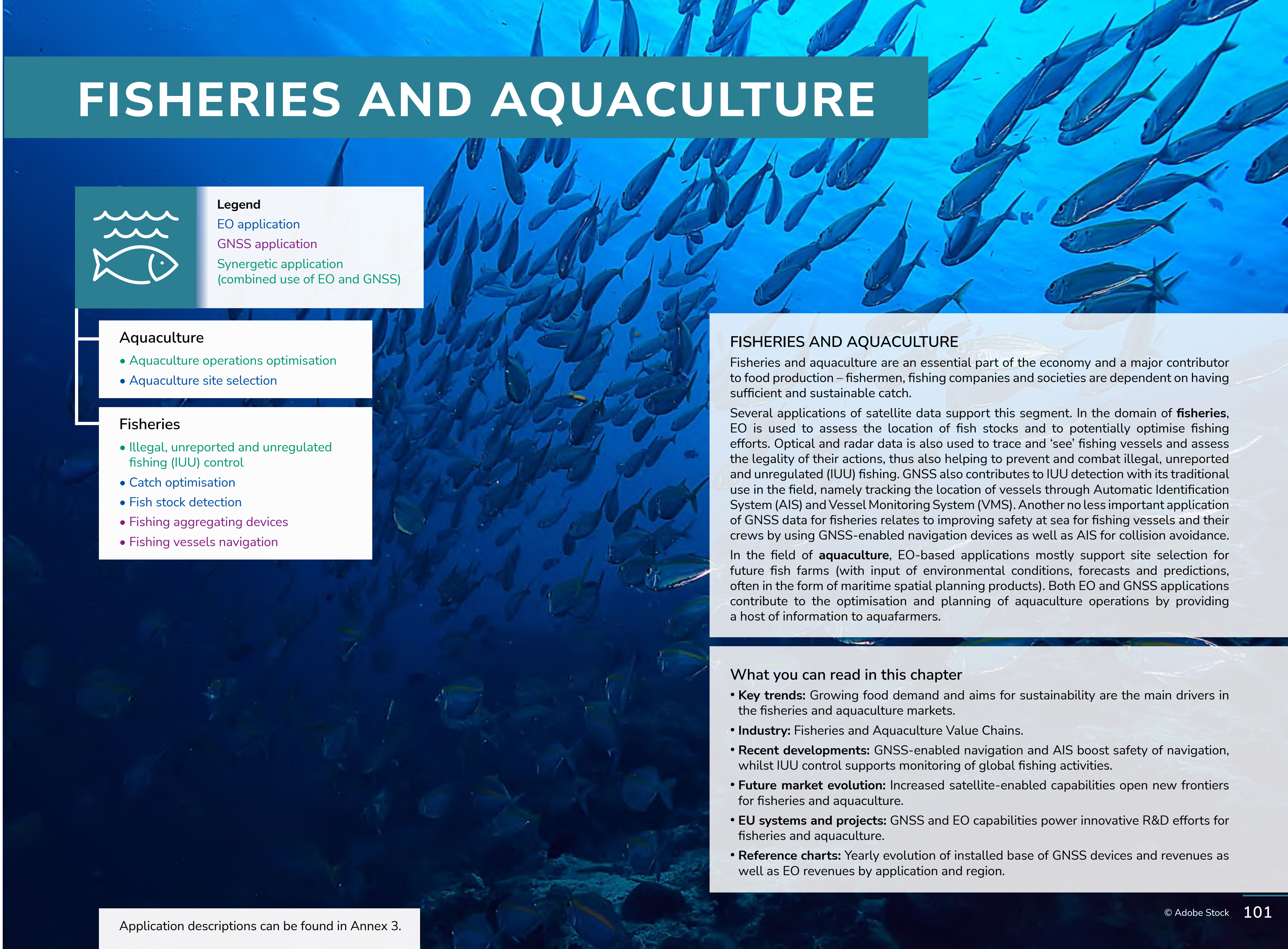
Non-EU27 Europe
North America
Asia-Pacific
South America + Caribbean
Middle East + Africa



FISHERIES AND AQUACULTURE

Legend
EO application
GNSS application
Synergetic application (combined use of EO and GNSS)

Aquaculture

- Aquaculture operations optimisation
- Aquaculture site selection

Fisheries

- Illegal, unreported and unregulated fishing (IUU) control
- Catch optimisation
- Fish stock detection
- Fishing aggregating devices
- Fishing vessels navigation

FISHERIES AND AQUACULTURE

Fisheries and aquaculture are an essential part of the economy and a major contributor to food production – fishermen, fishing companies and societies are dependent on having sufficient and sustainable catch.

Several applications of satellite data support this segment. In the domain of **fisheries**, EO is used to assess the location of fish stocks and to potentially optimise fishing efforts. Optical and radar data is also used to trace and 'see' fishing vessels and assess the legality of their actions, thus also helping to prevent and combat illegal, unreported and unregulated (IUU) fishing. GNSS also contributes to IUU detection with its traditional use in the field, namely tracking the location of vessels through Automatic Identification System (AIS) and Vessel Monitoring System (VMS). Another no less important application of GNSS data for fisheries relates to improving safety at sea for fishing vessels and their crews by using GNSS-enabled navigation devices as well as AIS for collision avoidance.

In the field of **aquaculture**, EO-based applications mostly support site selection for future fish farms (with input of environmental conditions, forecasts and predictions, often in the form of maritime spatial planning products). Both EO and GNSS applications contribute to the optimisation and planning of aquaculture operations by providing a host of information to aquafarmers.

What you can read in this chapter

- **Key trends:** Growing food demand and aims for sustainability are the main drivers in the fisheries and aquaculture markets.
- **Industry:** Fisheries and Aquaculture Value Chains.
- **Recent developments:** GNSS-enabled navigation and AIS boost safety of navigation, whilst IUU control supports monitoring of global fishing activities.
- **Future market evolution:** Increased satellite-enabled capabilities open new frontiers for fisheries and aquaculture.
- **EU systems and projects:** GNSS and EO capabilities power innovative R&D efforts for fisheries and aquaculture.
- **Reference charts:** Yearly evolution of installed base of GNSS devices and revenues as well as EO revenues by application and region.

Application descriptions can be found in Annex 3.

Growing food demand and aims for sustainability are the main drivers in the fisheries and aquaculture markets

Key market trends

- Fisheries are becoming increasingly important as land for agriculture diminishes and food demand increases
- Investment and Innovation seek to boost the Blue Economy including the fisheries and aquaculture sector
- Key policy efforts drive demand for solutions that enable sustainable and more resilient fisheries and aquaculture

Fisheries and aquaculture form a key component of the Green Deal

The EU's commitment to become the first climate-neutral continent by 2050 is driven by the European Green Deal. This commitment requires decisive steps towards restoring the health of our oceans, securing food production through fisheries and aquaculture and fostering a sustainable blue economy. Today the blue economy represents roughly 5.4 million jobs and generates a gross added value of almost €500 billion a year. When it comes to fisheries, Europe has seen a gradual progress towards environmental and economic sustainability. The Green Deal calls for 30% of the Maritime Fisheries Fund to contribute to climate action and biodiversity conservation.

For instance, whilst in 2009 the EU fishing fleet was barely profitable, in 2019 it documented estimated net profits of €1.3 billion. At the same time great strides have been made to fight illegal, unreported and unregulated (IUU) fishing and preserve fish stocks. In parallel, aquaculture is gaining strong political momentum as exemplified through the recent strategic guidelines for a more sustainable and competitive EU aquaculture, also in the light of Sustainable Development Goal (SDG) 14 – Life below water. Overall, the **effort to modernise, strengthen and to make the fisheries and aquaculture sector more resilient and sustainable increasingly relies on GNSS and EO,** both of which have proven to be invaluable tools supporting multiple applications.

Healthy oceans and sustainable food production become pillars of innovation and investment efforts

Accounting for about 3.3% of global fisheries and aquaculture production, the EU is the fifth largest producer worldwide. 80% of this production comes from fisheries and 20% from aquaculture. Forming part of the Blue Economy, this sector has been increasingly relying on cutting-edge solutions for safe navigation of fishing vessels, fish detection and catch optimisation, but also for improving aquaculture operations. Many of these topics are expected to show significant growth powered by recent trends around investment, research and innovation. Thus, the BlueInvest initiative aims to **boost innovation and investment in sustainable technologies** for the blue economy by supporting readiness and access to finance for early-stage businesses, SMEs and scale-ups. It is enabled by the European Maritime and Fisheries Fund.

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With global rise in fisheries an aquaculture consumption, traceability for sustainable fishing is crucial

The seafood market is growing due to increased demand worldwide, reductions in loss and waste and increased awareness of the health benefits linked to a seafood-based diet. In addition, the greater awareness of climate change has led to the creation of different initiatives (public, private and NGOs) for the protection of the oceans, seas, inland waterways and marine resources with the objective of **supporting sustainable fishing.** Organisations such as the Aquaculture Stewardship Council (ASC) are establishing standards to address key social and environmental impacts and stress the importance of traceability. **EO and GNSS technologies are key enablers of traceability features.** For instance, AIS can be used in combination with GNSS to seamlessly track certified fishing fleets, informing sustainable production all the way to the final product.

Fisheries and Aquaculture Value Chains[1]

EARTH OBSERVATION

INFRASTRUCTURE PROVIDERS

- AWS
- CLOUDEO*
- COPERNICUS DIAS*
- GOOGLE CLOUD PLATFORM
- HEWLETT PACKARD ENTERPRISE
- IBM CLOUD
- INTEL GEOSPATIAL
- MICROSOFT AZURE
- PENGUIN COMPUTING

- COPERNICUS COLLABORATIVE GROUND SEGMENT*

DATA PROVIDERS

- AIRBUS*
- COPERNICUS DIAS*
- DAMPIER
- DEIMOS IMAGING*
- E-GEOS*
- EARTH-I*
- EUROGOOS*
- FONDEN*
- GOOGLE
- HAWKEYE 360
- ICEYE*
- MAXAR
- MERCATOR OCEAN*
- PLANET

- COPERNICUS SENTINELS*
- USGS/NASA LANDSAT
- RELEVANT IN-SITU NETWORKS
- METEOROLOGICAL AGENCIES
- OCEANOGRAPHIC AGENCIES

PLATFORM PROVIDERS

- ADAM*
- CLEOS (E-GEOS)*
- COPERNICUS DIAS*
- MAXAR ARD
- PLANET EXPLORER
- RHETICUS (PLANETEK)*
- UP42*

- THEMATIC EXPLOITATION PLATFORM COASTAL (ESA TEP)*
- EMODNET*

EO PRODUCTS AND SERVICE PROVIDERS

- ACRI *
- CLS*
- DEIMOS*
- EOMAP*
- KSAT*
- MARIS PLATFORM
- OCEANMIND*
- PLANETEK*
- PML*
- SKYTRUTH
- VAKE*
- VITO*
- WATER INSIGHT*

- COPERNICUS SERVICES*

INFORMATION PROVIDERS

- BREVISCO*
- CLS*
- DELTARES*
- DNV*
- GLOBAL MARITIME*
- ILVO*
- INNOVASEA
- SEASCAPE*

END USERS

- **FISHERIES**
- **AQUAFARMERS**
- **ENVIRONMENTAL AGENCIES**
- **CONSERVATION GROUPS**
- **NGOS**
- **MARINE RESEARCH INSTITUTES**
- **MARINE PROTECTION AGENCIES**
- **SUPERMARKETS**

LEGEND

- Commercial Offering
- Public Offering
- User segments

GNSS

MARITIME ORGANISATIONS

CIRM is an international association for marine electronics companies

EFCA EUROPEAN FISHERIES CONTROL AGENCY

EMSA EU agency charged with reducing risks of maritime accidents, marine pollution and loss of human lives at sea

COMPONENT AND RECEIVER MANUFACTURERS

- COBHAM*
- COBRA ELECTRONICS
- FURUNO
- GARMIN
- NAVICO*
- KONGSBERG*
- OROLIA*
- SAMYUNG ENC
- WÄRTSILÄ *

SYSTEM INTEGRATORS

- INMARSAT*
- IRIDIUM
- KINEIS (ARGOS)
- PRONAV
- ST ELECTRONICS
- YANMAR
- WÄRTSILÄ *

USERS

- FISHING BOAT OPERATORS
- RECREATIONAL BOATERS

USERS OF POSITIONING INFORMATION

- FISHING COMPANIES
- PORT AUTHORITIES
- SURVEILLANCE AUTHORITIES
- DATA-ANALYTICS COMPANIES:

MARINETRAFFIC, MYSHIPTRACKING, VESSELTRACKER

European[2] EO and GNSS industry in the global arena

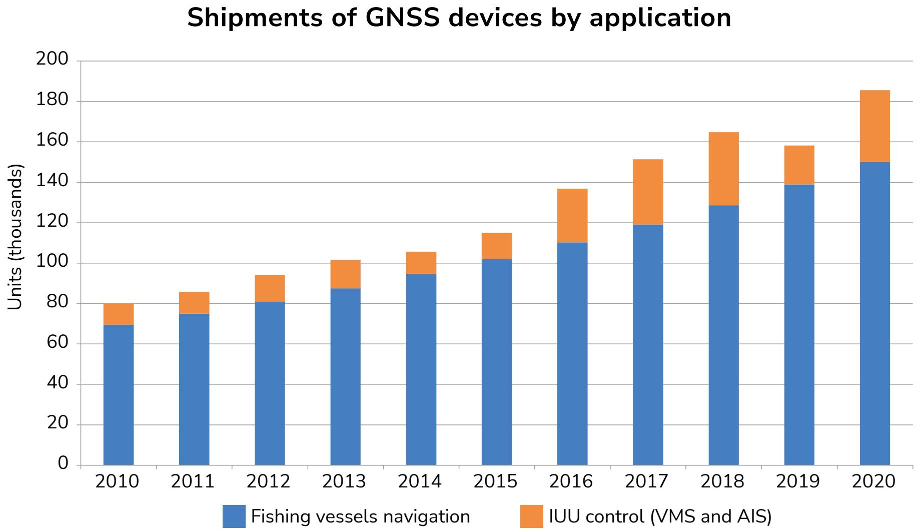
With CLS and ACRI (FR), Leonardo (IT), DHI FONDEN (DK) and Dampier (LU) there are 5 European companies in the top 10 worldwide companies providing EO data/services for fisheries and aquaculture. With regards to the data processing services, these companies hold roughly 60% of the global share, with their share amounting at almost 90% of the global market with regard to the provision of services such as Analysis, insights & decision support.

GNSS receivers in Fisheries and Aquaculture are similar to those used in Maritime and Inland Waterways, with a significant overlap in terms of industry. European companies such as Navico, Kongsberg, and Wärtsilä hold 47% of the total maritime market.

NOTES

[1] The value chain considers the key global and European companies involved in GNSS and EO downstream activities.
[2] In the market share analysis, Europe is defined as EU27 plus Norway, Switzerland and the UK.
* European-based companies. The region is defined with respect to the headquarters of the company, though the actual area of activity might be wider.

GNSS-enabled navigation and AIS boost safety of navigation, whilst IUU control supports monitoring of global fishing activities

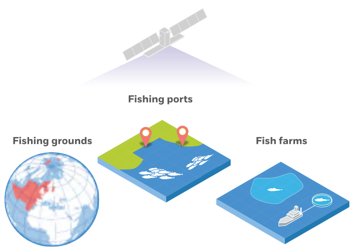


Over the past decade, the **annual sales of navigation devices doubled** from roughly 75,000 units in 2010 to slightly over 150,000 sales in 2020. The underlying reasons for this growth are twofold. First, safety of navigation is improved by relying on a dedicated navigation device, especially in combination with an Automatic Identification System (AIS) that supports collision avoidance. Second, innovative applications such as GNSS-tracked fishing buoys or EO products supporting fish stock detection (see next page) rely on trustworthy GNSS navigation to direct the fishing vessel to fishing grounds.

When it comes to aiding Illegal, unreported and unregulated (IUU) fishing control, the sales of **Vessel Monitoring Systems** (VMS) reached almost 20 thousands units in 2020, a figure very similar for the AIS shipments (roughly 18 thousand units).

VMS, mandatory for vessels of twelve metres or longer, is a satellite-based monitoring system providing data to the fisheries authorities on the location, course and of vessels. In turn, AIS is a safety radio system which enables the exchange of navigation and other dspeedata (ship-to-ship and with shore-based facilities) and is required for vessels of 15 meters or longer. Since both systems assist authorities with the monitoring of vessel movement, they provide useful information to combat IUU activities. For this reason, they are covered together under the IUU control application.

Combatting illegal fishing with the help of satellites



© EC

© BarentsWatch

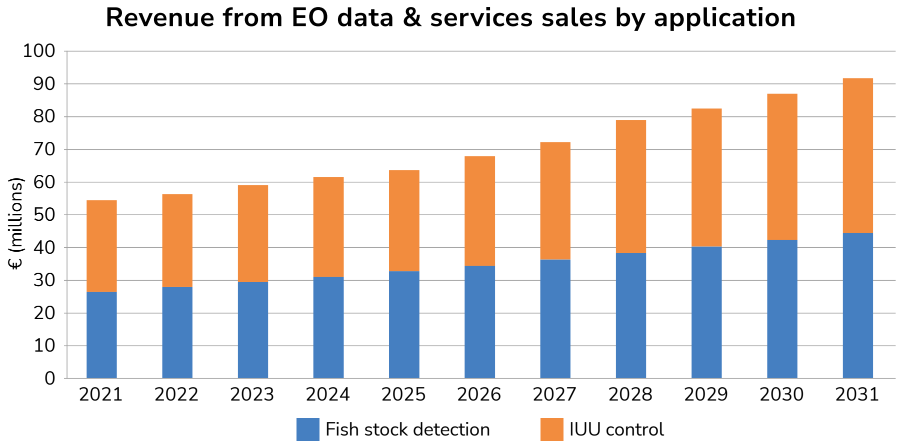
Illegal, unreported, and unregulated fishing makes up about 20% of the global catch. IUU fishing costs the global economy between € 9 and €21 billion annually. Most importantly, the underlying practices, arising from lacking, unenforced or breached regulations, pose a threat to biodiversity and human rights. There is therefore a need to increase transparency and stop IUU fishing by providing precise information on these illicit practices to policy makers and regulators, researchers, advocates, businesses and consumers. To this end, **EO-based services,** including the Maritime Surveillance component of the Copernicus Security Service **and GNSS-based solutions** utilising VMS and AIS, **are important contributors to the fight against IUU**. New tools are also emerging such as Radio-Frequency (RF) data analytics offered by NewSpace startups. All this is leveraged in major multi-actor collaborations.

© Global Fishing Watch

This is the case of The **Global Fishing Watch** – an initiative supported by major IT companies, NGOs and governmental actors – which produces a map that represents the world's first dynamic, global, near real-time measure of fishing activity. The free and open platform makes use of VMS and AIS data, satellite technology, cloud computing and machine learning. The satellite data used is a combination of data coming from various sources – a partnership with NOAA provides Visible Infrared Imaging Radiometer Suite (VIIRS) data, while other data is bought from space agencies (e.g., NASA, NOAA, ESA) or acquired from commercial satellite data providers (in the latter case either through agreements in place or through ad hoc requests).

Another example is the Norwegian Coastal Authority who, in collaboration with Mercator Ocean, have developed a tool called barentswatch.co. By combining GNSS and EO data with Artificial Intelligence (AI), the tool is capable of identifying vessels with 'suspicious' route patterns, contributing to a more efficient identification and monitoring of vessels that are possibly conducting illicit activities or are engaged with IUU fishing.

Increased satellite-enabled capabilities open new frontiers for fisheries and aquaculture



The **annual revenue from the sale of both EO data and services to the fisheries sector** is estimated to grow from €54 m in 2021 to €92 m in 2031.

Fish stock detection and **Illegal, unreported, and unregulated (IUU) fishing control** hold almost equal shares throughout the projected timeframe. The structure of the total revenue for each of the two applications is, however, very different.

For **Fish stock detection** revenues from services make up to 97% of the total by 2031. On the other hand, **IUU fishing control** revenues will comprise in 2031 of 67% in services and 33% in data sales.

The revenues from applications using EO data for aquaculture activities are not plotted, as this market is currently in its infancy. Nonetheless, given the importance aquaculture has gained in recent key policies as well as the overall growth of the market, one can expect that in the very near future such revenues will become substantial.

Aqua Farmers benefit from innovative services utilising Copernicus

Aquaculture production is projected to reach 109 million tonnes in 2030, an increase of 32 percent (26 million tonnes) over 2018. For this to be realised in an efficient, sustainable and environmentally friendly way, aquafarmers and governmental authorities responsible for regulation need information that helps them make informed decisions and timely interventions. This is precisely what Earth Observation in general, and Copernicus in particular, can offer for aquaculture site selection and operations optimisation. By integrating satellite measurements with in-situ observations and operational modelling, innovative EO companies provide solutions such as maps of suitability conditions for farm management that take into account key parameters such as temperature, salinity, turbidity and Chlorophyll-a. Moreover, EO-enabled systems can generate alerts for hazardous conditions, including heat waves and oxygen depleted conditions. Such solutions are progressively becoming operational, following their design and implementation in Research and Innovation projects such as H2020 FORCOAST, which supports the development of an advanced platform and cloud computing for Copernicus-based downstream services utilising one of the Data and Information Access Services (DIAS) systems. Much of the innovation work is also supported by the European Aquaculture Technology and Innovation Platform, often in collaboration with Mercator Ocean as the manager of the Copernicus Marine Environment Monitoring Service, and through platforms such as the WekEO DIAS.

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Aquaculture entering deeper waters with help from EO and GNSS

© DNV

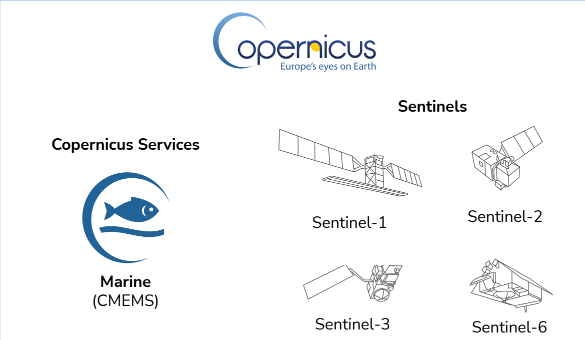
The share of fish production destined for human consumption is expected to continue to grow, reaching 89 percent by 2030. This will lead aquaculture production to new frontiers, further away from the shore. Still an emerging approach, offshore or open ocean aquaculture entails the positioning of farms in deeper and less sheltered waters, where ocean currents are stronger than they are inshore.

This comes with significant challenges. Firstly, the positioning of offshore platforms requires a host of data that would indicate the optimal conditions (e.g., salinity, currents, temperature, etc.). This is precisely and clearly where Copernicus Services and EMODnet data can add value. Secondly, the operation of offshore farms is often done by fully automated vessels (e.g. Ocean Farm 1 and Jostein Albert) which rely on accurate positioning and navigation provided by augmented GNSS solutions – mainly PPP due to the offshore nature of aquaculture. Other setups such as seaweed farms also benefit from IoT configurations that make use of GNSS for the localisation of networks of buoys.

GNSS and EO capabilities power innovative R&D efforts for fisheries and aquaculture

Current usage of Copernicus

The Copernicus Marine Service (CMEMS) User Uptake programme showcases important operational uses of the associated data and products. One illustrative example is SkyFISH: a web-based and free-to-use platform that can serve as a decision support tool for finding the most favourable fishing zones in the Black Sea, analysing the suitability of specific areas for aquaculture activities and the monitoring of existing ones. Most of the measured parameters are updated daily and result in a multitude of value-added services, primarily based on the suitability indices for fishing and aquaculture activities.



Current usage of EGNSS

With around 40 GNSS receivers for fishing vessel navigation enabled with Galileo, fishermen already rely on improved positioning and navigation information. When it comes to the monitoring of fishing vessels and their activities, a key role is set out for AIS and VMS, to which Galileo and its services can provide added value.

The upcoming evolution from AIS towards VDES (Very High Frequency Data Exchange System) and the possibility to use the authenticated signal from Galileo Open Service Navigation Message Authentication (OSNMA) could be a gamechanger for the efficient and effective monitoring of fishing vessels.

HORIZON 2020 Blue-Cloud

Towards the establishment of a marine-thematic European Open Science Cloud

To address the global climate, environmental and societal challenges, a pressing need has been identified for a new approach to ocean science and blue resource management. Indeed, a growing number of actors propose infrastructure collecting, accessing and managing marine data. Yet the currently existing capabilities cannot be used for complex or global challenges where multi-disciplinary and worldwide information is key.

A practical approach towards addressing this gap is proposed by Blue-Cloud, a Horizon 2020 project combining Copernicus with other distributed marine and interdisciplinary data sources, computing facilities and analytical services, working towards establishing a marine-thematic European Open Science Cloud. In their plankton genomic demonstrator, Copernicus data is combined with data from biomolecular and environmental domains to assess plankton distributions and fill the scientific knowledge gaps on its biology and biodiversity. A second demonstrator integrates existing services from Copernicus Marine Service, ECMW and EMODNET to combine parameters from marine environment, oceanography, meteorology and acidification. This will provide decision makers and environmental agencies with unified marine environmental indicators. A third tool, the aquaculture monitor, uses Copernicus data in producing national aquaculture sector overviews.

More information available at: https://www.blue-cloud.org/

Fundamental Elements BLUE PORBEAGLE

Complete shipborne equipment with integrated GNSS

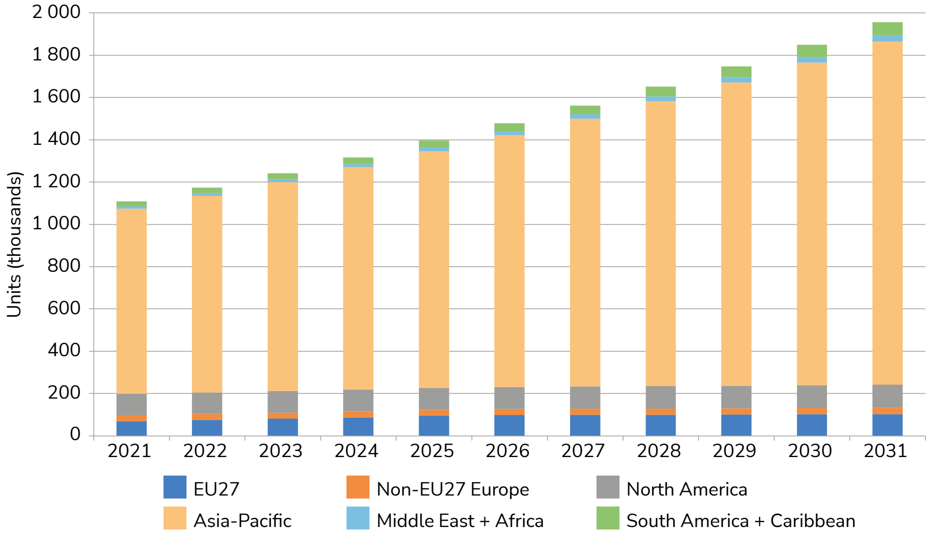
GNSS supports position reporting within VMS. In the EU, all vessels above 15 metres are fitted with a VMS, and a 'blue box' which transmits the GNSS-derived vessel position to the Fisheries Monitoring Centre (FMC) in the flag state, which then communicates this information to the state or regional fisheries body in whose waters the vessel is fishing.

A new EU project, called Bluebox Porbeagle aims to develop close-to-market complete shipborne integrated equipment, compliant with regulatory standards for Vessel Monitoring Devices required by EFCA and countries' regulations. The new product will disrupt current market solutions through the first use of anti-spoofing cybersecurity protection technology and improved accuracy with dual frequency, enhancing the fishery VMS with Galileo Open Service (OS).

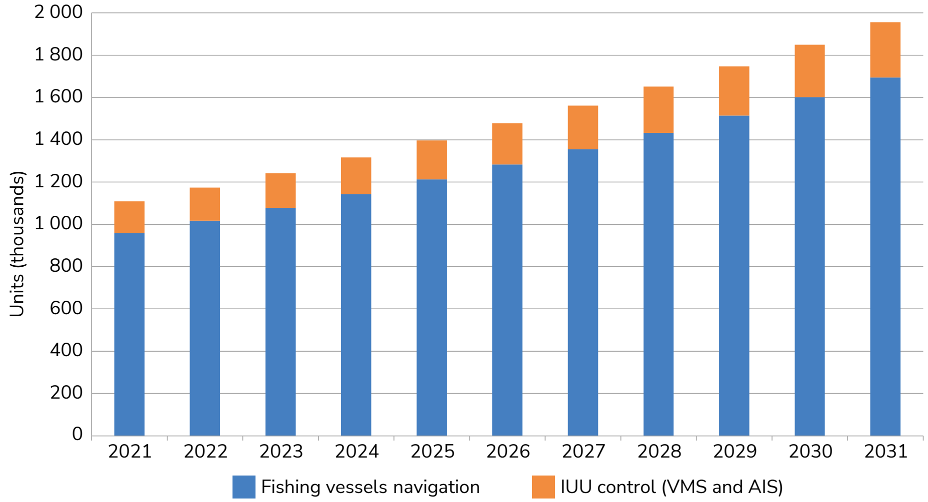
The Bluebox Porbeagle VMS shipborne equipment will decode dual frequency position, velocity, and time (PVT) information from E1/E5a Galileo signals and perform autonomous GNSS data messages authentication based on OSNMA.

More information available at: https://blueporbeagle.eu/

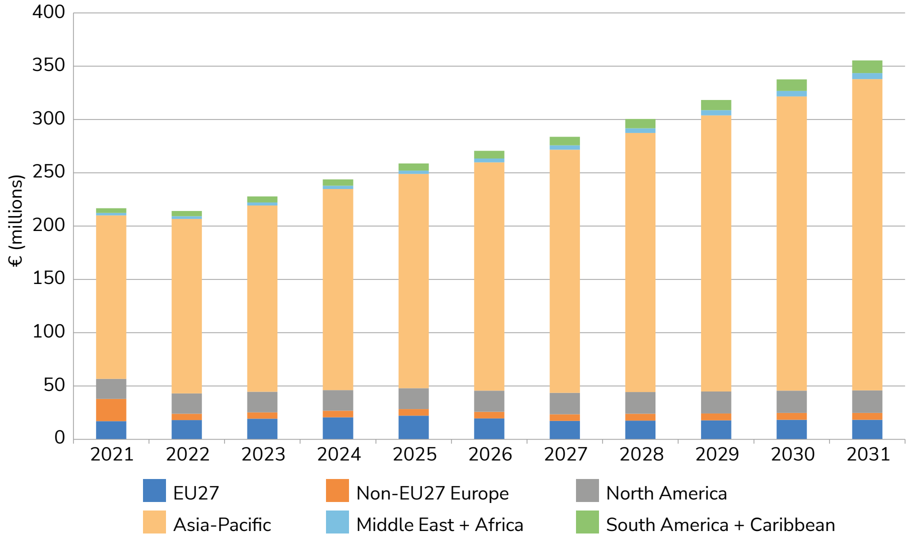
Installed base of GNSS devices by region



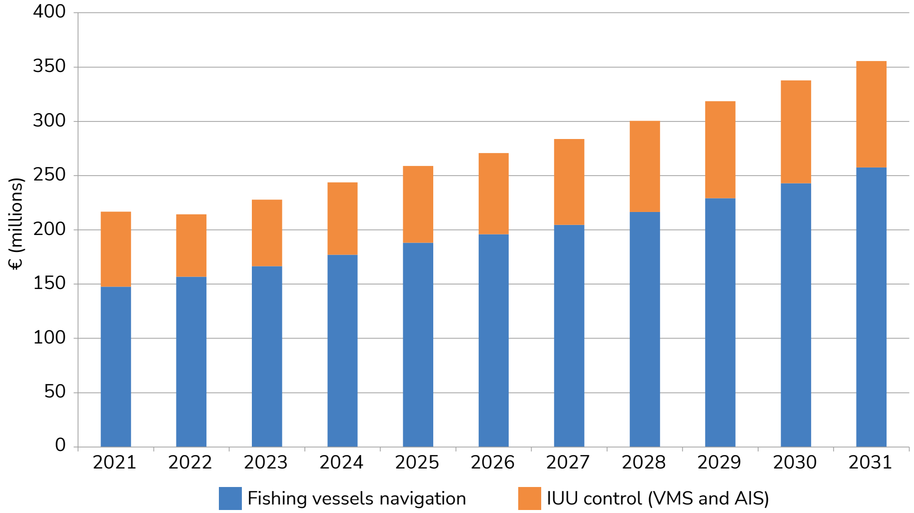
Installed base of GNSS devices by application

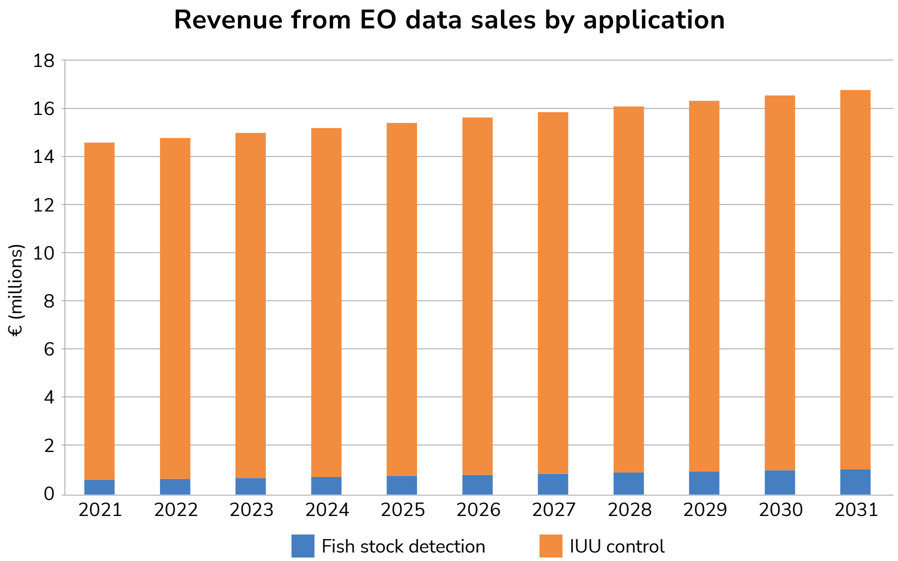


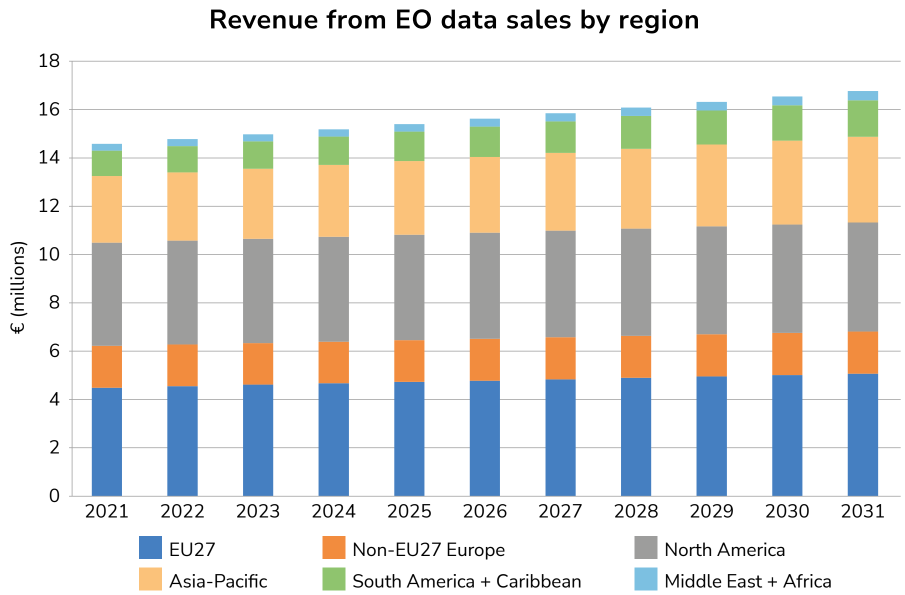
Revenue of GNSS device sales by region

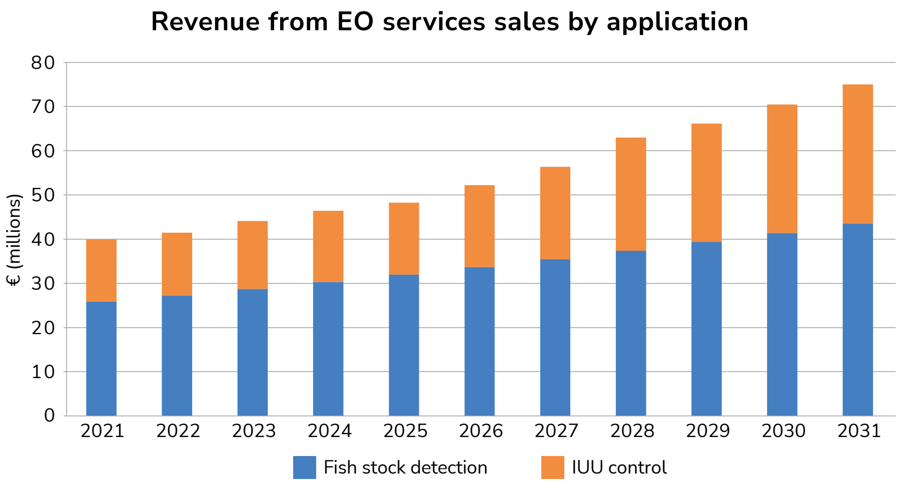


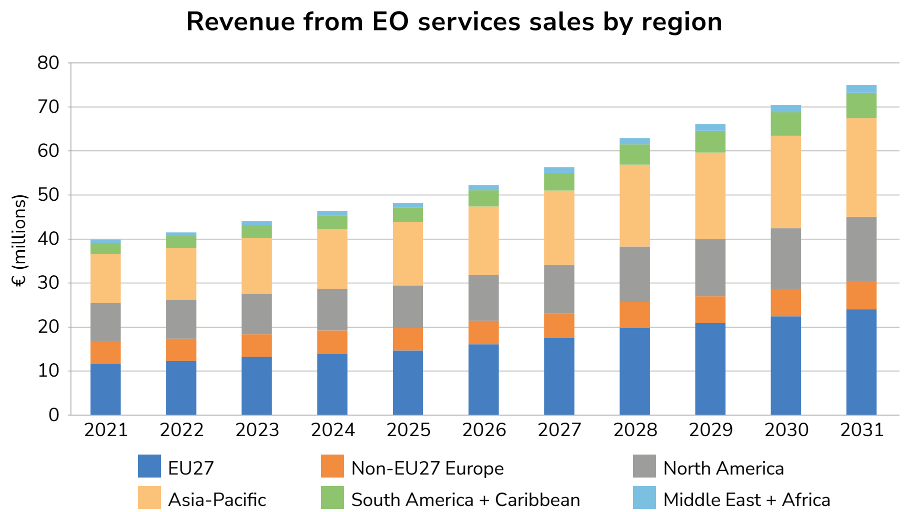
Revenue of GNSS device sales by application




Revenue from EO data sales by application
€ (millions)
18
16
14
12
10
8
6
4
2
0
2021
2022
2023
2024
2025
2026
2027
2028
2029
2030
2031
Fish stock detection
IUU control


Revenue from EO data sales by region
€ (millions)
18
16
14
12
10
8
6
4
2
0
2021
2022
2023
2024
2025
2026
2027
2028
2029
2030
2031
EU27
Non-EU27 Europe
North America
Asia-Pacific
South America + Caribbean
Middle East + Africa


Revenue from EO services sales by application
€ (millions)
80
70
60
50
40
30
20
10
0
2021
2022
2023
2024
2025
2026
2027
2028
2029
2030
2031
Fish stock detection
IUU control


Revenue from EO services sales by region
€ (millions)
80
70
60
50
40
30
20
10
0
2021
2022
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2024
2025
2026
2027
2028
2029
2030
2031
EU27
Non-EU27 Europe
North America
Asia-Pacific
South America + Caribbean
Middle East + Africa

FORESTRY

Legend
EO application
GNSS application
Synergetic application (combined use of EO and GNSS)

Environmental monitoring
- Biomass monitoring
- Deforestation/degradation monitoring

Natural resources monitoring
- Forest Inventory monitoring
- Forest vegetation health monitoring
- llegal logging monitoring

Operations management
- Automatic steering
- Forest asset management
- Forest exploitation certification
- Forest machinery guidance

Application descriptions can be found in Annex 3.

FORESTRY

Given the vast sizes and often remote locations of many forests, the use of EO and GNSS in the forestry sector is fast becoming a key enabler for forestry managers to efficiently execute forestry operations and for governmental bodies to monitor environmental impacts related to forestry activities.

EO allows for the remote monitoring and health assessment of forest inventories as well as the detection of issues such as illegal logging and deforestation, an issue that is becoming more and more critical as forest resources around the world become more vulnerable.

GNSS, particularly when coupled with EO, allows for the execution of precision forestry operations such as the guidance of machinery and variable rate application of fertilisers and irrigation, something particularly effective for the cultivation of young trees.

What you can read in this chapter

- **Key trends:** Forest protection, restoration & sustainable management requires ambitious policies and technological solutions to support them.
- **Industry:** Forestry Value Chains.
- **Recent developments:** Recent and future developments in EO have a strong impact on forestry applications.
- **Future market evolution:** Protecting and managing our forests will increasingly require high-tech solutions.
- **European systems and projects:** Several key projects use Copernicus and Galileo data to innovate in the forestry sector.
- **Reference charts:** Yearly evolution of installed base of GNSS devices and revenues as well as EO revenues by application and region.

Forest protection, restoration & sustainable management requires ambitious policies and technological solutions to support them

Key market trends

- The EU has a new Forest strategy that will cover the whole forest cycle and promote the many services forests provide
- Copernicus and EGNSS are fast becoming extremely valuable tools in monitoring and maintaining our 'forests of the future'
- Sustainable and traceable timber management helps secure our supply chains and aids in market monitoring

Securing sustainable timber supply chains

Given the enormity and complexity of global supply chains, it can be extremely difficult to know where products were sourced from and if they were produced sustainably. The global timber market is no exception, with the World Bank estimating that 15-30% of timber is harvested and exported illegally. To help **fight against illegal and unsustainable timber production**, GNSS is one of the technologies that can be adopted to help **trace timber movements**, right down to the tracking of individual logs. This can help increase the transparency and traceability of the timber supply chain, reducing the likelihood of illegal exportation going unnoticed. Not only does this practice help to bolster the sustainability of our timber supply chains, but it also increases operational efficiency. Timber handlers can reduce time and effort in finding logs and know exactly the location of the next pile for processing, allowing them to calculate optimal routes for timber transportation. Increasing visibility and oversight of timber supply chains also helps in overall market monitoring and supply planning. For example, during the COVID-19 lockdowns, homebuilders in the US took the opportunity to begin construction projects while they had the time, increasing timber demand. Unfortunately, suppliers were not able to meet demand in time, thinking the pandemic would have had a similar effect to previous economic downturns. As a result, prices surged and the market experienced huge fluctuations. Clearly, supply chain transparency, supported using GNSS, is crucial for many parts of the sector.

Planting Trees as part of the carbon offsetting trend

As climate change continues, we are all becoming more aware of and responsible for our CO_2 emissions. Leading companies and organizations are pledging to become **carbon neutral** (i.e. zero net CO_2 emissions) and are voluntarily purchasing carbon offsets. Forest carbon offsets are a cost-effective way to reach carbon neutrality goals. Restoring forests offsets CO_2 emissions while supporting biodiversity and helping communities thrive. EO can help by measuring the biomass present in a forest. This can help in estimating the forest's capacity for carbon absorption and can be achieved by deriving indices such as NDVI from remotely sourced optical imagery. The EU's 2030 climate plan explicitly emphasises the need for **efficient forestry conservation and management** in order to help offset some of the harm done so far and help reach carbon neutrality goals. Moreover, the use of EO and Copernicus in particular is regarded as key to achieving forest carbon offsetting activities over large areas.

Forests of the future

Sustainable management of forests is also a key component of the EU's effort to tackle climate change and build resilience. From carbon monitoring to sustainable logging, **Copernicus and EGNSS are becoming indispensable tools** which together with drones, robots and AI-powered capabilities allow **for evidence-based management of forests**. This is directly reflected in the new European Forest Strategy and has already translated in the proliferation of products and services by innovative companies all across Europe. Thus, forest management authorities in countries with long tradition in forestry are now increasingly partnering with companies that provide solutions for autonomous and automated forest maintenance tasks. This entails the processing of imagery obtained by satellites or drones (often equipped with LiDAR) to develop a digital inventory of forests, catalogue tree measurements and document species details. This in itself is very valuable for the whole supply chain, which has seen heavy disruptions in the COVID-19 pandemic. Moreover, the ability to proactively manage the forests can maximise the carbon sequestration of trees. Finally, the increased use of robots could fill an employment gap due to a lack of interest in forestry jobs, thus helping the sector to meet the challenges of the future.

Forestry Value Chains[1]

EARTH OBSERVATION

INFRASTRUCTURE PROVIDERS
- AWS
- CLOUDEO*
- COPERNICUS DIAS*
- GOOGLE CLOUD PLATFORM
- IBM CLOUD
- INTEL GEOSPATIAL
- MICROSOFT AZURE
- PENGUIN COMPUTING

Public offering:
- COPERNICUS COLLABORATIVE GROUND SEGMENT*

DATA PROVIDERS
- AIRBUS*
- BLACKSKY
- COPERNICUS DIAS*
- DESCARTES LABS
- E-GEOS*
- EARTH-I*
- ICEYE*
- MAXAR
- PLANET
- ZHUHAI ORBITA

Public offering:
- COPERNICUS SENTINELS*
- USGS/NASA LANDSAT
- RELEVANT IN-SITU NETWORKS

PLATFORM PROVIDERS
- BEIJING PIESAT INFORMATION TECHNOLOGY COMPANY
- CLEOS*
- CLOUDEO*
- COPERNICUS DIAS*
- MAXAR ARD
- NOR*
- PLANET EXPLORER
- SINERGISE* (SENTINEL HUB)
- TERRADUE*
- UP42*
- VITO*

Public offering:

FORESTRY TEP*

EO PRODUCTS AND SERVICE PROVIDERS
- ARBONAUT*
- BEIJING SUPERMAP SOFTWARE CO.
- DAVEY TREE EXPERT COMPANY
- EARTH DAILY
- ECOMETRICA*
- GAF*
- GEOVILLE*
- GMV*
- KONGSBERG SATELLITE SERVICE AS*
- METRIA*
- NIRAS ALECTIA FONDEN*
- SATELLIGENCE*
- SINERGISE*
- SPACE IMAGING MIDDLE EAST
- SPACEBEL*
- VITO*
- XYLENE*

Public offering:
- COPERNICUS SERVICES*

INFORMATION PROVIDERS
- COLLECTIVE CRUNCH*
- F&W
- FORLIANCE*
- SYMBIA SOLUTIONS*
- WUUDIS*

END USERS
- ENVIRONMENTAL AGENCIES
- FORESTRY CONSULTANTS
- FORESTRY MANAGERS
- FORESTRY-INSURERS
- INTERNATIONAL AGENCIES (E.G. FAO, WFP...)
- MACHINE MANUFACTURERS
- PAYING AGENCIES

LEGEND
- Commercial Offering
- Public Offering
- User segments

GNSS

AUGMENTATION SERVICE PROVIDERS
- DEERE & CO
- HEMISPHERE
- HEXAGON AB*
- TOPCON CORPORATION
- TRIMBLE NAVIGATION LTD

Public offering:
- NATIONAL AND REGIONAL RTK NETWORK PROVIDERS

COMPONENT AND RECEIVER MANUFACTURERS
- ARAG S.R.L*
- AVMAP S.R.L*
- CNH INDUSTRIAL N.V.*
- COMNAV TECHNOLOGY LTD
- DEERE & CO
- HEXAGON AB*
- TOPCON CORPORATION
- TRIMBLE NAVIGATION LTD

SYSTEM INTEGRATORS
- CNH INDUSTRIAL N.V.*
- DEERE & CO
- J.C.B SERVICE*
- KUBOTA CORPORATION

END USERS
- ENVIRONMENTAL AGENCIES
- FORESTRY CONSULTANTS
- FORESTRY MANAGERS
- FORESTRY-INSURERS
- INTERNATIONAL AGENCIES (E.G. FAO, WFP...)
- LOGGING COMPANIES
- MACHINE MANUFACTURERS
- PAYING AGENCIES

European[2] EO and GNSS industry in the global arena

With Leonardo (parent company of e-GEOS) (IT), Airbus (NL), Ecometrica (UK) and Kongsberg (NO), there are 4 European companies in the top 10 of the global EO data processing (roughly 41% of the global share).

GNSS receivers in Forestry are similar to those used in Agriculture, with a significant overlap in terms of industry. European companies such as Hexagon and CNH again hold 20% of the total forestry market with a slightly lower intensity on Forestry applications than their largest international competitors, yielding an estimated European share of 15% of the Forestry market.

NOTES

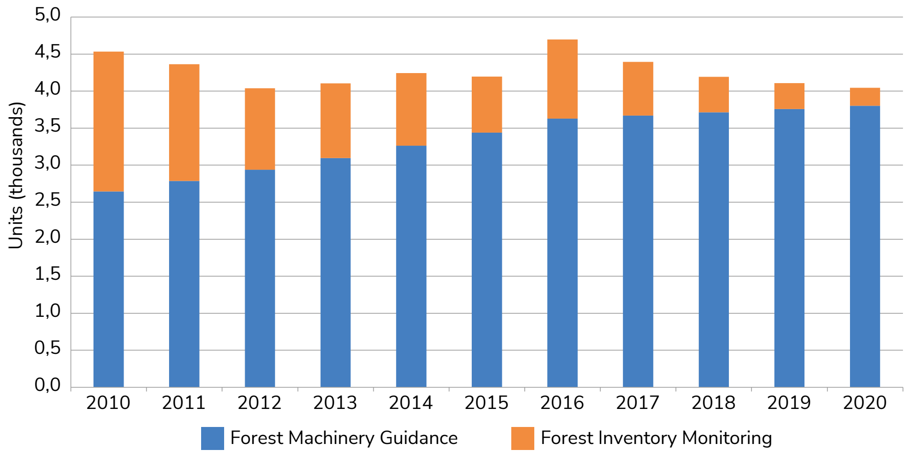
[1] The value chain considers the key global and European companies involved in GNSS and EO downstream activities.

[2] In the market share analysis, Europe is defined as EU27 plus Norway, Switzerland and the UK.

* European-based companies. The region is defined with respect to the headquarters of the company, though the actual area of activity might be wider.

Recent and future developments in EO have a strong impact on forestry applications

Shipments of GNSS devices by application



Overall, the shipments of GNSS receivers over the past decade have not exhibited strong growth. Despite a promising upwards trend in growth towards the middle of the decade, ultimately **shipment numbers are slightly down on where they were 10 years ago.**

Forest Machinery Guidance held the most dominant share of shipments throughout the last ten years and over the past three to four years has gained almost all market share compared to the Forest Inventory Monitoring application, which began the decade with close to a 40% share but has declined almost year-on-year since.

EO for forest carbon monitoring

Mapping of forest biomass allows for forest carbon sequestration potentials to be understood. The monitoring of carbon stocks in forested regions of the world, particularly the tropics, has attracted a great deal of attention in recent years as deforestation and forest degradation account for up to 30% of anthropogenic carbon emissions.

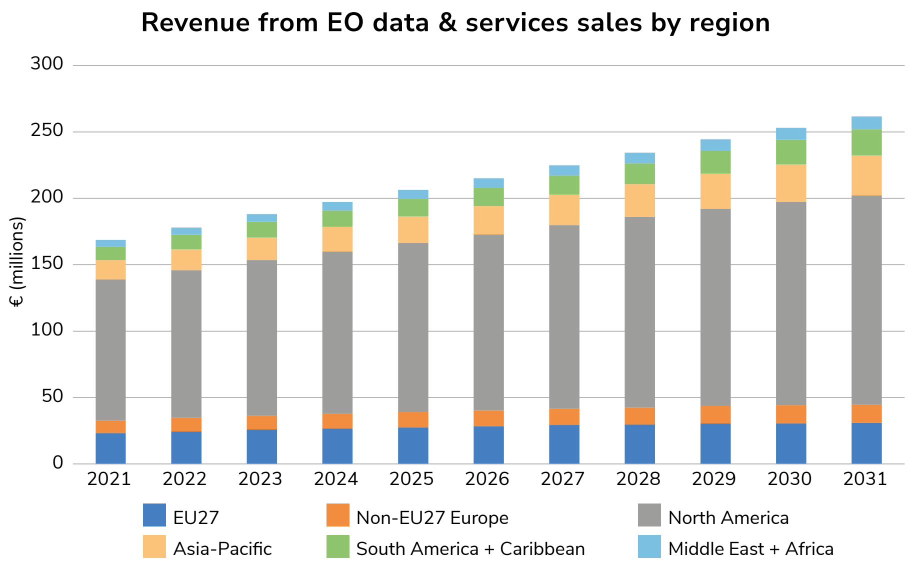
The **REDD+** initiative has the objective of mitigating climate change through reduced emissions from deforestation and forest degradation by enhancing forest management in developing countries. Organisations such as FAO have supported more than 50 countries in their development of robust National Forest Monitoring Systems (NFMS) and assessments. NFMS components include EO land monitoring systems which monitor forest biomass to help estimate carbon sink capacities all across the globe.

Copernicus: an essential tool to battle deforestation and degradation

The ongoing explosion of **new satellite data sources** presents novel opportunities for forest monitoring, with satellites of many types producing massive amounts of data daily. At regional to national scales, methods have been progressively developed to detect and map forest degradation, with these based on multi-resolution optical, synthetic aperture radar (SAR) and LiDAR data.

Particularly interesting for the global forestry community are the **optical and radar instruments** onboard the Sentinel satellites that provide global data with high acquisition frequency free of charge. Copernicus and other international and national EO programmes offer an unprecedented opportunity to monitor forest ecosystems from space. For more information visit: https://land.copernicus.eu/pan-european/high-resolution-layers/forests.

Protecting and managing our forests will increasingly require high-tech solutions



North America is expected to dominate the market in revenue from both the sales of EO data and services over the coming decade, reaching €157 m by 2031.

The Asia Pacific region will more than double its market share within the next 10 years, to almost match the share captured by the EU.

South America will too, slowly but steadily gain market share year-on-year given the relevance of forestry related activities in the Amazon.

New generation of robots and drones at the service of forestry

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Could **swarms of robots and drones** become a commonplace in forest management practices? Thanks to supreme, real-time localisation capabilities powered by GNSS aand advanced sensing features enabled by LiDAR and cameras (including hyperspectral) the answer seems to be in the affirmative. Many innovative companies are seeking to make the most of such capabilities and have provided advanced analytics that help build inventories, map forests for preservation, measure biomass and prevent the spread of wildfires.

Drones are also used for reforestation, planting a variety of species that are native to each location with the aim of maximising biodiversity. At the same time, unmanned ground vehicles are being deployed to support heavier operations such as log loading and planting.

Battling the increased and more extreme occurrence of forest fires will need full support from the EU Space Programme

Ensuring a sustainable future for our forests requires not only improved management practices and increased reforestation efforts but also **protection from fires.** Due to drier seasons, heatwaves and high winds, the occurrence, magnitude, and impact of devastating wildfires has dramatically increased. Reports on the 2020 wildfires show that over 18.6 m ha were charred in Australia, 3.9m ha in the USA, and 0.32m ha in Europe. Major wildfires such as those recently experienced in California and Australia cause economic losses over €10 billion for each country. Moreover, long term effects of air pollution and biodiversity loss are often hard to quantify but leave a significant footprint.

To battle the phenomenon of wildfires and minimise their impact, decision makers and practitioners (civil protection agencies and fire departments) are increasingly **seeking the help of Earth Observation.** Thanks to its wide geographic coverage, ability to see through clouds (with radar satellites) and rapid capture of images, Earth Observation is **used to forecast fire threats and then monitor wildfire events** (e.g. through spread speed, burnt areas, etc.). Thus, the European Forest Fire Information System (EFFIS) – a key component of the Copernicus Emergency Management Service – or GWIS (the global equivalent) are used to monitor fires across the world. The CAMS Global Fire Assimilation System (GFAS) also produces daily estimates of wildfire and biomass burning emissions. Additional added-value products developed by downstream companies enable fire management authorities to make informed decisions and take swift actions. Further information on the Copernicus Emergency Management Service can be found under the Emergency Management & Humanitarian Aid segment of this report.

Forest inventory monitoring allows for efficient operations

Forest inventory and management requirements are changing rapidly in the context of an increasingly complex set of economic, environmental and social policy objectives. Traditionally, forest inventory data were collected using cost-intensive field surveys in combination with yield tables. For small forestry owners this is often collected on the basis of questionnaires (e.g. wood felling reports). Now, up-to-date forest inventory information relating the characteristics of managed and natural forests is fundamental to **sustainable forest management** and required to inform conservation of biodiversity and assess climate change impacts and mitigation opportunities. Forest Asset Management Services allow forest owners to input the relevant data from inventories to create the optimal felling plan.

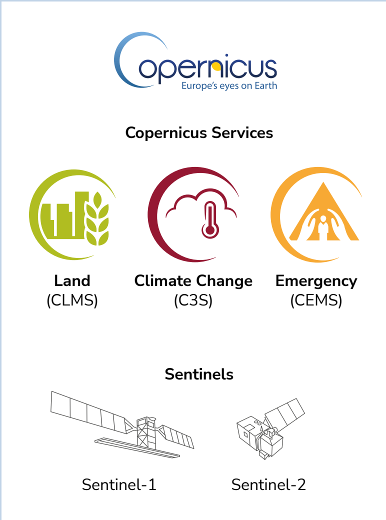
Strategic forest inventories are difficult to compile over large areas and are often quickly outdated or spatially incomplete as a function of their long production cycle. As a consequence, automated approaches supported by remotely sensed data are increasingly sought to provide exhaustive spatial coverage for a set of core attributes in a timely fashion. As a result, increasing numbers of advanced remote sensing technologies are being developed to provide data to help address the **escalating information needs** of the sector.

Several key projects use Copernicus and Galileo data to innovate in the forestry sector

Current usage of Copernicus

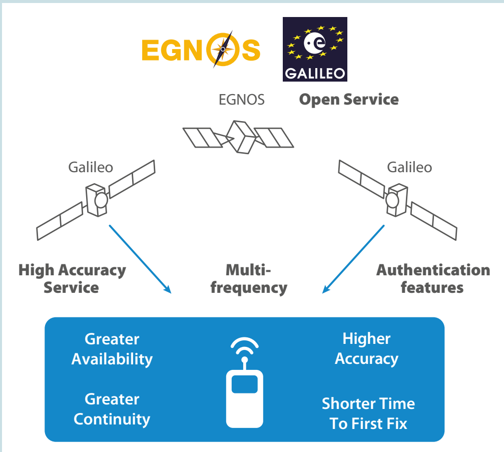
Extensive usage of Copernicus data and services are made by forest monitoring applications. The programme provides dedicated services for land monitoring (Copernicus Land Monitoring Service, CLMS) climate change (Copernicus Climate Change Service, C3S), and with particular relevance to forest fires; emergency response (Copernicus Emergency Management Service, EMS). Each of these have downstream communities.

The programme also provides satellite data from the Sentinels, which are integrated into many forest management services and applications.



Current usage of EGNSS

Galileo is used in a multi-constellation paradigm to power precision forestry operations. Thanks to its more robust signals, Galileo performs better under tree canopy thus enabling machine guidance in forest environments. Moreover, Galileo helps to guide drones which are increasingly used in forest management operations.



HORIZON 2020 SAFERS

Structured Approaches for Forest Fire Emergencies in Resilient Societies

In order to support societies becoming more resilient when acting against forests fires, the Horizon 2020 project SAFERS *'Structured Approaches for Forest Fire Emergencies in Resilient Societies'* is going to create an open and integrated platform featuring a forest fire Decision Support System.

The platform will use information from different sources: Copernicus and GEOSS; fire sensors in forests; topographic data; weather forecasts; and even crowdsourced data from social media and other apps that can be used by citizens and first responders to provide situational in-field information.

More information: https://safers-project.eu/

HORIZON 2020 REDDCopernicus

Assessing the future Copernicus EO forest monitoring service component

The REDDCopernicus project aims prepare a framework for a Copernicus REDD+ service which can make use of the planned Copernicus Data and Information Access Services (C-DIAS) platform for improving EO data and product accessibility and functionality to end users. Moreover, the project will additionally review the potential for EO applications for Sustainable Forest Management and identify exactly where the research gaps lie in the field of forest monitoring all across Europe.

More information: https://www.reddcopernicus.info/

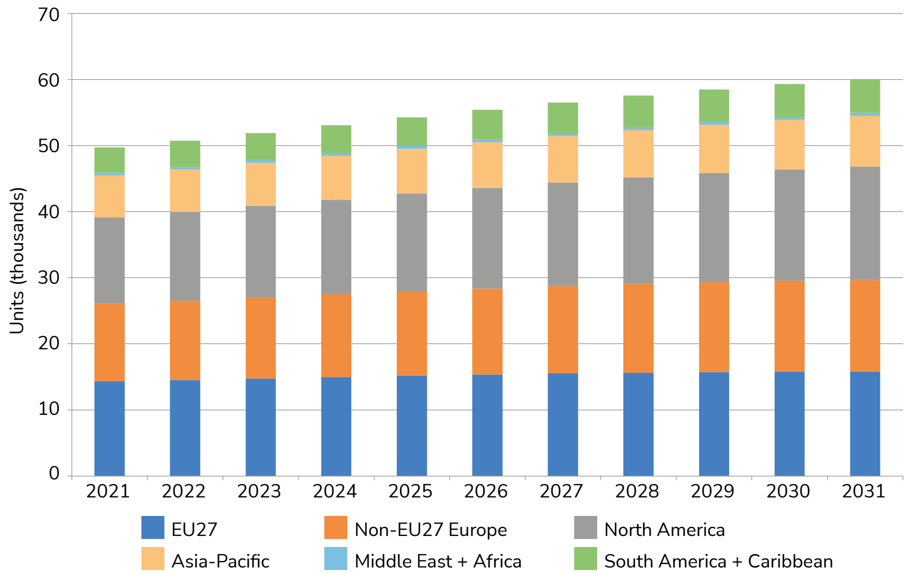
HORIZON 2020 NEXTLAND

Next Generation Land Management services for Agriculture and Forestry

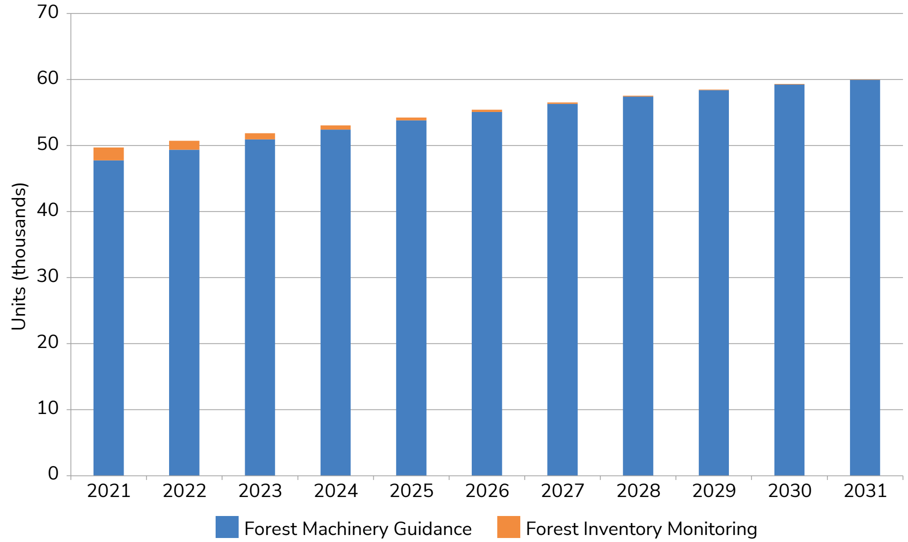
The Horizon 2020 NextLand project will develop 15 operational commercial midstream agriculture and forestry Earth observation services. The services developed will be fully scalable across the globe. The services will be able to leverage GEOSS and Copernicus data and products in the scope of seven use cases. Overall, the project will create an ecosystem that exhibits the strengths of European service providers along the entire value chain of the hi-tech agroforestry sector.

More information: https://ec-nextland.eu/

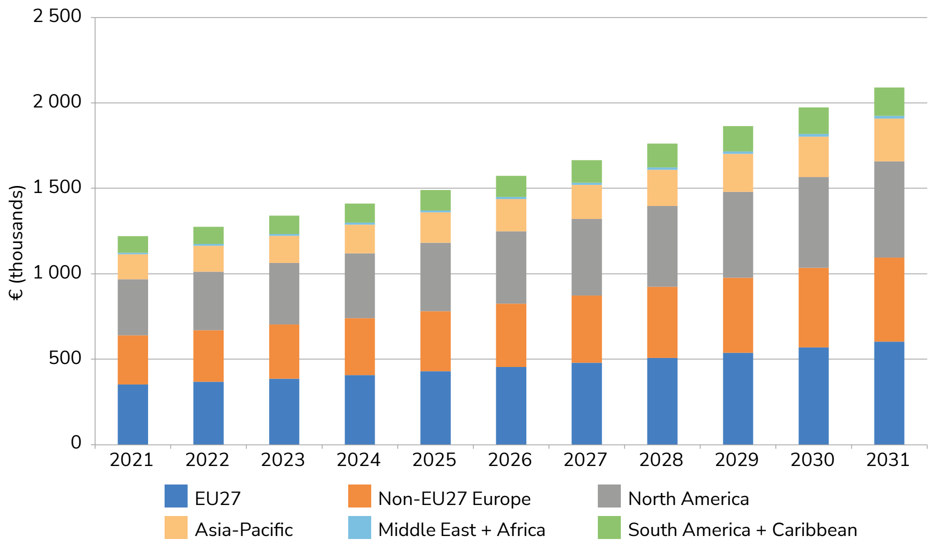
Installed base of GNSS devices by region



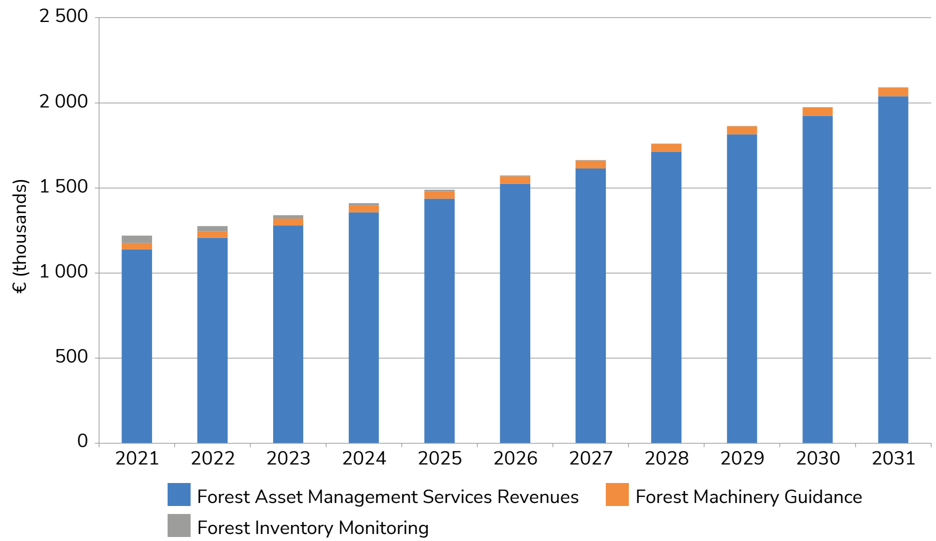
Installed base of GNSS devices by application



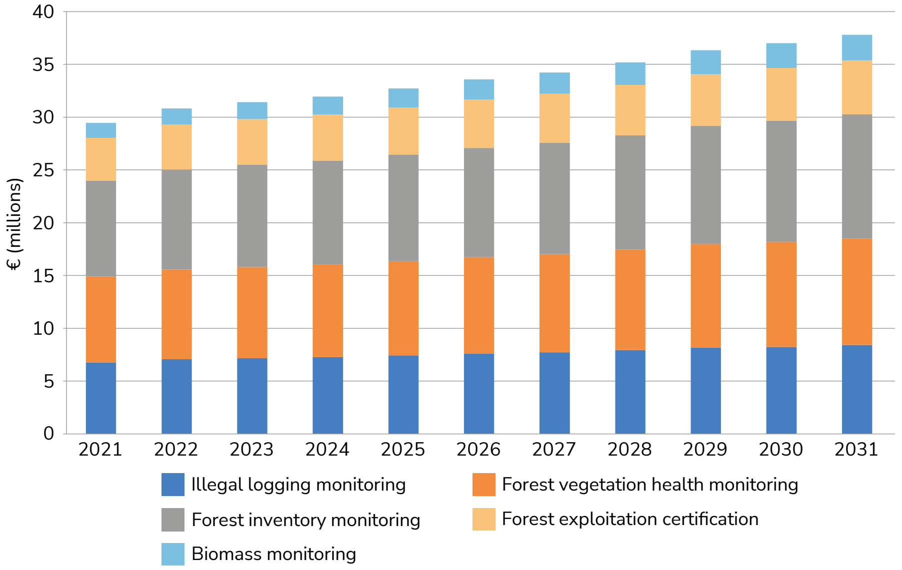
Revenue of GNSS device sales and services by region



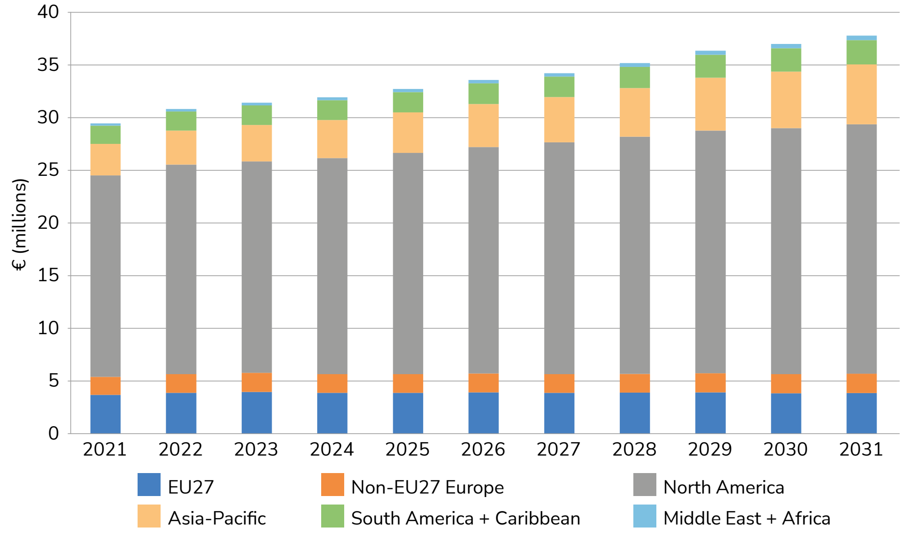
Revenue of GNSS device sales and services by application



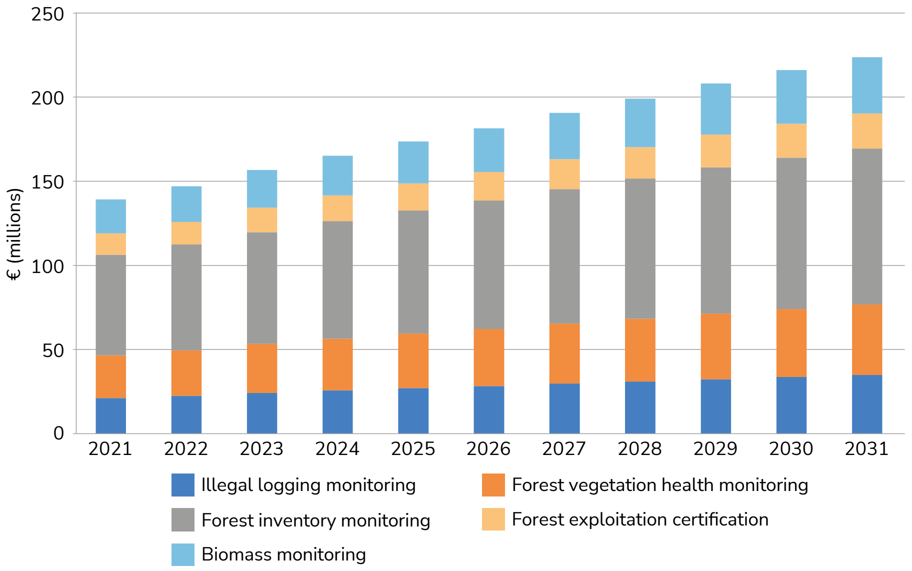
Revenue from EO data sales by application



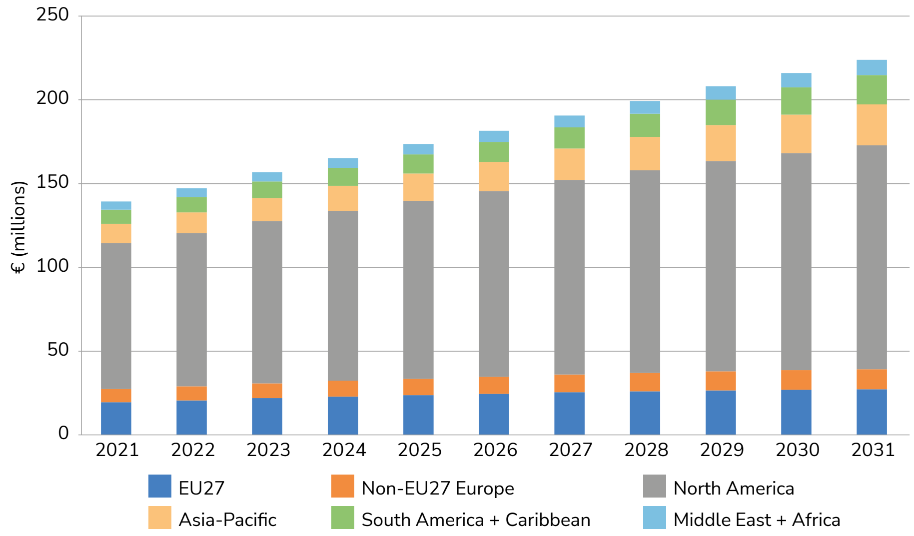
Revenue from EO data sales by region



Revenue from EO services sales by application



Revenue from EO services sales by region



INFRASTRUCTURE

Legend
EO application
GNSS application
Synergetic application (combined use of EO and GNSS)

Environmental Impact Monitoring

- Environmental impact assessment of infrastructure

Infrastructure Construction and Monitoring

- Construction Operations
- Monitoring of impact of human activities on infrastructure
- Oracle Database Appliance (ODA) Support Monitoring
- Pipeline Monitoring
- Post-Construction Operations

Infrastructure Planning

- Infrastructure Site Selection and Planning
- Permitting
- Vulnerability Analysis

Timing & Synchronisation of Telecommunication Networks

- Data Centre
- Digital Cellular Network (DCN)
- Professional Mobile Radio (PMR)
- Public Switched Telephone Network (PSTN)
- Satellite Communication (SATCOM)
- Small Cells

Application descriptions can be found in Annex 3.

INFRASTRUCTURE

GNSS and EO are invaluable assets in the toolbox of construction companies, infrastructure managers, public authorities and utility operators.

Used through handheld devices or receivers integrated within heavy machinery or drones, GNSS supports the various phases of the infrastructure life cycle, from the initial site selection to the monitoring of construction and post-construction operations. GNSS also helps to further protect and improve the resilience of critical infrastructure relying on timing and synchronisation, such as telecom networks.

Thanks to its capacity to provide historical data on risk exposure and projections on the future impacts of climate change, EO supports site selection as well as the design of more resilient infrastructure. Satellite-based imagery also supports the monitoring of construction operations and the long-term monitoring of infrastructure health and environmental impact.

Whatever the type of infrastructure (e.g. buildings, bridges, roads, dams, factories, power plants, telecommunication networks, etc.), GNSS and EO help actors involved in infrastructure management to increase the safety of operations and productivity, while improving infrastructure resilience and safeguarding the environment.

What you can read in this chapter

- **Key trends:** The EU Space Programme supports robust, resilient and sustainable infrastructure.
- **User perspective:** New infrastructure deployment requires more performant and robust technologies.
- **Industry:** Infrastructure Value Chains.
- **Recent developments:** GNSS and EO uptake is consolidated by the emergence of new usages and applications.
- **Future market evolution:** New GNSS service provision schemes and the combination of Copernicus data with new constellations will ensure sustainable growth of the market.
- **European systems:** The EU Space Programme provides invaluable benefits for infrastructure.
- **European Projects**: A number of European funded projects combine EO and GNSS to propose solutions in support of resilience and monitoring of various types of infrastructure.
- **Reference charts**: Yearly evolution of the installed base of GNSS devices and revenues as well as EO revenues by application and region.

The EU Space Programme supports robust, resilient and sustainable infrastructure

Key market trends

- The EU goal to be climate-neutral by 2050 drives a paradigm shift in planning, construction and maintenance of infrastructure
- Infrastructure resilience is increasingly supported by EU Space programme solutions from robust timing to accurate deformation monitoring
- The 'Next Generation EU' recovery plan provides strong impetus for infrastructure development and modernisation for the future
- The 5G telecom infrastructure roll out – a major driver of multiple economic activities – will rely heavily on solutions enabled by EU Space Programmes

Climate Neutrality and Climate Resilience are driving the infrastructure market

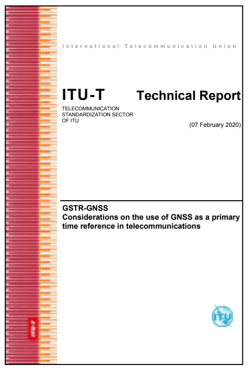
Climate neutrality has become a major global goal. In this regard, Europe aspires to become the first continent to reach climate neutrality by 2050. Achieving this will require a wide range of actions that reduce the environmental footprint of infrastructure and strengthen its climate resilience. A key area is the construction sector, which is responsible for over a third of the EU's total waste generation and 5-12% of its GHG emissions. Combined with the strong momentum on infrastructure projects, embedded in the Next Generation EU plans as a driver for the economy, it is apparent that the **need for smart solutions** that enable a sustainable built environment is stronger than ever. In this regard, all phases of planning, design, construction, operation and maintenance of infrastructure can benefit from GNSS and EO solutions. From **enabling better spacing** in our cities to **securing resilience** to extreme weather events, and from supporting **objective environmental impact assessments** to helping optimise supply chains of infrastructure projects, the EU Space Programmes are expected to be a critical component in achieving the goals of climate neutrality and resilience.

ITU standard on the use of GNSS as a primary time reference in telecommunications (ITU TP-GSTR-GNSS)

In July 2020, the International Telecom Union (ITU) released a technical report on the **use of GNSS as a primary time reference in telecommunications.** The report provides information relevant to optimal GNSS reception in telecom applications where highly accurate time recovery is critical.

In particular it provides guidance on designing and operating telecommunication GNSS-based clocks for accurate time-recovery applications. Moreover the report references several relevant reports on GNSS vulnerability prepared by the Alliance for Telecommunications Industry Solutions (ATIS).

The ITU TP-GSTR-GNSS report is available for free download here.


International Telecommunication Union

ITU-T Technical Report

TELECOMMUNICATION STANDARDIZATION SECTOR OF ITU

(07 February 2020)

GSTR-GNSS
Considerations on the use of GNSS as a primary time reference in telecommunications

A growing awareness of the role of GNSS-based solutions in European Critical Infrastructure and the need to protect them

Infrastructure faces increased threats from cyber attacks. In light of this, **ensuring the resilience of European infrastructure is both a major goal and a major challenge.** To this end, the **EU seeks to utilise Galileo for critical infrastructure that depends on timing and synchronisation,** a topic addressed in the Joint Communication to the European Parliament and the Council's Joint Framework on countering hybrid threats. Moreover, EU-funded projects are looking to further protect and improve the resilience of critical infrastructure that relies on the timing and synchronisation elements of satellite navigation, leveraging the key differentiator offered by Galileo in this respect. This is all the more important with the first deployment of 5G networks in Europe. On the other side of the Atlantic, similar considerations have triggered Space Policy Directive-7, which takes the form of a memo to Cabinet officers, directing them to take specific steps to protect, toughen and augment GPS signals with other PNT services.

Uptake of InSAR service across countries and regions

Interferometric Synthetic-Aperture Radar (InSAR) is a remote-sensing technique which can generate maps of surface deformations and elevation gradients. It has a wide range of applications, including – in the context of infrastructure – monitoring the movement of tunnels, roads, bridges and pipelines, or the displacement of dams to a precision of millimetres. It can thus can offer support across the design, construction and operational phases of infrastructure projects; from gaining insights into historic ground conditions, to monitoring the settlement of foundations. Likewise it is utilised in monitoring (for example) landslides and tsunamis, ensuring that the public, housing and infrastructure remain safe. A number of public authorities across Europe have already adopted InSAR solutions powered by Copernicus Sentinel-1 for such purposes. This uptake is also reflected both at EU level, with the recently launched European Ground Motion Service of Copernicus, and at Member State level (in Germany, Italy, Spain and France), with the roll out of regional or nationwide InSAR services. Finally, the number of currently deployed private satellite constellations with high-resolution SAR capabilities is increasing.

New infrastructure deployment requires more performant and robust technologies

The construction market is embracing updated GNSS standards

During the User Consultation Platform 2020 the user community discussed user requirements around autonomous construction and its related ecosystem of sensor fusion, simultaneous localisation and mapping (SLAM), robotics, virtual and augmented reality (VR/AR), cloud computing and 3D modelling, among others. Several GNSS performance parameters were identified as viable for construction: **Accuracy** (cm level, especially for height determination); **Orientation** (GNSS/Internal Measurement Unit (IMU) fusion for vehicle orientation and levelling); **Availability** (especially in complex environments such as mountains and reflective surfaces); and **Reliability** (for optimised work and vibration robustness). Furthermore, two GNSS standards important for **construction** surveys and **infrastructure monitoring** were published in 2020. The first concerns **IGS SSR**[1] which was released after a long push from the user community. This is the **first open standard** for dissemination of real-time **PPP** products to support the IGS Real-Time Service to the wider community. The messages support multi-GNSS and include corrections for orbits, clocks, differential code biases (DCBs), phase-biases and ionospheric delays. This standard may be well utilised by construction GNSS receiver manufacturers and facilitate high-accuracy GNSS workflows in the lack of network Real Time Kinematics (RTK) coverage – especially in remote construction areas.

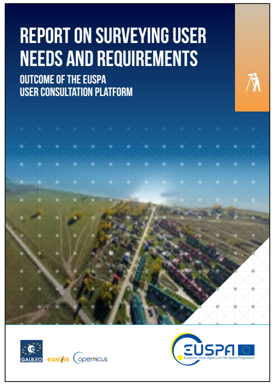
The second is **RINEX version 3.05** for static GNSS observations, which now provides better integration of Russian and Chinese GNSS (GLONASS and BeiDou respectively) for maximum high-accuracy applications, such as **infrastructure monitoring,** where precise post-processing of static GNSS data is increasingly demanded.

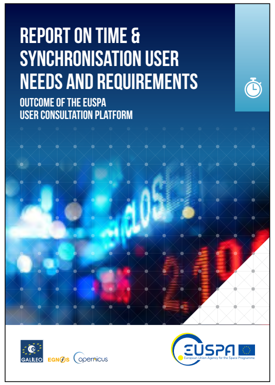
Key EO and GNSS user requirements

The key GNSS and EO user requirements for the different application groups within the **Infrastructure** segment are, at EU level, collected using the following procedures:

- For GNSS, information is collected through extensive interactions with user groups, providers and experts in a continuous process culminating at the User Consultation Platforms (UCP). In the case of **Infrastructure**, the relevant requirements can be found in two separate documents. On the one hand, information on requirements for geomatic applications within the Infrastructure segment can be found in the Report on Surveying user needs and requirements. On the other hand, information on requirements for timing and synchronisation applications (i.e. telecommunication networks) can be found in the Report on Time & Synchronisation User needs and requirements.
- User requirements for Copernicus services and products – as well as their evolution – are collected through an integrated process that involves different channels: (i) dedicated studies (e.g. "NEXTSPACE" project, "Copernicus for EC (C4EC)" study, Commission Staff Working Document on user needs), (ii) targeted consultations organised by the European Commission or the Entrusted entities with the relevant communities, (iii) regular and structured exchanges among representatives of the Copernicus governance structure and Member States through the Copernicus User Forum.

From the 2022 EUSPA`s UCP onward, EO user needs and requirements of commercial users will be validated and discussed with industry experts and user groups, mirroring the process implemented for GNSS.





5G opportunities and challenges for GNSS and EO

5G networks will enable new applications across a wealth of sectors. The expected high data rates, low latency and massive type communications on the same mobile infrastructure leads to stringent time and phase accuracy requirements, but also tight security and robustness requirements. The need for synchronisation in the radio access network has grown as new radio technologies and network architectures emerge to boost efficiency and support demanding 5G use cases. GNSS is instrumental in the global distribution of a UTC-traceable reference. A GNSS-based solution installed directly at base station sites can provide cost-efficient, accurate and predictable time synchronisation of the radio network without any support from the transport network. 5G efficiency relies, among other things, on signal strength and coverage to reach remote areas and enable the high-speed transmission of large amounts of data. On the EO side, Sentinel-2-derived land cover maps are being used for 5G infrastructure planning. Other means of EO such as Radio Frequency (RF) sensing can be applied to map wireless spectrum and available infrastructure to optimise wireless networks at planning stage or in monitoring (e.g. to detect and localise interference). In return, 5G may be a crucial enabler in the uptake of EO usage. In smart farming for instance, it would enable (two-way) transmission of EO data and integrate it into agricultural applications in real-time. At the same time, concerns around interference created by 5G networks impacting satellite-based weather forecasts need to be addressed by regulators and standardisation.

[1] More information on: https://www.igs.org/new-igs-ssr-format-has-been-released/

Infrastructure GNSS Value Chain[1]

AUGMENTATION SERVICE PROVIDERS

- HEMISPHERE (ATLAS)
- HEXAGON (LEICA GEOSYSTEMS, NOVATEL)*
- SAPCORDA*
- SPACEOPAL*
- SWIFT
- TERIA*
- TOPCON
- TRIMBLE

- NATIONAL AND REGIONAL RTK NETWORK PROVIDERS

COMPONENT MANUFACTURERS

Geomatics
- BEIJING BDSTAR NAVIGATION
- HEXAGON*
- NOVATEL
- QIANXUN SPATIAL INTELLIGENCE
- RENESAS ELECTRONICS
- SEPTENTRIO*
- SIERRA WIRELESS
- TAI-SAW TECHNOLOGY
- TRIMBLE
- U-BLOX*
- UNITED ELECTRONIC INDUSTRIES

Timing & Synchronisation
- FURUNO
- MICROCHIP TECHNOLOGY INC
- SEPTENTRIO*
- STMICROELECTRONICS*
- TRIMBLE
- U-BLOX*

RECEIVER MANUFACTURERS

Geomatics
- BEIJING UNISTRONG SCIENCE & TECHNOLOGY
- CAMPBELL SCIENTIFIC
- FARO TECHNOLOGIES
- HEXAGON*
- HI-TARGET SURVEYING INSTRUMENT CO
- KONGSBERG MARITIME*
- MEISEI ELECTRIC CO
- SYNERGY SYSTEMS
- TOPCON
- TRIMBLE

Timing & Synchronisation
- ARBITER
- BRANDYWINE
- CHRONOS TECHNOLOGY*
- ELPROMA*
- ENDRUN
- FREQUENCY ELECTRONICS INC
- GORGY TIMING*
- HEXAGON*
- HOPF ELEKTRONIK*
- JACKSON LABS
- MASTERCLOCK
- MEINBERG*
- MICROSEMI
- OMICRON*
- OROLIA SPECTRACOM*
- OSCILLOQUARTZ*
- SEIKO
- SEL
- SEVEN SOLUTIONS*
- TIMELINK*

SYSTEM INTEGRATORS DESIGN CONSULTANCIES TESTING & MAINTENANCE

Geomatics
- AB VOLVO*
- ACCUVER
- CATERPILLAR
- CHCNAV
- CNH INDUSTRIAL*
- DEERE & CO
- FARO TECHNOLOGIES
- GEMTECH TECHNOLOGY COMPANY LTD
- HITACHI
- IDEAL AEROSMITH
- INTELIBS
- INTELLION TECHNOLOGIES
- J.C.B. SERVICE*
- KOMATSU LTD
- KONGSBERG SATELLITE SERVICES*
- KRATOS DEFENCE AND SECURITY SOL. INC
- SOCIEDAD IBERICA DE CONSTRUCCIONES EL
- VAISALA OYJ*
- VRT FINLAND OY*
- ZTE CORP

Timing & Synchronisation
- ABB LTD*
- ACCENTURE
- CHRONOS TECHNOLOGY*
- EATON*
- ERICSSON*
- HUAWEI
- IBM
- JUNIPER
- MOTOROLA
- NOKIA*
- SIEMENS*

USERS

- CONSTRUCTION COMPANIES
- ENGINEERS
- PIPELINE OPERATORS
- REGULATING AUTHORITIES
- SURVEYORS
- TELECOM OPERATORS

European[2] GNSS industry in the global arena

GNSS receivers in Infrastructure are either used for T&S or geomatics-related purposes. The industry supporting the segment therefore overlaps with that serving Insurance and Finance, Energy and Material Resources and Urban Development and Cultural Heritage markets. European companies such as Orolia, u-Blox, and Meinberg hold 36% of the T&S market, with a slightly higher intensity on Infrastructure applications than their largest international competitors, yielding an estimated European share of 40% of the Infrastructure market. Conversely, European companies such as Hexagon hold 35% of the geomatics market, with a slightly higher intensity on Infrastructure applications than their largest international competitors, yielding an estimated European share of 40% of the Infrastructure market for geomatics devices. The total European share of the Infrastructure market is therefore estimated at 40%.

LEGEND
- Commercial Offering
- Public Offering
- User segments

NOTES

[1] The value chain considers the key global and European companies involved in GNSS downstream activities.
[2] In the market share analysis, Europe is defined as EU27 plus Norway, Switzerland and the UK.
* European-based companies. The region is defined with respect to the headquarters of the company, though the actual area of activity might be wider.

Infrastructure EO Value Chain[1]

INFRASTRUCTURE PROVIDERS

- AMAZON WEB SERVICES
- CLOUDEO*
- COPERNICUS DIAS*
- EODC*
- GOOGLE CLOUD PLATFORM
- IBM CLOUD
- INTEL GEOSPATIAL
- MICROSOFT AZURE
- PENGUIN COMPUTING

- COPERNICUS COLLABORATIVE GROUND SEGMENT*

DATA PROVIDERS

- AIRBUS*
- AXELSPACE
- BIRD.I
- CAPELLA SPACE
- CGG*
- CHANG GUANG SAT. TECH.
- COPERNICUS DIAS*
- EARTHDAILY
- E-GEOS *
- EODC*
- GEOCENTO*
- GEOIMAGE
- ICEYE*
- MAXAR TECHNOLOGIES
- ORBITA AEROSPACE
- PLANET
- SATELLOGIG
- 21AT

- COPERNICUS SENTINELS*
- USGS/NASA LANDSAT
- RELEVANT IN-SITU NETWORKS

PLATFORM PROVIDERS

- AIRBUS *
- CLOUDEO *
- COPERNICUS DIAS*
- E-GEOS*
- EODC*
- EXOLABS*
- MAXAR TECHNOLOGIES
- PICTERRA*
- PLANETEK*
- SKYGEO
- SPACESUR

EO PRODUCTS AND SERVICE PROVIDERS

- AIRBUS *
- C-CORE
- CLS*
- E-GEOS *
- EXOLABS *
- GEO4I*
- GAF*
- GEOVILLE*
- HYDROSAT
- INSAR.SK*
- MAXAR TECHNOLOGIES
- ORBITAL EYE*
- PIXSTART*
- PLANETEK *
- SATSURE
- SKYGEO
- SPACEPT
- SPACESUR
- TERRASIGNA*
- TRE ALTAMIRA*
- VITO*
- 3DEO*
- 21AT

- COPERNICUS SERVICES*

INFORMATION PROVIDERS

- 4EARTHINTELLIGENCE
- BUILDING RADAR*
- DARES TECHNOLOGY*
- DEWBERRY
- ESRI
- FUGRO*
- LIVEEO*
- MONITEYE
- ORBITAL EYE *
- SATSURE
- SENSAR*
- SIXENSE*
- SPACEKNOW
- SUPERVISION*
- TRIMBLE

END USERS

- CONSTRUCTION COMPANIES
- FINANCIAL INSTITUTIONS
- INFRASTRUCTURE MANAGERS
- INTERNATIONAL DEV. ORG.
- LOCAL & REGIONAL GOV.
- PUBLIC WORKS COMPANIES
- PIPELINE OPERATORS
- OIL & GAS PRODUCERS
- UTILITY COMPANIES

European[2] EO industry in the global arena

Except for the 'Infrastructure providers' where US giants Amazon, Google and Microsoft dominate, European companies have a strong presence in the market. Several companies like Airbus and e-GEOS have an international presence. In addition, a host of innovative service providers – including many European ones, offer added value services meeting the needs of the infrastructure sector.

LEGEND

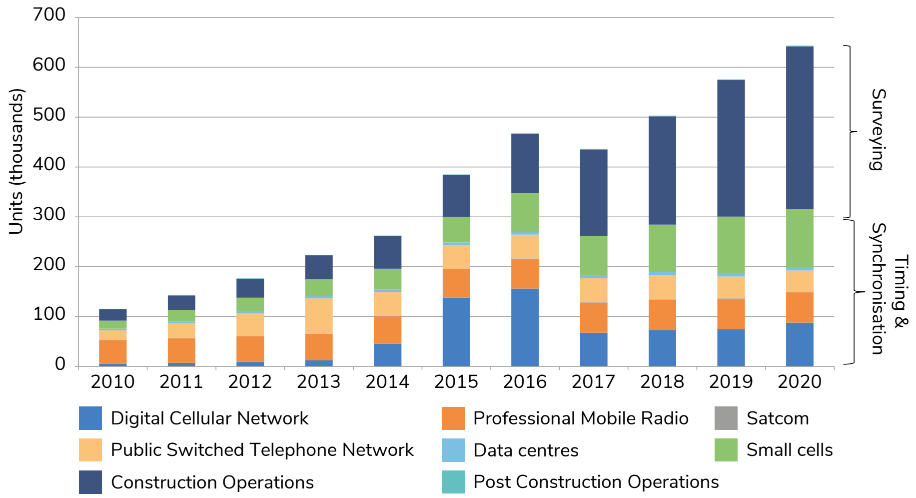
- Commercial Offering
- Public Offering
- User segments

NOTES

[1] The value chain considers the key global and European companies involved in EO downstream activities.
[2] In the market share analysis, Europe is defined as EU27 plus Norway, Switzerland and the UK.
* European-based companies. The region is defined with respect to the headquarters of the company, though the actual area of activity might be wider.

GNSS powers both traditional and novel solutions in the infrastructure sector

Shipments of GNSS devices by application



Modern infrastructure drives the demand for high end GNSS solutions

The GNSS Infrastructure Timing and Synchronisation market witnessed solid growth over the last decade favoured by the deployment of modern communication infrastructure such as 4G, small cells and, more recently, data centres. In particular, DCN operators, which benefited from the 4G base stations rollout, have driven the growth of the GNSS T&S market with more than 40% of the TSCI revenues in 2020 (and 28% of shipments). More recently, shipment growth was observed during the pandemic as the demand for high data transfer rate, high reliability and low latency connectivity positively affected the market. This trend is expected to sustain market growth in the future. This is also the case of the newly analyzed GNSS T&S data centre market that has gained importance thanks to an increased level of required timing accuracy and the need to comply with regulation. Consolidation is increasingly taking place in the data centre market towards hyperscale data centres; this growth should remain robust after 2020.

The same applies to all phases of construction work, whereby GNSS-based surveying and machine guidance solutions have become an invaluable tool for practitioners. This covers both handheld devices and those used in heavy machinery, both powering geomatics applications that support site selection and planning, but also operations during and after construction. In that regard, the strong growth of the construction industry up over the past decade and until COVID-19 (6% for residential, 10% for commercial) is mirrored by the increase of GNSS shipments over the same timeframe.

Integration of GNSS with autonomous robotics and drones for optimal site operations

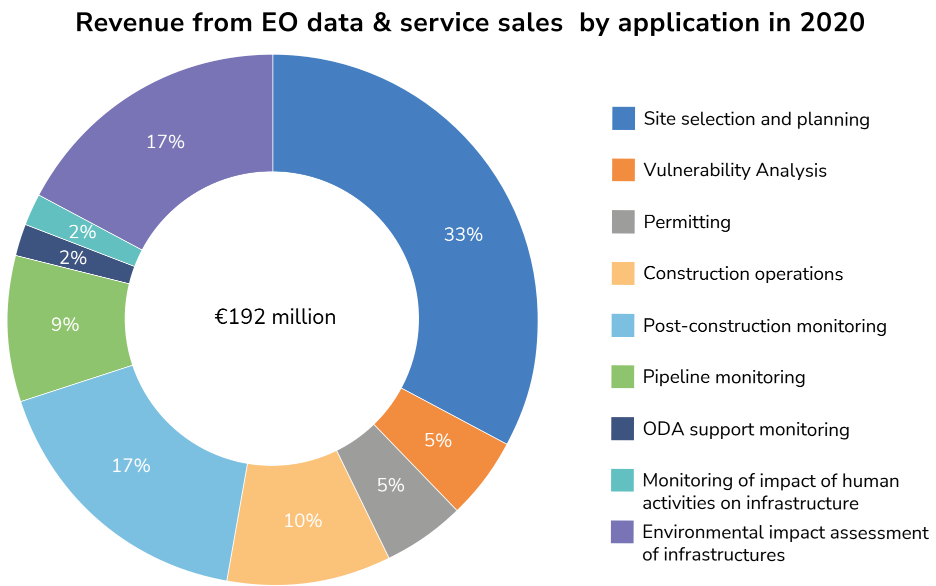
As the Construction GNSS market share rises globally, more innovative solutions aiming for increased work safety and productivity are being developed. The **fusion of GNSS with other sensors** in this segment represents technological cutting-edge. Construction-grade GNSS receivers are being integrated with **autonomous robots and 3D laser scanning** into intelligent operating machines. The continuous uptake of drone applications across infrastructure life cycles is also of vast interest. **Drones have become the fastest growing tool for site selection and mapping,** with techniques like hybrid aerial mapping on the rise. They can access hard-to-reach places faster, cheaper and at a lower risk than manual inspections, enabling remote engineering and network planning tasks, automated tower inspections and the enhanced measurement of wireless coverage and performance. Telecom operators apply **deep learning-based algorithms to analyse drone video footage** to detect defects and anomalies on cell towers remotely and in real-time. Drones are also expected to help accelerate the rollout of 5G networks and to enable new use cases leveraging 5G connectivity. In 2017, PwC estimated that the total addressable market value of drone-powered enterprise solutions exceeded €105 bn, with 35% of that value in infrastructure applications. GNSS is a key solution in ensuring drone navigation and providing PNT data to the video payload, thus benefiting from and contributing to that market potential.

Online gaming to generate new opportunities for network time synchronisation solutions

Online video gaming has steadily progressed over the last decade in terms of audience and volume of data broadcast. According to Mordor Intelligence, the **global gaming market was valued at €135 billion in 2020** and is expected to reach a value of €245 billion by 2026, registering a CAGR of 10.5% over that period. In particular, the **emergence of cloud gaming is driving the market** with a strong recent boost of video game live streaming that has gained further traction during the COVID-19 pandemic.

To ensure an engaging user and spectator experience, **voice and video must be precisely synchronised** in streaming applications and online gaming. Maintaining precise time synchronisation across the network is paramount to support seamless operations of digital infrastructure used in online gaming, such as ensuring the chronological order of play in multiplayer games. **GNSS is expected to be among the most relevant solutions to ensure this T&S function,** and is therefore expected to benefit from this market development.

Both traditional and emerging EO applications in infrastructure are on the rise



The use of EO data is progressively penetrating all infrastructure management activities at all stages of the infrastructure life cycle. From the initial site selection and planning to the assessment of infrastructure environmental impact and the regular monitoring of construction operations, the increasing exploitation of EO-based information brings solutions to an ever-growing user base in the infrastructure management area.

In 2020, the revenues from the sales of EO data and services to the infrastructure sector represented €192 m, the three largest application domains in terms of market shares (with a cumulative total of 66%) being, respectively: site selection and planning; environmental impact assessment of infrastructure; and post-construction operations. In the first application domain the main **added value of EO** is its capacity to **provide historical data** (e.g. exposure to natural risks) on potential sites, as well as projections related to the future impacts of climate change. The main added value of EO in the two other domains resides in its **ability to deliver frequently updated (very) high resolution data** to infrastructure managers wherever the infrastructure they are responsible for is located.

Today, the vast majority of revenues resulting from the sales of EO data and services can be attributed to application domains in which synergies with other space-based assets such as GNSS exist. This should remain the case in the years to come but 'EO-based only' applications should slightly increase their share.

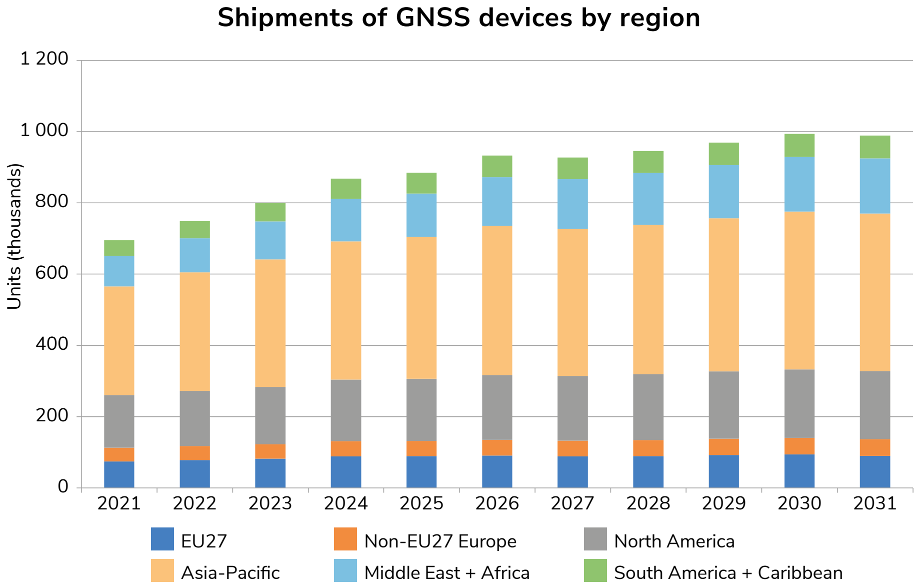
Monitoring pipelines from Space

The use of **InSAR imagery allows the measurement of millimetre-scale changes** in deformation over spans of days to years, and has proven its worth for geodesy-related applications, including **construction and infrastructure monitoring.** Pipelines are an excellent example of this EO technique's significant added value. Whatever matter they convey, **pipelines** are indeed critical infrastructure that must be monitored throughout their entire lifecycle, from planning, construction and operations up to their decommission. Used for long-distance transportation (e.g. fossil fuels), or inside cities (e.g. water, gas, sewage), they are built both above and below ground (or even underwater) and are therefore potentially exposed to environmental forces (e.g. natural disasters, soil movements), but also third party interference (e.g. theft, sabotage). They generally operate under strict safety and environmental regulations, and must guarantee a high-level of service continuity. Impacts on their integrity could lead to damages and leaks, with significant economic and environmental implications. In this context, **satellite observations can support the identification of ground deformation and leaks** (e.g. water, methane), allowing for targeted and timely maintenance in risk areas, contributing to a reduction of maintenance and downtime costs.

Developing climate change-resilient infrastructure

Generally designed to operate for long periods in very diverse locations, infrastructure is inevitably exposed to the rapid evolution of meteorological conditions caused by climate change, as wind, temperature, precipitation and natural disasters can significantly impact their durability and operation continuity. To address these evolving environmental constraints, EO-based developments such as the Copernicus Climate Change Service (C3S) provide trustworthy and traceable climate information (past, current and future) on **how extreme events and weather patterns impact infrastructure in Europe and worldwide.** Relying on climate indicators (e.g. frequency and intensity of extreme events such as intense rainfall, heat waves or wind storms, extreme air pollution levels, etc.) **this information can be used by civil engineers to build infrastructure in a more resilient way.** Supporting development and application of suitable practices and standards, especially in the planning and construction phases, the C3S toolbox can be used to support the assessment of climate change impact on infrastructure and to define robust risk assessment methodologies. In 2020, the International Institute for Sustainable Development (IISD) notably integrated Copernicus climate data into its sustainable asset valuation methodology, enhancing its models that now include and monetise a variety of climate impacts on infrastructure.

New service provision schemes ensure sustainable growth of the GNSS market



Infrastructure development companies form strategic alliances for new solutions at lower risk

Compared to industries like Urban Development, the Construction/Infrastructure industry is still lagging behind in terms of digital strategy and maturity – many customers engaged in infrastructure development, even in Europe, are still not using GNSS-guided machinery, let alone more advanced technologies. Despite that, many companies are feeling pressure to increase the pace of digital investments in GNSS-enabled workflows, provided that they will deliver value and return. One approach that is becoming familiar is for companies to identify ecosystem partners that they can work with to enable connected construction together. This **ecosystem approach** will continue to be a key enabler for adjusting to new market realities and better responding to disruptions like COVID-19. Post-COVID, construction surveying companies that embrace digital and form strategic ecosystems will be more prepared for future disruptions. The interest in joint products will be increasing and will find new customers, as many infrastructure projects across the globe are launched in the current post-COVID environment. Eventually, the integration of advanced technological solutions will help to protect personnel safety on site.

Asia Pacific, EU27 and North America pushing GNSS adoption

Wide-scale 5G deployment is still at its early stage in several regions, with EU27, Asia Pacific and North America leading the telecommunication infrastructure modernisation (with over 60% of global shipments combined). The peak of GNSS T&S sales is expected around 2024, coinciding with the most intense period of 5G rollout. Regarding the newly analyzed GNSS T&S data centre market, Asia Pacific (22% of shipments in 2021 and 29% in 2031) is expected to close in on North America (39% of shipment in both 2021 and 2031) within the next decade, at the expense of EU27 (22% of shipments in 2021 and 17% in 2031). Overall, the demand for more sophisticated devices should only impact the Telecom market marginally. Price stability or limited growth is expected in the coming years with new functionalities appearing (e.g. anti jamming, anti spoofing, integrity, multi bands and multi constellations).

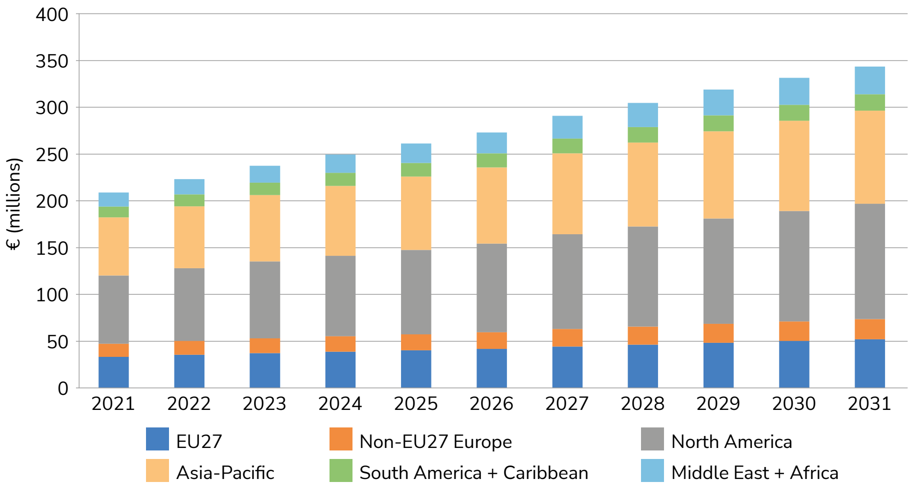
At the same time, construction activities are expected to show significant growth again (after a drop in 2020 due to COVID-19), with this effect spilling over to a steady growth of related GNSS shipments. This covers handheld devices and those used in heavy machinery, both powering geomatics applications where the use of GNSS has undoubted value.

Time Monitoring to Safeguard Transport Infrastructure

GNSS is used in several forms of transport infrastructure (e.g. Airport, Railway and Maritime), in particular for Timing and Synchronisation, which are both critical components for this infrastructure to operate. However, the **GNSS interference threat is rising,** as pinpointed by US Coast Guards or by several pilots in NASA's Aviation Safety Reporting System. Several technology providers have therefore developed solutions to increase situational awareness at the level of local infrastructure (e.g. ports, airports, etc.) to ensure that the 'Timing' service is provided safely.

This technology consists of monitoring GNSS observables and comparing the expected GNSS signal characteristics with observed characteristics in order to detect anomalies. Some systems can identify the type of interference as well as pinpointing the location of the devices causing the interference, allowing authorities to take immediate remedial action. These **time monitoring systems can be combined with atomic clocks and trusted time distribution to secure the communications network.** Although they are not quantified in this report, new business opportunities and services are appearing that ensure protection and greater resilience of the transport infrastructure that relies on GNSS.

Copernicus and emerging EO constellations support market growth



Behind a global revenue increase there are strong regional disparities

Globally, the use of EO data and services for infrastructure management purposes is expected to increase over the next decade. However, significant regional disparities exist, with the clear dominance of North America (predominantly the US) in terms of cumulative income, followed closely by the Asian-Pacific region (predominantly China). Between them, these regions account for more than 60% of the revenue over the period.

Although the capacity to develop and commercialise EO-based services – which are expected to drive the growth of EO-related sales for infrastructure management – is not necessarily dependent on regional upstream capacities (value-added service providers can purchase data from any observation satellite operator in the world), the fact is that the two dominant regions are also the ones that happen to have the most dynamic upstream sector. This can be partly explained by a trend towards vertical integration which leads most observation satellite operators to offer their own value-added services in addition to the provision of EO data. This increases the corresponding revenue in the regions where a large number of observation satellite operators exist.

While Europe also plays an important role in the provision of EO-based data and services for infrastructure management-related activities, this is not fully reflected in the corresponding revenue since the data coming from the Sentinels and the products delivered by the Copernicus services (made available free-of-charge) are not accounted for in data and service sales.

Improved revisit and resolution – the rise of private EO constellations

Copernicus offers a full, free and open access to the data coming from its dedicated satellites, the Sentinels. For infrastructure monitoring, many applications based on ground deformation monitoring and change detection are benefiting from the radar and optical images delivered by Sentinel-1 and Sentinel-2 respectively.

However, certain applications such as construction monitoring, asset monitoring, vegetation monitoring and environmental impact monitoring require optical and/or radar imagery with higher revisit rates and higher resolution. In the near future, this gap will be increasingly filled by commercial constellations of Earth Observation satellites.

Up until recently, the manufacturing of Earth Observation satellites was limited to the historical actors of the sector, but the emergence of low-cost small satellite technology has enabled the arrival of new private actors on the market. These newcomers plan to launch and operate large fleets of small satellites at a reasonable cost, serving a growing user base ready to pay for sub-meter resolution images updated every hour or even less.

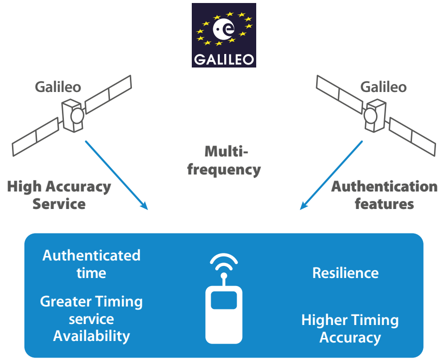
EO in support of development projects

Developing countries typically lack specific infrastructure (e.g. transport networks) and utilities (e.g. water, electricity, sewage), preventing them from competing with industrialised countries in terms of quality of life that they can guarantee to their citizens.

In general, filling this gap requires major infrastructure projects, which are often co-financed by international institutions such as the World Bank. While Earth Observation can support the implementation of such projects in many domains (see https://eo4society.esa.int/eo_clinic/ for instance) and many ways – from detecting needs and performing feasibility studies to monitoring operations and assessing their environmental impact – it can also be a crucial element in the financing itself.

In this regard, Earth Observation can help to verify that the aid is indeed used for the purpose and under the conditions at which it has been granted. For instance, satellite imagery can support the monitoring of construction operations and their adequation to agreed plans. While on-site inspections are costly and may not be easy to organise due to local conditions (e.g. remoteness), satellites can remotely spot progress and deviations, support progress reporting and thus enable smoother disbursement schemes.

The EU Space Programme provides invaluable benefits for infrastructure



Current usage of Galileo

Galileo is integrated in GNSS Timing & Synchronisation devices to improve the availability and robustness of the overall Timing solution. Implementing Galileo in multi-constellation products offers more reliability and accuracy of the Timing solution with quantified integrity, multiple source comparison and a versatile adaptive approach in mixing constellations and satellites. Galileo Open Service currently exceeds the target performance for UTC Time dissemination as during Q1 2021 it achieved 4.4 ns [95%] (Galileo OS mission requirement aims to achieve less than 30 ns [95%]) and a Frequency dissemination of 1.4*10-14 [95%]. Similarly, to most segments, T&S device manufacturers integrate GNSS chipset that are often Galileo-enabled.

During the User Consultation Platform 2020, operators of several national RTK networks* in Europe reported an increased availability when Galileo satellites have contributed to their measurements. As an example, Galileo is used in an ongoing geodetic re-survey of the national boundary between Sweden and Norway, facilitating the GNSS operations in dense vegetation. Another example is the Galileo utilisation in the milestone infrastructure project 'Norrbotniabanan', in which Galileo is mandatory for all contractors working on the project because of the benefits it bring to the construction site.

EGNSS services and features to be explored

Galileo's Open Service Navigation Message Authentication will be particularly relevant to Infrastructure operators to improve trust, resilience and ease of traceability for network synchronisation.

In addition, the Precise Point Positioning (PPP) approach of Galileo's High Accuracy Service (HAS) will provide highly accurate measurements as required during the phases of infrastructure planning and construction.

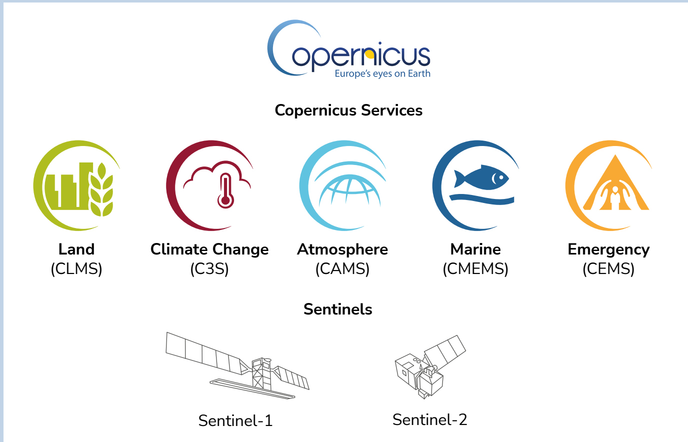
EGNOS contributes to improve position and time accuracy and stability. Trust is also enhanced via the provision of an independent time source, the EGNOS Network Time, and built-in integrity that could be used to provide a certified Time service in the future.

Current usage of Copernicus

With its Full, Free and Open (FFO) data policy, Copernicus provides a one-of-a-kind data access for infrastructure developers and operators and supports the development, monitoring and maintenance of safe, sustainable and resilient infrastructure.

The Sentinels offer a spatial coverage which goes beyond any other in-situ-only monitoring solution, allowing the quick receipt of valuable information over large and/or difficult-to-access areas. They also offer possibilities of change detection free of charge that can then be followed-up with other High Resolution (HR) or Very High Resolution (VHR) imagery (tip and cue paradigm).

The diversity and the amount of data and products offered by Copernicus enable the development of a wealth of applications that address the various phases of the infrastructure life cycle. In the planning phase for instance, the programme's services allow for the efficient assessment of the impact of climate change on future construction, in order to consider such effects from the very early phases of the projects. During the entire lifetime of infrastructure, the myriad of data delivered by Copernicus (e.g. related to land cover, atmosphere, emergency risks and mapping) also offers the possibility to assess impacts on the environment and on local surroundings, and to closely monitor structural health. This latter capacity will be further improved with the European Ground Motion Service (EGMS) to be delivered in 2022 as part of the Copernicus Land Monitoring Service, which will provide millimetre-accuracy deformation measures of great interest to infrastructure monitoring activities.



* More on RTK networks and the quantification of this application can be found in the 'Urban Development and Cultural Heritage' segment
Terminology used on this page is explained in Annex 2 for both GNSS and EO performance parameters.

A number of European funded projects combine EO and GNSS to propose solutions in support of resilience and monitoring of various types of infrastructure

Corridor and Asset Monitoring using Earth Observation - CAMEO

CAMEO is a 2-year project funded by the European Space Agency under the 'EO science for society' activity which aims to boost the understanding and integration of satellite EO services by companies and agencies managing pipeline and energy transmission corridors.

Based on the gathering of user requirements and the analysis of existing practices and challenges, the project will develop a set of prototype services which will showcase the added-value of EO data to corridor and asset monitoring stakeholders. These prototype services will address three main domains: structural integrity (e.g. surface deformation, leak occurrence); environmental and geo-hazards (e.g. flooding, landslides, vegetation condition monitoring); and threat assessment (e.g. third-party interference, encroachment).

The services developed by CAMEO will be implemented in scalable cloud computing environments and will combine EO and non-EO data to provide users with information, having a true operational value.

More information on: https://eo4society.esa.int/projects/cameo/

Deployed Applications and Monitoring of Critical Mobile Broadband Communication Infrastructure and Assets for PPDR - BroadGNSS

BroadGNSS is a 40-month EU-funded Pre-Commercial Procurement (PCP) project which will procure Innovation activity for Applications, Synchronisation and Monitoring of Critical Mobile Broadband Communication Infrastructure and Information Assets for Public Protection and Disaster Recovery (PPDR) Operations.

This PCP will pull innovative solutions from the user-side that will bring higher accuracy and higher reliability EGNSS applications to support public safety communications.

The project will enable discussions between a buyers' group of three public bodies (the French Ministry of Interior, the Estonian State Infocommunication Foundation and the Finnish State Security Network Group) and potential suppliers. The PCP process will consist of three phases which will eventually lead to the selection of one or several EGNSS-based solutions for potential commercial roll-out. Thus, BroadGNSS will contribute to increase Galileo market penetration in the domain of high precision timing and synchronisation.

More information on: https://www.broadgnss-info.eu

Development of a Decision Support System for increasing the Resilience of Transportation Infrastructure based on combined use of terrestrial and airborne sensors and advanced modelling tools - PANOPTIS

The 3.5-year project PANOPTIS aims to improve the resilience of road infrastructure and ensure reliable network availability under unfavourable conditions, such as extreme weather, landslides and earthquakes. The project combines climate change scenarios with structural and geotechnical simulation tools, using actual data from sensors (terrestrial and airborne) to provide operators with an integrated tool able to support more effective management of their infrastructure at planning, maintenance and operation level.

To do so, the project will utilise high-resolution modelling data to determine and assess climatic risks, existing structural health monitoring data, weather forecasts and multi-temporal, multi-sensor UAV- and satellite-based observations.

More information on: http://www.panoptis.eu/

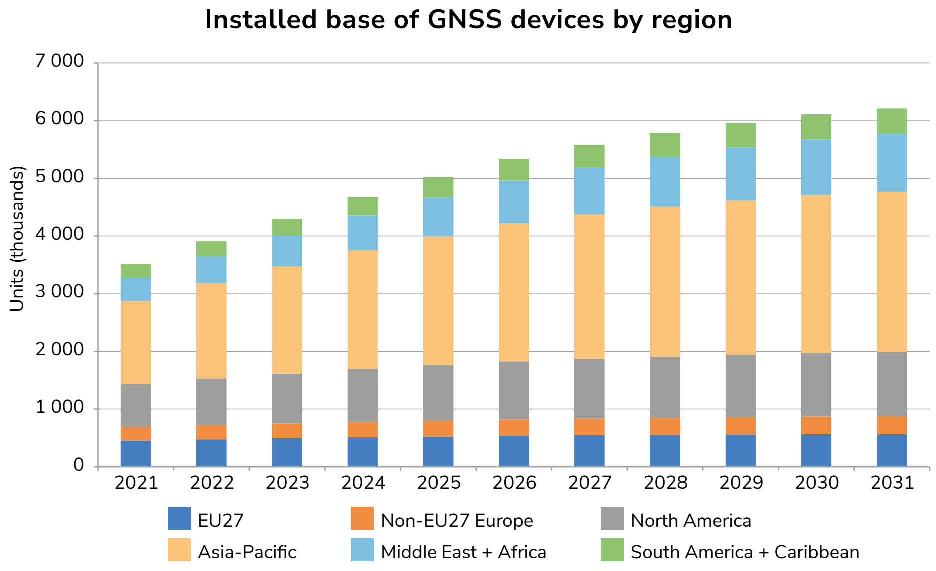
Rolling Out OSNMA for the secure synchronisation of Telecom networks - ROOT

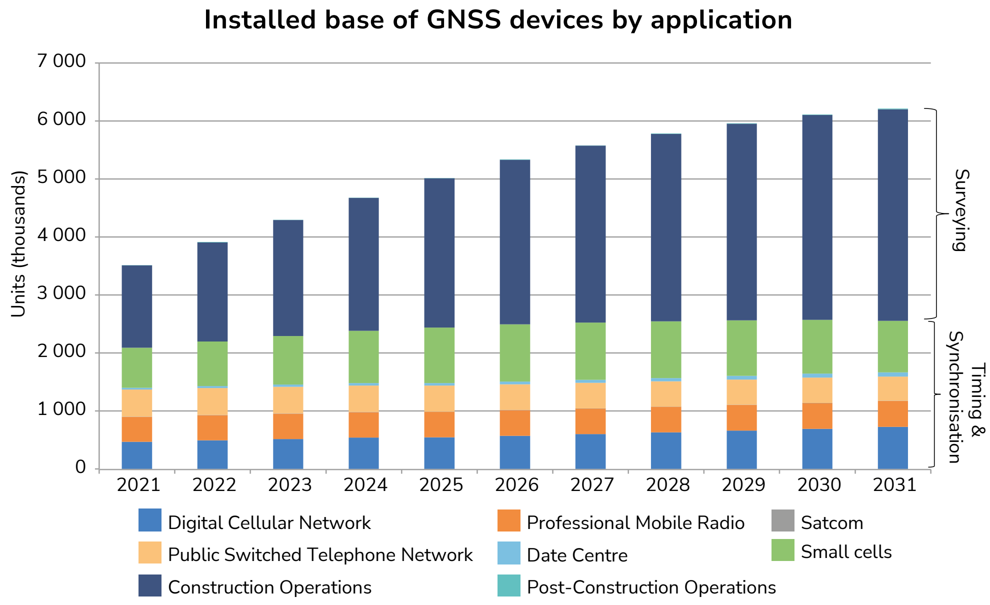
ROOT is a 18-month EU-funded project which will assess the benefits introduced by the Galileo authenticated signals (OSNMA) in the specific context of the synchronisation of 5G telecommunication network.

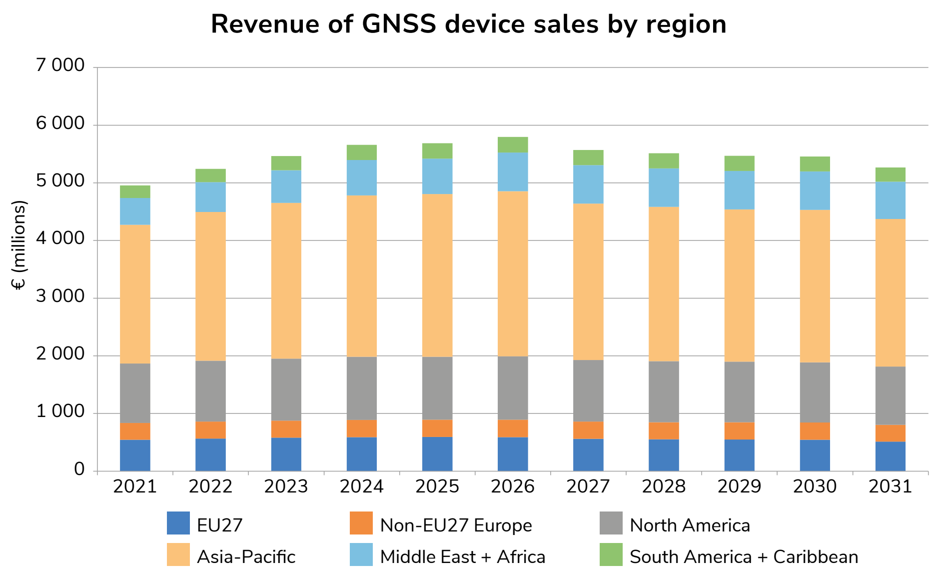
Based on a four-step experimental approach (selection of the attack within a set of radio-frequency and cyberattacks / setting-up of the experimental testbed and intentional attacks / test and post-processing analysis / quantification of benefits), the project will perform measurements of the increased level of robustness provided by new multi-frequency, OSNMA-ready Galileo receivers and will estimate the increased resilience that OSNMA can bring to GNSS-based timing sources.

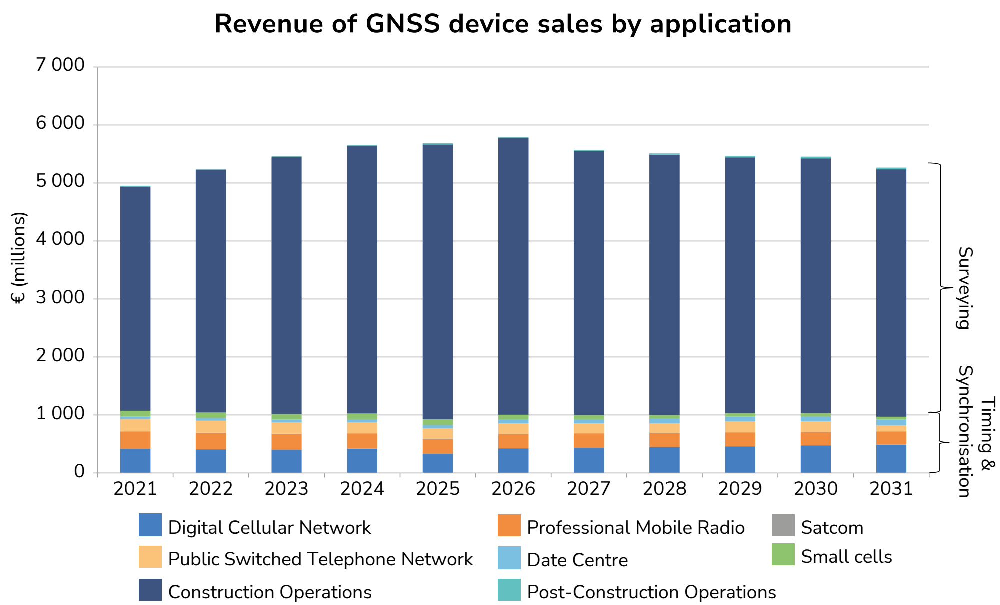
ROOT will foster the adoption of Galileo signals featuring authentication mechanisms in terrestrial infrastructure that depend on satellite-derived time.

More information on: https://www.gnss-root.eu


Installed base of GNSS devices by region
Units (thousands)
7 000
6 000
5 000
4 000
3 000
2 000
1 000
0
2021
2022
2023
2024
2025
2026
2027
2028
2029
2030
2031
EU27
Non-EU27 Europe
North America
Asia-Pacific
Middle East + Africa
South America + Caribbean


Installed base of GNSS devices by application
Units (thousands)
7 000
6 000
5 000
4 000
3 000
2 000
1 000
0
2021
2022
2023
2024
2025
2026
2027
2028
2029
2030
2031
Surveying
Timing & Synchronisation
Digital Cellular Network
Professional Mobile Radio
Satcom
Public Switched Telephone Network
Date Centre
Small cells
Construction Operations
Post-Construction Operations


Revenue of GNSS device sales by region
€ (millions)
7 000
6 000
5 000
4 000
3 000
2 000
1 000
0
2021
2022
2023
2024
2025
2026
2027
2028
2029
2030
2031
EU27
Non-EU27 Europe
North America
Asia-Pacific
Middle East + Africa
South America + Caribbean


Revenue of GNSS device sales by application
€ (millions)
7 000
6 000
5 000
4 000
3 000
2 000
1 000
0
2021
2022
2023
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2028
2029
2030
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Surveying
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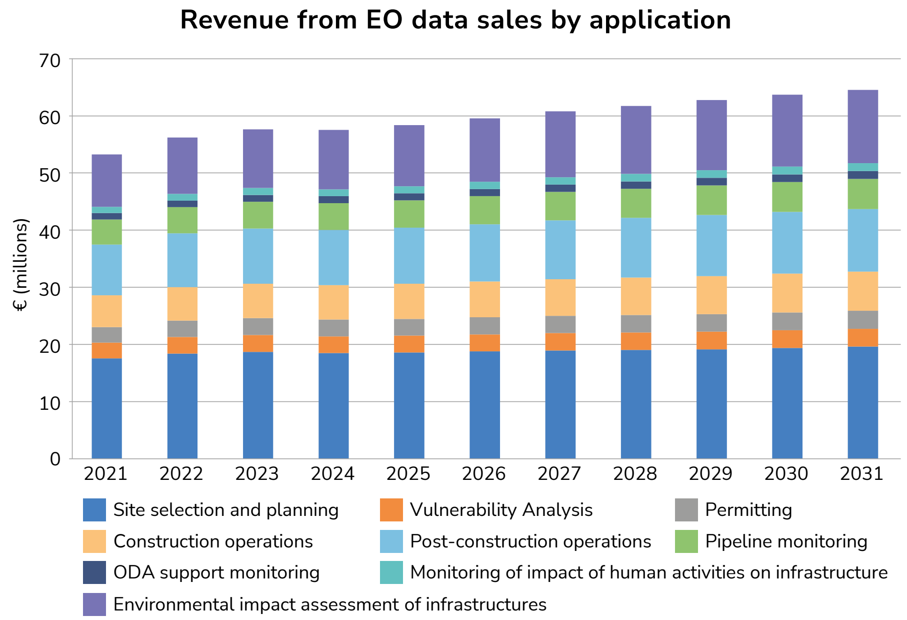
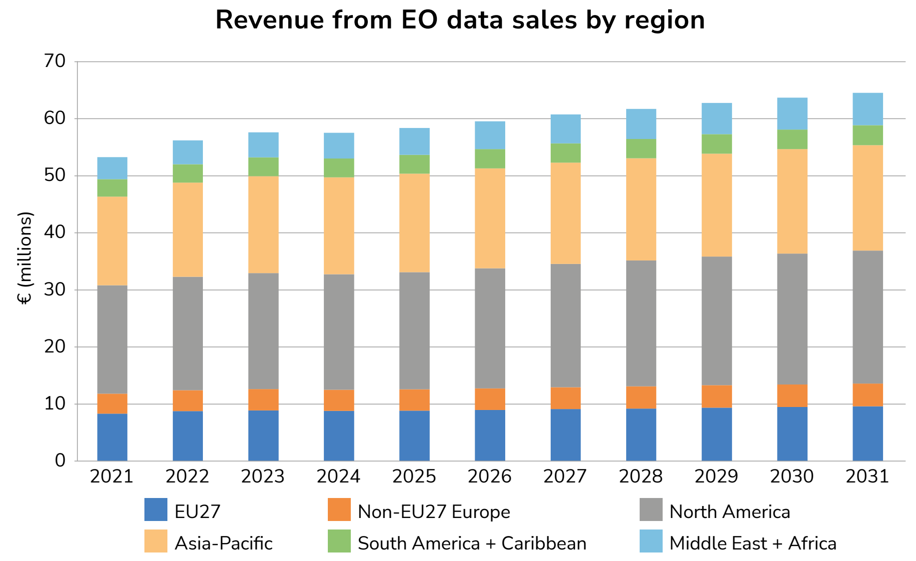
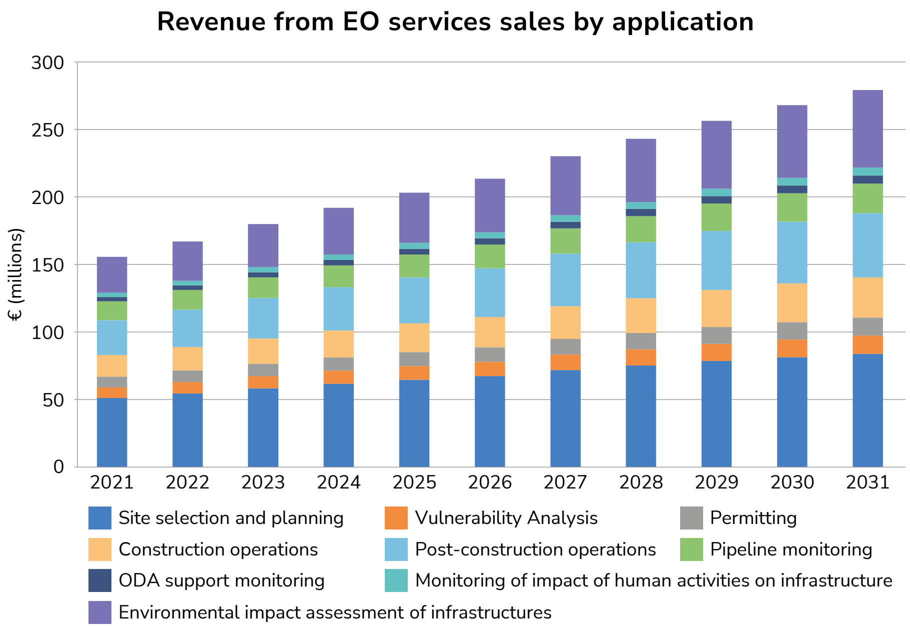
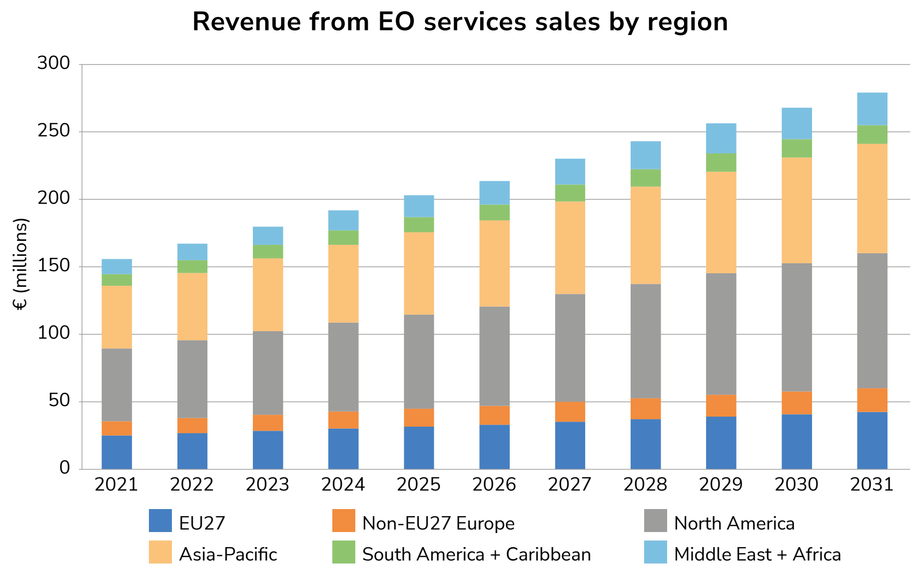
Digital Cellular Network
Professional Mobile Radio
Satcom
Public Switched Telephone Network
Date Centre
Small cells
Construction Operations
Post-Construction Operations


Revenue from EO data sales by application
70
60
50
40
30
20
10
0
€ (millions)
2021
2022
2023
2024
2025
2026
2027
2028
2029
2030
2031
Site selection and planning
Vulnerability Analysis
Permitting
Construction operations
Post-construction operations
Pipeline monitoring
ODA support monitoring
Monitoring of impact of human activities on infrastructure
Environmental impact assessment of infrastructures


Revenue from EO data sales by region
70
60
50
40
30
20
10
0
€ (millions)
2021
2022
2023
2024
2025
2026
2027
2028
2029
2030
2031
EU27
Non-EU27 Europe
North America
Asia-Pacific
South America + Caribbean
Middle East + Africa


Revenue from EO services sales by application
300
250
200
150
100
50
0
€ (millions)
2021
2022
2023
2024
2025
2026
2027
2028
2029
2030
2031
Site selection and planning
Vulnerability Analysis
Permitting
Construction operations
Post-construction operations
Pipeline monitoring
ODA support monitoring
Monitoring of impact of human activities on infrastructure
Environmental impact assessment of infrastructures


Revenue from EO services sales by region
300
250
200
150
100
50
0
€ (millions)
2021
2022
2023
2024
2025
2026
2027
2028
2029
2030
2031
EU27
Non-EU27 Europe
North America
Asia-Pacific
South America + Caribbean
Middle East + Africa

INSURANCE AND FINANCE

Legend
EO application
GNSS application
Synergetic application (combined use of EO and GNSS)

Finance
- Commodities trading
- Risk assessment
- Timing and synchronisation for finance

Insurance for natural disasters
- Event footprint
- Index production
- Risk modelling

INSURANCE AND FINANCE

The Insurance and Finance market segment contains services and products provided and consumed by institutions and organisations in the insurance and financial service domains. This includes insurers (and re-insurers) and international and local financial institutions (e.g. private and commercial banks, stock exchanges or traders).

From claims assessments in the insurance industry to time-stamping of transactions in finance, GNSS timing and positioning information plays a key role. In addition to time-stamping of transactions in financial (bank and stock exchange) applications, GNSS is used for claim assessment (using GNSS-enabled drones for pre- and post-event analysis and data gathering) in the insurance industry.

Earth Observation is used to compute indices for parametric products particularly for crops and livestock insurance (i.e. index production), calibration of risk models (i.e. risk modelling) and assessing damage and thereby claim management (i.e. event footprint), benefitting both the insurance and finance stakeholders. In addition, EO data supports screening processes (i.e. risk assessments) undertaken by financial institutions for their investments and contributes to the development of logistics strategies of organisations exploiting natural resources (e.g. indices for commodities trading).

What you can read in this chapter

- **Key trends:** Rising stakes for spatial finance and insurance.
- **User perspective:** Satellite data provides more accurate intelligence for informed decision-making.
- Industry: Insurance and Finance Value Chains.
- **Recent developments:** Space data integration goes hand in hand with sectors' digitalisation.
- **Future market evolution:** EO set to become and instrumental tool in the financial world.
- **European Systems and projects:** Copernicus and Galileo working together for more sustainable finance.
- **Reference charts:** Yearly evolution of sector and application specific EO revenues; GNSS devices' installed base and revenues by application and region.

Application descriptions can be found in Annex 3.

Rising stakes for spatial finance and insurance

Key market trends

- EO data helps financial institutions to improve their processes for more informed and responsible investment decisions towards a more sustainable future
- In parallel, synchronisation services based on GNSS time continue to support the financial markets
- Insurers keep integrating satellite data into their product portfolios for increased granularity in risk selection and pricing

Insurance and finance are working better with space-based solutions

Parametric insurance is a relatively new innovative approach to insurance provision whereby payouts are based on a predetermined index for loss of assets and investments as a consequence of weather and/or catastrophic events. **Satellite imagery** is a tool used to monitor remotely conditions on ground and a source of information to verify claims.

Satellite-based insurance emerges as a way to assist smallholder farmers facing the consequences of natural perils. CGIAR (formerly known as Consultative Group for International Agricultural Research) Water, Land and Ecosystems policy briefs provide further evidence and recommendations on the way such insurance schemes can improve disaster preparedness and response, advance equity and strengthen institutions, particularly when they are incorporated in wider disaster-management plans. These refer to pilot projects in India and Bangladesh which show how index-based weather insurance products assisted by Earth Observation (EO) data can reduce financial risks to smallholder farmers as a consequence of floods and droughts.

At the same time, financial institutions (FIs) face a similar, increasing need to consider climate risks in their assessments. EO constitutes a major source of data to feed FI's screening processes. Combined with other relevant data, EO data help investors and asset managers to better understand current and future risks to their investments (e.g. inland flood risk, coastal erosion, etc.).

With accessible satellite data, existing insurance programmes can potentially be extended to cover a range of natural hazards, (e.g. encompassing cyclones, droughts and coastal inundation), while for FIs, EO can translate into more responsible investment decisions (e.g. by providing an impartial assessment of the environmental impacts, such as deforestation, that investment projects have).

Programme/Product	Key partners	Risk covered	Geographic coverage
Global Index Insurance Facility (GIIF)	World Bank Group, EU, Japan	Multi Peril	Sub-Saharan Africa, Asia, and Latin America and the Caribbean.
Index Based Flood Insurance (IBFI)	Indian Council for Agricultural Research, Disaster Management Department, Institute of Water Modelling (IWM), SwissRe	Flood	India, Bangladesh
G4AW	Netherlands Space Office, research institutions, NGOs and EO-data providers	Multi perils	Sub-Saharan Africa, Asia

Growing offer of synchronization services to comply with regulation and provide competitive advantage

Since 2018, the European Securities and Markets Authority (ESMA) has imposed on EU member states a series of technical requirements on business clock synchronization in the Commission Delegated Regulation (EU) 2017/574, which complements the MiFID II Directive 2014/65/EU in markets of financial instruments. The most stringent requirement is 100 microseconds deviation from UTC with 1 microsecond of timestamping granularity. Traceability and the capacity to demonstrate where the timestamp is applied and that it remains consistent are also required. In the US, the Securities and Exchange Commission's Rule 613 imposes a less stringent requirement with a synchronization accuracy requirement of 50 milliseconds to the time maintained by the National Institute of Standards and Technology. However, financial institutions often go beyond these 50 ms accuracy to be competitive. In trading especially, time lags as small as 10 microseconds can be a deadly disadvantage.

In the meantime, financial institutions are increasingly concerned by the potential impact of GNSS disruption or outage. A host of GNSS receiver vendors offer services to implement, operate and maintain their networks according to the MiFID II regulation requirements, but also to protect timekeeping from any GNSS issues. Synchronization service for business clocks offers are therefore growing accordingly.

Accelerated digital transformation in Agri-insurance

Based on a recent survey conducted by Agroinsurance, the main innovations introduced for underwriting needs in 2020 due to COVID-19 included a more extensive use of digital solutions for crop monitoring, mobile applications for online premium payments and electronic communication with the insurance buyers. The use of satellite technology for loss assessment remains limited in the global market, although more initiatives emerge to showcase its advantages.

For instance, Swiss Reinsurance are working with start-up GreenTriangle's remote monitoring software to improve the loss adjustment processes. The platform integrating satellite data helps settle claims in a more transparent and efficient way – from detection of erroneous insurance claims to differentiating impacts of adverse weather events as opposed to diseases on the crop's yield – benefiting both insured and insurers.

Satellite data provides more accurate intelligence for informed decision-making

Three types of EO-based activities in insurance for natural disasters

EO FOR:	APPLICATIONS	END USERS
RISK MODELLING	• Calibration of risk models and refinement of hypotheses • Imputs for digital models such as elevation maps	• Reinsurers • Insurers • Catastrophe modelling companies
EVENT FOOTPRINT	• Comprehensive vision of the affected area • First estimates of extent of damages	• Reinsurers • Insurers • Insured people • Emergency services
INDEX PRODUCTS	• Computation of indexes based on image analyses • Provision of informative maps for farmers	• Reinsurers • Insurers • Farmers or local authorities • Financial institutions

TRADITIONAL (Risk modelling, Event footprint)

Insurance companies require complete and accurate data to understand risk exposure both in **traditional**, indemnity insurance and **index products**.

Risk modelling (or catastrophe modelling) is the process of building a probabilistic model estimating the likelihood and severity of a loss. In support of underwriting, premium pricing and portfolio management, satellite imagery can be used as inputs for calibration and improvement of models. EO data is used mostly by Value Added Services (VAS) companies, and few large (re)insurance groups. For instance, Willis Re utilise satellite data (Shuttle Radar Topography Mission (SRTM) and Sentinel-2 multispectral imagery) with artificial neural networks for better flood risk modelling in South East Asia.

For post event-analysis or **Event footprint**, inputs from EO allow (re)insurance companies to obtain a comprehensive view of the affected area. This allows companies to anticipate organisation and planning, including being able to provide a better customer service for the benefit of policy holders.

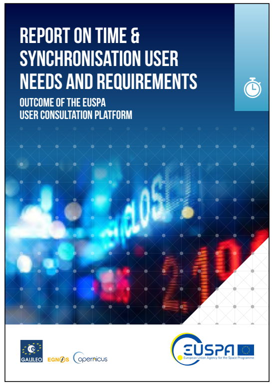
Finally, for the most innovative approach to insurance, **Index products,** EO data is linked with local parameters and knowledge (e.g. agronomists in crop insurance) for a more accessible (e.g. reduced basis risk and wider coverage in remote areas), efficient and transparent means of risk transfer.

Event footprint – clear overview and distribution of damages

Fast and accurate analysis of the extent of destruction caused during a natural disaster is essential to assess its economic impact. EO imagery from Sentinel-1 and Sentinel-2 satellites can be used for the mapping of natural hazard footprints and to determine the hazard impact, thereby supplementing and augmenting existing information in the claims management phase.

A Kick-start Activity by ESA, the EO-Claim Ledger B2B platform, was designed to support the insurance industry to overcome high administrative costs associated with managing a large number of related claims issued from an increasing number of natural disasters. The automated claim management system makes use of EO imagery for mapping damages caused by natural hazards and GNSS positioning data from field visits. In turn, using blockchain technology allows the provision of a secured system to prevent fraud and is expected to lower insurance premium for the benefit of the insured.

Key EO and GNSS user requirements



The key GNSS and EO user requirements for the different application groups within the **Insurance and Finance** segment are, at EU level, collected using the following procedures:

- For GNSS, information is collected through extensive interactions with user groups, providers and experts in a continuous process culminating at the User Consultation Platforms (UCP). All relevant requirements are documented in detail and updated regularly within the Report on Time & Synchronisation User needs and requirements.
- User requirements for Copernicus services and products – as well as their evolution – are collected through an integrated process that involves different channels: (i) dedicated studies (e.g. “NEXTSPACE” project, “Copernicus for EC (C4EC)” study, Commission Staff Working Document on user needs), (ii) targeted consultations organised by the European Commission or the Entrusted entities with the relevant communities, (iii) regular and structured exchanges among representatives of the Copernicus governance structure and Member States through the Copernicus User Forum.

From the 2022 EUSPA`s UCP onward, EO user needs and requirements of commercial users will be validated and discussed with industry experts and user groups, mirroring the process implemented for GNSS.

Insurance and Finance Value Chains[1]

EARTH OBSERVATION	INFRASTRUCTURE PROVIDERS	DATA PROVIDERS	PLATFORM PROVIDERS	EO PRODUCTS AND SERVICE PROVIDERS	INFORMATION PROVIDERS	END USERS
	• AWS • CODE-DE* • COLLGS* • COPERNICUS DIAS* • CLOUDEO* • GOOGLE CLOUD PLATFORM • IBM CLOUD • PENGUIN COMPUTING • USGS EARTH EXPLORER	• AIRBUS SE* • COPERNICUS DIAS* • DESCARTES LABS • EARTH-I • E-GEOS* • MAXAR • PLANET • URSA	• ATOS • CLOUDEO* • COPERNICUS DIAS* • GBDX PLATFORM • MAPBOX • ONEATLAS • SINERGISE* (SENTINEL HUB)	• EARTHDAILY ANALYTICS • EARTH-I LTD • GAF* • GEOVILLE* • LUXCARTA S.À R.L.* • SATELLIGENCE* • SINERGISE* • SPACEKNOW • SPARK INSIGHTS INC • VANDERSAT* • VITO*	• ACCLIMATISE* • ACCUWEATHER INC • ASSET RESOLUTION* • EARTHLAB AI SYSTEMS • ECOMETRICA • EQT MID MARKET LIMITED PARTNERSHIP • FLINT PRO • GEOSPATIAL FINANCIAL HUB • GREEN TRIANGLE • RISCOGNITION* • VERISK ANALYTICS	**RE/INSURANCE SECTOR** • AIG • SWISS RE* • WILLIS TOWERS WATSON* **FINANCIAL INSTITUTIONS** • REFINITIV LTD • INTERNATIONAL DEVELOPMENT ORGANISATIONS
	• COPERNICUS COLLABORATIVE GROUND SEGMENT*	• COPERNICUS SENTINELS* • USGS/NASA LANDSAT • RELEVANT IN-SITU NETWORKS	• GEOHAZARDS-TEP	• COPERNICUS SERVICES*		

GNSS	COMPONENT AND RECEIVER MANUFACTURERS	DEVICE MANUFACTURERS	SYSTEM INTEGRATORS DESIGN CONSULTANCIES TESTING & MAINTENANCE	END USERS
	• FURUNO • NOVATEL • SEPTENTRIO* • STMICROELECTRONICS* • TRIMBLE • U-BLOX*	• ARBITER • CHRONOS TECHNOLOGY* • ELPROMA* • ENDRUN • GORGY TIMING* • JACKSON LABS • MASTERCLOCK • MEINBERG* • MICROCHIP • OROLIA SPECTRACOM* • OSCILLOQUARTZ* • SEVEN SOLUTIONS*	• ACCENTURE • CHRONOS TECHNOLOGY* • IBM • JUNIPER	BANKS AND STOCK EXCHANGES

European[2] GNSS & EO industry in the global arena

GNSS receivers in Insurance and Finance are used for timing and synchronisation purposes and the industry supporting the segment overlaps with that serving both Infrastructure and Energy and Raw Materials. European companies such as Orolia, u-Blox, and Meinberg hold 36% of the timing and synchronisation market, with a slightly lower intensity on Insurance and Finance applications than their largest international competitors, yielding an estimated European share of 25% of the Insurance and Finance market.

In EO, the EU market is dominant with almost 58 % of the total share and a segment value of €0.17bn.

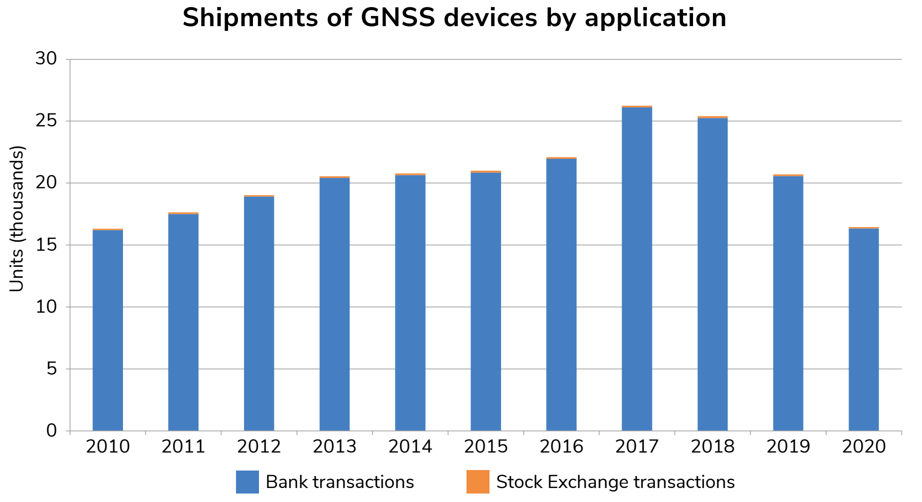
LEGEND

- Commercial Offering
- Public Offering
- User segments

NOTES

[1] The value chain considers the key global and European companies involved in GNSS and EO downstream activities.
[2] In the market share analysis, Europe is defined as EU27 plus Norway, Switzerland and the UK.
* European-based companies. The region is defined with respect to the headquarters of the company, though the actual area of activity might be wider.

Space data integration goes hand in hand with sectors' digitalisation



GNSS equipment is used for Time Stamping functions, to log events in a chronologic manner and therefore be able to recreate causal links. All stock exchanges are equipped with large data centres holding the exchanges' matching engines in racks of interconnected servers using GNSS receivers as timing and synchronisation sensors.

The MiFID II (in EU) and FINRA (US) regulations had a distinct, positive impact on sales of GNSS receivers peak of shipments in 2017: over 33,000 units of new equipment were acquired by financial institutions.

With the average device lifetime of about 5 years and the volume of funds at stake, financial markets are more likely to keep up the pace with latest technological developments. Although the market appears to reach a maturity in terms of shipments from 2018 onwards, the willingness of finance users to pay a premium in order to acquire state of the art timing and synchronisation solutions, provided the benefits outweigh the costs, is expected to maintain the historical trend of equipment purchase. In addition, financial markets will be encouraged renew their current devices by additional amendments to regulation: for instance, from 2021 onwards FINRA will begin supporting timestamps up to nanosecond granularity.

On top of the need for accurate timestamps, as explained below, GNSS location data is becoming essential for the evolving financial landscape being sourced from various devices and applications.

Role of drones in insurance*

Insurers use drones to deliver and document aerial footage of houses, building sites, landscapes, and events that are known to be occurring. When it comes to assessing risks and measuring losses, they already represent significant extra value to the industry. For loss adjustment purposes, using drones for insurance inspections dramatically reduces the time for processing claims – a crucial factor for people whose properties have affected by natural disasters such as hurricanes. In the underwriting process, drones can be used to pro-actively monitor risk in disaster-prone areas, gathering data for more accurate quotes to residents. Drones equipped with infrared cameras have proven effective at detecting water and air leaks, previously a time-consuming process for loss adjusters.

The new harmonised regulation on the use of drones in the EU (2021) and technology developments (e.g. AI) will pave the way in the future towards seamless integration between various data sources within the (re)insurance value chain (including autonomous drones capable of covering greater areas), collection and integration (e.g. via AI pattern recognition) of more useful information, and further optimisation of the underwriting and claim management processes.

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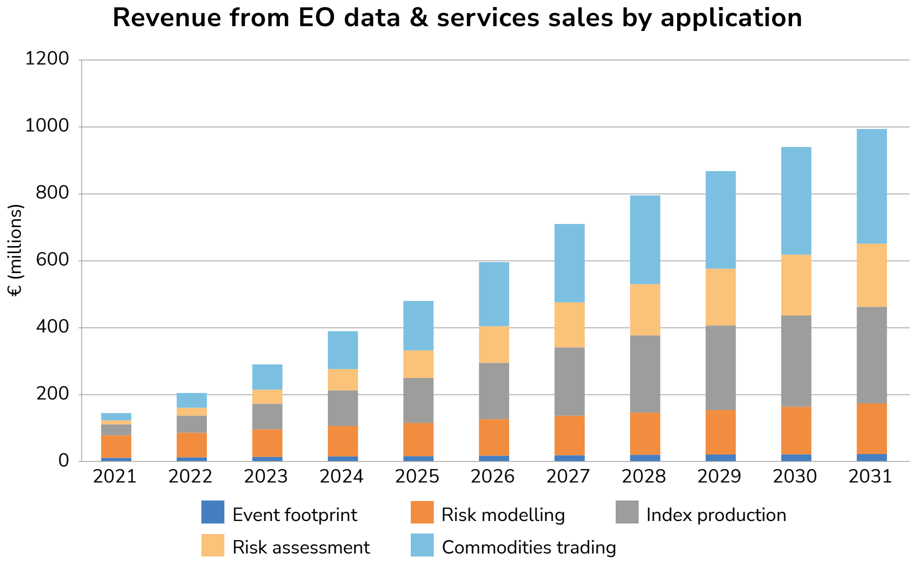
*Drones are quantified in Aviation and Drones segment, and the revenues from this activity (described in the box) are attributed to the dedicated segment.

Big data, Machine Learning and GNSS increasingly used by fintech to develop new services

According to a recent note from the Worldbank on Finance competitiveness and innovation, credit reporting service providers are increasingly using artificial intelligence and machine learning to assess credit risk. Some service providers have developed proprietary credit scoring technology to process up to 20,000 data points per application, the majority of which are drawn from social media to estimate human behavior. These algorithms use advanced analytics and Machine Learning to process a range of data pulled out of users' phones, including telephone use data, messaging content, browser data and GPS locational data.

With these new algorithms enabled (among other technologies) by GNSS, the credit reporting landscape is being evolving and new fintech players are driving the whole sector towards more innovation. However, the new solutions introduce new challenges with respect to cybersecurity concerns, potential for fraud and data privacy and protection issues. This calls for robust and reliable data to be used in the AI and ML algorithms, including GNSS data.

EO set to become and instrumental tool in the financial world



The total amount of **EO data and services for 2021 accumulates to €145 m** across the five categories of applications (event footprint, risk modelling, index production, risk assessment and commodities trading) considered in this market report. From 2021, the EO data and services for the insurance and financial market segment will see a **CAGR of 20% by 2031, resulting in almost €1 bn total revenues**. The massive boost which will accelerate the uptake of both EO data and value-added services across the industry is related to the use of parametric insurance products in the context of disaster resilience frameworks as well as by commercial entities in areas with high exposure to extreme events at global level.

In 2021, around 46% of the total revenues come from **risk modelling**, presenting the largest customer base for EO data and services. However due to its slower future growth, which is below the average of the whole market segment in terms of CAGR (8%), the revenues from this application will represent only 15% of the total revenues in 2031, even if the revenue generated will amount for €151 m, compared to €67 m in 2021.

Risk assessment and commodities trading are the two applications with the biggest growth rate (32%) between 2021 and 2031. The revenues from risk assessment go from €12 m in 2021 up to €189 m in 2031. In its turn, the revenues from commodities trading goes from almost €22 m up to more than €343 m in 2031.

Earth Observation to support smallholders' access to microfinance

A significant portion of the world's population remains unbanked and for these people, who mostly live in developing countries, accessing financial services is very challenging. The lack of financial history, limited incomes and the difficulty for lenders to assess credit risk are part of the obstacles they face. When these people are in remote areas, the high operational costs to reach them constitute an additional barrier.

Combined with other digital technologies like Artificial Intelligence, EO can help financial institutions develop products fitted to these potential customers. In the domain of agriculture for instance, EO can provide historical information on farm performance, estimate crop production thanks to vegetation, soil and water-related data, and help to monitor the progress of farming activities. These EO-based insights can support loan decision-making by feeding credit risk assessment models and help to assess small farmers' creditworthiness. EO can also support loan monitoring by identifying or forecasting events likely to have an impact on reimbursement, while limiting the need for on-site inspections. Thus, EO can help financial institutions to provide numerous smallholder farmers, who were previously considered as unreachable, with access to microfinance.

GNSS to support authentication in financial transactions

Improving security of financial transaction and ensuring protections of his customers against attempted frauds is increasingly high on the agendas of banking institutions and regulatory authorities. In EU, the revised Directive on Payment Services (PSD2) reflects this concern as an important element of PSD2 is the requirement for strong customer authentication on most electronic payments which came into full effect on 31 December 2020.

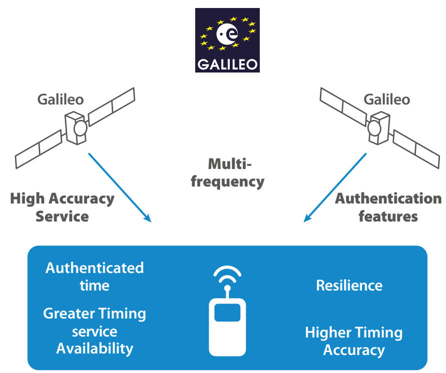
While cell phones have now reached full maturity, a new area of GNSS usage is linked to improving security transaction and fraud detection leveraging on mobile-enabled GNSS as a security mechanism. The interest would be to adopt multi-layered security with a context-aware online security approach to fraud detection that would include GNSS data. Using mobile GNSS data as an added layer of security allows banks or service providers to use the geolocation information gained from mobile app to determine whether a transaction aligns with the location of the customers' mobile, giving them another way to detect that a fraudulent transaction is underway. Several banks and fintech payment providers have already incorporated location-based authentication based on a mobile phone's GNSS data such as PayPal's Venmo, Velmie, Temenos, MasterCard and Visa.

Copernicus and Galileo working together for more sustainable finance

Current usage of EGNSS

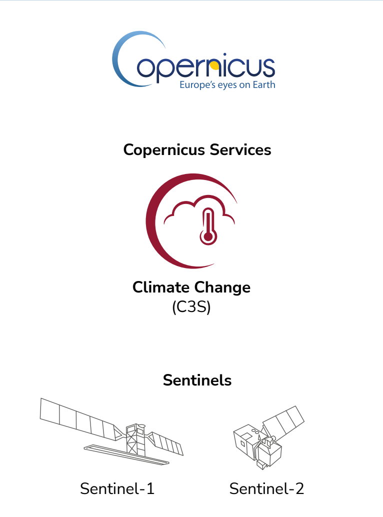
Galileo is integrated into GNSS Timing & Synchronisation devices to improve the availability and robustness of the overall Timing solution. Implementing Galileo in multi-constellation products offers more reliability and accuracy of the Timing solution with quantified integrity, multiple source comparison and versatile adaptive approach in mixing constellation and satellites. Galileo Open Service already provides UTC Time dissemination better than 30 ns [95%] and a Frequency dissemination better than 3*10-13 [95%].

Similarly to most segments, T&S device manufacturers integrate Galileo-enabled chipsets.



Current usage of Copernicus

Both the Copernicus Sentinel and the Copernicus core services are providing useful information and data to insurance companies. Sentinel data are particularly useful to conduct risk assessments: Sentinel-2 images are used to collect environmental impacts and land classification data (e.g. farms detection) at high resolution with high revisit capability, or can be used for plant growth monitoring through the delivery of timely data on numerous plant indices (particularly useful for precision farming and agricultural insurance). Sentinel-1 radar imagery also increases the transparency of crop insurance programmes and speeds up pay-outs regardless of weather conditions.



BEACON

Boosting Agricultural Insurance based on Earth Observation data - BEACON

© Beacon project

The BEACON project aims to develop a commercial service package enabling insurance companies to exploit the untapped market potential of Agricultural Insurance, taking advantage of innovations in EO, weather intelligence and ICT/ blockchain technology. The service will help insurers alleviate the effect of weather uncertainty, optimise operational and administrative costs for monitoring, contract handling and on-site visits and design more accurate and personalised contracts.

Data products will be developed using EO data derived by Copernicus Sentinel missions and contributing missions. BEACON services are expected to be piloted with ten representatives from the insurance sector to globally confirm their value proposition.

More information on: https://beacon-h2020.com/

TWIGA

Transforming Weather Water data into value-added Information services for sustainable Growth in Africa - TWIGA

The overarching objective of TWIGA is to provide currently unavailable geo-information on weather, water and climate for sub-Saharan Africa by enhancing satellite-based geo-data with innovative in-situ sensors and developing related information services that answer needs of African stakeholders and the Global EO System of Systems (GEOSS) community. One of the defined target 'user clusters' are (crop) insurance providers, seen as an essential part of the agricultural value chain for smallholders trying to move from subsistence farming to market-oriented production.

An optimal combination of satellites, in-situ observations and models will support insurance providers with products, including climate map of rainfall, detailed near-real-time rainfall maps, hail maps and information such as drought risk maps, actual rainfall at farm level and hail storm trails.

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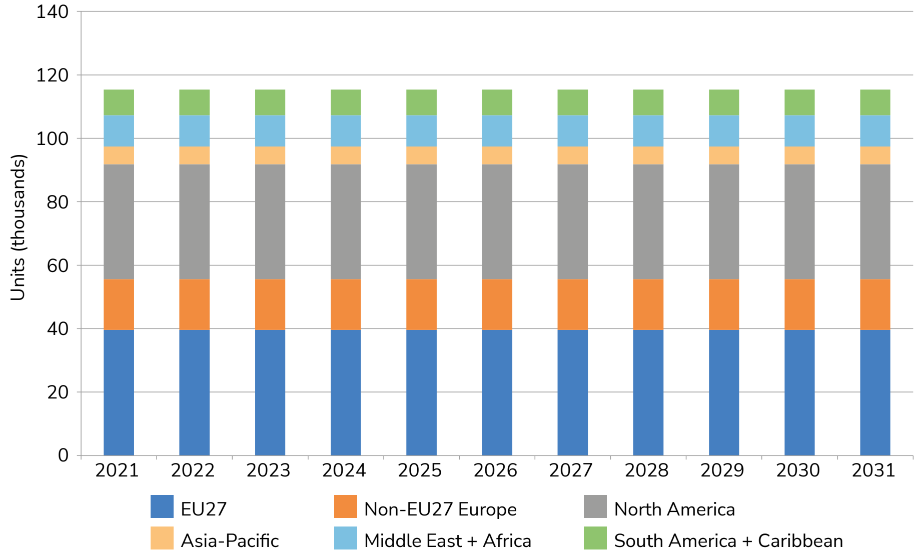
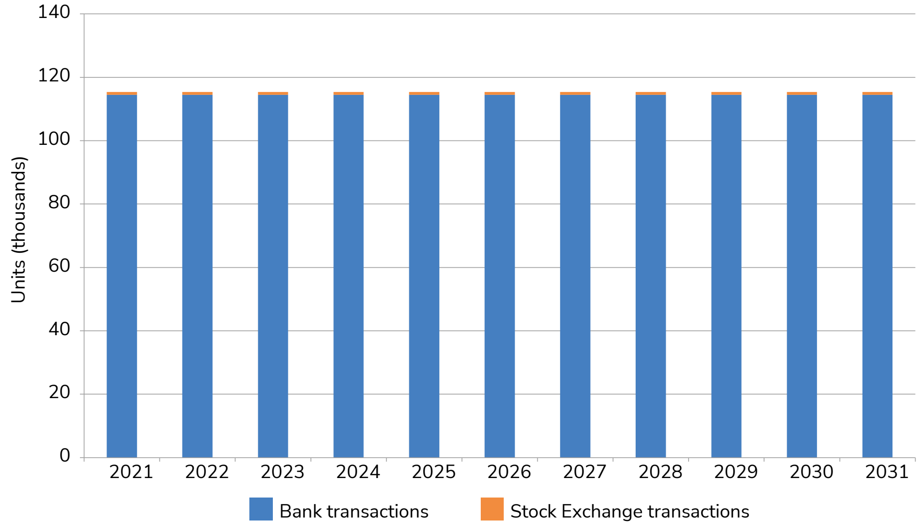
More information on: https://www.twiga-h2020.eu/

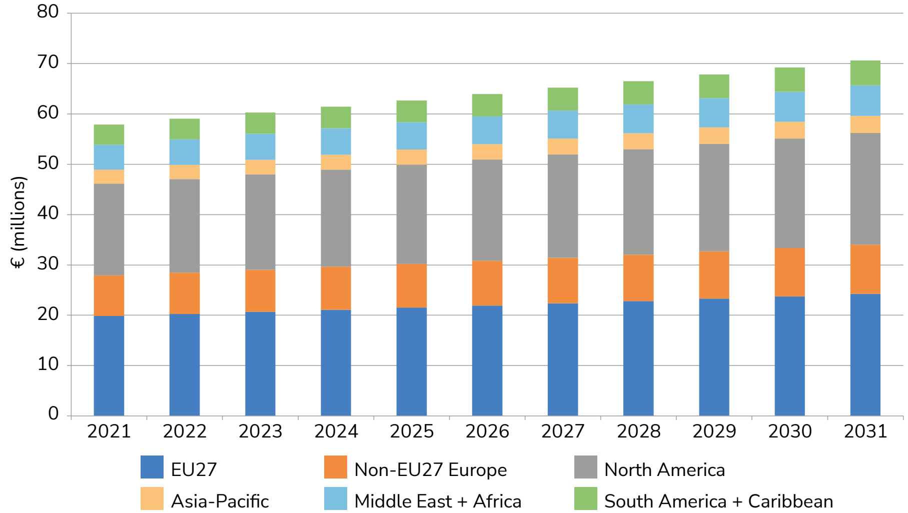
Installed base of GNSS devices by region



Installed base of GNSS devices by application



Revenue of GNSS device sales by region



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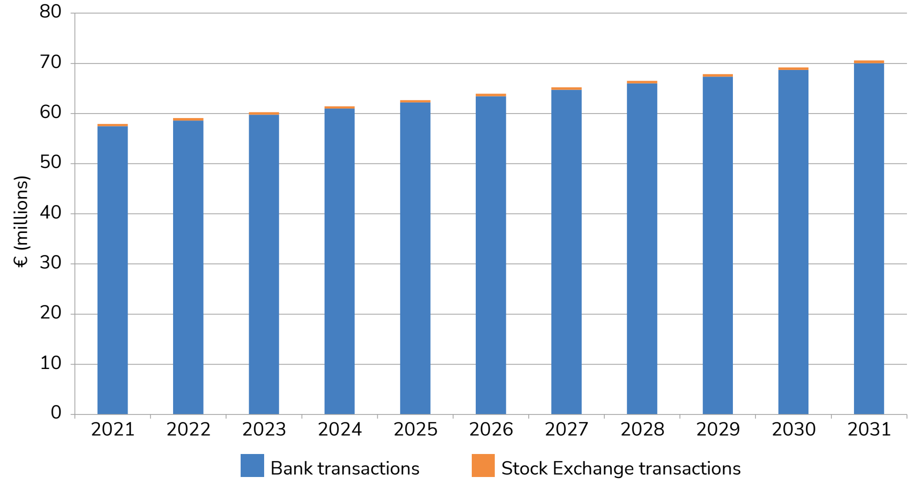
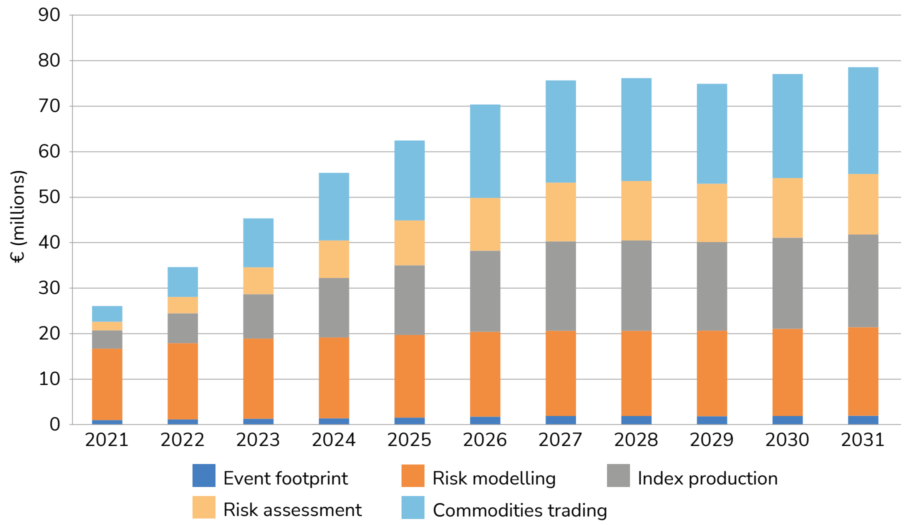
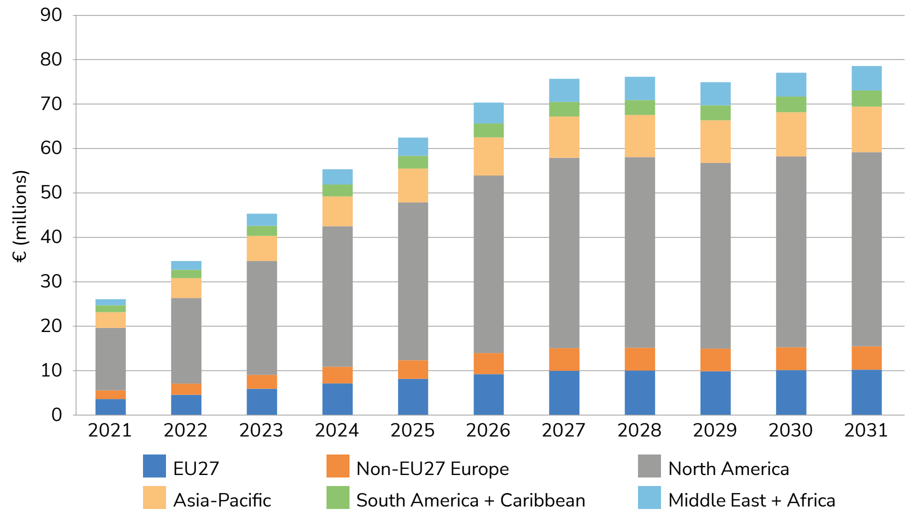


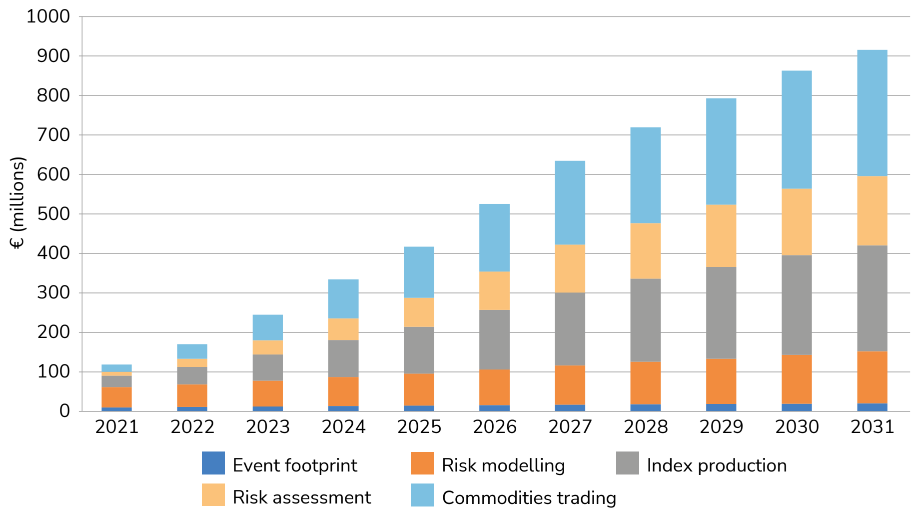
Revenue from EO data sales by application



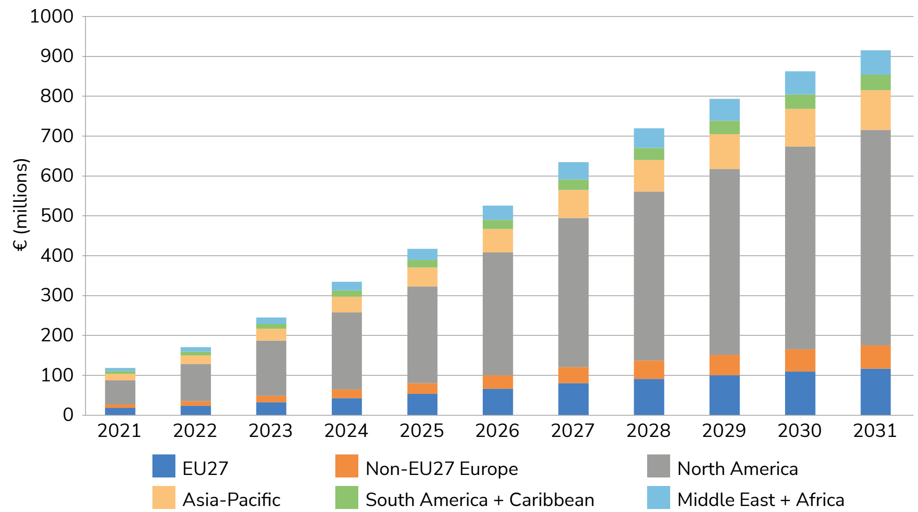
Revenue from EO data sales by region



Revenue from EO services sales by application



Revenue from EO services sales by region



MARITIME AND INLAND WATERWAYS

Legend
EO application
GNSS application
Synergetic application (combined use of EO and GNSS)

Environmental monitoring
- Marine pollution monitoring

Inland Waterways
- Inland waterways navigation

Maritime engineering
- Marine surveying and mapping
- Dredging

Merchant vessels
- Collision avoidance (AIS)
- GNSS vessel engine management systems
- Merchant navigation
- Navigation through sea ice
- Ship route optimisation

Ocean services
- Metocean

Ports
- GNSS automated port operations
- Piloting assist at ports
- Port safety
- Port security
- Ports[1]

Recreational craft
- Recreational navigation

Vessel tracking
- Dark vessel monitoring

[1] incl. Port-based Port navigation devices, PPUs and Vessel docking)

Application descriptions can be found in Annex 3.

MARITIME AND INLAND WATERWAYS

GNSS and EO contribute substantially to the maritime and inland waterways sector, assisting a diverse pool of stakeholders ranging from vessel operators and recreational boaters to port authorities in their day-to-day operations and activities.

In addition to safe and efficient navigation, GNSS devices provide a multitude of applications for inland waterways and port operations, while High Accuracy Services enable automation. Combined with EO, navigation efficiency can be optimised, and further explored in areas previously considered too dangerous or inaccessible such as new maritime routes or shallow inland waters.

Besides supporting different synergetic applications with GNSS, EO data itself provides precious insights for ocean services such as ocean monitoring, forecasting and ocean climate records, generating many coastal and marine environment applications.

What you can read in this chapter

- **Key trends:** The Maritime sector is sailing towards a more green, autonomous and digital future.
- **User perspective:** Towards more secure and resilient maritime operations.
- **Industry:** Maritime and Inland Waterways Value Chains.
- **Recent developments:** Stable growth of GNSS shipments despite historical stall in international maritime trade.
- **Future market evolution:** EO market is showing steady growth supported by public sector demand.
- **European Systems and projects:** Enhanced devices and advanced data for better performance in maritime activities.
- **Reference charts:** Yearly evolution of installed base of GNSS devices and revenues as well as EO revenues by application and region.

Maritime sector is sailing towards a more green, autonomous and digital future

Key market trends

- GNSS has been used to monitor the impact of COVID-19 on the maritime sector, and GNSS-enabled digitalisation efforts have helped companies cope with social distancing requirements
- GNSS and EO expected to contribute to green maritime solutions at the European level
- Synergetic use of EO and GNSS will lead to more fuel-efficient and safer navigation of maritime vessels through shipping route optimisation

Importance of uninterrupted supply chains highlighted through maritime GNSS data analytics

Maritime has been profoundly impacted by COVID-19, with global changes to trade and a highlighting of the fundamental importance of uninterrupted supply chains. Maritime tracking insights obtainemeasuringd via GNSS data from Automatic Identification System (AIS) are a great method for the impact of the the pandemic on trade. GNSS has allowed various bodies to track global changes to shipping patterns and frequency and provide important information. Data from Marine Traffic and other providers has offered an overview of the decline in port calls in 2020 relative to the same period in 2019, while companies such as the Maritime intelligence specialist VesselsValue are using AIS data to map cruise ship activity throughout the pandemic.

In addition, the COVID-19 pandemic has shown that digitalisation has become more important than ever, as has reducing staff onboard while ensuring safety, thus paving the way for automated solutions.

5G enables greater adoption of autonomous port use cases

5G is accelerating the path towards automation, enabling vessels, port vehicles and port equipment such as gantries to operate more autonomously (due to its high bandwidth and low latency capabilities), and in larger quantities (given its ability to support a massive amount of connected devices). **5G trials are ongoing at ports around the world,** including Hamburg, Rotterdam, Singapore, Shanghai and Antwerp.

The port of Antwerp, in particular, created a 5G-connected tugboat to relay images and radar data of the port's conditions in real-time, with a view to employ autonomous ships and trucks in the near future. The **trend towards 5G in ports in turn is increasing the adoption of GNSS-based navigation tools,** as equipment that was previously manually operated becomes automated.

In addition to automation, 5G has the potential to impact a wide range applications within ship-to-ship, ship-to-shore, and onboard communication. As part of the H2H Project, SINTEF has looked into the potential applications of 5G communication within the context of maritime operations in various waters.

Regulatory focus on green solutions

The EU Green Deal has heralded change across many fields, sustainable transport being one of them. Technologies such as EO and GNSS applications will play a role in addressing the Green Deal call for innovative ways to manage maritime fuel and space more sustainably.

In this context, many European projects have been put in place. The FLAGSHIPS project showcases the readiness of **zero-emission waterborne transport** by demonstrating two commercially operated hydrogen fuel cell vessels, while NEXUS will develop and demonstrate novel, state of the art, **specialised vessels and logistics for safe and sustainable servicing** of offshore wind farms.

Standards for autonomous vessels pave the way for adoption

While there have been many developments in autonomous vessels in recent years, there is a **lack of standard for communication formats, international legislative framework, terminology and data exchange.** This gap in standards makes it difficult to deploy port-to-port autonomous ship trials. Nations and port authorities have begun to work together to agree a set of standards in order to facilitate port-to-port autonomous vessel voyages. These standards will be key to the wider adoption of autonomous vessels, which are at present largely confined to single-port or national trials.

Operational guidelines have been developed by taking into consideration the Interim Guidelines for Maritime Autonomous Surface Ships (MASS) trials developed at the International Maritime Organisation (IMO). The creation of these operational guidelines also came as the product of enhanced co-operation among the European Maritime Safety Agency (EMSA) and all parties involved MASS trials. The objective of thoee guidelines is to provide assistance for relevant actors that want to perform tests/trials on MASS systems in a safe, secure and environmentally friendly manner.

Towards more secure and resilient maritime operations

Increased cyberattacks calls for advanced solutions

The IMO has issued Resolution MSC.428(98) for maritime cyber-risk management, effective from January 2021. The resolution focuses on cyber threats against the integrity and availability of technology systems.

An increase in shipping cyberattacks has been seen during the COVID-19 pandemic, as hackers attempt to exploit the vulnerabilities of maritime systems during a period of reduced staffing. The long-term focus for maritime users will be on ensuring continuity of service and protection against cyber-threats.

With low-cost spoofing devices being easily available and such cyber attacks becoming a recurring issue, a **key role for authenticated GNSS is envisioned as a response to the growing threat of spoofing** at sea or at ports. EU projects such as Prepare Ships and Bluebox Porbeagle are addressing this issue by creating secure devices equipped with authentication services.

Maritime Resilience is of utmost importance

Increasing cybersecurity risks, ship traffic and volume, in combination with the advanced automated function of vessels and future autonomous capabilities, together make the **integrity concept for maritime positioning** of utmost importance. Maritime positioning requirements for integrity services are assessed by organisations such as the Resilient Navigation and Timing Foundation (RNTF) and the Royal Institute of Navigation (RIN), stressing the needs of users.

To tackle this challenge, the **R-MODE BALTIC project** is developing and demonstrating a new maritime backup system for position, navigation and time purposes. It provides a safe ship navigation solution when the established GNSS fail due to interference or jamming. In fact, the project promotes the first worldwide operational test area for a new maritime system for PNT as a backup for GNSS in the Baltic Sea.

Another project (MarRINav) has explored the vulnerabilities of the GNSS PNT solutions to complement current GNSS performance by adding layers of integrity and resilience.

Key EO and GNSS user requirements

The key GNSS and EO user requirements for the different application groups within the **Maritime and Inland Waterways** segment are, at EU level, collected using the following procedures:

- For GNSS, information is collected through extensive interactions with user groups, providers and experts in a continuous process culminating at the User Consultation Platforms (UCP). All relevant requirements are documented in detail and updated regularly within the Report on Maritime and Inland Waterways user needs and requirements.
- User requirements for Copernicus services and products – as well as their evolution – are collected through an integrated process that involves different channels: (i) dedicated studies (e.g. "NEXTSPACE" project, "Copernicus for EC (C4EC)" study, Commission Staff Working Document on user needs), (ii) targeted consultations organised by the European Commission or the Entrusted entities with the relevant communities, (iii) regular and structured exchanges among representatives of the Copernicus governance structure and Member States through the Copernicus User Forum.

From the 2022 EUSPA`s UCP onward, EO user needs and requirements of commercial users will be validated and discussed with industry experts and user groups, mirroring the process implemented for GNSS.

Maritime and Inland Waterways Value Chains[1]

EARTH OBSERVATION

INFRASTRUCTURE PROVIDERS
- AWS
- CODE-DE*
- COLLGS*
- COPERNICUS DIAS*
- GOOGLE CLOUD PLATFORM
- IBM SPECTRUM COMPUTING
- INTEL GEOSPATIAL
- MICROSOFT AZURE
- PENGUIN COMPUTING
- PEPS

Public offering:
- COPERNICUS COLLABORATIVE GROUND SEGMENT*

DATA PROVIDERS
- AIRBUS SE*
- BLACKSKY
- COPERNICUS DIAS*
- DESCARTES LABS
- EARTH-I
- E-GEOS*
- ICEYE
- KANVAS
- MAXAR
- PLANET
- UP42

Public offering:
- COPERNICUS SENTINELS*
- USGS/NASA LANDSAT
- RELEVANT IN-SITU NETWORKS

PLATFORM PROVIDERS
- BLACKSKY GLOBAL
- BLUEFIELD
- CAPELLASPACE
- COPERNICUS DIAS*
- EOS DATA ANALYTICS

Public offering:
- COASTAL TEP
- MARITIME CONNECTIVITY PLATFORM

EO PRODUCTS AND SERVICE PROVIDERS
- ACRI*
- AIRBUS SE*
- BEIJING PIESAT INFO TECH CO LTD
- BMT ARGOSS HOLDINGS BV*
- CLS*
- EQT MID MARKET
- GMV
- INDRA SISTEMAS
- KONGSBERG SATELLITE SERVICES AS
- LEONARDO SPA*
- MAXAR TECHNOLOGIES
- VITO*

Public offering:
- COPERNICUS SERVICES*

INFORMATION PROVIDERS
COASTAL AND MARITIME EXPLOITATION AND PRESERVATION:
- BROCKMANN CONSULT
- EOMAP*
- GEOOPTICS
- GHGSAT
- HYSPECIQ

SHIPPING AND MARITIME TRANSPORT:
- ESRI UK
- HERA SYSTEMS
- OCEANROUTE
- SAT-OCEAN
- STORMGEO

END USERS
- **DATA-ANALYTICS COMPANIES**
- **PORT AUTHORITIES**
- **PUBLIC-PRIVATE COMPANIES**
- **SHIP OPERATORS**
- **SURVEILLANCE AUTHORITIES (both national and international)**

GNSS

MARITIME ORGANISATIONS
CIRM is an international association for marine electronics companies
EMSA EU agency charged with reducing risks of maritime accidents, marine pollution and loss of human lives at sea
IALA is an international technical association harmonising aids to navigation
IAPH and ESPO port & harbour associations
ICS and BIMCO shipping associations
IMO sets the standards for safety, security of shipping and pollution prevention
IMPA and EMPA maritime pilots associations

COMPONENT AND RECEIVER MANUFACTURERS
- BEIJER ELECTRONICS*
- BEIJING BDSTAR NAVIGATION
- BEIJING UNISTRONG
- COBHAM*
- COBRA ELECTRONICS
- FURUNO
- GARMIN
- GMT CO
- JAPAN RADIO CO
- JOHNSON OUTDOORS
- KONGSBERG MARITIME*
- NAVICO*
- OROLIA*
- SAMYUNG ENC
- WÄRTSILÄ*

SYSTEM INTEGRATORS
- AB VOLVO*
- HYUNDAI HEAVY INDUSTRIES
- INMARSAT*
- KAWASAKI HEAVY INDUSTRIES
- MITSUBISHI HEAVY INDUSTRIES
- PRONAV
- ST ELECTRONICS
- SUNGDONG SHIPBUILDING & MARINE ENGINEERING
- YANMAR

USERS
SHIP OWNERS/ OPERATORS
- APL
- CMA CGM GROUP*
- EVERGREEN LINE
- HAPAG-LLOYD*
- MAERSK LINE*
- MSC*

OFF-SHORE OPERATORS

RECREATIONAL BOATERS

SOLE MARINERS

USERS OF POSITIONING INFORMATION
- **DATA-ANALYTICS COMPANIES:** MARINETRAFFIC, MYSHIPTRACKING, VESSELTRACKER
- **PORT AUTHORITIES**
- **SURVEILLANCE AUTHORITIES**

European[2] GNSS and EO industry in the global arena

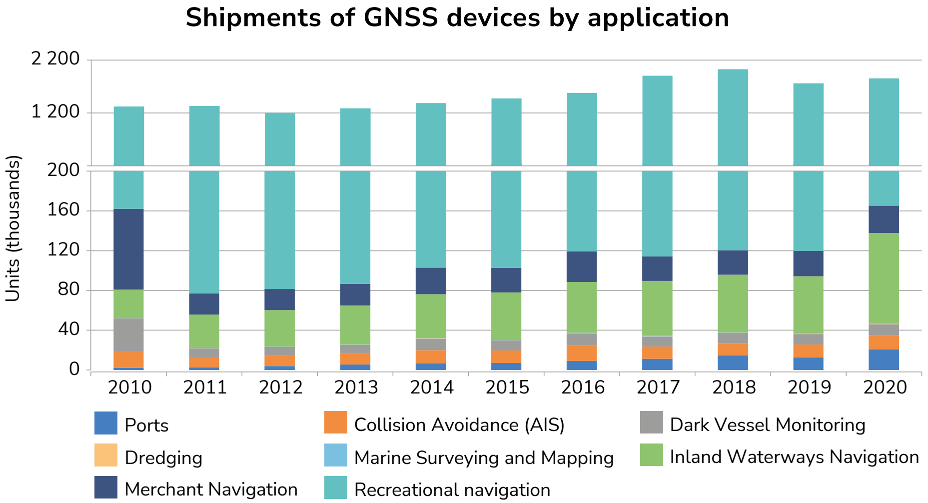
GNSS receivers in Maritime and Inland Waterways are similar to those used in Fisheries and Aquaculture, with a significant overlap in terms of industry. European companies such as Navico, Kongsberg, and Wärtsilä hold 47% of the maritime market.

In EO, EU has a very large share of the overall market at 64%, followed by North America (22%). The biggest EU players are Leonardo, Airbus and Thales.

LEGEND
- Commercial Offering
- Public Offering
- User segments

NOTES
[1] The value chain considers the key global and European companies involved in GNSS and EO downstream activities.
[2] In the market share analysis, Europe is defined as EU27 plus Norway, Switzerland and the UK.
* European-based companies. The region is defined with respect to the headquarters of the company, though the actual area of activity might be wider.

Stable growth of GNSS shipments despite historical stall in international maritime trade



In 2020, the global size of the GNSS application shipments totalled 1.8m units across all applications used for positioning and navigation for maritime vessels and port operations. **Over the last decade, maritime GNSS shipments have witnessed a 6% CAGR, from 1.0m units in 2010.**

Growth in international maritime trade stalled in 2019, reaching its lowest rate since the global financial crisis of 2008–2009. Until 2019, total gross tonnage witnessed a CAGR of 3% whereas the world merchant fleet has only grown by a CAGR of 1.9% as ships continue to become bigger in size.

Recreational navigation remains the largest market, totalling over 1.6m units shipped in 2020, up from 0.9m units in 2010. Maintaining the historical trend, the category of Ports applications which includes applications such as Portable Pilot Units (PPUs), saw the largest growth with a CAGR of 25% over this timeframe.

Augmented Reality (AR) can become a main digital tool for the Maritime sector

Once only available to military and professional users, **Augmented Reality** as a navigational aid is now becoming a reality for any ship-owner. Systems such as Raymarine's ClearCruise AR integrated with its Axiom chart plotters use real-time video to overlay a view of the horizon with AR markers, which highlight ships or buoys and display information such as their distance, identity and heading. AR eases the navigation by helping understand complex navigational situations and increase safety, especially in difficult meteorological conditions.

On top of this, AR provides real situational awareness, thus improving decision making via maintenance assistance for machinery and remote assistance from land offices. AR can also be used for training with real-world videos, when advanced technology equipment are introduced to the crew.

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In future, AR technology could be improved with AI-based object recognition features to tag ships which do not have AIS identification. By combining natural and digital experience, AR technology can revolutionise many maritime operational tasks.

Remotely assisted pilotage improves collision avoidance in busy waterways

Tugboats are key for the safe and efficient operation of ports and other busy waterways. They allow port masters to quickly spot potential hazards and divert traffic away from them to prevent collisions. New automation solutions are developed to enhance their capabilities, such as semi-automated remotely assisted pilotage to increase their efficiency of hazard detection, while enhancing safety. Further, Crowley Engineering Services developed and completed the design of the first fully autonomous electric tugboat for the US market. In Europe, Svitzer has remotely controlled a harbour tug using Kongsberg Maritime's bridge and dynamic positioning technology in several trials.

Moreover, the Hull to Hull (H2H) project developed a system that allows maritime vessels to navigate safely in close proximity to other vessels and to stationary objects, supporting decision-making and creating the fundamental conditions for autonomous maritime navigation. The project leverages EGNSS, particularly the accuracy offered by Galileo's dual frequency and multi-constellation capacity.


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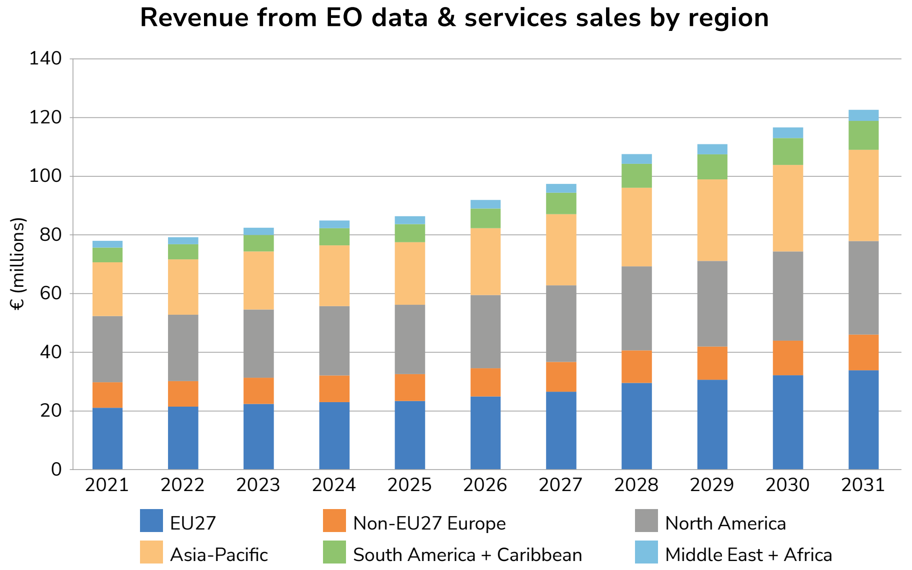
EO market is showing steady growth supported by public sector demand



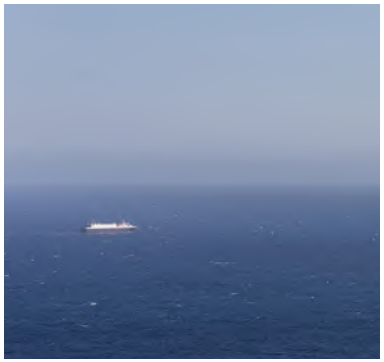
The total amount of EO data and services for the Maritime sector for 2021 accumulates to €78 million across the six main regions (Europe, non-EU Europe, North America, Asia Pacific, Latin America, Africa & Middle East) considered in this market report.

North America is the dominant region in the market segment, with generated revenues forecasted to grow from €23 m in 2021 up to €32 m in 2031. Market growth overtime in North America (CAGR of 4%) will be slightly below the one from Asia Pacific and Europe (both with a CAGR of 5%).

Europe represents the second largest market and will become the largest market over the coming decade: revenues will rise from €21 m in 2021 up to €34 m in 2031, corresponding to 28% of the total data and service sales. **The highest growth rate** over the next ten years in the market segment **will be registered in South America + Caribbean** (7% CAGR).

EO data revenues for the maritime sector are representing between 38% (2021) and 26% (2031) of the total revenues, data and services included. The customers of EO data are mainly public entities (mostly defence and coastguard agencies). Their demand is not likely to increase much over time, explaining why the growth in revenues for this market segment is lower compared to other segments.

Ship-route optimisation combines GNSS and EO for speed and efficiency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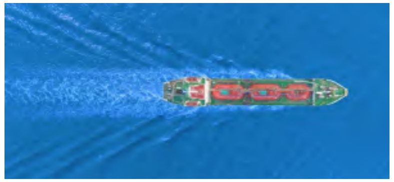
With the risk of congestion in ports, the importance of significantly shortened shipping time and the speed of container movements is growing in the shipping sector. This is leading to pressure on vessels to transport and return containers as quickly as possible. In addition, there is a focus on fuel efficiency to lower costs and reduce environmental impact.

Due to these pressures, the optimisation of ship routes for speed and fuel efficiency is more important than ever. **GNSS and Earth Observation can be combined to achieve higher levels of optimisation than previously possible. The Prepare Ships** project provides a robust and accurate navigation solution based on the features of Galileo signals and EO data, in combination with other in-ship sensors for full route optimisation, reduction in environmental impact of emissions and an overall increase in safety of operations.

EO and GNSS amongst the technologies needed to achieve Zero-Emission Shipping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Maritime shipping represents about 2-3% of the world's total annual greenhouse gas emissions (in turn this pollution is present in ports and can potentially affect nearby residents). Without immediate and concerted efforts, emissions from the sector could increase between 50% and 250% by 2050.

Denmark, Norway and US are leading the new **Zero-emission Shipping Mission**, aiming to accelerate the international public-private collaboration when it comes to scaling and deployment of green maritime solutions.

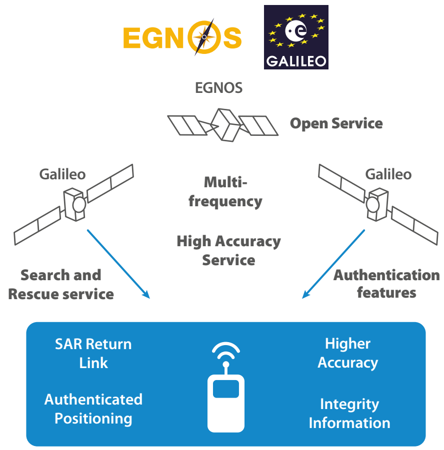
The ambition is to work on zero-emission international shipping via technological innovation such as the **combined use of EO and GNSS, usage of clean energy and leveraging international collaboration** (e.g. with Singapore, France, India and the UK). The main goals of the Mission are to develop, demonstrate and deploy zero-emission fuels, ships and fuel infrastructure in a coordinated way, taking into account the entire maritime value chain. The Zero-Emission Shipping Mission is part of Mission Innovation, a global initiative of 24 countries and the European Commission working to accelerate clean energy innovation.

Enhanced devices and advanced data for better performance in maritime activities

EGNSS services and features to be explored

GNSS authentication, both at data level and at range level, is important for the overall trustworthiness of the service. **OSNMA, as an integral part of Galileo OS,** will be a **data authentication** function available worldwide for free, which will protect from service disruption (jamming and spoofing) and incidents.

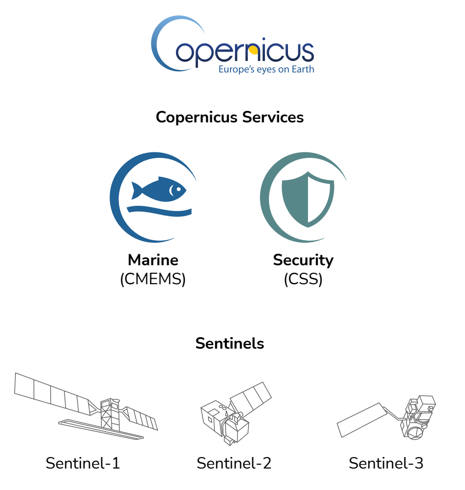
Galileo High Accuracy Service (HAS) will be gradually rolled out for the benefit of the Maritime sector. This will be useful specifically for Merchant Navigation and Pilotage operations in Ports, Inland Waterways, Offshore supply vessels with dynamic positioning, Autonomous Surface Vessels and others.



Current usage of Copernicus

EO has the ability to contribute to most of the main maritime activities as different products can be derived (e.g. maps, images, forecasts, etc.). EO data can complement EGNSS capabilities; for example, ship routing can be optimised with the availability of measurements of sea surface water, height, sea surface temperature, ocean currents and waves, thus aiding the development of current maps. EO data is used for shipping, ice navigation and costal management.

In the specific domain of inland waterway navigation (e.g. rivers, canals, etc.) the information on the water levels, provided also by Copernicus data, gives boat operators the needed insights to manoeuvre their boat through shallow or uncharted waters.



Fundamental Elements

ASGARD

Advanced shipborne Receivers to take advantage of all Galileo Open Service (OS) features

The ASGARD project was launched under the Fundamental Elements R&D funding mechanism supporting the development of EGNSS-enabled chipsets, receivers and antennas. It is a research project targeting de-development of shipborne double-frequency receivers. ASGARD focused on developing a multi-constellation and double frequency (E1/E5) maritime receiver that uses Galileo and that complies with European and International specifications. This receiver must implement the required algorithms to process OSNMA encrypted GNSS signals.

ASGARD shipborne receiver will take benefit of all Galileo OS features (improved performance and robustness thanks to dual-frequency and OSNMA capabilities), which in turn will ease the use of the Resilient PNT concept in maritime navigation.

More information on: https://www.asgard-project.eu/

HORIZON 2020

Prepare Ships

Resilient and smart positioning based on EGNSS and EO data for safer navigation

The 'PREPARE SHIPS' project develops a collaborative resilience navigation solution. It aims to develop and enhance existing software solutions by exploiting the distinguished features of the Galileo signals as well as combining it with other nautical information and sensor technologies. The accurate position of the solution is based on EGNSS, data and machine learning. The project is also using the Copernicus Marine Service Analysis and Forecast model products for wind, current and waves. The project is using eight EO products (one example being analysis-forecast outputs).

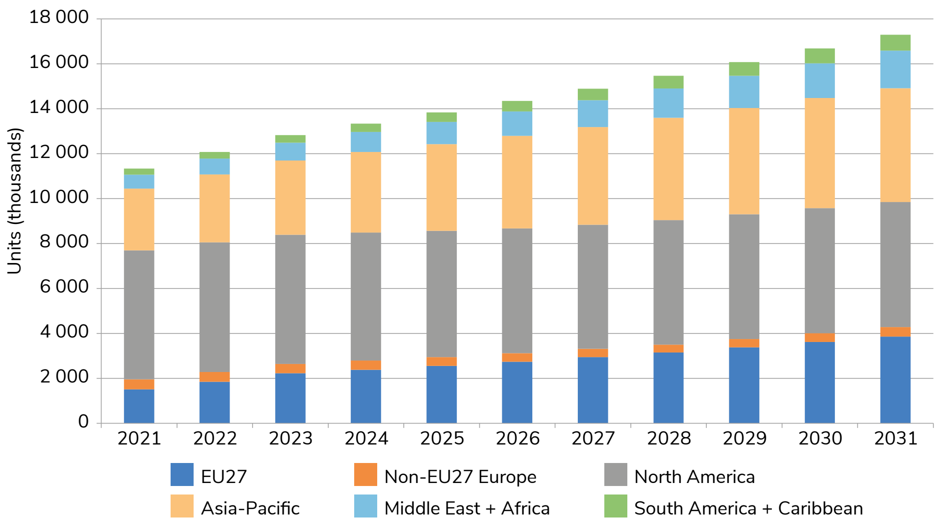
The benefits generated by this smart positioning solution are: reduction of the environmental impact (in line with IMO targets); prediction behaviour of vessels; decreased risk for collisions; and more energy-effective manoeuvring. Those potential benefits are of critical importance, taking into consideration the current challenges the industry is facing, including vulnerability of safety critical applications, increased automation and increased traffic.

To address these challenges, 'PREPARE SHIPS' is focusing on a support system covering EGNSS resilience positioning, Real time dynamic predictor, Ship-to-ship/ship-to-shore interaction and geo-fencing.

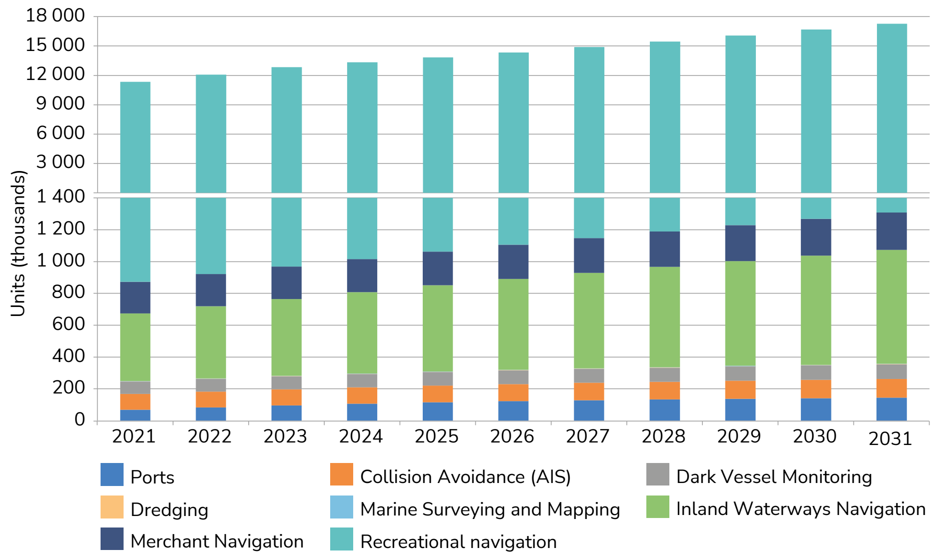
More information on: https://prepare-ships.eu/

Terminology used on this page is explained in Annex 2 for both GNSS and EO performance parameters.

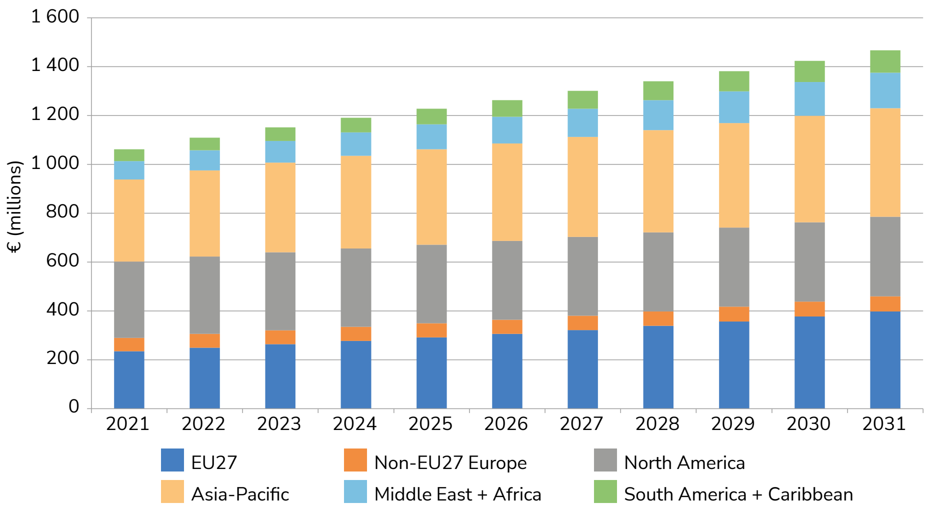
Installed base of GNSS devices by region



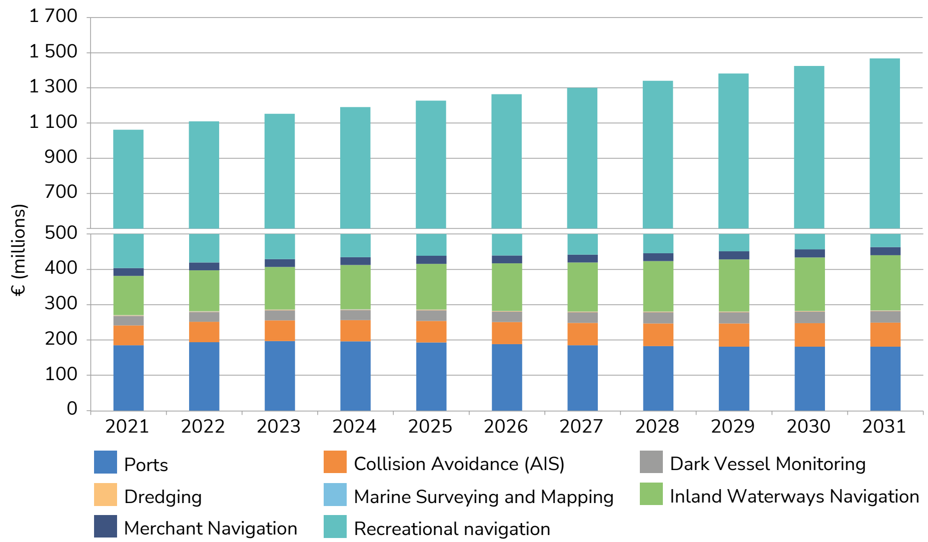
Installed base of GNSS devices by application

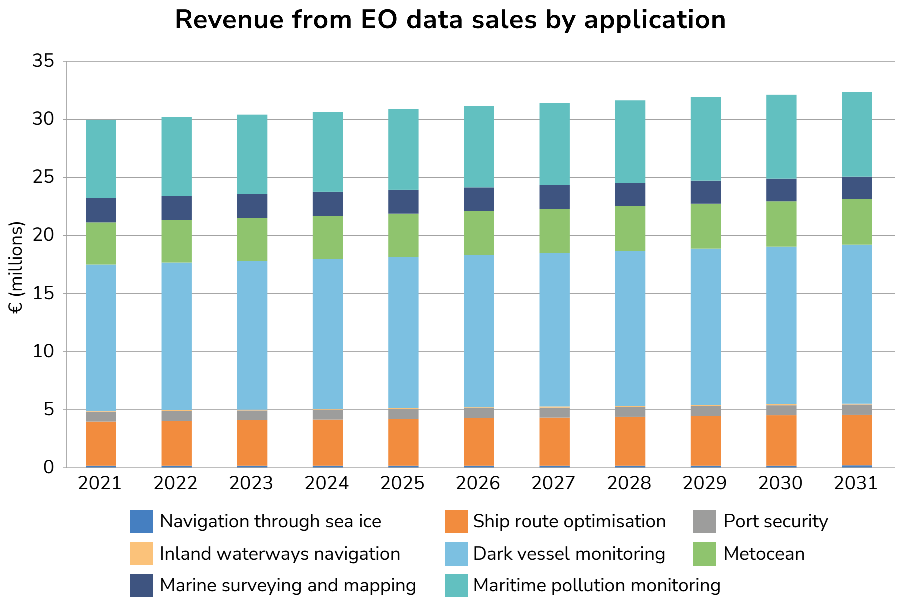


Revenue of GNSS device sales by region



Revenue of GNSS device sales by application




Revenue from EO data sales by application
€ (millions)
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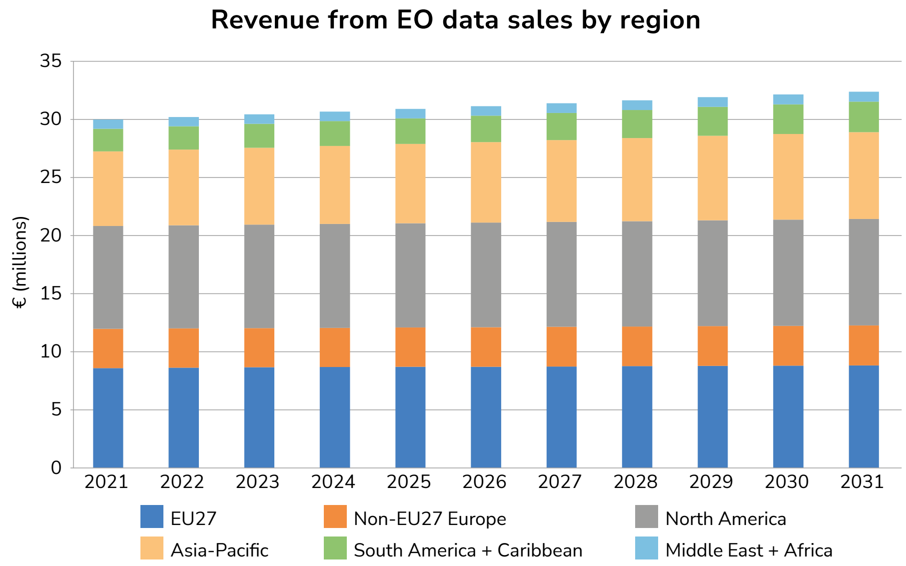
Navigation through sea ice
Ship route optimisation
Port security
Inland waterways navigation
Dark vessel monitoring
Metocean
Marine surveying and mapping
Maritime pollution monitoring


Revenue from EO data sales by region
€ (millions)
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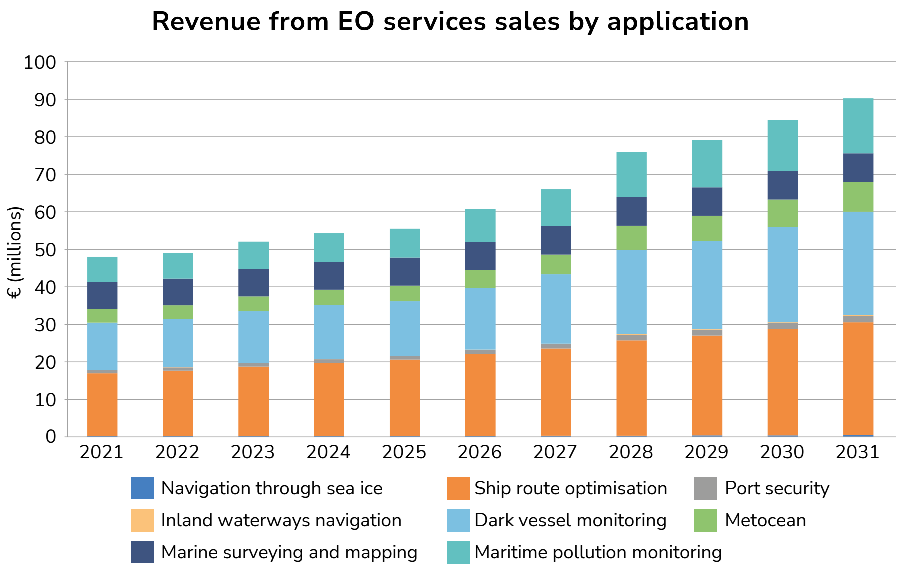
Asia-Pacific
South America + Caribbean
Middle East + Africa


Revenue from EO services sales by application
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Navigation through sea ice
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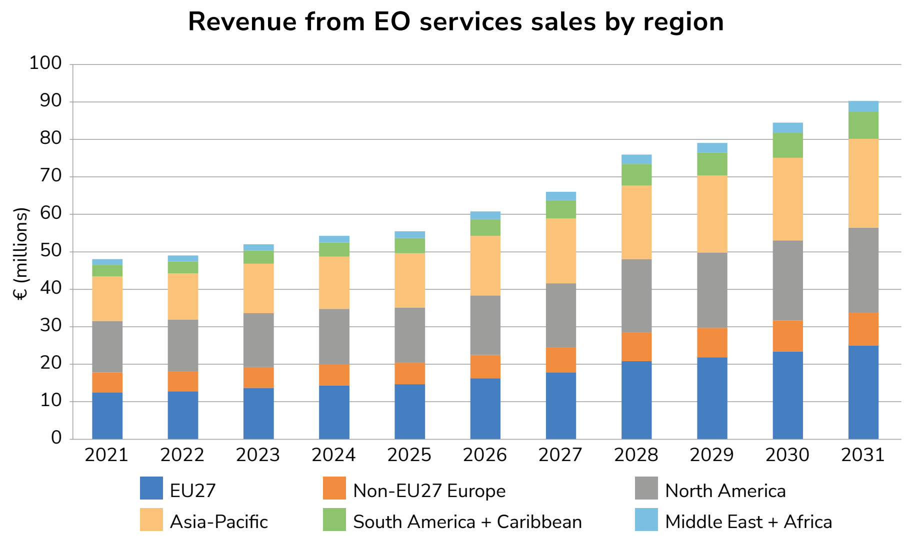
Revenue from EO services sales by region
€ (millions)
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2031
EU27
Non-EU27 Europe
North America
Asia-Pacific
South America + Caribbean
Middle East + Africa

RAIL

Legend

EO application

GNSS application

Synergetic application (combined use of EO and GNSS)

Attractiveness enhancement

- Passenger information systems
- Public Transport – Tram and Light Rail

Maintenance improvement

- Condition-based maintenance[1]
- Infrastructure monitoring[2]
- Predictive maintenance[1]

Safety related

- Enhanced Command & Control Systems
- Trackside personnel protection systems

Train driving optimisation

- Driver Advisory Systems (DAS)
- Fleet management[1]

[1] Fleet management, Condition-based maintenance and Predictive maintenance are non-safety related applications relying on the position of fixed and moving elements of the railway environment (from the infrastructure to the track-side equipment, and also rolling stock, wagons…). On the charts, these applications are grouped under the name "Asset management".

[2] Used to monitor trackside vegetation, landslide and track deformation

Application descriptions can be found in Annex 3.

RAIL

GNSS and EO serve the rail sector in many ways. First, GNSS plays a role in rail digitalization; from asset management to infrastructure monitoring and enhanced passenger information, GNSS is already largely deployed in non-safety critical applications. Moreover, a large number of initiatives are preparing for the introduction of GNSS in High- and Low-Density Command & Control Systems, paving the way for new train operations.

Furthermore, satellite-based imagery offers solutions around track deformation monitoring, vegetation encroachment detection and natural hazard risk assessments, leading to reduced needs for on-site inspections.

GNSS and EO therefore both increase safety and reduce the cost of infrastructure management and operations compared to legacy solutions. The number of global initiatives demonstrates the consideration given to GNSS and EO-based developments in Rail.

What you can read in this chapter

- **Key trends:** Satellite-based services contribute to transport use shifting towards rail.
- **User perspective:** New satellite-based services boost rail sector attractiveness and competitiveness.
- **Industry:** Rail GNSS Value Chain.
- **Recent developments:** The growth of the GNSS market goes hand in hand with the diversification of its usage.
- **Future market evolution:** A GNSS safety-related market is emerging.
- **European GNSS**: EGNSS is on track to integrate all kinds of train location-based applications.
- **Reference charts**: Yearly evolution of GNSS devices' installed base and revenues by application and region.

Satellite-based services contribute to transport use shifting towards rail

Key market trends

- GNSS plays an important role in many non-safety related applications, improving railway services through digitalisation
- The introduction of GNSS in future safety-related applications is expected to increase railway network capacity whilst decreasing operational costs
- Earth Observation (EO) services have great potential to enhance infrastructure monitoring at lower costs

Digitalisation is steering rail into a safer, more efficient and attractive segment

In order to increase rail efficiency and attractiveness, railway stakeholders are taking advantage of new digital and computer-based technologies to become increasingly user-centred and to improve passenger and freight management services.

GNSS is part of the digitalisation that is reflected in the development of new applications, allowing passengers to get real-time journey information and to reserve and to purchase tickets. These also aim to drive shipping back towards rail freight by proposing means to facilitate freight tracking.

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Railway operators and infrastructure managers benefit from digitalisation because it **improves asset management and maintenance, thereby reducing the operational costs.** A growing number of operators are deploying real-time remote diagnostics monitoring systems (e.g. SNCF Logistics with Traxens, DB Cargo, etc.). They collect various pieces of data such as the loading of wagons, within-wagon temperature and humidity, and the position and condition of cargo and rolling stock (which can subsequently be remotely controlled). Such data and its analysis will increase rail freight efficiency, allowing the planning of preventive maintenance actions with greater efficiency.

Digital transformation is also driven by the development of digital twins, particularly for the predictive maintenance of railway infrastructure and rolling stock and for predicting future incidents. These models are based on the collection of real data, some of which is provided by GNSS and EO services.

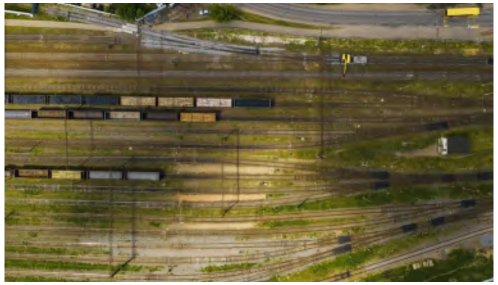
Enhanced infrastructure monitoring thanks to EO services

The maintenance of railway infrastructure is essential to **ensure the safety, efficiency, availability and reliability of railway operations.** Indeed, defects on tracks, catenary or signalling infrastructure can lead to traffic interruption or even derailments and accidents. Whereas classical infrastructure monitoring procedures rely on the use of measurement vehicles with dedicated runs, **new methods based on EO data provided by satellites or drones are being introduced.** The use of these technologies meets railway exploitation challenges and allows a global high-frequency monitoring capacity at lower costs.

Among the potential railway applications of EO, **vegetation supervision** is currently the most industrialised. For the last two years, some railway operators, such as SNCF or Deutsche Bahn, have been using very high-resolution optical Earth-imaging satellites to get large amounts of information on vegetation development along tracks. This data is used to assist vegetation management teams to operate more efficiently.

Moreover, industrial R&D projects are carried out to study the potential wide operational deployment of satellite-based synthetic aperture radar interferometry (InSAR) or LiDAR acquisition by drones. This application could be used to detect subsidence and monitor landslide risks over large areas with centimetre-level precision.

More information on Infrastructure Monitoring can be found in the Infrastructure segment.



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GNSS as part of the train signalling future

Ensuring the optimal train signalling system within European countries is a cornerstone of railway operations and is ensured by the European Rail Traffic Management System (ERTMS), which is the standard of European signalling. Through the adoption of the own-initiative procedure 2019/2191 (INI) in July 2021, the European Parliament highlights the need to take advantage of the **potential cost savings that GNSS offers in railway signalling.** Indeed, GNSS may be used to increase the capacity of the railway network by allowing the development of future train operations such as moving block or virtual coupling. These systems are evaluated with the aim of ensuring fail-safe train location and location integrity. For example, this allows a reduction in trackside location equipment such as the replacement of physical balises (beacons) with virtual ones, or the introduction of a multi-sensor data fusion algorithm to compute a continuous and accurate train position. However, the use of GNSS requires current railway regulations and operations to be adapted.

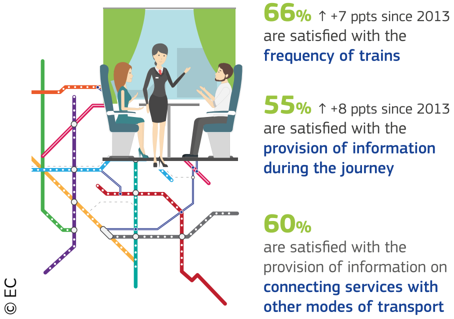
New satellite-based services boost rail sector attractiveness and competitiveness

Rail contributes to the European Green Deal

The European Commission recognises the benefits of **rail as a sustainable, smart and safe means of transport,** putting rail in the spotlight across the continent throughout 2021. Not only is rail exceptionally safe, it is also responsible for less than 0.5% of transport-related greenhouse gas emissions across the EU, making rail one of the most sustainable forms of passenger and freight transport.

To contribute to the EU Green Deal goal of becoming climate-neutral by 2050, railway use must increase.

GNSS is a key enabler for improving railway attractiveness

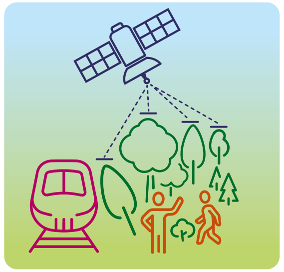


GNSS-based solutions can contribute toward Rail's goal of improving its attractiveness with the development of client services and professional applications.

Railway stakeholders benefit from **predictive maintenance** that allows the infrastructure managers to react before traffic interruptions occur, and from **asset management** that allows them to increase reliability, availability and efficiency alongside reducing operational cost. Overall this boosts the **attractiveness and competitiveness of the railway system.**

Passengers or freight customers benefit from location-based applications such as enhanced real-time information as well as door-to-door flexible services, leading to efficiency in terms of punctuality and competitive prices.

EO facilitates tackling vegetation issues along tracks



Large stretches of European tracks are located in areas with vegetation that has to be monitored in order to ensure the correct exploitation of the network. These surveillance operations represent one of the main areas of expenditure by railway operators, but vegetation issues still occur. For instance, trees falling onto tracks during storms has already brought a part of the German rail network to a standstill and led to over 830 train-vegetation collisions between 2015-2017, costing Deutsche Bahn millions of euros.

As a result, railways have a **substantial need to expand vegetation care** along their lines. This is a complex task given the need to examine millions of trees and plants along the vast railway networks. In order to tackle this challenge, European railway companies are taking advantage of **high-resolution optical Earth-imaging satellites,** such as Pleiades, **to improve vegetation monitoring at lower costs.** Images provided by these satellites contain key information – multi-band imagery is used at various resolutions to distinguish different vegetation types and network assets, stereoscopic imagery provides information on tree height estimations, and difference detection aims at identifying changes alongside the tracks.

This data can be used to optimise operations in monitoring ground vegetation in several ways. SNCF internally develops and uses technical solutions to inventory vegetation along its tracks, while Deutsche Bahn uses start-up solutions to identify trees that are particularly vulnerable to storms.

Key EO and GNSS user requirements

The key GNSS and EO user requirements for the different application groups within the **Rail** segment are, at EU level, collected using the following procedures:

- For GNSS, information is collected through extensive interactions with user groups, providers and experts in a continuous process culminating at the User Consultation Platforms (UCP). All relevant requirements are documented in detail and updated regularly within the Reports on user needs and requirements of respectively Rail and Public Transport.
- User requirements for Copernicus services and products – as well as their evolution – are collected through an integrated process that involves different channels: (i) dedicated studies (e.g. "NEXTSPACE" project, "Copernicus for EC (C4EC)" study, Commission Staff Working Document on user needs), (ii) targeted consultations organised by the European Commission or the Entrusted entities with the relevant communities, (iii) regular and structured exchanges among representatives of the Copernicus governance structure and Member States through the Copernicus User Forum.

From the 2022 EUSPA`s UCP onward, EO user needs and requirements of commercial users will be validated and discussed with industry experts and user groups, mirroring the process implemented for GNSS.

Rail GNSS Value Chain[1]

COMPONENTS AND RECEIVER MANUFACTURERS

- ANALOG DEVICES INC
- BEIJING BDSTAR NAVIGATION
- BROADCOM
- COMNAV TECHNOLOGY LIMITED
- CORE CORPORATION
- GLARUN TECHNOLOGY
- GMV*
- HITACHI
- LANNER ELECTRONICS INC.
- NOTTINGHAM SCIENTIFIC LIMITED*
- OHB SE*
- SATEL OY*
- SEPTENTRIO*
- ST ELECTRONICS
- THALES*
- TRIMBLE NAVIGATION
- U-BLOX*

SYSTEM INTEGRATORS

- ALSTOM TRANSPORT*
- AZD PRAHA*
- CAF*
- CATERPILLAR INC.
- CRRC CORPORATION LIMITED
- GMV*
- HITACHI
- INTERMODAL TELEMATICS
- KAWASAKI
- KINTETSU RAILCAR ENGINEERING
- MITSUBISHI
- SIEMENS*
- SOCIEDAD IBERICA DE CONSTRUCCIONES ELECTRICAS*
- ST ELECTRONICS
- THALES*
- VTG AKTIENGESELLSCHAFT*
- WABTEC
- XIAMEN YAXON NETWORK

TRAIN MANUFACTURERS

- ALSTOM*
- CAF*
- CHINA SOUTH LOCOMOTIVE AND ROLLING STOCK
- HITACHI
- SIEMENS*
- STADLER RAIL AG
- WABTEC

TRAIN OWNERS / OPERATORS

TRAIN AND FREIGHT OPERATING COMPANIES:

- ARRIVA*
- COLAS*
- DEUTSCHE BAHN*
- RENFE*
- SBB*
- SNCF*
- STAGECOACH*
- TRENITALIA*
- URBAN TRANSPORT OPERATORS

ROLLING STOCK OPERATING COMPANIES:

- CONSORTIA
- INVESTMENT BANKS
- NATIONAL COMPANIES

INFRASTRUCTURE MANAGERS

- ADIF*
- DEUTSCHE BAHN*
- INFRAESTRUTURAS DE PORTUGAL*
- NETWORK RAIL*
- RFI*
- SBB*
- SNCF*
- URBAN TRANSPORT OPERATORS

European[2] GNSS industry in the global arena

The bulk of the rail industry is spread across Europe, Asia/Russia and North America, considering components and receivers as well as system integrators.

Over the past two years, European companies have had a **stable market share of around 15%** among components and receivers manufacturers, whilst the market is largely being dominated by North Asian companies – Hitachi alone have almost 50% of the worldwide market share. European GNSS system integrators, led by Alstom Transport and Siemens, generated 36% of the turnover in 2019, trailing behind North America (41%).

LEGEND

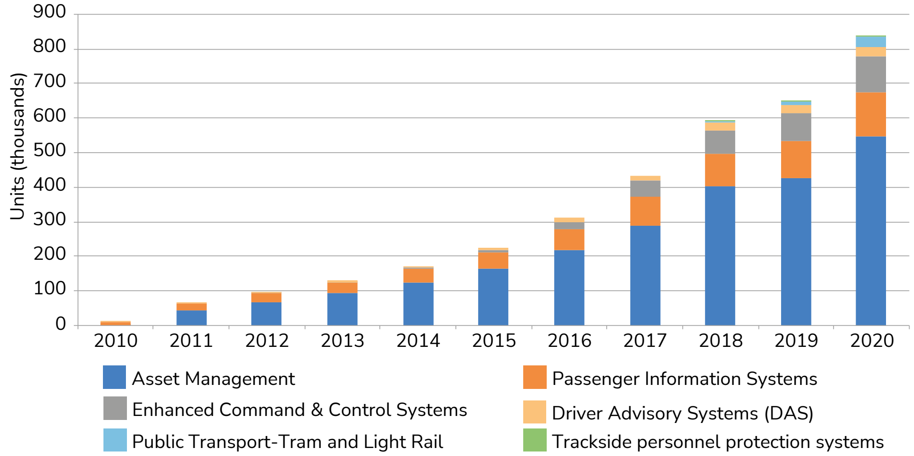
- Commercial Offering
- User segments

NOTES

[1] The value chain considers the key global and European companies involved in GNSS downstream activities.
[2] In the market share analysis, Europe is defined as EU27 plus Norway, Switzerland and the UK.
* European-based companies. The region is defined with respect to the headquarters of the company, though the actual area of activity might be wider.

The growth of the GNSS market goes hand in hand with the diversification of its usage

Installed base of GNSS devices by application



Non-safety applications are the main use of GNSS

The installed base of GNSS receivers mainly consists of GNSS integration in **non-safety critical** applications, highlighting the importance of these satellite-based systems in rail development and digitalization since 2011. Indeed, around 60% of GNSS receivers are integrated in asset management and 20% in passenger information systems respectively.

With this recent growth comes the diversification of sectors and applications in which GNSS is used. For instance, the Driver Advisory System is an emerging market segment. Increasing numbers of Tram and Light Rail operators are taking advantage of GNSS to facilitate their activities and enhance passenger services.

The growing importance of safety related applications in the GNSS market

Primarily since 2016, GNSS devices have started to be integrated into enhanced Command & Control Systems. Even though GNSS receivers intended for such applications only represent 15% of the shipments, the revenue generated by them is disproportionately large because these receivers are much more expensive than those used in non-safety critical applications.

Moreover, since 2018 GNSS has been used to ensure trackside personnel protection. This market is expected to grow mainly in the European and North African regions.

A first certified data fusion algorithm using GNSS for fail safe train location

Train location is a key element in enhancing railway capacity and fostering new concepts within the sector. **Use of GNSS** to compute train location may improve position accuracy and integrity at the same time as decreasing operational costs by reducing the need for trackside equipment. However, in a railway environment with tranches, vegetation and urban buildings, GNSS may suffer from performance degradation regarding accuracy or availability. In order to improve train positioning performances, multi-sensor architectures and data fusion algorithms are essential, and have been investigated in several R&D projects (see projects in section on European GNSS).

In June 2020, Alstom was certified to implement its data fusion algorithms using both GNSS and inertial movement in a new odometry system to accurately and safely measure the location and speed of trains. It is one of the first safety-related GNSS applications within railway signalling.

EGNSS empowers urban public transport efficiency

As a cornerstone of urban development plans, public transport needs constant improvement. Tramway and light rail can take advantage of GNSS technology to facilitate operators' activities and enhance passenger services. In this context, **EGNSS** constitutes an essential enabler for GNSS-based applications. This is because it **improves location performance in urban environments,** thanks to the introduction of multi-constellation, multi-frequency and mitigation of multipath capabilities.

Prague Public Transit Company (DPP) has decided to modernise its tram fleet by replacing GPS-only receivers with Galileo-enabled multi-frequency and multi-constellation receivers. Tests that have been carried out have shown that it could allow tram location accuracy down to 1.5 metres. This will be used to improve the user experience by providing enhanced real-time data about tram departures. Furthermore, this will reduce operational costs by improving maintenance and tram on-board systems (e.g. automatic speed limitation over switches).

Dopravní podnik hlavního města Prahy

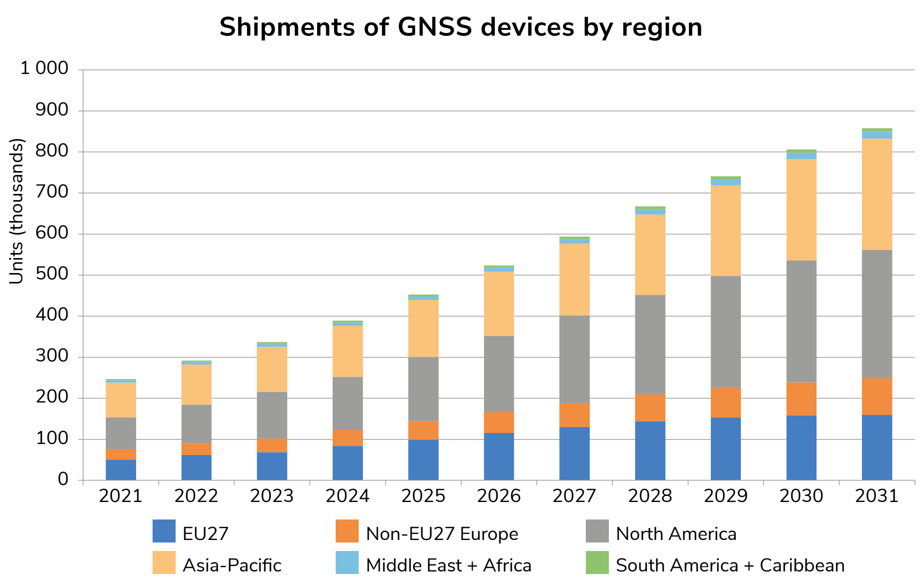
Validation tools for fail-safe location systems - Gate4Rail/Sim4Rail

The development of fail-safe location systems must be accompanied by the development of validation tools. Due to safety needs and the complexity of the railway environment, stakeholders require highly controllable laboratory tools. Some developments are supported by the Shift2Rail programme (Gate4rail project) and ESA (Sim4Rail project). The testbeds developed intend to simulate the behaviour of these future solutions under both nominal and extreme conditions.

More information on: https://gate4rail.eu/home.aspx and https://space4rail.esa.int/projects/sim4rail

[1] **Fleet management, Condition-based maintenance and Predictive maintenance** applications are grouped under the label **Asset Management**.

A GNSS safety-related market is emerging



GNSS to figure in future Technical Specifications for Interoperability

The Technical Specifications for Interoperability (TSI) are prepared by the European Railway Agency and adopted in a Decision by the European Commission, to ensure the interoperability of the trans-European rail system. They define the technical and operational standards, which must be met by each subsystem or part-subsystem in order to meet essential requirementas and ensure interoperability.

Satellite location, as a game-changing technology underpinning future evolutions of the ERTMS system, will have to be included in future TSI. On-going actions are investigating how to include GNSS, but also how to ensure the on-board availability of EGNOS correction data in ETCS through the EURORADIO.

A growing market over the world

GNSS receiver shipments are expected to increase significantly over the next decade. Indeed, the current 250,000 yearly shipments of GNSS receivers could exceed 800,000 units in 2031. Such growth highlights the importance of GNSS in rail sector development.

Significant differences in market dynamics between regions

GNSS market growth is uneven across regions. Worldwide GNSS shipment **growth is mainly driven by North America and Asia-Pacific.** Yearly shipments in these regions represent around three-quarters of the number of worldwide shipments. The remaining quarter is almost entirely comprised of the European market.

In contrast, while the forecast shows an incipient GNSS market in the Middle East, Africa, South America and the Caribbean, it nevertheless highlights the railway development divide between these regions and the regions driving future growth.

Autonomous Train development needs GNSS accuracy and integrity

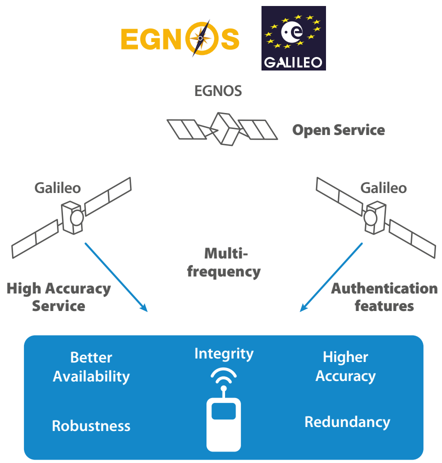
Train operation is on the path towards automation. **Automation will help the railway sector to boost its attractiveness** by improving its capacity, punctuality, reliability, energy efficiency, flexibility, safety and cost effectiveness. The first automated trains are expected in early 2023, with driverless trains for passenger operations and unattended trains for shunting operations.

Automation is highly challenging in open railway environments because of the complexity of the system and environments, as well as the variety of trains, operations or stakeholders involved. To face such challenges, **location data is required with strong accuracy and integrity requirements** in order to ensure, among other complementary functions, automatic driving or obstacle detection. Automation is likely to mean an improvement to radio communication, the evolution of signalling, and the development of train control applications to become more modular and less expensive.

Drones as a future tool for rail asset management

With the development of drones, new railway applications can be envisioned. First of all, projects such as RADIUS (EUSPA) or In²Smart (Shift2Rail) study the potential of **drones being used to inspect railway catenary lines** and other vital aspects of railway infrastructure, such as the alignment of tracks and switching points. These activities are currently performed by humans and are highly demanding in terms of personnel labour costs and operational constraints. The use of drones will allow these **inspections** to be performed more regularly with improved safety, reliability and punctuality of the service, all while reducing operational costs. Drones can also be used to provide additional information to satellite-based observations. For instance, the possible use of drone LiDAR data to detect signs of landslides is being studied.

EGNSS is on track to integrate all kinds of train location-based applications



Added value brought by EGNSS

Railway users (freight customers or passengers) benefit from direct EGNSS services with train tracking or enhanced passenger information applications. Stakeholders also benefit from EGNSS for system operations, such as better asset management and new cost-effective sensors for enhanced odometry.

Galileo-enabled receivers already serve millions of passengers using SNCF high-speed trains (TGV) with the provision of enhanced services (e.g. real-time, precise train location information in stations). Furthermore, GNSS receivers are currently used to track rolling stock (more than 50,000 freight wagons of multiple EU railway undertakings are already equipped with GNSS-based telematic solutions).

EGNSS services and features to be explored

The on-going development of fail-safe applications involves the investigation of the multi-frequency potential of EGNSS for more availability, accuracy and integrity.

Although the refinement of the railway users' specific needs and requirements is progressing, there is some concern on how an EGNSS-based safety service must be tailored to answer these requirements.

The High Accuracy Service (HAS) and authentication features could support an attractive and robust localization solution for the future digital rail agenda.

HORIZON 2020

Development of an EGNSS-based safety service for rail - EGNSS-R and IMPRESS projects

In order to assess the feasibility of an EGNSS-based safety service improving the efficiency of train localisation within the future ERTMS evolution, two mission evolution studies, named EGNSS-R and IMPRESS, were launched in 2020 under H2020. The main challenge of these studies is to provide an appropriate integrity concept definition associated with the EGNSS service.

First of all, an analysis has been performed in order to identify user needs, service performances, operational requirements and safety and legal requirements. Based on this information, an EGNSS-based rail safety service, including a user-level integrity concept, has been defined. The success criteria of this new service has been analysed, focusing on actions that will be taken to influence the decision-making process of railway stakeholders. The next step will focus on aspects of service implementation to prepare its operational introduction and adoption by service providers and users.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These activities involve key railway stakeholder reviews along the development process.

HORIZON 2020

Integration of EGNSS in multi-sensor localisation units - CLUG and HELMET projects

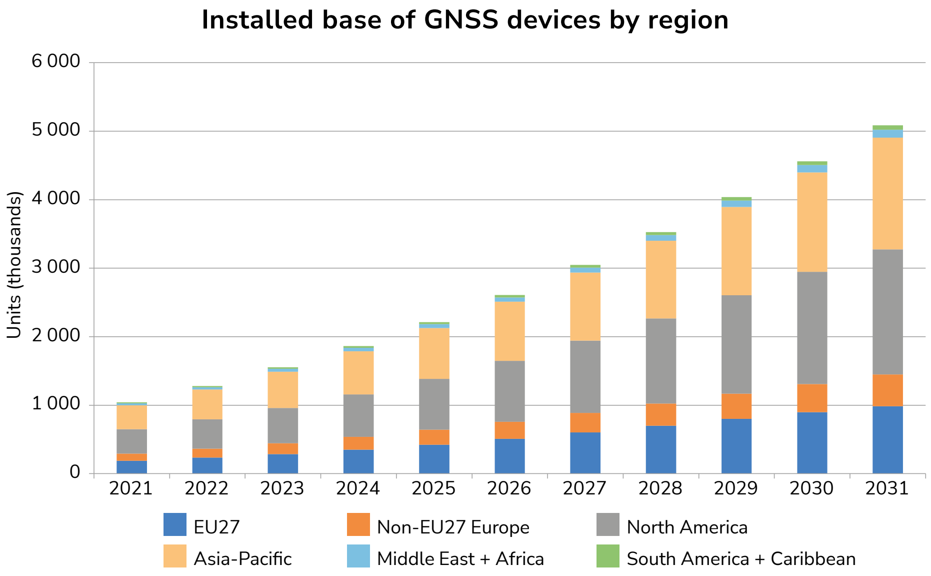
To use EGNSS for rail safety applications such as signalling, sensor data fusion will be necessary to mitigate the known impact of local effects on GNSS performances. Two studies under H2020 have been launched to investigate this topic.

The CLUG project has developed a proof-of-concept of an on-board continuous and safe localisation unit providing information on the train's position, velocity and acceleration. This localisation unit may be useful in replacing or enhancing the existing on-board equipment, such as odometry and balise readers. The cost of trackside equipment should therefore decrease whilst new railway concepts are fostered, such as the moving block for ERTMS.

The HELMET project has developed an augmentation and integrity monitoring platform for rail and road, given that railways and highways are often close to each other and share the same electromagnetic environment and similar requirements. A multimodal architecture has been designed, using Satellite-Based Augmentation Systems (SBAS) and Galileo services, to support a high integrity and high accuracy positioning service.

More information on: http://clugproject.eu/en and https://www.helmet-project.eu/

Terminology used on this page is explained in Annex 2 for both GNSS and EO performance parameters.


Installed base of GNSS devices by region
Units (thousands)
6 000
5 000
4 000
3 000
2 000
1 000
0
2021
2022
2023
2024
2025
2026
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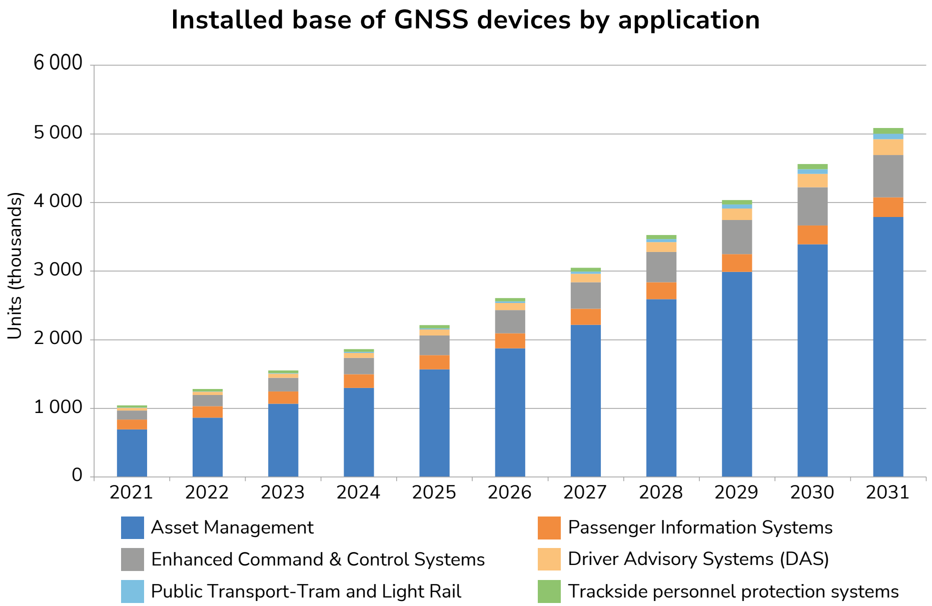
EU27
Non-EU27 Europe
North America
Asia-Pacific
Middle East + Africa
South America + Caribbean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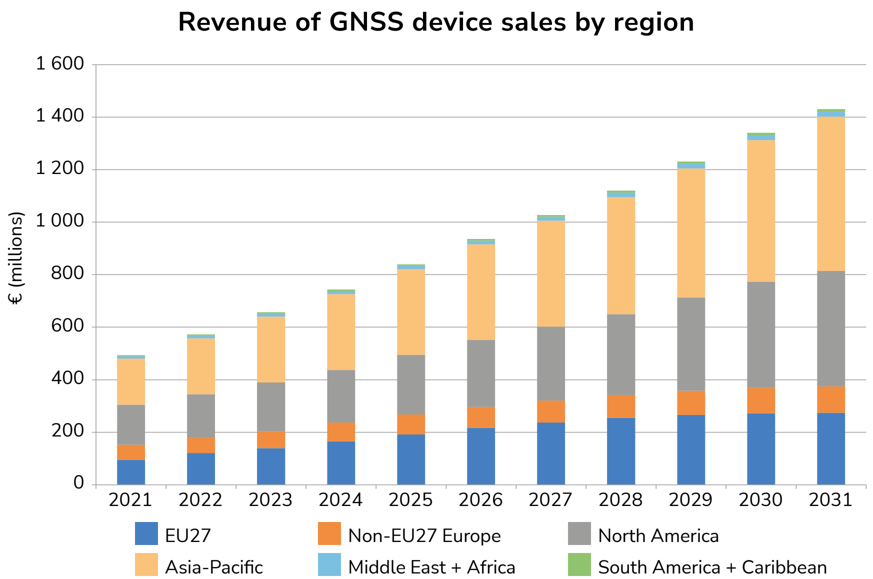
Asset Management
Passenger Information Systems
Enhanced Command & Control Systems
Driver Advisory Systems (DAS)
Public Transport-Tram and Light Rail
Trackside personnel protection systems


Revenue of GNSS device sales by region
€ (millions)
1 600
1 400
1 200
1 000
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200
0
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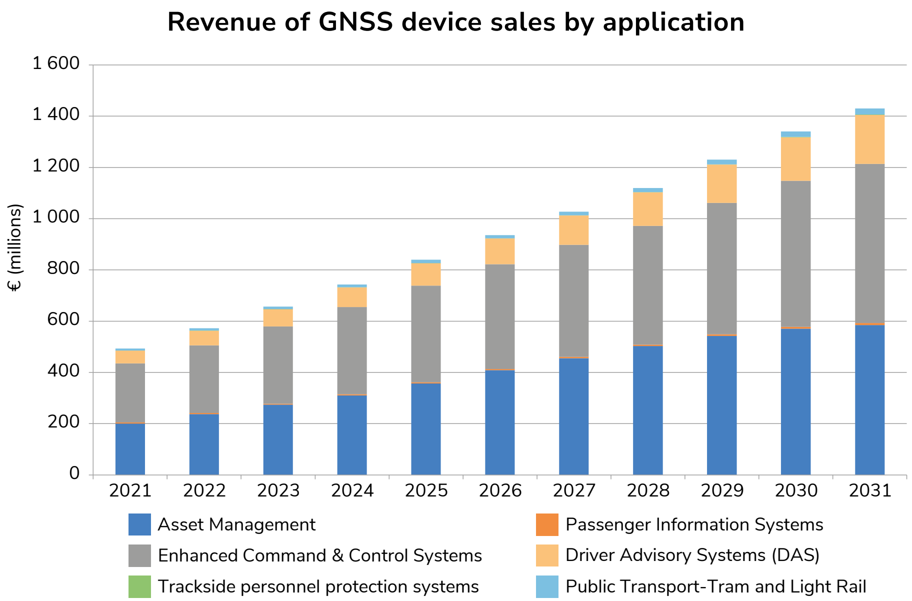
EU27
Non-EU27 Europe
North America
Asia-Pacific
Middle East + Africa
South America + Caribbean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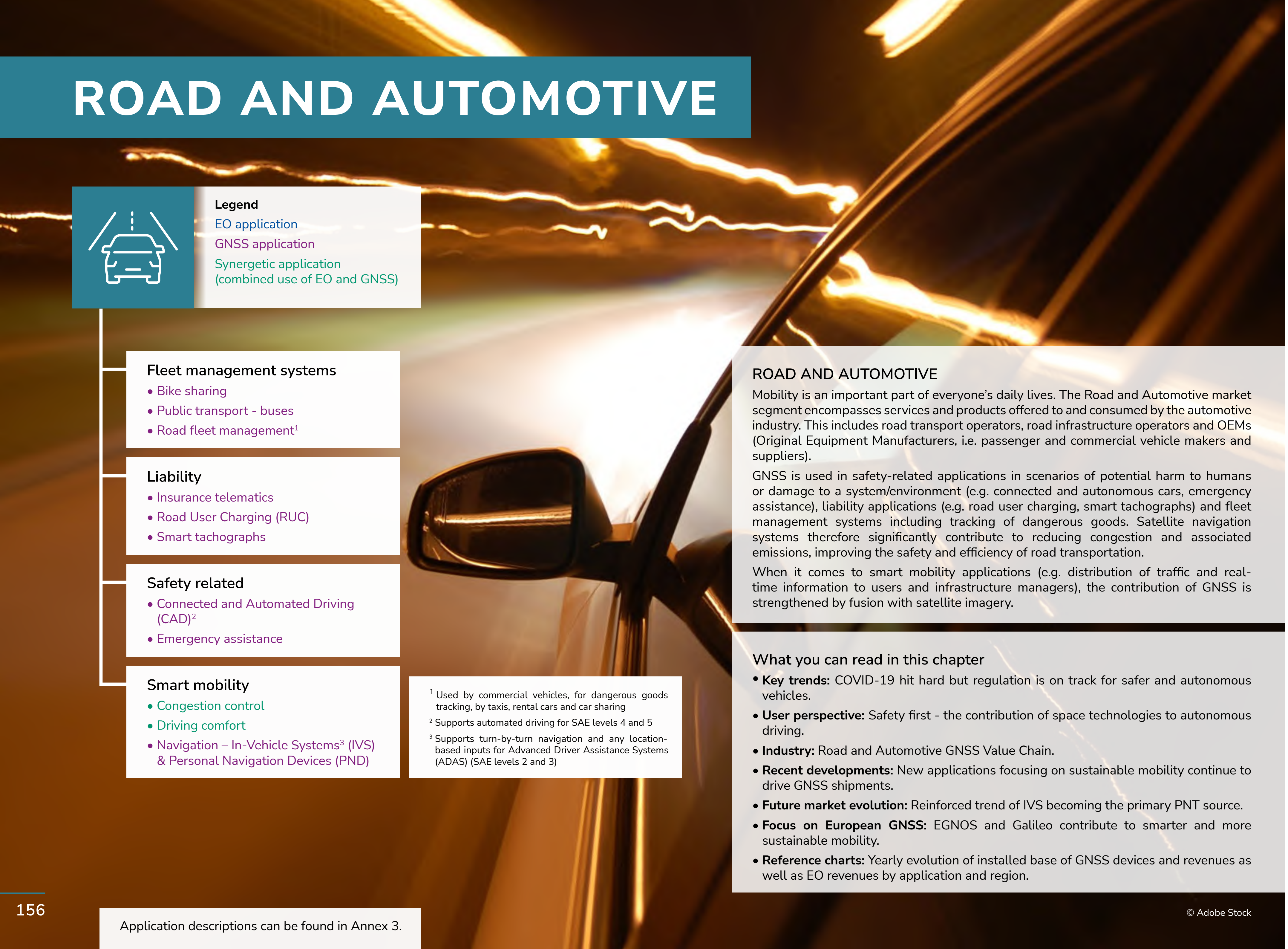
ROAD AND AUTOMOTIVE



Legend
EO application
GNSS application
Synergetic application (combined use of EO and GNSS)

Fleet management systems
- Bike sharing
- Public transport - buses
- Road fleet management[1]

Liability
- Insurance telematics
- Road User Charging (RUC)
- Smart tachographs

Safety related
- Connected and Automated Driving (CAD)[2]
- Emergency assistance

Smart mobility
- Congestion control
- Driving comfort
- Navigation – In-Vehicle Systems[3] (IVS) & Personal Navigation Devices (PND)

[1] Used by commercial vehicles, for dangerous goods tracking, by taxis, rental cars and car sharing

[2] Supports automated driving for SAE levels 4 and 5

[3] Supports turn-by-turn navigation and any location-based inputs for Advanced Driver Assistance Systems (ADAS) (SAE levels 2 and 3)

ROAD AND AUTOMOTIVE

Mobility is an important part of everyone's daily lives. The Road and Automotive market segment encompasses services and products offered to and consumed by the automotive industry. This includes road transport operators, road infrastructure operators and OEMs (Original Equipment Manufacturers, i.e. passenger and commercial vehicle makers and suppliers).

GNSS is used in safety-related applications in scenarios of potential harm to humans or damage to a system/environment (e.g. connected and autonomous cars, emergency assistance), liability applications (e.g. road user charging, smart tachographs) and fleet management systems including tracking of dangerous goods. Satellite navigation systems therefore significantly contribute to reducing congestion and associated emissions, improving the safety and efficiency of road transportation.

When it comes to smart mobility applications (e.g. distribution of traffic and real-time information to users and infrastructure managers), the contribution of GNSS is strengthened by fusion with satellite imagery.

What you can read in this chapter

- **Key trends:** COVID-19 hit hard but regulation is on track for safer and autonomous vehicles.
- **User perspective:** Safety first - the contribution of space technologies to autonomous driving.
- **Industry:** Road and Automotive GNSS Value Chain.
- **Recent developments:** New applications focusing on sustainable mobility continue to drive GNSS shipments.
- **Future market evolution:** Reinforced trend of IVS becoming the primary PNT source.
- **Focus on European GNSS:** EGNOS and Galileo contribute to smarter and more sustainable mobility.
- **Reference charts:** Yearly evolution of installed base of GNSS devices and revenues as well as EO revenues by application and region.

Application descriptions can be found in Annex 3.

COVID-19 hit hard but regulation is on track for safer and autonomous vehicles

Key market trends

- COVID-19 is impacting global car production and sales, slowing down industry plans and uptake of GNSS
- With the ongoing shift towards added-value services and the vehicle as a platform, the industry accelerates its commitment to sustainable transport (e-mobility) in response to the Green Deal objectives
- Safer and more sustainable transport in urban environments will integrate autonomous vehicles, demanding improved robustness and availability of GNSS
- Safety regulation will further broaden the reach of GNSS in the European automotive market

COVID-19 impacting global car production and sales, slowing uptake of GNSS

Initially, COVID-19 containment measures affected **production** of both passenger and commercial vehicles. The plunge in **sales** that followed reflects the economic downturn triggered by the pandemic with **10-27% contractions** of vehicle sales in China and other markets recorded in 2020. Forecasts indicate that vehicle sales are unlikely to return to pre-COVID levels **until 2023.**[1] When it comes to implementing regulation, despite the initial delay of the type approval for **eCall, no impact** was observed over the year 2020.

Besides production, COVID has influenced our use of transport with significant reductions in traffic volume (passenger transport and private vehicle traffic) registered during and post-confinement. Nevertheless, the road freight sector continued to secure essential supplies throughout the emergency situation. Here, the **'Galileo Green lanes'** app played an important role in easing traffic pressure at borders by providing better monitoring of transport flows for an efficient transit of critical goods. The prompt and cost-efficient implementation of the app was possible due to the widespread adoption of fleet management systems, with the majority of information collected from in-vehicle units located in trucks and made available through mobile devices.

Green Deal calls for more sustainable mobility and transport efficiency

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Efficiency across the whole transport system is essential. European GNSS, including EGNOS, is making everyone's life on the road easier by significantly reducing congestion and consequently CO_2 pollution, improving the efficiency of road transportation through navigation, fleet management opportunities and satellite road traffic monitoring.

EGNSS impact will be especially strengthened by important future developments including **automated mobility and smart traffic management systems, smart applications and 'Mobility as a Service'** where Galileo is expected to deliver new accuracy and reliability for location-dependant services to enhance urban mobility.

[1] The China automotive industry recovering fast from the pandemic: Aion, Xpeng and Hongqi car brands have relaunched level-4 models enabled by Galileo.

Autonomous and connected mobility: industry slowing down race to levels 4 and 5 ...

The automotive industry continues its activity, albeit at a slower pace as a result of the pandemic. Car models released in 2020 have been confirmed and committed the year before. Therefore a **one year lag** is expected for the COVID impact to be visible with fewer type approval applications.

COVID has also scaled down the sector's future plans and investments, including the development of driverless car technology. The pandemic is expected to delay the deployment of level 4 models at least by 1 year. This includes BMW Group and Mercedes-Benz AG putting their joint development of autonomous driving technology on hold, a collaboration which set out to introduce autonomous driving (up to level 4) on passenger cars from as early as 2024. OEMs such as Daimler announced withdrawal from level 5 autonomy development altogether, preferring instead to focus on Level 4 automation in commercial vehicles. Finally, Ford's ambitious plan to launch a fleet of robo-taxis by 2021 was pushed back until at least 2022.

... yet on track with safety regulation

The European revised **General Safety Regulation** entered into force on 5 January 2020. From July 2022, new types of vehicle models introduced on the European market will be equipped with advanced safety features, such as intelligent speed assistance, technology to detect drivers' drowsiness and distraction, improved impact zones to mitigate the risk of injury to pedestrians and cyclists, systems reducing dangerous blind spots on trucks and buses and data recording technology. Features improving the safety of road transport that will be able to take advantage of Galileo include:

- **Intelligent speed adaptation,** set automatically as a function of the speed limits indicated on the road and **automatic lane keeping** system independent of weather and the condition of lane markings;
- **Event (accident) data recorders,** where vehicles equipped with blackboxes recording location are linked with the eCall system in case of accident, while also influencing driving behaviour in relation to insurance costs (telematics based policies);
- **Alcohol interlock,** which would prevent driving with excess alcohol (with limits varying between countries) by requiring the driver to blow into an in-car breathalyser before starting the ignition.

Safety first - the contribution of space technologies to autonomous driving

V2X use cases are critically dependent on accurate time and position data

Robustness and availability are key GNSS requirements for forward-looking vehicle-to-everything (V2X) communication and automated driving technology. Continuous lane-accurate positioning is seen as an important milestone in the expansion of autonomous capability and situational awareness. The most important value added is safety achieved through redundancy (where GNSS-based lane determination acts as an independent source to supervise the vision-based systems) and alleviating tasks from the perception system (which can focus on changing surroundings). In such a way incorporating precision GNSS into LiDAR-based systems can unlock robustness and additional fallbacks for safety and utility, while high-integrity GNSS lane determination integrated into vision-based architectures can unlock lane-level manoeuvres and provide oversight to guarantee safety.

V2X is a communications technology for smart infrastructure, the exchange of information between vehicles helps avoid accidents, and information exchanges to road infrastructure in order to improve traffic efficiency. As autonomous vehicles will target operating beyond specific routes and cities, GNSS can emerge as a global standard to ensure interoperability across autonomous systems and act as a common reference for precise position and time information.

Key EO and GNSS user requirements

The key GNSS and EO user requirements for the different application groups within the **Road and Automotive** segment are, at EU level, collected using the following procedures:

- For GNSS, information is collected through extensive interactions with user groups, providers and experts in a continuous process culminating at the User Consultation Platforms (UCP). All relevant requirements are documented in detail and updated regularly within the Reports on user needs and requirements of respectively Road and Public Transport.
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From the 2022 EUSPA`s UCP onward, EO user needs and requirements of commercial users will be validated and discussed with industry experts and user groups, mirroring the process implemented for GNSS.

High performance GNSS paves the way towards autonomous driving

Autonomous driving is among the most demanding road applications as its high accuracy requirement must be coupled to a high level of integrity. Reaching accuracies and integrity performance metrics simultaneously is enabled by GNSS receivers that can utilise data received from a sufficient number of satellites and correction services. Various industry players are developing Autonomous Driving Systems (ADS), relying on a range of sensors including GNSS for absolute localisation, HD maps, LiDAR, radar and Internal Measurement Units (IMUs). With ongoing trials, the emerging approach is that GNSS is a key component of the sensor fusion system contributing to the safety of autonomous systems. This is the case for Navya, who reached a new milestone with its level 4 fully autonomous shuttle (tested without an operator on board) and VW who plan to roll out a first fleet of self-driving test cars in Hefei (China). Similarly, this combination of sensors in Sensible 4's autonomous driving software allows operation in various weather conditions and environments. Its performance will be tested in the north of Europe, together with Ruter and Holo, on Toyota vehicles to explore the integration of AVs into public transport service and new mobility services. In such a way GNSS continues to play a key role in the development of ADS with robustness (integrity) and availability as key requirements.

A unified view of road conditions: the EO contribution to road safety

With 80% of the world's road network not paved, road networks tend to be particularly vulnerable to environmental, weather and vehicle-related damage with direct impact on its users. Inferred to connected cars with autonomous driving features, Copernicus data can support drivers in remote areas and on roads affected by meteorological conditions.

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The start-up Bareways combines different data sources (e.g. ground sensors, Sentinel data, historical data) in a mobility platform to give users a unified view of specific road conditions (thus helping avoid risks, delays and fatal incidents).

Current road condition information will be made available to the vehicle navigation system, together with other criteria for route planning and optimisation such as vehicle type, load fragility and driver safety needs. The platform is expected to boost e-mobility applications by suggesting routes depending on battery charge status and possibilities for regenerative braking.

Road and Automotive GNSS Value Chain[1]

SYSTEM INTEGRATORS

COMPONENTS AND RECEIVER MANUFACTURERS

- ANALOG DEVICES
- BEIJING BDSTAR NAVIGATION
- BOSCH*
- BROADCOM
- CONTINENTAL*
- FURUNO ELECTRIC CO
- GARMIN
- HERE*
- HEXAGON*
- HIRSCHMANN*
- JAPAN RADIO CO
- KATHREIN-WERKE KG*
- LAIRD*
- MEDIATEK
- NXP SEMICONDUCTORS*
- ORBCOMM
- PULSE ELECTRONICS
- QUALCOMM
- STMICROELECTRONICS*
- TE CONNECTIVITY*
- TOMTOM*
- TRIMBLE NAVIGATION
- U-BLOX*
- VALEO*

TIER 1 SUPPLIERS

- ACTIA*
- ALPINE
- BOSCH*
- CONTINENTAL*
- DENSO
- FICOSA*
- GEMALTO (now part of THALES)
- PIONEER
- SIEMENS*
- STONERIDGE
- VALEO*

HD MAP PROVIDERS

- GOOGLE
- HERE*
- TOMTOM*

VEHICLE MANUFACTURERS

- BMW*
- CHINA FIRST AUTOMOBILE GROUP CORPORATION
- DAIMLER*
- FCA (FIAT CHRYSLER AUTOMOBILES)*
- FORD
- GM
- HONDA
- HYUNDAI
- MAZDA MOTOR
- NISSAN
- PEUGEOT-CITROEN*
- RENAULT*
- SUBARU
- SUZUKI
- TATA MOTORS
- TOYOTA
- VOLKSWAGEN*
- ZHEIJIANG GEELY HOLDING

AFTERMARKET DEVICE VENDORS

- GARMIN
- MAGNETI MARELLI*
- MASTERNAUT*
- OCTO TELEMATICS*
- TOMTOM*
- TRAKM8*
- WABCO

SERVICE PROVIDERS

MOBILE NETWORK OPERATORS:
AIRTEL, AT&T, CHINA MOBILE, T-MOBILE*, TELEFONICA*, VODAFONE*

TRAFFIC INFORMATION PROVIDERS:
GARMIN, GOOGLE, TOMTOM*

ROAD TOLLING:
KAPSCH*, MHIESA, NTPS*, SATELLIC*, SIEMENS*, SKY TOLL*, TOLL COLLECT*

AUGMENTATION SERVICE PROVIDER
SAPCORDA*

CAR SHARING OPERATORS

TELEMATICS SERVICE PROVIDERS

FUEL/FLEET CARD ISSUING COMPANIES

MAINTENANCE & DIAGNOSTICS

USERS

- CAR OWNERS
- COMERCIAL VEHICLES DRIVERS
- ENFORCERS
- FLEET OPERATORS
- INSURANCE COMPANIES
- MEMBER STATES
- ROAD NETWORK OPERATORS

European[2] GNSS industry in the global arena

With Bosch, TomTom, Valeo, Hexagon, STMicroelectronics, u-Blox and Continental, Europe held seven of the top 15 positions among GNSS Component and Receiver manufacturers in 2020. Overall, EU companies lead this market with a share of 53%, followed by North America with 25%. European GNSS system integrators, led by Volkswagen, Fiat Chrysler and many others generated 30% of the turnover in 2020, trailing behind Asia (53%).

LEGEND

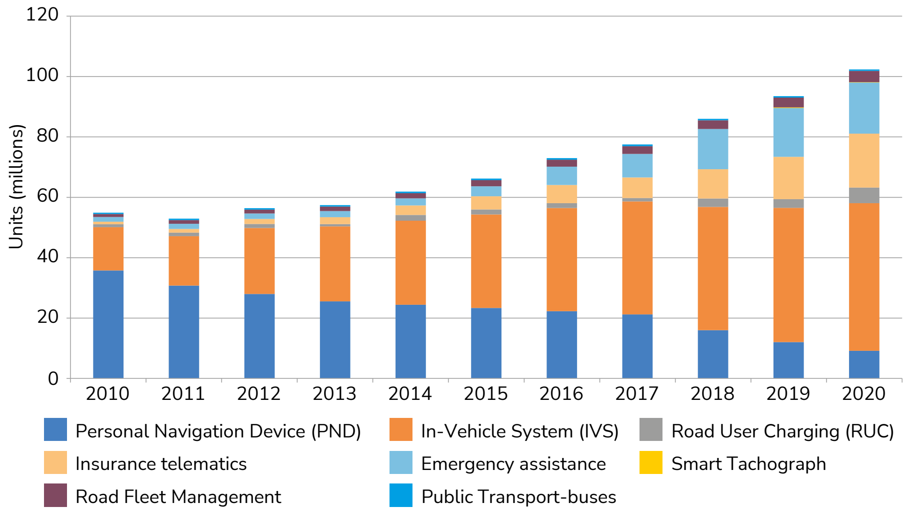
Commercial Offering
User segments
Green denotes EO-enabled services.

NOTES

[1] The value chain considers the key global and European companies involved in GNSS downstream activities.
[2] In the market share analysis, Europe is defined as EU27 plus Norway, Switzerland and the UK.
* European-based companies. The region is defined with respect to the headquarters of the company, though the actual area of activity might be wider.

New applications focusing on sustainable mobility continue to drive GNSS shipments

Shipments of GNSS devices by application



Since the end of the plateau in 2013, the road GNSS shipments grew by a CAGR of 10% leading to more than 110 million shipments in 2020. The automotive market continues to be dominated by the Navigation application as the trend of increasing In-Vehicle Systems (IVS) and shrinking Personal Navigation Devices (PNDs) shipments persists over the same period: IVS shipment has more than doubled from almost 25 million units in 2013 to more than 48 million in 2020.

The development of telematics services contributes to the persistent growth in the automotive sector as insurance telematics reached almost 18 million units in 2020, witnessing the highest historical CAGR of 35%, compared with other applications.

Another application substantiating market growth is emergency assistance, which is linked in the European market to the growing number of cars equipped with the mandatory eCall system since 2018.

Finally, during the pandemic, micro-mobility has once again emerged as a sustainable alternative to personal car usage. In particular urban bike sharing (along with e-scooter sharing) schemes account for about 7% of GNSS shipments in 2020.

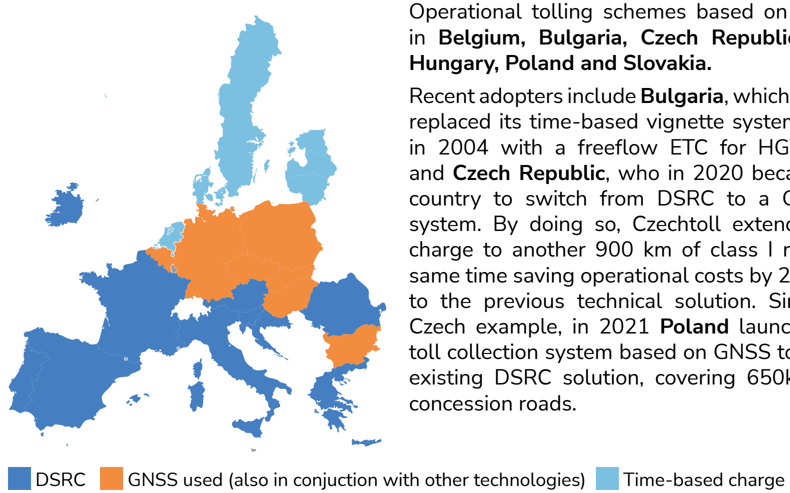
Satellite navigation supports on-demand bus services in remote and low density population areas

Geolocation technologies open up new opportunities to improve public mobility through various initiatives, such as demand-responsive transit services (on-demand buses) explored in the H2020 Galileo 4 Mobility project. The pilot was organised by Pildo Labs in collaboration with the Metropolitan Area of Barcelona (AMB), and aimed to tackle the low usage of bus services in the area. Taking advantage of the willingness of the local authorities to permanently implement an on-demand bus service for small villages in the area, Pildo launched a spin-off to commercialise developments performed within the project in the form of NE-MI, a tool enabling flexible bus routes and making mobility in low-density areas feasible.

©UITP

A similar platform powered by satellite navigation, Shotl, supports the transition of companies with on-site employee movement to sustainable mobility, cutting costs and emissions in compliance with COVID-19 measures.

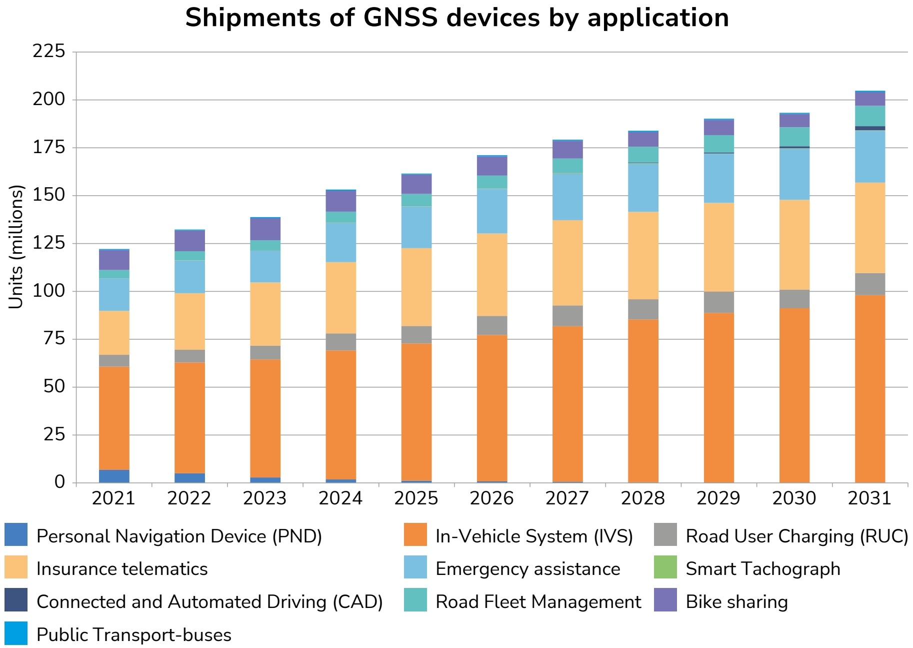
State of tolling - EU27



Operational tolling schemes based on GNSS exist in **Belgium, Bulgaria, Czech Republic, Germany, Hungary, Poland and Slovakia.**

Recent adopters include **Bulgaria**, which successfully replaced its time-based vignette system introduced in 2004 with a freeflow ETC for HGVs in 2020, and **Czech Republic**, who in 2020 became the first country to switch from DSRC to a GNSS based system. By doing so, Czechtoll extended its road charge to another 900 km of class I roads, at the same time saving operational costs by 2/3 compared to the previous technical solution. Similar to the Czech example, in 2021 **Poland** launched its new toll collection system based on GNSS to replace the existing DSRC solution, covering 650km of tolled concession roads.

Reinforced trend of IVS becoming the primary PNT source



Growing with a CAGR of 5% over the next decade, the dominant role of IVS will continue, leading to annual shipments of 98 million units in 2031. Shipments of CAD, which will allow cars and their passengers to enjoy autonomous driving features (SAE level 4 and 5), are estimated to reach 247,000 units in 2028. By 2031, this application is forecasted to surge to almost 2 million units, accelerating the deployment of autonomous vehicles. With all new vehicles equipped with a GNSS-enabled IVS, IVS evolves into the leading source of PNT data for a wide range of in-vehicle applications.

After a significant slowdown of smart tachograph adoption in Europe with a 50% drop in annual shipments registered in 2020, the market is expected to pick up in the coming years due to regulatory developments. An extension of the tachograph's scope to light commercial vehicles, retrofitting provisions for vehicles with analogue and digital tachographs (expected by winter 2024), as well as introducing the first version of the smart tachograph by autumn 2025, will drive annual shipments up to 167,000 units by 2025.

Although globally new vehicle sales are unlikely to return to pre-pandemic levels until 2023, as evident from the figures above, the penetration of GNSS-enabled applications is expected to grow substantially over the next decade.

Achieving proof of safety for autonomous systems: standards and testing

Comprehensive evaluation of performance and safety considerations is critical to successful deployment of autonomous systems. International organisations contributing to proving safety for autonomous vehicles include ISO (standards related to safety of execution, performance and intended functionality, as well as requirements for Electrical/Electronic/Programmable Electronic systems), Radio Technical Commission for Maritime Services (RTCM), standards related to Integrity for High Accuracy GNSS-based Applications, Third Generation Partnership Project (3GPP) standards linked to mobile GNSS assistance data and the emerging **European standard EN16803.**

Focusing on this latest development by CEN-CENELEC, EN16803 explores the use of GNSS positioning in the automotive framework and in particular the assessment of the basic performance of GNSS positioning terminals. In the ongoing phase, the main effort is concentrated on security performance including definition and validation of future testing scenarios.

Ongoing standardisation activities continue to unlock the benefits of autonomous features in cars and pave the way towards a driverless future, which is in turn associated with increased road safety.

Fundamental Elements

H-GEAR

Extending the reach of GNSS through eCall for motorcycles

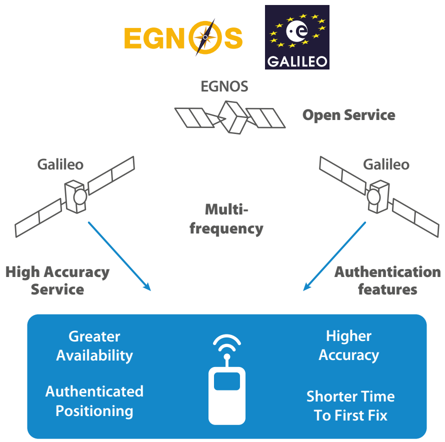
Road safety is one of the major elements of the European Union's transport policy; **eCall** continues to contribute to the reduction of road fatalities and alleviating the severity of road injuries. One of the ongoing initiatives that is looking to expanding eCall reach **to L3 vehicle categories** (2-wheeled powered vehicles or motorcycles) is H-Gear. This project aims to develop a system composed of a device integrated into the motorcycle (provided by Honda), a software suite for the monitoring and control of the **eCall and Anti-Theft services** and a user mobile application for the interaction with the driver.

The H-Gear system will leverage on **EGNSS features** such as spoofing incident from the Galileo navigation message detection and mitigation using OSNMA, as well as the use of GNSS raw measurements (jointly with accelerometer data) during the alert/theft or accident mode, in order to verify the motorcycle's movement and position.

More information on:
https://h-gear.vitrocisetbelgium.com/

©H-GEAR

EGNOS and Galileo contribute to smarter and more sustainable mobility



Current usage of EGNSS

Present in all European new vehicle types equipped with eCall, **Galileo** is already contributing to **improved safety and transport efficiency** on European roads.

EGNOS improves GPS accuracy and provides information on the reliability of the positioning information. Together with Galileo and shortrange communications technologies implemented in smart tachographs, EGNOS contributes to enforce EU legislation (social regulation) on professional drivers' driving and resting times.

EGNSS services and features to be explored

Galileo will provide significant added value to the connected and automated vehicles of the future, thanks to its **dual-frequency, high accuracy and unique authentication feature.**

Galileo's Open Navigation Message Authentication (OSNMA) feature will contribute to addressing the security challenge faced by many applications as potential targets of spoofing attacks, including smart tachographs used in trucks, taxis and ride-sharing vehicles, and tracking devices used in commercial cargo.

UITP ADVANCING PUBLIC TRANSPORT

SPACE - Integrating automated vehicles (AVs) into the public transport network

The introduction of automated vehicles in cities represents a unique opportunity for a fundamental change in urban mobility. An effort lead by UITP, together with over 50 partners covering the whole urban mobility sector, aims to place public transport at the centre of the automated vehicles revolution. SPACE will bring a high-level reference architecture to ensure a seamless integration of driverless vehicles with other IT systems in the mobility ecosystem. This will in turn help operators and cities make the right technical decisions when integrating AVs into the public transport network, speeding up the deployment of driverless mobility services.


©CAD

An effective integration of AVs as shared vehicles in the public transport network (e.g. shuttle buses, car or ride-sharing schemes) is expected to drastically reduce car ownership, regain essential urban space, and result in better mobility for all.

HORIZON 2020 molière

MObiLIty sERvices Enhanced (MOLIERE) by Galileo & Blockchain

MOLIERE is a joint initiative led by Factual to coordinate a consortium formed, among others, by SEAT. The study's main goal is to unlock much more precise, accurate and highly available location data enabled by Galileo through an open Mobility Data Marketplace underpinned by blockchain.

The demonstrated platform is expected to pilot Mobility as a Service (MaaS) and Urban Mobility applications where geolocation data sourced by Galileo is leveraged. The focus on more accurate geolocation data in urban mobility of this H2020 call, launched shortly after the start of the pandemic, becomes especially relevant in the context of social distancing.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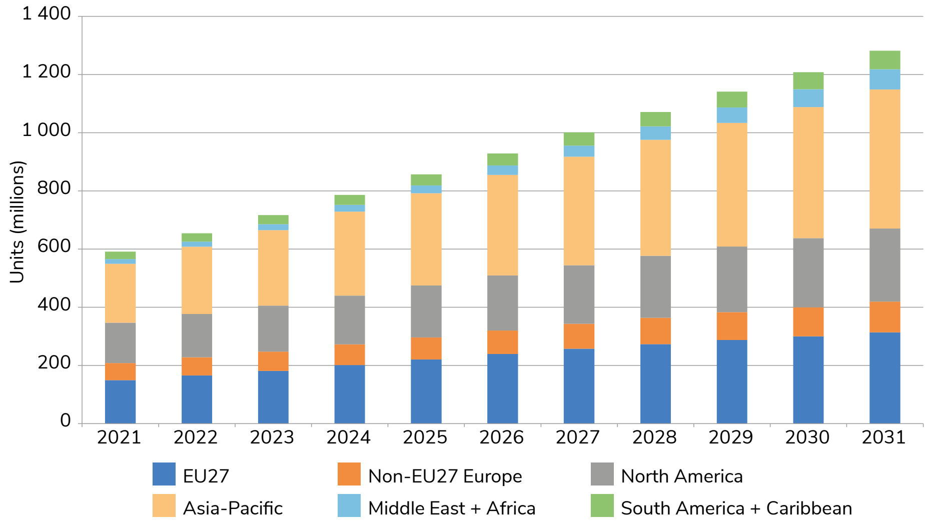
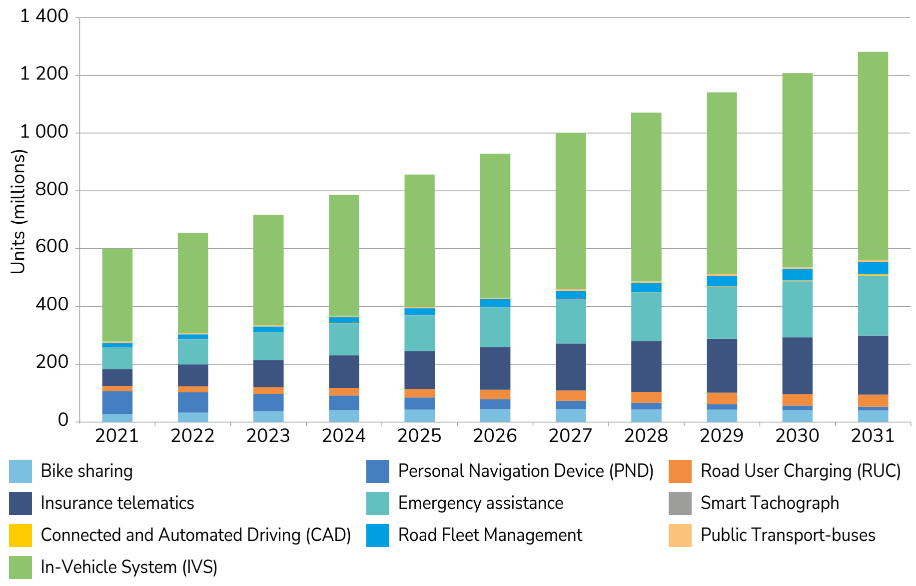
Terminology used on this page is explained in Annex 2 for both GNSS and EO performance parameters.

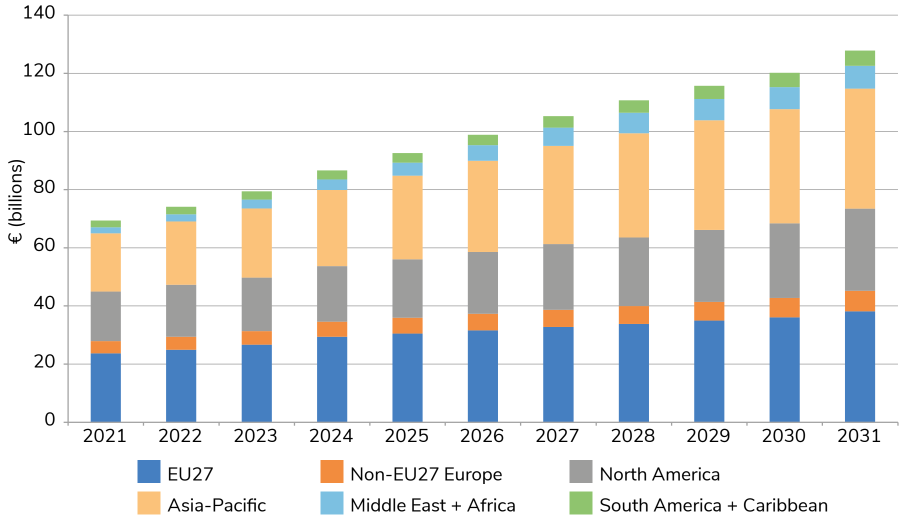
Installed base of GNSS devices by region



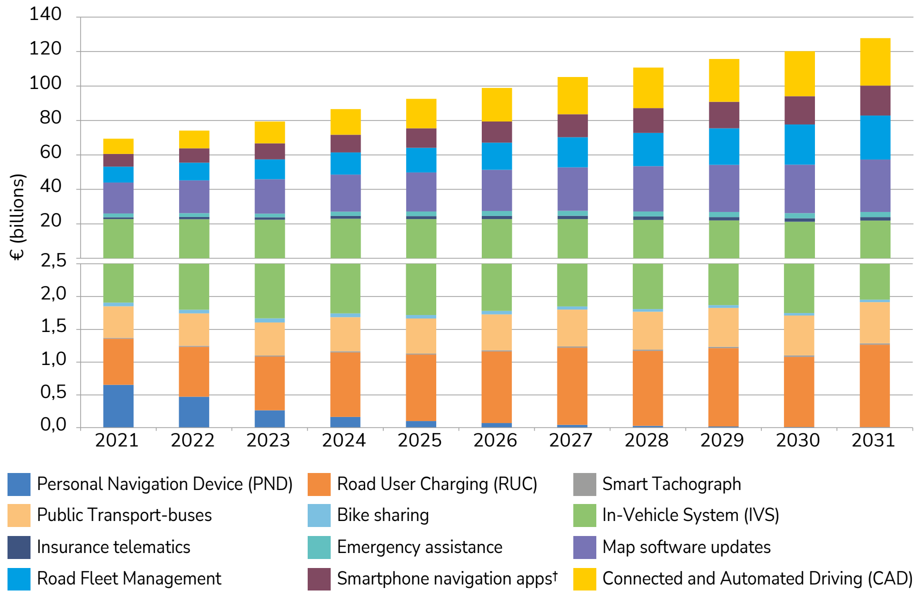
Installed base of GNSS devices by application



Revenue of GNSS device sales and services by region

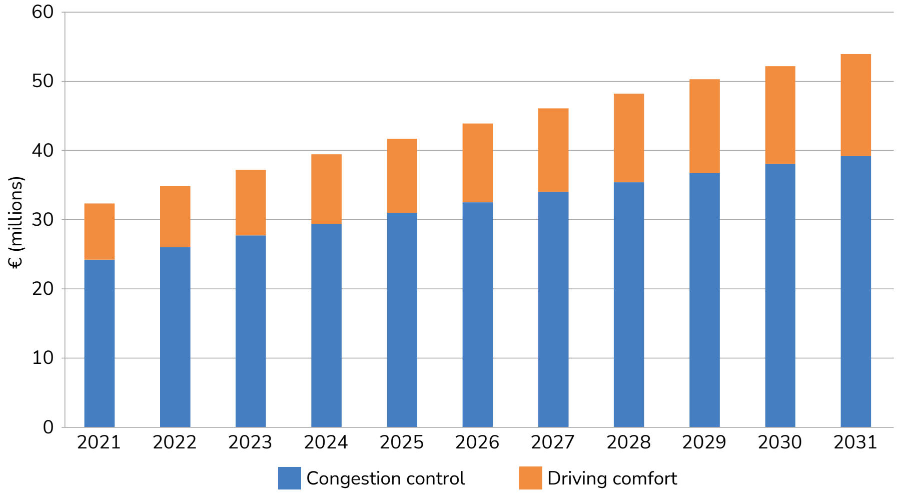


Revenue of GNSS device sales and services by application

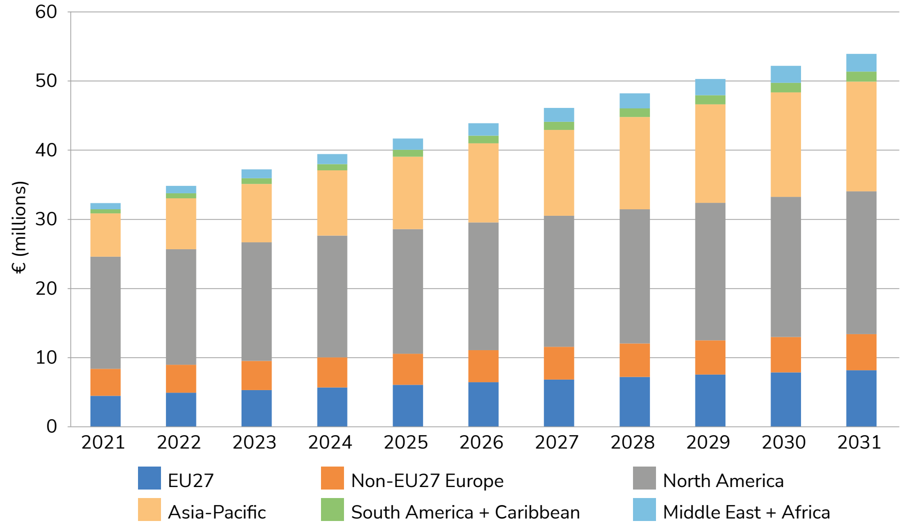


†: Pay-to-download, In-app-purchases and ad-revenue from navigation apps

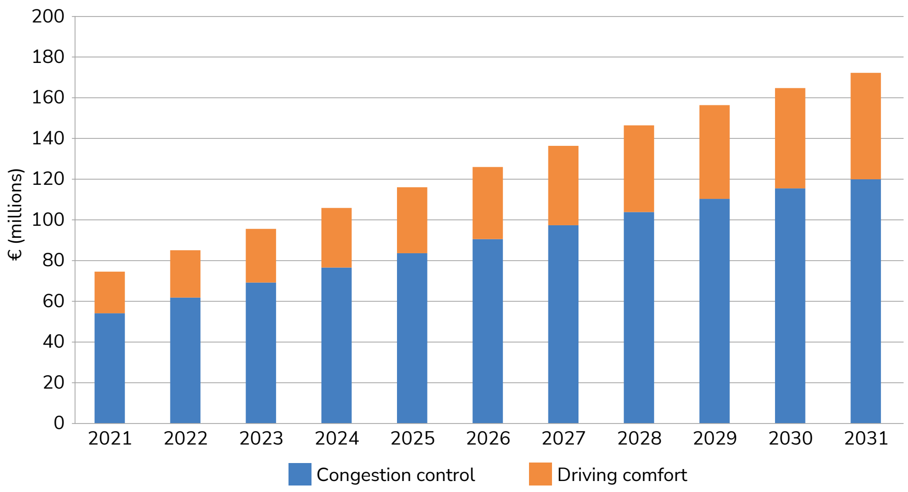
Revenue from EO data sales by application



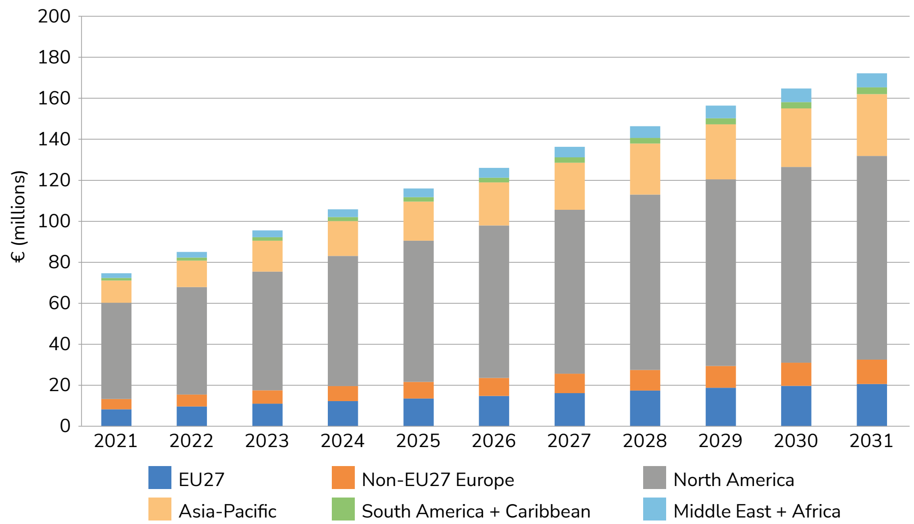
Revenue from EO data sales by region



Revenue from EO services sales by application



Revenue from EO services sales by region



URBAN DEVELOPMENT AND CULTURAL HERITAGE

Legend

EO application

GNSS application

Synergetic application (combined use of EO and GNSS)

Environmental Monitoring

- Air quality monitoring in urban environments
- Light pollution
- Thermal auditing
- Urban greening
- Urban heat islands

Smart Cities Operations

- Smart streetlights
- Smart waste management

Urban planning and monitoring

- Cultural heritage monitoring
- Informal dwellings
- Real estate
- Surveying and mapping of urban areas
- Urban modelling, 3D modelling, Digital Twins
- Urban planning

Application descriptions can be found in Annex 3.

URBAN DEVELOPMENT AND CULTURAL HERITAGE

EO and GNSS are invaluable tools for the transition to smart, connected and climate-neutral cities. City authorities, urban planners, real estate agencies, cultural heritage managers and surveyors all use solutions powered by EO and GNSS to perform a wide range of applications.

Earth Observation provides valuable information in support of urban planning, monitoring of informal dwellings, and informing the progress of urban greening. Moreover, EO-based services provide essential information on air quality in urban environments, measuring particles that might affect the heath of citizens and monitoring greenhouse gas emissions. This is also critical when monitoring cultural heritage sites, whereby the impact of air quality and potential ground subsidence may become catastrophic.

GNSS-based solutions are also used, in conjunction with EO, to accurately survey and map urban areas and to build advanced 3D models of the built environment.

What you can read in this chapter

- **Key trends:** Making our cities climate-neutral, smarter and better connected will increasingly rely on digital solutions powered by EO and GNSS.
- **User perspective:** Multi-dimensional cadastre is the backbone of modern urban development.
- **Industry:** Urban Development and Cultural Heritage Value Chains.
- **Recent developments:** EO and GNSS solutions are driving several innovations at city level.
- **Future market evolution:** Digital solutions contribute to a more resilient future for urban development and cultural heritage.
- **EU Systems:** The EU Space Programme presents a strong value proposition for urban development and cultural heritage applications.
- **EU Projects:** number of European funded projects apply and combine EO and GNSS to solutions in support of digitalisation, resilience, and sustainability of urban environments.
- **Reference charts:** Yearly evolution of installed base of GNSS devices and revenues as well as EO revenues by application and region.

Making our cities climate-neutral, smarter and better connected will increasingly rely on digital solutions powered by EO and GNSS

Key market trends

- Achieving climate-neutrality and climate-resilience in cities will require innovative solutions powered by EO data and GNSS services
- Smart cities are increasingly seeking to use EO or GNSS-based solutions to support a wide range of applications
- Digitalisation strategies – the most prominent of which is digital twins – will greatly benefit from EO and GNSS solutions
- Satellite-based technologies provide a fundamental contribution to the preservation and sustainable management of cultural heritage sites

Digital solutions support a climate-neutral future in cities

Climate neutrality is a key goal on a global scale. In the EU, the Urban Agenda sets forth the priorities around air quality, housing, poverty, inclusion, sustainability, cultural heritage and digitalisation to name a few. To this end, the **adoption of digital solutions, including those powered by EO and GNSS, is increasingly recognised in policy making.** In particular, digitalisation strategies such as the concept of digital twins, which also promises to be a useful tool for urban planning, will greatly benefit from EO and GNSS-based solutions.

Nature-based solutions drive innovation towards a more climate-resilient EU

Cost-effective solutions that are inspired and supported by nature, or in short ***nature-based solutions (NBS),*** are increasingly sought to provide environmental, social and economic benefits and to help build resilience in urban environments. NBS supports major EU policy priorities such as the European Green Deal, the EU Biodiversity Strategy and the EU adaptation strategy, making Europe more climate-resilient. Therefore, multiple EU-wide initiatives and Research & Innovation (R&I) projects are developing NBS in different contexts, all of which are represented in a dedicated platform (https://platform.think-nature.eu/). The environmental and socioeconomic impact of NBS can be assessed with the help of Copernicus data and the unprecedented computing and modelling capabilities offered by different platforms (e.g. Urban-TEPS).

The urban environment is well on the path to digital maturity

Advanced modelling capabilities are increasingly sought in relation to urban planning and modelling. This includes digital twins and 4D/5D Building Information Modelling (BIM). The integration of accurate and reliable GNSS and EO data into BIM assists urban planners to homogenise the geolocation of all city elements. Applications like land surveying and mapping/GIS provide the necessary framework for collecting data and transforming observations to facilitate software-based solutions around smart cities. In practice, this enables city authorities to integrate and manipulate large amounts of versatile data, from the position and status of utility assets (streetlights, hydrants, pipelines, etc.) to 3D models of new quarters and 4D BIMs of whole buildings. Furthermore, GNSS-equipped augmented/virtual reality technologies provide immersive ways for the visualization of urban designs, either in the field or layered onto high-resolution satellite imagery. So far only a handful of **digital twins of smart cities** (DTSC) exist, with some prominent examples including Newcastle, Rotterdam, Boston, New York, Singapore, Stockholm and Helsinki. DTSC enable users from different sectors to develop sophisticated tools and applications for test-bedding concepts and to support decision-making along the whole urban planning process. According to research from ABI, in 2025 there will be around 500 DTSCs. The future twins will provide a complete live city view through processing versatile sources of Big Data: live real-time data streams including sensor readings, transport updates and social media information (such as geolocated tweets), overlaid with photorealistic 3D models (created via vertical and oblique photography together with laser-scanned height measurements).

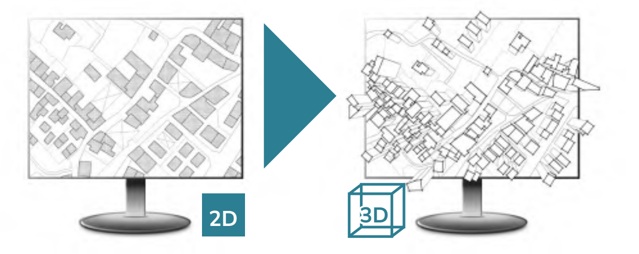
Space opens-up new possibilities for the protection of cultural heritage

Beyond the economic asset it represents, cultural heritage also constitutes a universal source of remembrance and identity for humankind, thereby contributing to social cohesion and stability. While about 5% of the 1,121 UNESCO World Heritage sites are today in danger, the need for their protection is globally recognised. In this context, the increasing availability of free and open satellite-based data and information, combined with the development of cutting-edge technologies (e.g. artificial intelligence, machine learning) can provide a crucial contribution to this field. In practice, EO data is used to monitor the impact of pollution, settlement pressure, climate change and natural hazards on cultural heritage sites.

Multi-dimensional cadastre is the backbone of modern urban development

3D and 4D cadastre is where GNSS-EO joint capabilities make all the difference

Many Smart City initiatives focus on renewable energy and the reduction of greenhouse gases. This means that **urban planning needs to reflect the exploitation of different sources** (e.g. solar, geothermal, wind) **and their respective impact on the built environment.** Thus, to perform a proper evaluation of the energy balance, urban planning must progress from 2D (i.e. cadastral information on property distribution) to 3D (i.e. including geometry and semantics around wall and roof structure, number of windows, height between floors, etc.) and even 4D (temporal dimension). This vertical (3D) integration concept takes into account the source of the data and the production process. The 2D borders of the property's building layer may be obtained (e.g. via cadastral GNSS surveying), and then merged with the third dimension from laser scanning as a topographic source. Another approach is to create 3D city models from high-resolution satellite images with footprint in the meter/submeter range. The standard format for 3D buildings is CityGML. In urban planning, GNSS-equipped mobile augmented reality is increasingly used in combination with CityGML building models to enhance some typical workflows in planning, execution and operation processes. A concrete example is the geo-referenced on-site visualization of planned buildings or building parts, to simplify planning processes and optimise the communication between the participating decision-makers.



AI powered solutions for cities require advanced computing capabilities

Smart Cities are urban areas whose infrastructure and services are made more efficient through the use of ICT and Big Data. Making sense of **huge amounts of diverse data** – including EO data – requires computing power and automation. Artificial Intelligence (AI) is an approach that allows machines to take over tasks such as analytics in an automated fashion. Algorithms are trained to recognise certain patterns (e.g. in EO imagery) and perform appropriate actions (e.g. annotation of imagery). Given the vast amount of data in terms of size, and the diversity of types and sources of data, **computing power is needed to perform analysis that makes sense of this data in a reasonable time.** High Performance Computing (HPC) has the capacity to meet this challenge and support applications like urban planning and modelling. It is regularly defined as a requirement to enable data-driven Smart Cities. With growing amounts of data and tasks, HPC capacity may not be sustainable; however, a further trend towards edge computing – distributed computing bringing storage and computing closer to each other – is evolving.

Key EO and GNSS user requirements

The key GNSS and EO user requirements for the different application groups within the **Urban Development and Cultural Heritage** segment are, at EU level, collected using the following procedures:

- For GNSS, information is collected through extensive interactions with user groups, providers and experts in a continuous process culminating at the User Consultation Platforms (UCP). All relevant requirements are documented in detail and updated regularly within the Report on Surveying user needs and requirements.
- User requirements for Copernicus services and products – as well as their evolution – are collected through an integrated process that involves different channels: (i) dedicated studies (e.g. "NEXTSPACE" project, "Copernicus for EC (C4EC)" study, Commission Staff Working Document on user needs), (ii) targeted consultations organised by the European Commission or the Entrusted entities with the relevant communities, (iii) regular and structured exchanges among representatives of the Copernicus governance structure and Member States through the Copernicus User Forum.

From the 2022 EUSPA`s UCP onward, EO user needs and requirements of commercial users will be validated and discussed with industry experts and user groups, mirroring the process implemented for GNSS.

Urban Development and Cultural Heritage GNSS Value Chain[1]

AUGMENTATION SERVICE PROVIDERS

- HEMISPHERE (ATLAS)
- HEXAGON (LEICA GEOSYSTEMS, NOVATEL)*
- SAPCORDA*
- SPACEOPAL*
- SWIFT
- TERIA*
- TOPCON
- TRIMBLE

- NATIONAL AND REGIONAL RTK NETWORK PROVIDERS

COMPONENT AND RECEIVER MANUFACTURERS

- BEIJING BDSTAR NAVIGATION
- BEIJING UNISTRONG SCIENCE & TECHNOLOGY
- CHCNAV
- HEXAGON*
- NVS TECHNOLOGIES*
- HI-TARGET SURVEYING INSTRUMENT
- SATEL*
- SBG SYSTEMS
- SEPTENTRIO*
- STONEX*
- TOPCON
- TRIMBLE
- U-BLOX*

SYSTEM INTEGRATORS

- AB VOLVO*
- CATERPILLAR
- CNH INDUSTRIAL*
- FARO TECHNOLOGIES
- HITACHI
- J.C.B. SERVICE*
- KOMATSU
- RIEGL*
- CHCNAV
- VAISALA OYJ*

SOFTWARE, APPLICATIONS AND ADDED VALUE SERVICES

- CARLSON
- HEMISPHERE
- HEXAGON*
- HYPACK
- JAVAD
- SEPTENTRIO*
- SOUTH
- TOPCON
- TRIMBLE

PROFESSIONAL USERS

- CONSTRUCTORS
- EDUCATORS
- ENGINEERS
- ENVIRONMENTALISTS
- PRESERVATIONISTS
- SCIENTISTS
- SURVEYORS

CUSTOMERS OF SURVEYING SERVICES

- ARCHITECTS
- CONSTRUCTION COMPANIES
- INSURERS
- CITIZENS
- PUBLIC AUTHORITIES
- URBAN UTILITIES

European[2] EO industry in the global arena

GNSS receivers in Urban development and cultural heritage are used for mapping and other geomatics purposes, and the industry supporting the segment overlaps with that serving Infrastructure. European companies such as Hexagon hold 35% of the geomatics market, with a slightly lower intensity on Urban development applications than their largest international competitors, yielding an estimated European share of 25% of the Urban development and cultural heritage market.

LEGEND

- Commercial Offering
- Public Offering
- User segments

NOTES

[1] The value chain considers the key global and European companies involved in GNSS downstream activities.
[2] In the market share analysis, Europe is defined as EU27 plus Norway, Switzerland and the UK.
* European-based companies. The region is defined with respect to the headquarters of the company, though the actual area of activity might be wider.

Urban Development and Cultural Heritage EO Value Chain[1]

INFRASTRUCTURE PROVIDERS

- AWS
- CLOUDEO*
- COPERNICUS DIAS*
- GOOGLE CLOUD PLATFORM
- IBM CLOUD
- INTEL GEOSPATIAL
- PENGUIN COMPUTING
- MICROSOFT AZURE

- COPERNICUS COLLABORATIVE GROUND SEGMENT*

DATA PROVIDERS

- 4EI
- AIRBUS*
- CONSTELLR*
- COPERNICUS DIAS*
- DEIMOS IMAGING*
- EARTH-I*
- E-GEOS*
- EUROPEAN SPACE IMAGING*
- ICEYE*
- MAXAR
- PLANET
- TWENTY FIRST CENTURY AEROSPACE TECHNOLOGY

- COPERNICUS SENTINELS*
- USGS/NASA LANDSAT
- RELEVANT IN-SITU NETWORKS

PLATFORM PROVIDERS

- ADAM*
- ASTROSAT*
- CESIUM
- CLEOS (E-GEOS)*
- COPERNICUS DIAS*
- DESCARTES LABS
- LATITUDO 40*
- MAXAR ARD
- PLANET EXPLORER
- ORBITAL INSIGHT
- SOBOLT*
- TERRASOLID*
- TWENTY FIRST CENTURY AEROSPACE TECHNOLOGY
- UP42*

- URBAN TEP

EO PRODUCTS AND SERVICE PROVIDERS

- 4EI
- AIRBUS*
- CARTO*
- EGEOS*
- EUROPEAN SPACE IMAGING*
- FLYCOM*
- GEOVILLE*
- GIM*
- GREEN URBAN DATA*
- KARTEN SPACE*
- KONGSBERG*
- PIXSTART*
- SATIM*
- SATSENSE*
- SENSAR*
- SINERGISE*
- TESSELO*
- VITO*
- WORLD FROM SPACE*

- COPERNICUS SERVICES*

INFORMATION PROVIDERS

- AMBICITI*
- CITTAMAP*
- DAVEY
- ECOMETRICA*
- GENEGIS GI*
- GEOFEM*
- HAWADAWA*
- IHI CORPORATION
- SPACEKNOW
- SUPERMAP
- TERRALOUPE*
- TETRA TECH

END USERS

- URBAN PLANNERS
- ARCHITECTS
- CONSTRUCTION COMPANIES
- URBAN PUBLIC TRANSPORT PROVIDERS
- HEALTH AND ENVIRONMENTAL AUTHORITIES
- ENGINEERING COMPANIES
- CITIZENS
- UTILITY COMPANIES
- REAL ESTATE AGENCIES
- INSURANCE COMPANIES
- TAX AUTHORITIES

European[2] EO industry in the global arena

In 2019, European EO companies had a worldwide market share of 33% (EU27) and 4% (European non-EU27). Together they accounted for around €86m in the Urban Development and Cultural Heritage segment. The top ten EO companies in this segment account for more than 80% of the total market share. Among these, three are headquartered in Europe.

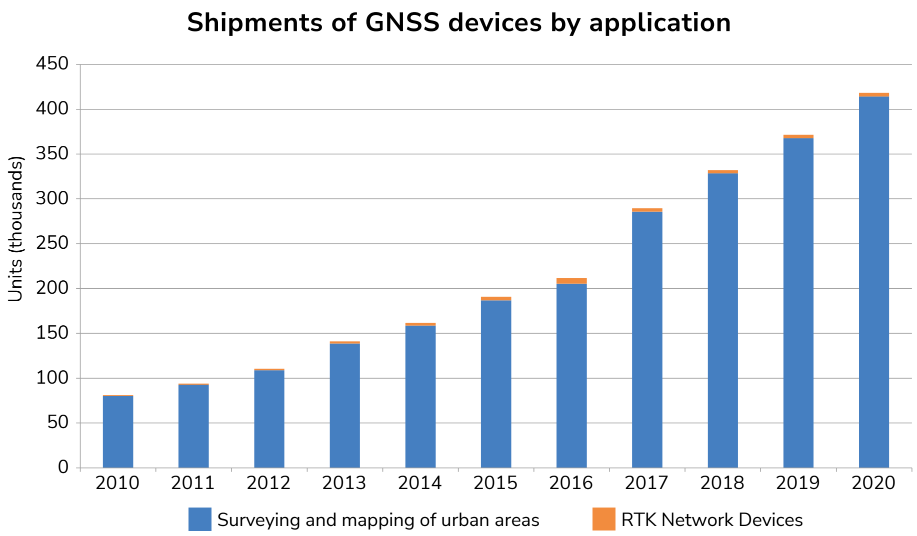
LEGEND

- Commercial Offering
- Public Offering
- User segments

NOTES

[1] The value chain considers the key global and European companies involved in EO downstream activities.
[2] In the market share analysis, Europe is defined as EU27 plus Norway, Switzerland and the UK.
* European-based companies. The region is defined with respect to the headquarters of the company, though the actual area of activity might be wider.

Advanced GNSS capabilities support solutions sought in smarter cities



Diversified GNSS technologies empower proper cadastral management in cities

The main players in the cadastral GNSS market strive to provide **complete portfolios of products and services** that may be used at every stage of urban land management. The most elaborate and expensive products are used to establish city geodetic control points. This **requires infrastructure GNSS receivers that may be used in either RTK networks or as standalone devices.** These products are usually used by municipalities or large companies, which generally provide network RTK services in urban areas and are responsible for maintenance of the city's geodetic control points. Another group comprises the field data collection receivers, in which mobility, sensor fusion and cloud data management are proving popular. Depending on the operability and accuracy needed, either geodetic RTK rovers or mapping/GIS are implemented; the former for 2D or 3D property boundary measurements, and the latter for inventory of city assets. GNSS-enabled systems (mobile mapping platforms, drones) form a separate group, used in cities primarily for 3D data collection on street, building or skyline level.

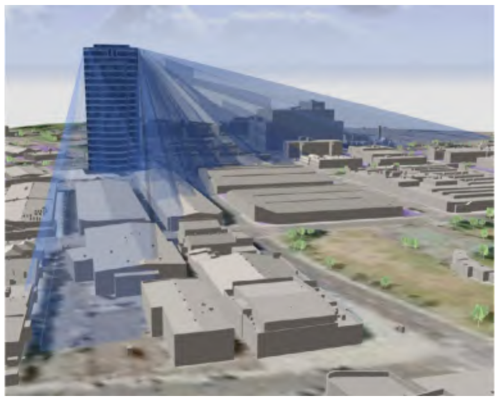
GNSS-based mapping for smarter cities shows strong growth over the past decade

The use of GNSS receivers in mapping applications for urban development has shown steady growth over the past ten years, with the leading position held by site selection and monitoring. Over this timeframe, shipments of GNSS receivers in this application area have grown six-fold. At the same time, augmentation services, including new techniques such as PPP-RTK, are becoming an important tool for cadastral surveying, mapping and GIS activities.

The fusion of sensors to align the city tensors

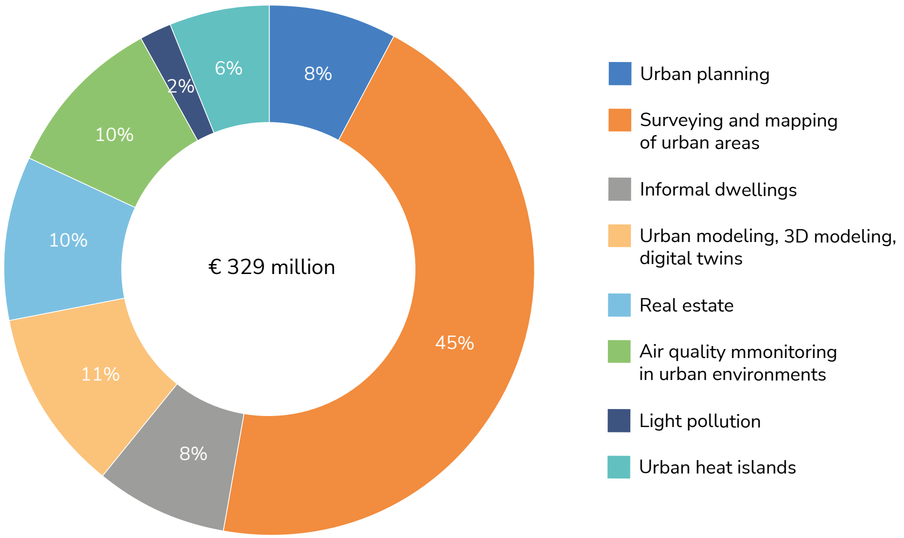
The vast opportunities that **sensor fusion** provides for architects and urban planners can hardly be overstated. Indoor and outdoor positioning with lightweight devices, without any accuracy compromises, is becoming the norm. At the same time, SLAM technology, with its laser/IMU/camera integration, and portable laser scanners have opened a huge field for detailed realistic modelling inside buildings. When combined with GNSS receivers, these systems are **providing seamless indoor-outdoor transition.** Compared to their indoor cousins, the GNSS-equipped powerful mobile mapping systems are the ultimate way to create street-like experiences, which can then be transferred to digital twins and augmented reality concepts.

Furthermore, high-accuracy GNSS positioning with mass market devices, until recently an exploratory technology, is now becoming a reality. In 2021 the company Pix4D released a product that enables survey-grade 3D modelling with RTK Accuracy on a Mobile Device. The viDoc RTK rover geotags the images of a 3D scan (photogrammetric or LiDAR) in real time, while connected to any GNSS NTRIP service, and reportedly achieves city 3D models with an absolute geolocation accuracy of less than 5cm.



EO solutions are driving several innovations at city level

Revenue from EO data & service sales by application in 2020



Revenues from the sale of both EO data and services in 2020 amounted to €329 m. Surveying and mapping dominates the market outright with 45% of the sales.

Beyond this, the breakdown in terms of application is relatively fragmented. Urban modelling, 3D modelling and digital twins document a 11% share. This should come as no surprise, given the efficacy of EO in helping the likes of urban planners, construction companies, transport authorities, real estate agencies and even citizens to map and plan daily activities and operations. InSAR in particular delivers huge value when it comes to public authorities and construction companies monitoring for potential subsidence associated with urban development and infrastructure. This capability is leveraged by many service providers in the EO-based solutions they offer and thus contributes to the reported revenues.

Air quality monitoring and real estate applications also proved valuable to the sector, holding roughly 10% market share each. Again, given the constant concern of air pollution in built environments, as well as the lucrative nature of the real estate sector, these shares reflect where the market materialises substantial value.

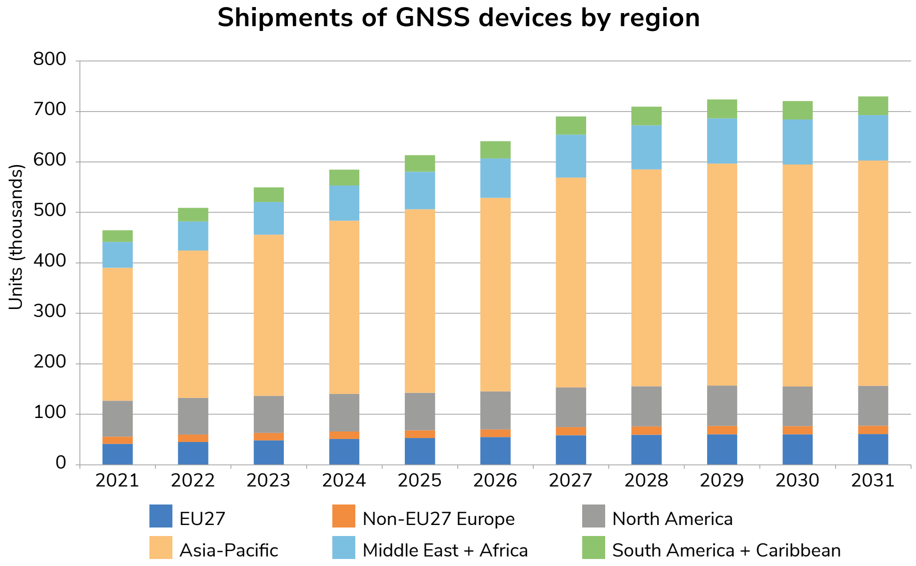
Urban greening contributing to climate, air quality, and wellbeing

The contribution of green spaces to local climate, air quality, and the general wellbeing of citizens has made it to the agenda of cities worldwide. **Cities promote their green spaces** as areas for recreation, boosting the wellbeing of their citizens. Brussels, for example, has mapped all its parks for that purpose. ESA's EO4SD-Urban 'Urban Green Areas' and 'Open and Green Spaces' products demonstrated **EO capabilities in mapping urban green spaces.** Using the Copernicus Urban Atlas, the EC's working paper assessing access to green areas in Europe's cities produced indicators on the proximity of green areas to urban population. H2020-funded projects such as Green City Solutions aim at targeted greening of urban spaces to reduce air pollution. Competitions such as the Copernicus Masters address greener cities with specific challenges, fostering EO-based applications. Further, services such as Green Urban Data (supported by, for example, Copernicus Accelerator, EIT Climate Knowledge and Innovation Community, or Climate-KIC) provide EO-based information to cities or citizens for planning and utilization of green spaces. Because it is still a niche application, urban greening-related revenues are not quantified in this report.

Reducing the urban heat island effect

Due to human activities such as creating dense concentrations of surfaces that absorb and retain heat, zones significantly warmer than the surrounding urban areas can occur. These are known as **urban heat islands** (UHI). EO can support mapping temperatures and temperature variations across urban areas, to (for instance) alert citizens or health authorities of related risks for vulnerable demographic groups. These capabilities have been demonstrated in several projects. Funded by the European Civil Protection and Humanitarian Aid Operations, the TREASURE project developed a mobile Personalised Heat Wave Risk App for citizens. The project LIFE ASTI has implemented a forecasting system for the UHI effect for the development of urban adaptation strategies. The C3S Urban project provides information based on climate reanalysis and climate scenario data, downscaled for several cities, including urban temperature data. Thermal satellite images in combination with on-the-ground thermal sensors were used in the research project 'Remote Sensing of London's Urban Heat Island, by day and night'. Finally, Copernicus' future Land Surface Temperature Monitoring will deliver global high spatio-temporal daytime and night-time land surface temperature measurements, also supporting services addressing heat island issues.

Digital investments in data infrastructure are the core enabler of future success



Investment in smart cities in Asia-Pacific drives the future evolution of the sector

With multiple mega-investments in smart cities, Asia-Pacific is driving the growth of the installed base of GNSS receivers. On the other hand, EU27 and North America, both representing stable markets, present marginal projected growth until 2031. The Middle East (primarily) and Africa (secondarily) are also showing significant growth, powered by investments in ultra-modern cities and increased attention toward informed urban planning, respectively.

GNSS-EO is an invaluable data source to build Spatial Data Infrastructure

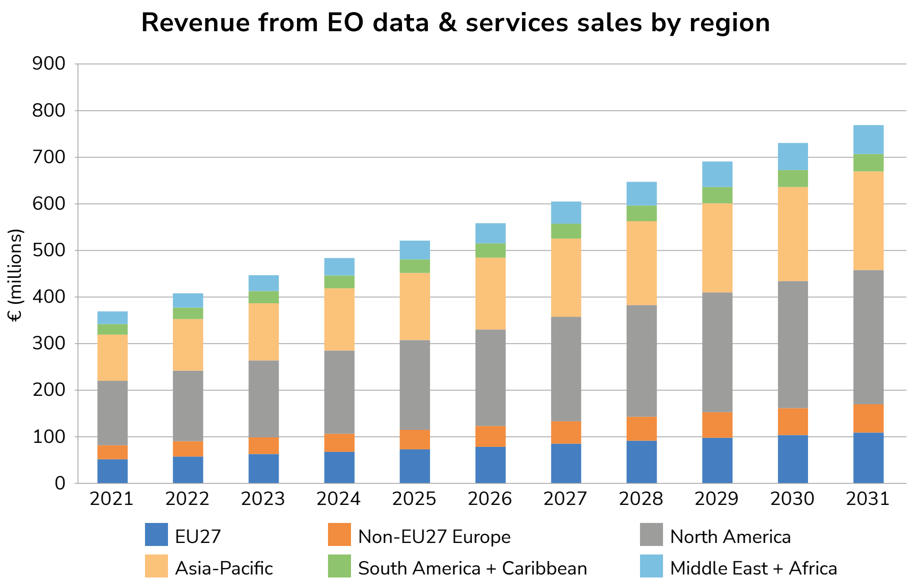
The general vision of future Smart City developments entail the **incorporation of traditional cadastre layers, obtained with EO, GNSS or other equipment, within complex Spatial Data Infrastructure** (SDIs) with the ultimate goal of creating a digital twin. A good example is the European initiative to build multinational SDIs, known as the INSPIRE Directive. As cadastral data is increasingly being collected digitally, cities make better use of geospatial services for their purposes. For instance, many methods for automated classification based on INSPIRE data and Sentinel-2 satellite imagery have been developed recently. When it comes to GNSS-based solutions, these have reached high technological maturity. This is thanks to **enriched and stable satellite signals** that facilitate surveying work within any type of urban environment. Nevertheless, many traditional mapping and cadastre surveying workflows are still obtaining the geometry and the semantics of a building separately, instead of in a seamless, digitally synchronised way. Thus, one of the many challenges for the GNSS industry will be to actually put its well-developed solutions into the hands of users. This is especially valid for many settlements in developing countries, where the goal to become 'sustainable cities and communities' (as targeted by the UN SDG 11) will require careful balance between device price and capability.

Inventory of city assets is becoming unthinkable without GNSS

The **urban GNSS market will continue to focus on fast, reliable and accurate data collection for the wide range of city assets.** Indeed, every modern city is a complex labyrinth of assets, closely overlapped in both horizontal and vertical dimensions, so the best approach to guarantee appropriate modelling is through high-accuracy measurements.

Up to a point this is secured by the integration of various sensors (e.g. IMUs, photo cameras) that allow surveyors to make many more measurements, much faster, without needing to be on-site. It is expected that all main market players will continue to upgrade their latest receivers, taking full advantage of the sensor integration approach. While the increased use of Ground Penetration Radars (GPR), combined with GNSS to map the underground city cadastre, is bringing positioning below the visible surface, powerful GNSS-enabled drones with RTK accuracy may now fly over it and collect data in mere minutes. With all this machinery working around, the problem of personnel safety is of utmost importance. That is why the industry is becoming more aware of the need to: 1) develop solutions that increase surveyors' safety; and 2) establish proper safety regulations, which is of special importance for flying drones within a city. In this regard, taking the cadastral GNSS surveyor off a heavy traffic street or the mapping drone away from the crowd below, without loss of operability and accuracy, will continue to be the challenge for the urban geomatics market.

The future market evolution will see increased adoption of EO data in analytics powered by high performance computing and artificial intelligence



The revenues from the sale of EO data and services in 2021 amounted to €369 m, growing year-on-year to expected aggregate revenues of €769 m by 2031.

North America and Asia Pacific hold the largest market shares in terms of revenues from the sale of EO data and services in 2021, with €138 m and €100 m respectively. Throughout the upcoming decade, both will remain the largest markets, achieving revenues in 2031 of €288 m and €212 m respectively. The huge and ever-expanding urban metropolises and mega cities in the USA and East Asia will help drive this strong and dominant growth in the industry.

The dominance of North America and East Asia markets over the coming years will mean all other regions will maintain smaller market shares. Nonetheless, the EU market is foreseen to double, growing from €52 m in 2021 to €109 m in 2031.

EO data safeguarding humankind cultural heritage

Ranging from the improved characterisation of their conservation status for preventive restoration actions and the detection of potential threats, to the development of new possibilities for archaeological discoveries, the potential of **EO space-based data and information for monitoring, protecting, and documenting World Heritage sites** is manifold. These different areas of intervention require the availability and integration of information from various sources in order to improve understanding and risk assessment capacities with regards to these sites. EO data and solutions can therefore provide useful insights related to (for instance) air pollution, coastal erosion, land-use and climate change. Change maps or millimetre InSAR-based deformation monitoring are also examples of key elements EO can contribute to the preservation of these priceless assets. Such technological solutions constitute a valuable and cost-efficient resource for the domain's stakeholders, at a time where cultural funding is declining. Government and philanthropic funds are increasingly moving towards healthcare and environmental causes and the COVID-19 pandemic has caused the long-lasting closure of many sites as well as the suspension of rehabilitation, conservation and archaeological exploration works. Whilst great progress has been achieved in recent years on the use of EO solutions, the cultural heritage market is still at a nascent stage and thus revenues are not quantified in this report.

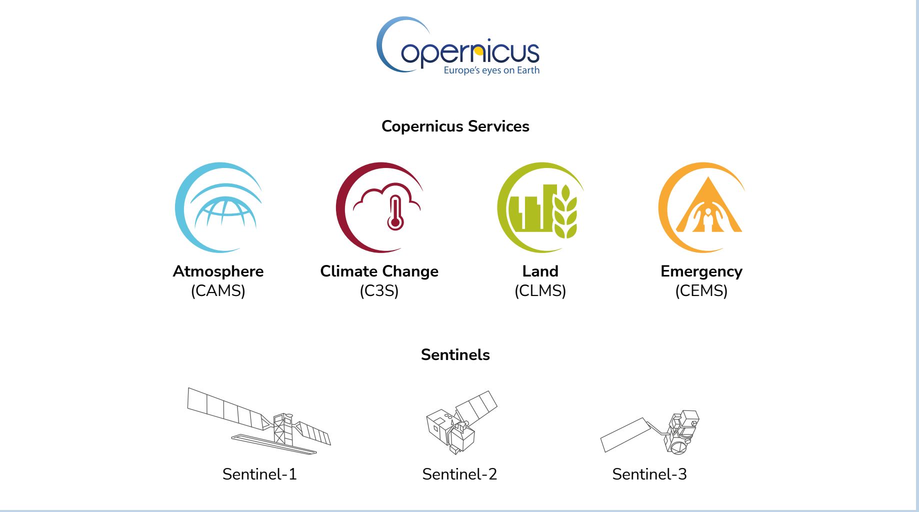
EO data powering real estate analytics

The **real estate market has been embracing satellite imagery** as a major catalyst for enhanced awareness of the characteristics of the urban environment. The ability to accurately and securely obtain real-time data on land and construction changes allows real estate developers, retailers, brokers, contractors and asset managers to gain advanced insights before, during and after a real estate project. High-resolution EO data is being **integrated into smart algorithms** to more accurately calculate crucial performance parameters for buildings and landscapes, giving the involved real estate actors the ability to save time and money. Further, quality-of-life indicators linked to (for instance) poverty, recreational spaces and safety and security can be measured by means of EO and location-based data, providing crucial information for the valuation of properties. The competitive edge provided by satellite imagery has been increasingly recognised by major real estate analytics companies who team up with fast-growing EO start-ups. This is why many of the companies developing new satellite constellations are explicitly targeting the real estate industry and adopt platform-as-a-service or intelligence-as-a-service business models to serve it. Aside from hi-res imagery, they use Copernicus Sentinel data to support land valuation and environmental impact assessments connected to real estate projects.

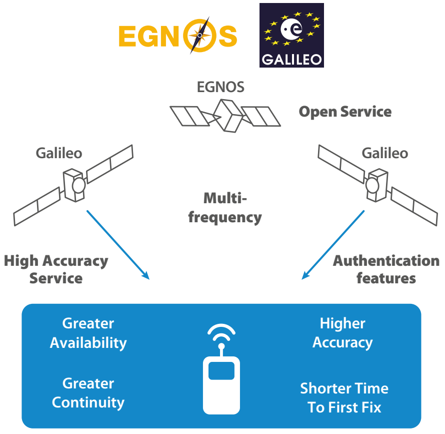
The EU Space Programme presents a strong value proposition for urban development and cultural heritage applications

Current usage of Copernicus

The Copernicus programme supports urban planning and monitoring through its satellite and in situ data as well as through its services such as the Copernicus Land Monitoring Service (CLMS) (e.g. with its Urban Atlas). The CLMS is also critical for monitoring of cultural heritage, identifying and mapping risks such as coastal erosion or ground subsidence. In addition, the Copernicus Emergency Management Service (CEMS) provides a range of products related to natural and man-made disasters that can affect the urban environment (e.g. floods, landslides). Additional value is provided by the Copernicus Atmosphere Monitoring Service (CAMS) (e.g. with its air quality forecasts and particulate matter measurements) and the Copernicus Climate Change Service (C3S) (e.g. with data on urban heat). Both these services support the preservation and maintenance of cultural heritage by enabling the assessment of sites' vulnerability with regard to climate change effects (e.g. heat waves, sea level rise). Sentinel-1 and Sentinel-2 data can be applied to building height detection. Sentinel-2 is further applied to mapping green urban areas, urban sprawl, and classification of (urban) land use. Sentinel-1 also supports InSAR monitoring of urban infrastructure such as tunnels, bridges and roads, identifying potential displacement or ground movement. Finally, Sentinel-5P measurements support the monitoring of air quality in urban environments.



Terminology used on this page is explained in Annex 2 for both GNSS and EO performance parameters.



Current usage of EGNSS

Increasing global urbanization rates mean taller city environments with more difficult satellite penetration and availability. However, with Galileo's full operational capability, surveyors now have many more tools to approach confined spaces and collect data. As of 2020, around 80% of surveying GNSS receivers already supported Galileo, and around 98% were EGNOS-capable. In Europe, the majority of RTK providers have already upgraded or have started to upgrade to Galileo. The trend to adopt Galileo within geomatics equipment will inevitably continue to rise, as it helps surveyors with rapid identification of property boundaries and city assets. Galileo's increased availability also facilitates the navigation and positioning of other GNSS-enabled devices, like drones that map the energy balance of a building or a mobile mapping system that creates immersive 3D street models. Crowdsourced mapping of city assets or traffic measurement also benefits from Galileo's availability.

EGNSS services and features to be explored

With HAS, Galileo will be the first constellation able to provide a high-accuracy PPP service globally, directly through the Signal-in-Space (SiS). This will unlock a multitude of new business opportunities in urban planning. The HAS will provide much higher continuity of cadastral or mapping/GIS GNSS operations in urban territories. Another differentiator – authentication – is being identified as important by an increasing number of users, especially in building construction, where lack of proper GNSS signals may result in projects falling behind schedule, incurring damages or lowering personnel safety. Finally, the multipath mitigation capabilities of Galileo make its signals very attractive for working within the tall city skyline.

A number of European funded projects apply and combine EO and GNSS to solutions in support of digitalisation, resilience, and sustainability of urban environments

HORIZON 2020 Shelter

Improving resilience of cultural heritage sites

The SHELTER *(Sustainable Historic Environments hoListic reconstruction through Technological Enhancement and community based Resilience)* project, funded under H2020 and running until May 2023, aims to develop a data-driven and community-based knowledge framework that will bring together the scientific community and heritage managers. Proposing useful methodologies, tools and strategies, SHELTER intends to increase resilience, reduce vulnerability and promote better and safer reconstruction processes in historic areas.

Due to the information complexity and the diverse data sources, SHELTER's framework will be implemented in a multiscale and multisource data-driven platform, able to provide the necessary information for planning and adaptive governance. All the developments of the project will then be validated in five open-labs (i.e. pilots) representative of the main climatic and environmental challenges in Europe, covering different heritage's typologies and specific socioeconomic conditions.

More information on: https://shelter-project.com/

HORIZON 2020 URBANFLUXES

Urban Anthropogenic heat flux from Earth observation Satellites

The H2020-funded Urban Fluxes project investigates cities' warming by breaking down the urban energy budget and targeting the anthropogenic heat flux. It uses imagery from Earth Observation satellites combined with conventional meteorological measurements at street level. The satellite-based approach is expected to be easily transferable to any city. With this knowledge, measures to reduce urban heat can be monitored and tested.

More information on: http://urbanfluxes.eu/

HORIZON 2020 DUET

Digital Urban European Twins

Source: DUET

The H2020-funded project, enabled by Cloud-basedsolutions and High Performance Computing, integrates geo data and data sources such as mobile phones or vehicles to create digital twinsof cities to support policy impact exploration and experimentationacross entire cities and regions. Test beds are created in the citiesof Athens, Pilsen and the Flanders regions for the policy domains of mobility, health, and environment.

More information on: https://www.digitalurbantwins.com/

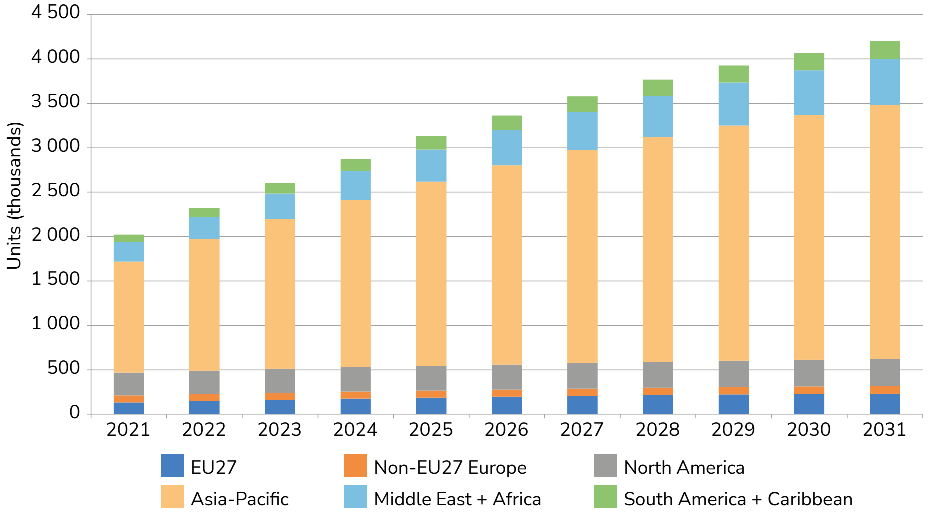
HORIZON 2020 SMURBS ERA-PLANET

Smart URBan Solutions for air quality, disasters and city growth (SMURBS)

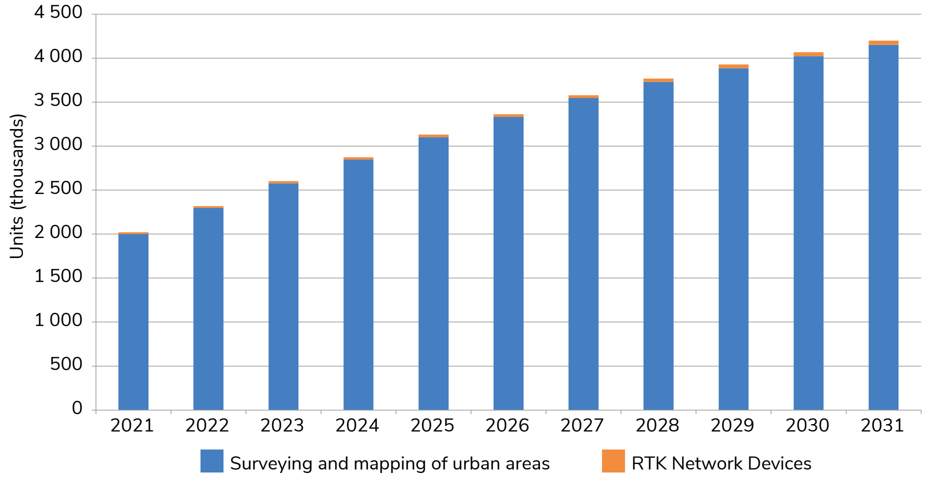
The SMURBS project ran between September 2017 and August 2020 with the aim of promoting the 'smart-city' concept through the integration of EO. It focused on increasing urban resilience targeting challenges with respect to air quality, urban growth, natural/manmade disasters and relevant impacts, as well as more entangled issues such as the migrant crisis and the health implications of such environmental pressures.

More information on: http://smurbs.eu/

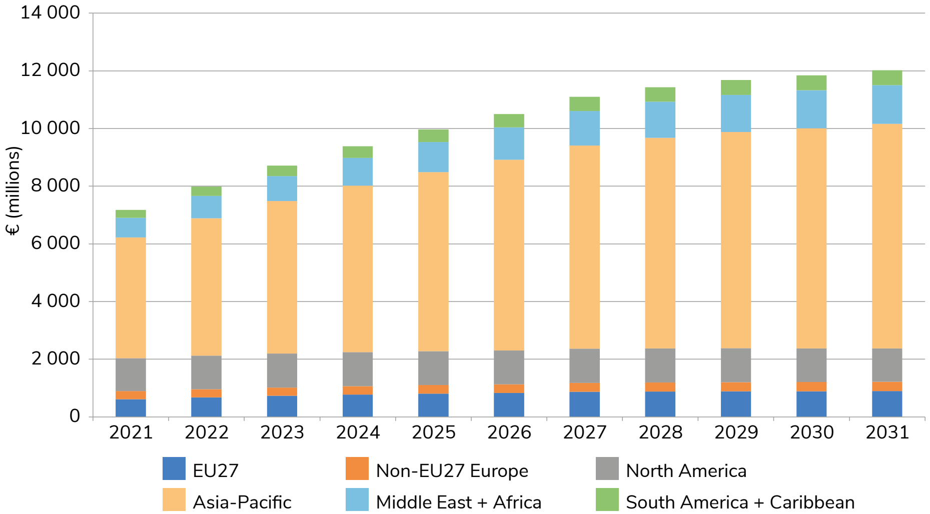
Installed base of GNSS devices by region



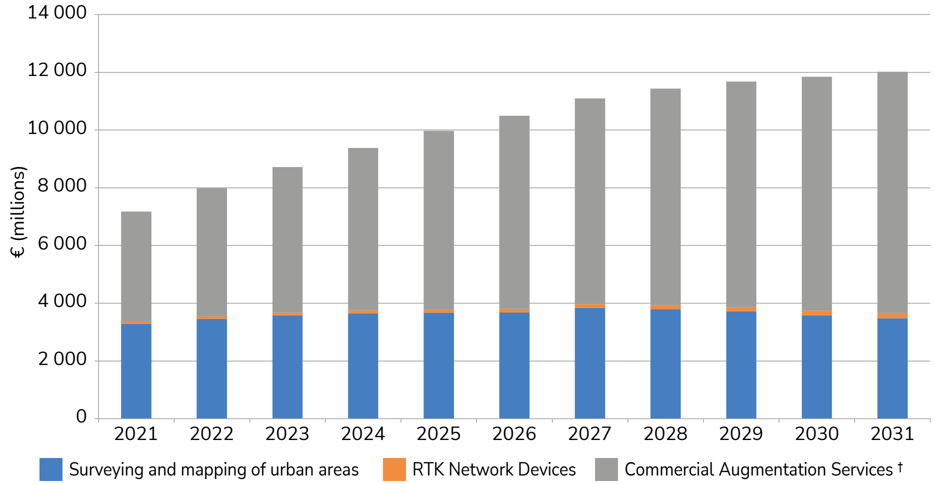
Installed base of GNSS devices by application



Revenue of GNSS device sales and services by region

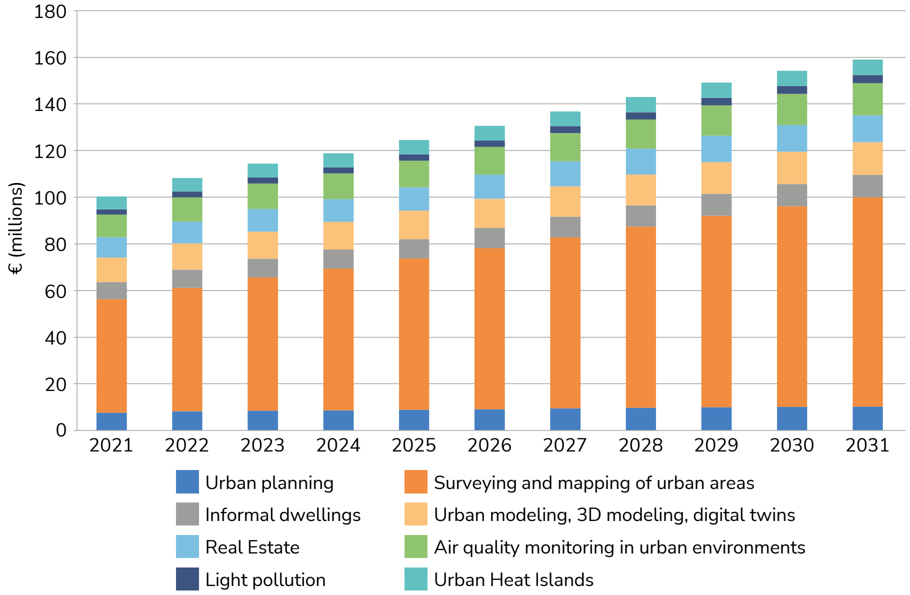


Revenue of GNSS device sales and services by application

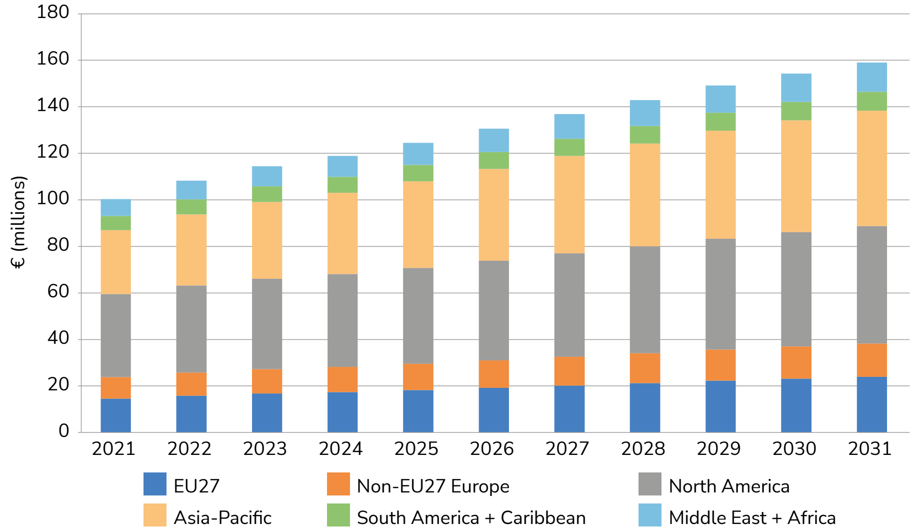


†: Commercial Augmentation Services also include revenue from applications in Maritime and Inland Waterways and Infrastructure segments

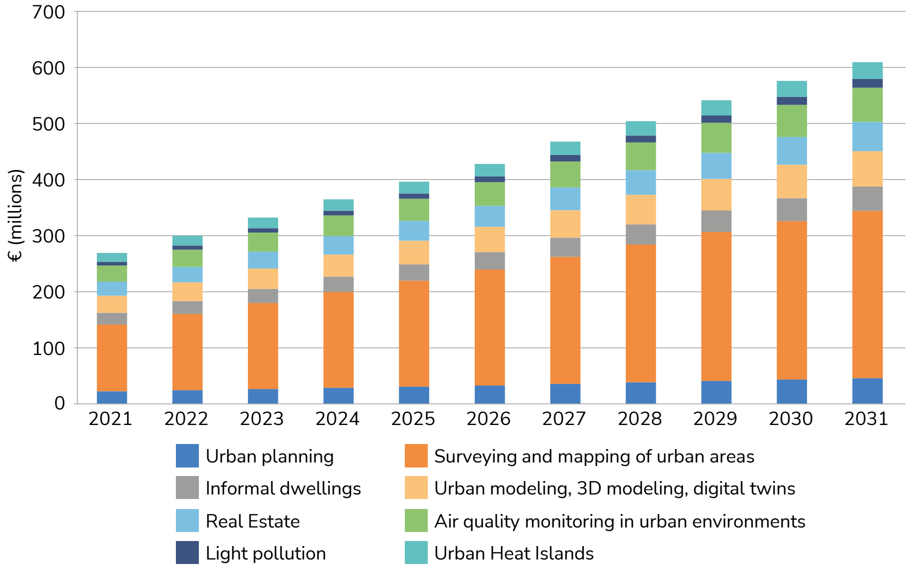
Revenue from EO data sales by application



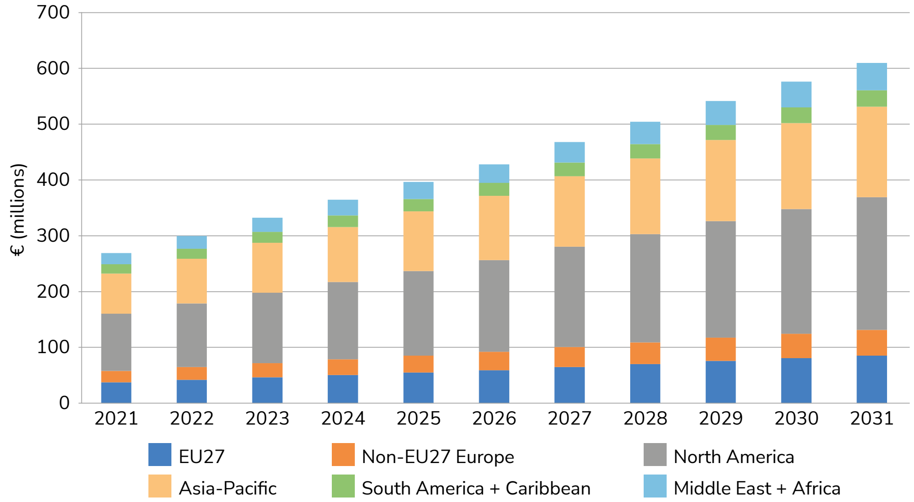
Revenue from EO data sales by region



Revenue from EO services sales by application



Revenue from EO services sales by region



SPACE

Legend
EO application
GNSS application
Synergetic application (combined use of EO and GNSS)

Acting/Supporting Mission Payloads
- Technology Demonstration (TechD)
- Scientific & Operational Missions (SOM)

Deep Space Applications
- Lunar Transfer Orbit (LTO)

Navigation and Control (GNC) Subsystem
- Attitude Determination (AD)
- Precise Orbit Determination (POD)
- Space Timing and Synchronisation (S-T&S)

SPACE

Although GNSS was originally designed to serve terrestrial users, it has also proven its worth as a valuable tool in space. Within the last decade the space industry has experienced a profound transformation. Driven by technological advancements and a new entrepreneurial spirit, the space environment is now hosting an increasing number of platforms and has therefore become a new playground for GNSS technologies.

Whatever the mission type (telecommunication, Earth observation, scientific development, navigation, etc.), providing reliable real-time GNSS data to Earth-orbiting satellites can bring many financial, technical and societal benefits such as reduced mission costs, improved navigation performances and the provision of trustworthy EO data.

What you can read in this chapter

- **Key trends:** A restructured space industry for a new space ecosystem.
- **User Perspective:** Spaceborne GNSS receivers must respond to a very diverse market.
- **Industry:** Space-borne GNSS Value Chain.
- **Recent Developments:** Megaconstellations and new associated business models drive the next decade of shipments.
- **Future Market Evolution:** Flourishing space applications, calling for appropriate regulation.
- **European Systems and Projects:** Galileo solutions taking their place within the Space Service Volume.
- **Reference Charts:** Yearly evolution of installed base of GNSS devices and revenues by application and region.

Application descriptions can be found in Annex 3.

A restructured space industry for a new space ecosystem

Key market trends

- Driven by the *New Space* momentum, Space users are becoming increasingly diverse, both in the public and private sectors
- Extensively sought-after, the Low Earth Orbit becomes a crowded space area, where megaconstellations projects are accumulating
- A victim of its own success, outer space is calling for enhanced Space Situational Awareness (SSA) activities, to ensure the continuity of space-based services

Democratisation & diversification of the space ecosystem

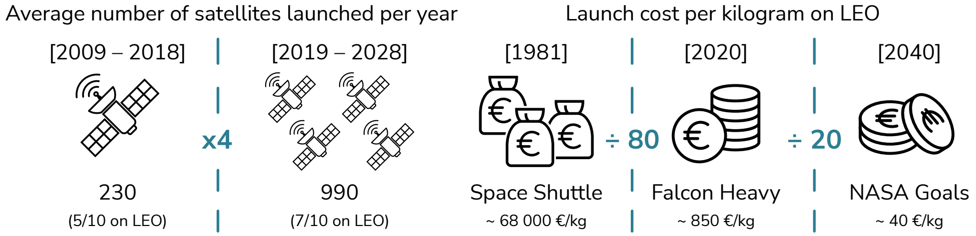
More than just a trend, *NewSpace* is a philosophy linked to the emergence of a private space industry and the democratisation of space activities. Driven by unprecedented technological advancements such as artificial intelligence, digitalisation and miniaturisation, and a new entrepreneurial mindset, access to space has become significantly cheaper and faster. The rapid diversification of the space ecosystem, made possible through innovative geo-information business models and significant private capital investment, is therefore propelling space activities into the commercial realm.

Space data is today the basis of innovative value-added products and services, and has become a cornerstone of our economic growth and societal well-being. This ongoing democratisation of the access to space is ultimately pushing society to consider the space environment as a commodity, at the same level as any other component of the global industrial infrastructure. No longer reserved to a minority of stakeholders, space is now a tool that can be used individually or more collaboratively to the benefit of scientists, businesses or public bodies, pushing towards the uptake of new space-based applications and the development of new space infrastructure.

Digitalisation & new megaconstellations systems

The launch of Low Earth Orbits (LEO) **megaconstellation projects** has become a symbol of this new era, showcasing incredibly diverse commercial possibilities such as EO in particular, but also in Satellite Communication for broadband connections and the Internet of Things (driven by the needs of global coverage and low latency). This phenomenon is inevitably leading to an unprecedented number of satellites orbiting the Earth and **calls for new performance needs.**

GNSS has a major role to play in this evolution, thanks to the financial and technical benefits it brings (e.g. reduced number of instruments, reduced dependence on ground-based stations, improved navigation performances, etc.) and its applicability to both historical and emerging stakeholders. New business philosophies based on a rapid prototyping, production and deployment of small satellites are today driving down the costs-to-orbit, particularly on LEO. Coupled with a permanent quest for smaller, lighter and lower-cost solutions, this brings new challenges to the space sector and unprecedented opportunities for the spaceborne GNSS industry.



Space Situational Awareness: safeguarding the space environment

Entering the third millennium, about 800 satellites were actively orbiting the Earth. Twenty years later, this number has exceeded 3,500 satellites and is expected to quadruple over the next decade. Outer space has become unbelievably crowded and the risk of collision between space objects statistically increase with every new launch.

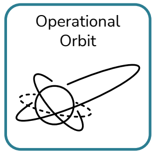
> **Space Situational Awareness** (SSA) is usually defined as a holistic approach encompassing activities in three main areas: Space Surveillance & Tracking (SST), Near-Earth Objects (NEO) and Space Weather (SWE).

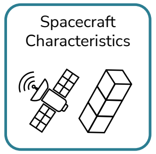
Limiting pollution and avoiding potential collisional cascading (i.e. the Kessler effect) is today a concern shared by the entire space community, not only in Europe, but at a global scale.

Considering space debris as a serious threat to the security, safety and sustainability of space activities, an **EU SST Support Framework** has thus been established at the European level in 2014, contributing to a global burdensharing in the SSA domain. Subsequently, the 2016 *'Space Strategy for Europe'* pointed out the Union interest for SSA activities in order to reinforce its strategic autonomy 'in accessing and using space in a secure and safe environment' through the development of European SSA capabilities. Implemented by a Consortium of EU member states (France, Germany, Italy, Poland, Portugal, Romania and Spain) and in cooperation with the EU Satellite Centre (SatCen), the EU SST Cooperation today serves over 100 EU organizations with free services and operates a growing network of sensors (i.e. radars, telescopes and lasers).

In early 2021, the European Parliament welcomed the adoption of the new Space Regulation. Based on political agreements reached in December 2020, this confirms the creation of a new flagship SSA component within the EU Space Programme, fostering the development of key SST activities in Europe.

Spaceborne GNSS receivers must respond to a very diverse market





Operational drivers for the use of GNSS receivers aboard spacecrafts

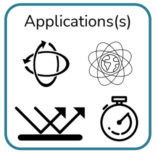
Although all space users operate in a similar environment – i.e. outer space – many variables actually come into play when identifying case-to-case GNSS requirements.

Depending on their characteristics (e.g. mass, designed lifespan, mission type, mission costs, etc.) and the orbit they are targeting (due to variable geometrical constraints and signal availability), spacecraft are indeed not expected to be equipped with the same kind of spaceborne GNSS receivers. At relatively low altitudes (3,000-8,000 km), GNSS receivers generally benefit from a good signal availability from any single constellation. On the contrary, high altitude (8,000-36,000 km) are much more challenging as they often have to cope with a significantly reduced GNSS signal availability and therefore need ultra-sensitive receivers (i.e. able to exploit GNSS signals first side lobes) which are at the cutting edge of current technology. Also, large satellites can embark relatively heavy receivers (a few kilogrammes) while SmallSats must avoid this extra mass. Similarly, most CubeSat missions cannot afford expensive pieces of equipment while long-term missions are ready to do so to guarantee system robustness.

Three receiver categories covering variable applications

Whether it is for real-time on-board autonomous navigation (i.e. attitude determination [AD], precise orbit determination [POD] and space timing and synchronisation [S-T&S]), supporting specific scientific or operational satellite missions [SOM], performing technology demonstration [TechD], or enabling deep-space activities such as a translunar trajectories [LTO], user needs and associated priorities vary. Three categories of receivers are defined.

While 'Low-End' receivers encompass COTS NewSpace technologies and low-cost products offering appreciable trade-offs between performances and affordability, 'High-End' receivers correspond to much more robust – and expensive – hardware systems expected to run safely for at least a decade in outer space. Eventually, 'Payload/Scientific' receivers, used as part of the payload instrumentation, either in support of specific missions or for technology development, must respond specific needs (not necessarily navigation-related) while fitting within missions' variable budgets.



Applications	POD	AD	S-T&S	SOM	TechD	LTO
Low-End	Early Stage	Early Stage	Used	Used	-	-
High-End	Used	Used	Used	Used	-	Used
Payload/ Scientific	-	-	-	Used	Used	-

Key GNSS user requirements

The key GNSS user requirements for the different application groups within the **Space** segment are, at EU level, collected through extensive interactions with user groups, providers and experts in a continuous process culminating at the User Consultation Platforms (UCP).

All relevant requirements are documented in detail and updated regularly within the Report on Space user needs and requirements.

Space debris removal, the emerging yet essential GNSS-based application

To tackle the **space debris** issue and avoid its escalation, mitigation measures and remediation services are today being considered and entrusted to the EU SST Consortium through the new Space Regulation. From the definition of post-mission disposal guidelines, to regular spacecraft evasive actions or the development of cutting-edge space debris removal technologies (e.g. robotic arms, harpoons, nets), some of these measures require the use of accurate positioning systems, representing a real opportunity for the spaceborne GNSS market. **Active debris removal** is indeed seen as particularly valuable for the imminent age of megaconstellations, while thousands of satellites will soon be formation-flying in low orbits to offer low-latency telecommunications or global high-repeat Earth observation coverage.

The Astroscale ELSA-M spacecraft which aims, for example, to remove multiple retired satellites from LEO in a single mission, will use the off-the-shelf 'Constellation On Board Computer' (cOBC) GPS and a Galileo-enabled RUAG GNSS receiver. Astroscale announced a funding award from OneWeb, to mature their technology and capability towards a commercial service offering by 2024.

In 20 years, such systems might be used to bring space debris into dedicated recycling stations, in order to reuse part of their materials and components – these will rely on Galileo-based positioning systems.

Space-borne GNSS Value Chain[1]

COMPONENTS AND RECEIVER MANUFACTURERS	SPACECRAFT MANUFACTURERS & DEVELOPERS	SPACECRAFT OPERATORS	PROVIDERS OF SERVICES GENERATED IN SPACE	FINAL USER COMMUNITIES
• ACCORD • AIRBUS* • BAE SYSTEMS • DLR* • GENERAL DYNAMICS • HEXAGON* • HONEYWELL • HYPERION* • MEISEI ELECTRIC • MICROSHIP TECH. • MOOG BROAD REACH • NEC/TOSHIBA • NEWSPACE SYSTEMS* • NOVATEL • PUMPKIN • QASCOM* • RUAG* • SKYTRAQ • SPACEMANIC* • SPACE QUEST • SURREY SATELLITE TECHNOLOGY LTD* • SYRLINKS* • THALES ALENIA SPACE* • U-BLOX*	• OHB* • THALES ALENIA SPACE* • ADS* • INVAP • BOEING • LOCKHEED MARTIN • NORTHROP GRUMMAN • MAXAR TECHNOLOGIES • SPACE X • CHINA GREAT WALL INDUSTRY CORPORATION • SMALL SATS DEVELOPERS (E.G. PUMPKIN, HARRIS CORP., ISIS, ETC.) • UNIVERSITIES	• ESA (ESOC)* • NASA • NATIONAL SPACE AGENCIES • UNIVERSITIES • RESEARCH CENTRES • PRIVATE COMPANIES • NON-PROFIT ORGANISATIONS (E.G. AMSAT) • ARMED FORCES • EU*	• UNIVERSITIES • RESEARCH CENTERS • PRIVATE COMPANIES • EU (E.G. COPERNICUS)* • GOVERNMENTAL INSTITUTIONS	• EARTH SCIENCES RESEARCHES • TERRITORY PLANNERS • ENVIRONMENTAL MONITORING • PUBLIC SAFETY • INFRASTRUCTURE OPERATORS • LAW ENFORCEMENT • EMERGENCY SERVICES • GEOSPATIAL INTELLIGENCE AGENCIES

European[2] industry in the global arena

Europe dominates the market for GNSS Components and Receivers, with a share of 73%, ahead of North America's 21%, in 2019, thanks to a combination of both historical stakeholders and new actors answering NewSpace needs. Led by Airbus, Hexagon and U-Blox, European companies hold six of the top 10 positions among manufacturers in the market.

Note: Contrary to the value chain of other market segments, the value chain of the Space Users does not discern any difference between module/chipset manufacturers and receiver manufacturers. Indeed, it is assumed that the high environmental constraints to be taken into account (e.g. high dynamics, use of radiation hardened integrated circuits, etc.) force receivers' manufacturers to develop their own chipsets.

LEGEND

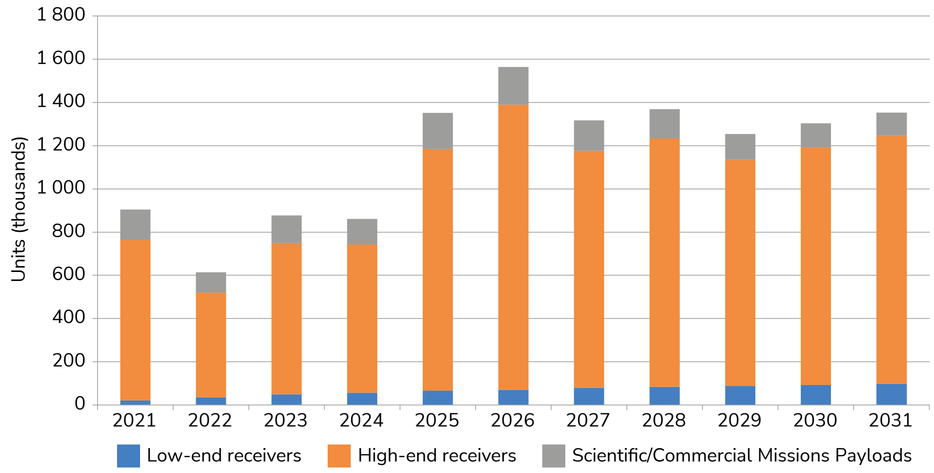
User segments

NOTES

[1] The value chain considers the key global and European companies involved in GNSS downstream activities.
[2] In the market share analysis, Europe is defined as EU27 plus Norway, Switzerland and the UK.
* European-based companies. The region is defined with respect to the headquarters of the company, though the actual area of activity might be wider.

Megaconstellations and new business models drive the next decade of shipments

Shipments of GNSS receivers per type of receivers*

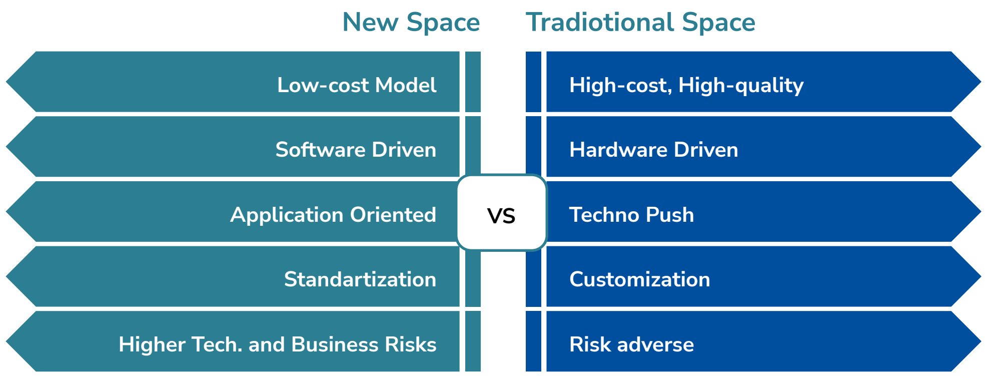


** See table p.180 for the correspondence between type of receivers & applications.*

New scalable business models

The NewSpace stands out for sure by its technological innovations. Yet, the other transformation underlying this dynamic lies in the advent of new scalable business models leading to a reduction in costs, shorter lifecycles and a bolder approach to risk taking in the space sector.

Indeed, NewSpace opens the space sector to a economic model where satellites are manufactured in batch, launches occur every month, parts and units are mass-produced and processes are industrialised. Most importantly, in the age of (mega)-constellations, projects can be launched rapidly, adopting a more trust-based and risk-tolerant approach.



Source: Euroconsult

New actors are however not expected to replace historical ones, but to challenge and complement them. The technological push that has always defined the space industry is now strengthened by the user pull generated by new stakeholders' arrival and the need they create. Most of the new small LEO satellites are coming out with a need for GNSS receivers. With a relatively short lifetime and therefore a higher replacement rate, these satellites stand as the key driver of the spaceborne receivers' market. The technical adaptations required to evolve in this space environment are well-known and technically mastered in these low-altitude regions. The GNSS market for LEO satellites is therefore mature and several companies already propose off-the-shelf products (e.g. SSTL, GOMspace, Thales Alenia Space, etc.).

Megaconstellation pushes to the adoption of low-end, yet reliable receivers

Resulting from an ever-increasing adoption of GNSS-based solutions among the space users and the continuous development of new megaconstellation projects, the **number of spaceborne GNSS receivers to be sold is expected to progressively increase in the coming years.** The variable levels of certainty on the long-term success of these megaconstellations however prevent from properly assessing their potential replacement cycles and the impact it could have on the market on the second part of the decade.

High-end receivers are and will probably remain for the next decade the main option for most Space applications (except for technology development, due to their high cost). Yet, it is expected that Low-end receivers – which are today mainly used to support specific scientific or operational satellite missions, or for space timing and synchronisation – may significantly expand to Attitude Determination and Precise Orbit Determination applications, covering a growing part of LEO needs. As of today, two reasons suggest that these estimations with of future *Low-End* unit sales are conservative. First, only megaconstellations with granted FCC filings were captured within the model and no satellite replacement was included. Second, the CubeSat market might be slightly underestimated, since reliable data on forecasted university/academia missions are not available. Nevertheless, budgeted values for these missions are very low and are not expected to significantly impact the order of magnitude of total market value.

Software-defined receivers

Software-defined receivers constitute a very interesting approach for space users, offering features such as **re-programmability** (i.e. upgradeability) **or self-healing capabilities.** The most vivid examples could be the possibility to upload algorithms yet-to-be-invented at the receiver's launch time, or the ability to recover from a single-event effect by remotely rewriting damaged functionalities, reducing the need of onboard redundancy.

Flourishing space applications, calling for appropriate regulation

In-orbit servicing – Towards sustainability

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In-orbit satellite (IoS) servicing refers to the **refuelling or the repairing of space satellites while in orbit.** Although considered since the early days of spaceflights, the recent easier access to LEOs and space debris-related issues has generated a renewed interest for the practice.

IoS has the potential to open-up new opportunities through satellite life extension, robotics and salvage, while also offering sustainability benefits through debris removal and material recycling over the longer term. While GNSS could be used as a mean of absolute (for the approach) and relative (for the connection) positioning, it is also suggested that IoS services may go beyond life extension and up to service enhancement, by providing additional capabilities to the client satellite (e.g. equip an already flying satellite with a new piece of hardware, such as a GNSS receiver).

Up to the dark side of the Moon

The characterization of an **interoperable GNSS Space Service Volume** (SSV) – which is an important enabler for new missions and a key driver for new technological developments – is today limited to Earth orbits up to an altitude of 36,000 km (i.e. GEO). Yet, navigation is also a key technological enabler for cislunar and lunar volume discovery, and all the moon exploration missions that define the emerging lunar economy share similar navigation needs. The **international space community plans therefore to extend GNSS PNT applications up to the Moon.** Different phases could be considered, starting with the use of the already existing Earth-GNSS constellations via high-sensitivity space receivers, leveraging the use of GNSS signal side lobes. Yet, such approach only allows to reach cislunar areas (not occulted by the Moon). Plus, if the objective is to get enough accuracy and availability to enable autonomous landing and rover guidance, Earth GNSS signals alone are not sufficient.

Going a step further[1], it is therefore possible to consider that Earth-GNSS constellations may be augmented with dedicated lunar orbiting satellites and lunar beacon ranging sources, marking a gradual deployment leading to a full autonomous lunar navigation system. Beyond the primary navigation purpose of such an ambitious system, any other GNSS-based applications could also be considered, such as the study of lunar soil deformation based on GNSS-R.

[1] https://insidegnss.com/across-the-lunar-landscape-towards-a-dedicated-lunar-pnt-system/, Inside GNSS, December 2020.

A new era calling for automated Space traffic Management (STM) activities

The diversification and the expansion of space users is of great interest to the spaceborne GNSS receivers market. Yet, the consequence it has on the space environment raises the question of the awareness system and traffic management policies it requires. NewSpace activities could indeed overwhelm current space flight safety processes, putting at risk space infrastructure and human spaceflight. Currently, no 'highway code' has been established in outer space by the international community.

Today, space traffic is mainly 'ruled' by the Outer Space Treaty – establishing that no nation may claim sovereignty over outer space (article II) – and the IADC space debris guidelines, that aim to limit the generation of space debris. This is and will therefore remain an international concern. Cooperation – on a global scale – offers an unprecedented opportunity to enhance the safety of active satellites, in order to preserve space operations and all the benefits it brings to the global economy and society.

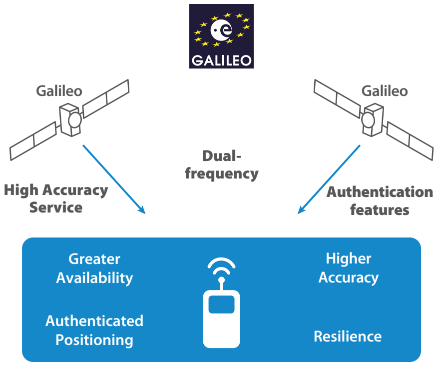
Business-as-usual will obviously not work. But although the enforcement of Space Traffic Management (STM) policies may soon become inevitable, its implementation is extremely complex for political (no sovereignty over outer space) and practical reasons.

Tracking potential collisions, notifying impacted parties and coordinating how they respond is still a largely manual process, which is not sustainable as the number of satellites grows. In the past, developing automated systems for a handful of satellites making a few avoidance measures a year was not worth the investment. Today, with the influx of new LEO satellites, handling avoidance measures manually no longer makes economic sense.

Paving the way towards the building of an international approach to STM, the European Commission has recently launched a new 'EU strategy for Space Traffic Management (STM)' flagship project. As announced in the Action Plan on Synergies between Civil, Defence and Space Industries, the project aims to develop STM rules and best practices, limiting the risk that non-EU standards become the norm and supporting the EU in its efforts to achieve technological sovereignty.

The question of the role GNSS solutions could play in this long-lasting process is legitimate. Traffic management requires a good knowledge of each vehicle positioning and attitude, based on standardised and robust technological solutions. The development of spaceborne GNSS receivers and their deployment at a wider scale could therefore be one of the building blocks toward future space regulations. These moreover must be formulated and implemented in the very short term to ensure both space users can safely operate their systems and terrestrial users can benefit from their associated critical services (e.g. navigation, telecommunication, etc.).

Galileo solutions taking their place within the Space Service Volume



Added value brought by EGNSS

Galileo offers significant advantages to space users, whose applications vary in terms of priority needs and accuracy requirements.

Dual-frequency capacities guarantee better performances for lower orbits, while the increase of the overall number of GNSS satellites allows the significant improvement of availability for spacecrafts orbiting at MEO and beyond.

EGNSS services and features to be explored

Galileo high-accuracy and authentication features are also of great interest for space users. Achieving position accuracy levels which can otherwise only be achieved with POD processing on the ground (thus adding undesirable delays), HAS is of high interest for many space applications and should be made as advanced as possible to achieve competitive advantage with Galileo.

Driven by a rising interest in authentication for resilient GNSS-based navigation in space – in particular against jamming and spoofing – Galileo OSNMA and CAS are attractive options to make navigation more robust and increase availability of a trusted navigation solution.

HORIZON 2020

The first GSA-funded receiver launched into orbit – ENSPACE

Launched late 2017 by the GSA and led by Qascom, the ENSPACE (Enhanced Navigation in Space) project has recently developed an innovative GNSS spaceborne receiver. Targeting the needs for robust positioning, navigation and timing of satellites with the flexibility of a software solution, the ENSPACE technology fosters the use of GNSS in space. Configurable for multiple applications (e.g. navigation in space, timing determination, precise orbit determination, attitude determination) and diverse mission contexts (from Earth orbits to space exploration), ENSPACE aims to become a reference low-cost product on the market.

Three years after the project kicked-off, ENSPACE Receiver was integrated in a NASA/Ohio University 3U CubeSat(BOBCAT-1) and deployed from the ISS on the 5th of November 2020, with three main objectives: test the receiver in a real LEO space environment; assess its ability to continuously compute PVT information; and exploit its reconfigurability. Two weeks after its deployment, the ENSPACE receiver successfully computed BOBCAT-1 in-orbit first positions, combining GPS and Galileo signals. While the ENSPACE project has now come to an end, space experimentation and operations continue, including GNSS positioning with ground Assistance Data and the validation of the receiver's Attitude Determination, POD and Authentication algorithms.

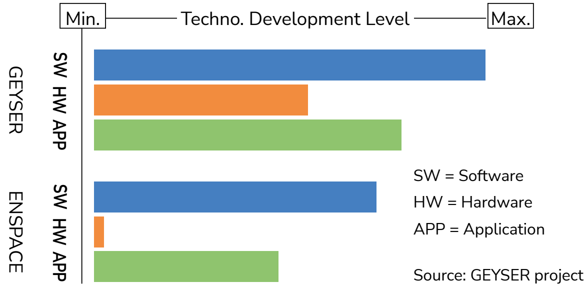
In addition to the physical deployment of the receiver in space, the ENSPACE project has set up an innovative test platform, offering multiple experimentation possibilities for innovative space concepts and Galileo added-value. The platform was especially used to demonstrate the capability of the software-defined radio ENSPACE receiver, which was able to track the signal of the Spirent constellation simulator and to propose a real-time multi-constellation PVT solution in multiple space scenarios. In 2021, the ENSPACE receiver has a Technology Readiness Level (TRL) of 7 (i.e. a system prototype demonstration in operational environment). On the market it will take the commercial name of QN400.

More information on: https://www.gsa.europa.eu/enhanced-navigation-space

GEYSER project taking over

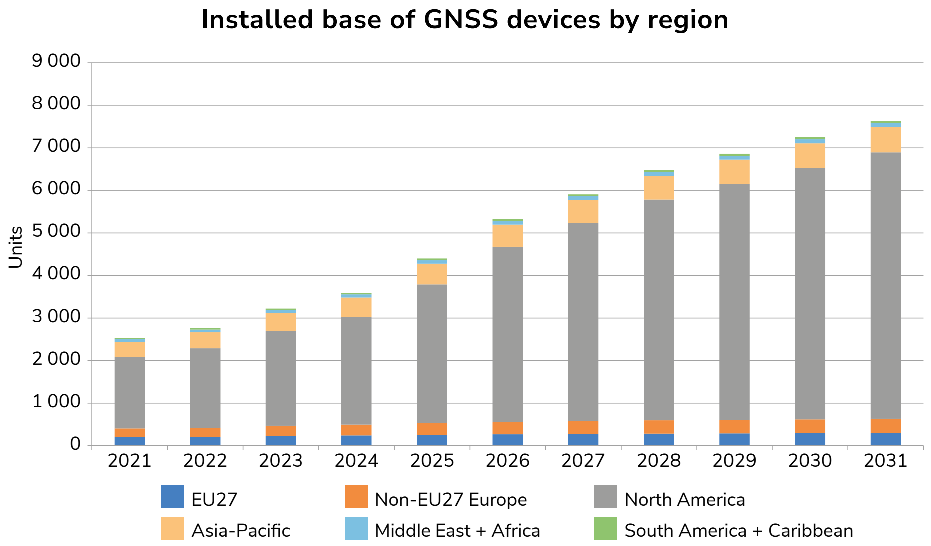
With the GEYSER (GalilEo cYber SpacE Receiver) project, Qascom and its consortium are committed to follow in ENSPACE footsteps.

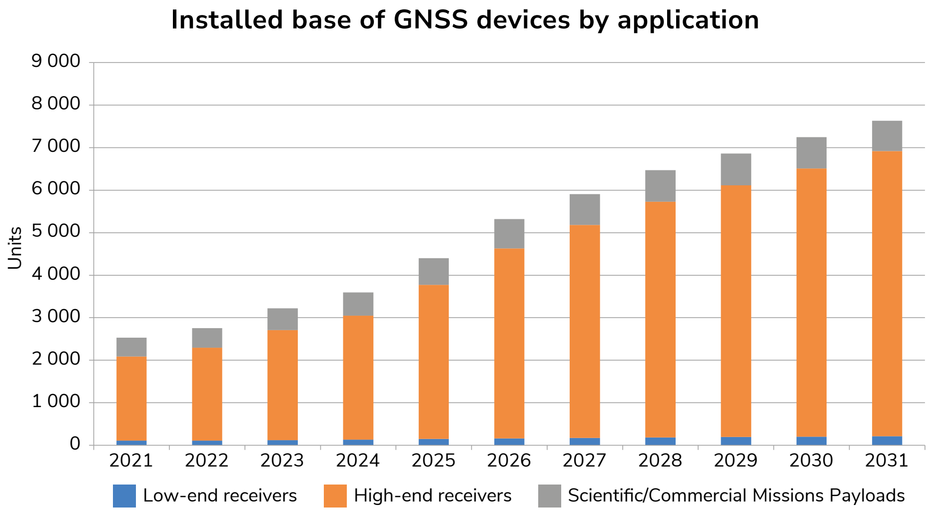
GEYSER complements developments over the past few years with new added-value functionalities, with the objective to become a close-to-market space receiver, and compatible with COTS. Targeting new applications (e.g. cybersecurity and robust PNT, dual-frequency POD for station keeping and collision avoidance, high dynamics navigation, etc.), the GEYSER project aims for new technological development targets, both on software and hardware levels.

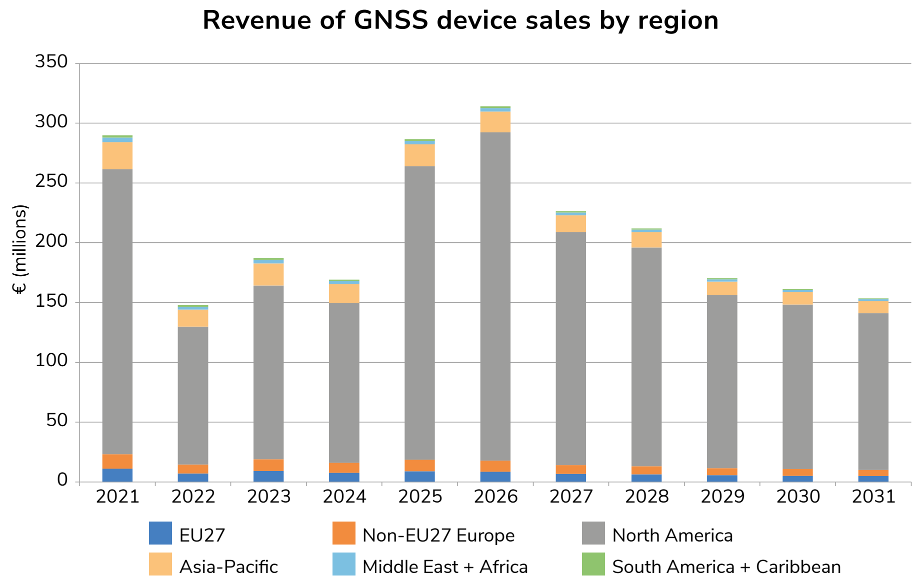


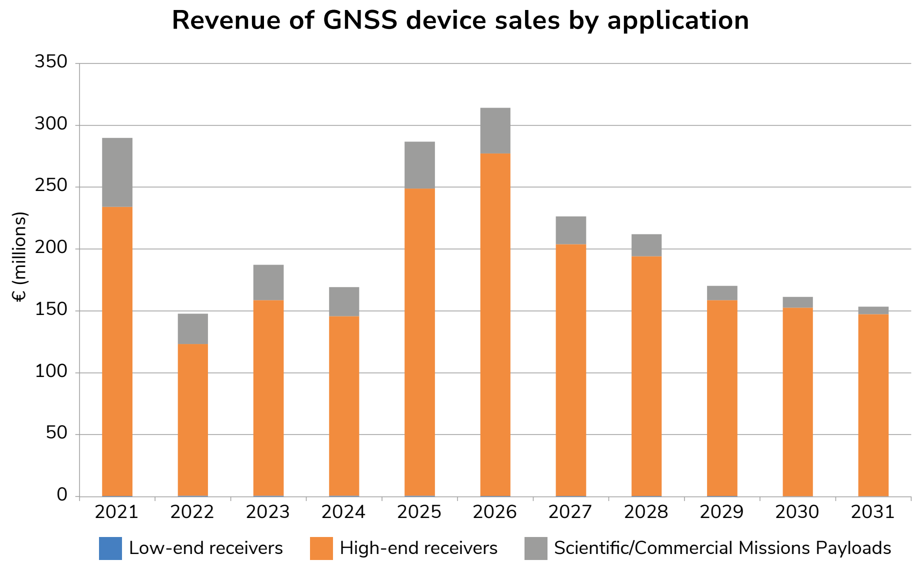
Source: GEYSER project

Terminology used on this page is explained in Annex 2 for both GNSS and EO performance parameters.


Installed base of GNSS devices by region
Units
9 000
8 000
7 000
6 000
5 000
4 000
3 000
2 000
1 000
0
2021 2022 2023 2024 2025 2026 2027 2028 2029 2030 2031
EU27
Non-EU27 Europe
North America
Asia-Pacific
Middle East + Africa
South America + Caribbean


Installed base of GNSS devices by application
Units
9 000
8 000
7 000
6 000
5 000
4 000
3 000
2 000
1 000
0
2021 2022 2023 2024 2025 2026 2027 2028 2029 2030 2031
Low-end receivers
High-end receivers
Scientific/Commercial Missions Payloads


Revenue of GNSS device sales by region
€ (millions)
350
300
250
200
150
100
50
0
2021 2022 2023 2024 2025 2026 2027 2028 2029 2030 2031
EU27
Non-EU27 Europe
North America
Asia-Pacific
Middle East + Africa
South America + Caribbean


Revenue of GNSS device sales by application
€ (millions)
350
300
250
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100
50
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2021 2022 2023 2024 2025 2026 2027 2028 2029 2030 2031
Low-end receivers
High-end receivers
Scientific/Commercial Missions Payloads

Editor's Special: Innovative solutions for Health

HEALTH

As defined by the World Health Organisation (WHO), health is a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity. In turn, good health is an asset and a source of economic and social stability, benefiting all sectors and the whole of society. As a synthesis of this Market Report covering a wide spectrum of topics, the Editor's Special returns back to this important resource and fundamental right of every human being.

The global COVID-19 pandemic has in some respects showcased the fragility of global healthcare systems, but has also more importantly revealed how countries across the world have reached out to each other to provide support and assistance. In this respect, global systems such as EO and GNSS can transcend borders to assist healthcare systems worldwide.

The Editor's Special looks deeper into how space-based data from GNSS and EO is used across the healthcare segment and presents the latest GNSS- and EO-enabled tools, used by people and governments all across the world to and improve healthcare systems.

As shown in the adjacent figure, many applications covered in segments throughout this report play an important role for public health (circled in green). More specifically we highlight developments such as:

- ✓ **Automation and digitalisation trends integrating spatial data for a more effective response to global health crises:** the digitalisation trend (e.g. eHealth) is highlighted through GNSS-enabled applications and EO data responses to the pandemic.
- ✓ **EO and GNSS provide essential contributions toward better responses to evolving global health care needs:** this covers examples of the way the healthcare ecosystem can benefit from medical drone deliveries (especially in remote areas), GNSS-IoT trackers adapted for ageing population needs and the way EO data monitors can prevents future pandemics or outbreaks of (for example) Mosquito-Borne Diseases (MBDs).
- ✓ **The role of location information for emergency situations:** GNSS takes emergency response to the next level as illustrated by the role of accurate positioning in each step of the emergency response chain (including access to automated external defibrillators and supporting Next Generation (NG) 112 architecture).
- ✓ **Earth observation data and services as a key instrument for addressing the invisible threat of air pollution:** this comprises focusing on air quality guidelines by WHO, the contribution of EO data for Worldwide Analysis and Forecasting of Atmospheric Composition for Health, and monitoring the implementation of air quality legislation.
- ✓ Finally we highlight **the contribution of EU space programme to support challenges faced by healthcare systems globally.**

Automation, digitalisation and spatial data are contributing to a more effective response to global health crises

Towards a stronger European Health Union

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The current health crisis has exposed the need to strengthen Europe's crisis preparedness and management of cross-border health threats. The initial lessons learned from the pandemic has made clear the necessity of a move toward a **stronger European Health Union.** One of the main goals will be to reinforce the EU's framework for detecting and responding to serious cross-border health threats.

New initiatives are on board, among which is the **European health data space** that aims to make better use of data for better healthcare, better research and better policy making to the benefit of patients. A Health Emergency Response Authority (HERA) will be established to provide more coordination at EU level with more efficient tools.

GNSS and EO capabilities will also contribute to maintaining and building even stronger health systems in Europe. From high precision position accuracy, which enables health care providers find the most efficient way to send patients to the medical institution in the shortest time, to EO data for personal monitoring of allergies, the added value of GNSS and EO in the health sector is becoming more and more evident.

Digitalisation of the Health sector

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The **health sector is digitalising at high speed** thanks to the development of eHealth platforms, telemedicine, telehealth and other mHealth applications. The usage of different, often GNSS-enabled technologies (e.g. for location of patients, medical vehicles and medical devices) is increasing rapidly as hospitals and medical institutions are focusing more on efficiency and improved delivery of services to patients.

The current pandemic, overall rising prevalence of chronic diseases, advancing age of the population and rise in overall medical service costs are leading to this increasing adoption of technology in the healthcare industry. In fact, Health Services are setting up increasing numbers of **partnerships with leading technology companies** in order to analyse data and optimise the provision of their services. In addition, digitalisation opens access to personalised health applications.

Specifically EO data helps predictive mapping of diseases enabling decision makers (with the contribution of health professionals and the general public) to ensure adequate policies, cost-effective responses that could prevent or mitigate the occurrence of disease outbreaks.

GNSS has been an invaluable asset to assist and support citizens and governments in tackling the 'new normal' following the COVID pandemic

Following the rapid global spread of COVID-19, governments, companies and citizens have had to quickly adapt to a new way of operating business activities and organising personal lives. In response, numerous measures have been taken to curb the rise in COVID-19 infections.

GNSS-enabled applications became even more pervasive in our lives: from goods and food home delivery, to smartphone apps providing a real-time overview of transport occupancy, adapting to the new normal involved more reliance on location services to respect temporary quarantine and social distancing measures. At the same time, dedicated tracking and tracing applications (e.g. health status verification/Covid safe apps) were developed to help monitor as well as anticipate outbreaks.

Whilst the majority of these measures were taken to temporarily respond to a growing emergency, some of these measures could find their way into future response strategies. Indeed, technologies and applications surging during temporary lockdowns could remain part of our daily lives. The figure below provides some insights into how GNSS-enabled applications and EO data have contributed to the response, monitoring, mitigation and adaption to this global pandemic.

"Stay-at-Home" lifestyle
- Contactless food and goods delivery enabled by GNSS

Mobility
- MaaS applications to avoid crowded transport options
- Social distance monitoring
- Traffic management e.g. Galileo Green Lane app enabling efficient transit of goods
- Drone and robotics operations

Telemedicine
- Online doctor consultations
- Remote patient monitoring

Mapping & Tagging
- Mapping nearby points of interest such as pharmacies, hospitals, convenience stores, testing centres

Analytics
- EO and GNSS data for monitoring of traffic flows, urban heat maps, greenhouse gases as well as air and water quality

Safety management
- Mapping of high-risk areas
- Monitoring disease spread e.g. COVID safe apps for health status verification

Track & trace
- Contact tracing
- Quarantine enforcement
- More efficient management of disease outbreak

EO and GNSS provide essential contributions toward better responses to evolving global health care needs

Drones for medical needs

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The global **medical drones** market is estimated to reach almost €800 million by 2027[1]. Such drone deliveries are welcomed by governments as they are quicker, more efficient (especially in remote areas) and can help cut logistics costs. The pandemic has helped to move drone delivery trials forward across the globe.

For instance, Ghana was one of the first countries to **deliver COVID 19 vaccines using drones.** Ghana's health ministry partnered with Zipline and logistics firm UPS to get the vaccines to remote, rural areas that would be difficult and costly to reach by road. From test samples and medical supplies to blood banks, medical drones will become an essential part of the healthcare ecosystem.

In Europe, Italy has tested a five-kilometre Beyond Visual Line of Sight (BVLoS) flight for the delivery of biomedical products. In France, La Poste is working toward a drone that can deliver medical packages. Similar flights between hospitals have taken place in Belgium where a command centre for medical drones has opened up to oversee medical transportation at an altitude of 150 meters. In Poland, test flights between facilities have also taken place. GNSS is a key enabler for drones and Unmanned Aerial Vehicles (UAVs), ensuring safety of navigation and providing increased reliability for health applications.

Fundamental Elements

prolong

PROLONG: EGNSS supporting Active and Healthy Ageing products and services

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The PROLONG project combines high accuracy Galileo-based location with gait analysis and Opportunistic Networking to detect abnormal and dangerous walking patterns of older adults. To achieve these results, the consortium is developing a GNSS-IoT tracker that is small enough to be integrated into the users belt, necklace or bracelet.

Since the success of the PROLONG project will be measured through its commercial viability, users are actively engaged with the project. Over the course of 2021, end users received a first prototype at home and were encouraged to try out the device and share their feedback and recommendations to the team. To ensure the privacy of end users, the prototype relies on the latest authentication and security mechanisms.

EO increasingly helps to fight contagious and infectious diseases

For several years, **Earth Observation has helped to monitor parameters known to have negative impacts on human health,** such as aerosols (associated to cardiovascular and respiratory diseases), Ultraviolet (UV) radiation (which can cause skin cancer) or algal blooms (which can contaminate seafood).

While it is recognised that public health is closely related to environmental conditions, it becomes essential in a context of globalisation of **human activities and climate change** to fully understand how the evolution of our environment may affect the emergence and **spread of infectious diseases** (e.g. malaria, cholera) and pandemics (e.g. COVID-19) at local, regional, continental and global scales.

Satellite Earth observation data, combined with state-of-the-art data analytics technologies, enable the provision of tailor-made climate-health indicators that contribute to monitoring, modelling and forecasting of key environmental and climatic factors favouring infectious diseases and outbreaks. These indicators thereby support **prevention, early warning and health-care planning.** For instance, the EYWA initiative (see box below), is a specific example of the way Copernicus Core Service data, contributing missions, and EO derived proxies from Sentinels are integrated to address the critical public health need for prevention and protection against Mosquito-Borne Diseases (MBDs).

EYWA – Early Warning System for Mosquito Borne Diseases

EYWA Early Warning System for Mosquito Borne Diseases

According to the World Health Organisation (WHO), mosquitos are responsible for an estimated 750,000 global deaths annually. Of all Vector-Borne Diseases (VBDs), the diseases spread by mosquitos such as Dengue, Zika and Chikungunya are considered to be the three fastest spreading diseases in the northern hemisphere.

To address this growing threat to the public health, a partnership of a dozen research centres, tropical disease institutes and universities established the EYWA prototype system.

This system combines an interdisciplinary scientific field including Earth Observation, entomology, epidemiology, Big Data Analytics, and so on, with the main objective to offer a scalable, reliable, sustainable and cost-effective Early Warning System to forecast and monitor MBDs.

[1] Source: https://www.polarismarketresearch.com/industry-analysis/medical-drones-market

In emergency situations, space applications offer faster responses and contribute to saving lives

Each action of answering an emergency is aided by GNSS-enabled applications and geo-location

Since the introduction of **GNSS-enabled emergency calls** – such as eCall in recent car models, and as geo-location of emergency calls – has brought significant benefits to Public Safety Answering Point (PSAP) operators by providing a first indication and often a confirmation of where the emergency is situated.

Once the emergency call has been received, the following GNSS-enabled actions take place:

Tasking of vehicles: The deployment of emergency vehicles needs to happen in the most organised and efficient way. Using GNSS-enabled fleet management services, the dispatcher has the means to direct the nearest emergency vehicle to the scene of the emergency.

Navigation to location: Traffic and hazardous road conditions can lead to substantial emergency response delays. Navigating to destinations using a GNSS-enabled solution will not only optimize routes with a safe, fast-paced blue-light transfer, but also free up co-drivers to prepare themselves for the emergency.

Solving the emergency: This step depends on the nature of the emergency; for instance, geospatial information in the form of crowd-sourced map updates can facilitate deployment of aid, whereas health-related emergencies typically do not use GNSS to solve the emergency. Nevertheless in the case of road accidents, by speeding up emergency response times by up to half of their original time, eCall helps to prevent countless of road deaths.

Navigation to next location: Optimized vehicle routing protocols remain key throughout emergency response operations. This step too uses GNSS to navigate to the hospital, next incident, patrol area or back to base.

Next Generation 112

'112', the common EU number for emergency communications, has been saving lives for 30 years, helping Europeans travel safely and reach emergency services in any EU country through the single EU number. In 2019, Europeans called '112' close to 150 million times, which represents 56% of all emergency calls, while in the last 10 years, some 1.5 billion calls have been made to the number.

Emergency services will have to upgrade their technology to **embrace internet-based communications** in the upcoming years. In order to ensure the right technical conditions for accurate and quick location detection in emergency situations, the Commission Delegated regulation, which will apply from 22 March 2022, will oblige smartphone manufacturers to ensure that data from GNSS (at minimum from EU's Galileo) and Wi-Fi are made available in emergency communications. This will ensure that the caller is accurately and quickly located. Furthermore, the new **Next Generation 112 (NG112) architecture will allow for far more data collection** (text, video, location or additional data) **for more efficient responses,** thereby ensuring equal access for all citizens, including people with disabilities.

Galileo to improve the accessibility to automated external defibrillators

'Galileo for AEDs' will improve accessibility to automated external defibrillators (AEDs). The aim of the project is to investigate the possibility of using the Galileo-enabled location transmitted to Public Safety Answering Point (PSAP) during an emergency communication in order to locate available AEDs to decrease the deployment time if one is needed. The main expected outcome of this pilot project shall consist of an analysis of possibilities to develop and manage a mechanism, based on an EU digital registry of publicly available AEDs in EU Member States, that could be used in case of an emergency situation requiring the use of an AED.

In 2020, the EU-funded project Help112 II aimed at deploying Advanced Mobile Location (AML) in 7 Member States and providing recommendations on improving the use of Galileo in emergency communications. One recommendation from the Help112 II was to update the relevant standards so that A fields are included in the AML string, such as the altitude of the caller and the emergency number triggered. This suggestion is adressed in the current AED project.

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The invisible threat of air pollution can be tackled through Earth Observation data and services

Air quality: a major public health issue

With more than 55% of the world population currently living in urban areas, and projections indicating that this proportion should reach 68% by 2050, air quality is undoubtedly a hot topic for public health.

Each of us breathes 23,000 times every day, inhaling 14 kg of air. This incontrovertible action necessarily leads people living in polluted areas to inhale substances proving to be harmful to health when accumulated over long periods. It is thus estimated that chronic exposure to aerosols and toxic gases reduces the human life expectancy by eight months on average.

Based on the combination of large-scale satellite-based observations of atmospheric constituents, *in-situ* measurements and modelling, a wide range of air quality services have been developed offering a **near-real time monitoring of air quality** as well as short and medium-term forecasts. In addition to continuous information on air quality, these services can also trigger alerts in case of pollution peaks and assess the long-term effectiveness of health-related public policies. For instance, CAMS provides daily analyses and forecasts of worldwide long-range transport of atmospheric pollutants and assesses the background air quality for the European domain, reaching millions of users.

HORIZON 2020

Copernicus-based worldwide analysis and forecasting of air quality to improve public health (AQ-WATCH)

The project makes use of satellite observations, in-situ measurements and modelling to improve air quality forecasts and foster the use of Copernicus outside the European Union. It develops a supply chain for the delivery of seven thematic downstream services to be used by governmental institutions and private companies to help mitigate air pollution.

In particular, the project aims to develop: new global and regional air pollution atlases; software packages with the capability to provide more accurate regional daily air quality forecasts; a source apportionment service to mitigate air pollution; and a new toolbox to enable decision-makers to evaluate the efficiency of the proposed mitigation measures.

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Within AQ-WATCH, the design, production and evaluation of prototype products and services will be performed jointly with prime users originating from US, Chile and China, three regions of the world chosen for their specific level of economic, social end environmental development.

More information available at: http://www.aq-watch.eu/

EO data supports implementation of air quality legislation and provides evidence for new global air quality guidelines by WHO

Monitoring and modelling using Earth Observation data combined with in-situ sources are essential tools supporting policymakers to oversee the implementation of existing air quality legislation.

The primary global guidance on air quality is scientifically provided by the World Health Organization (WHO) air quality guideline values for ambient air quality. In 2019, 99% of the world population was living in places where the WHO air quality guideline levels were not met.

Since the last update of guidelines in 2005 by WHO, there has been not only a marked increase of evidence showing how air pollution affects different aspects of health, but significant advances have also occurred associated with measuring levels and trends in ground-level air pollution concentrations. In particular, the use of satellite remote sensing instruments in combination with advanced chemical transport models and ground-based measurements has substantially improved the understanding of worldwide pollution levels and trends. This has made information on key air pollutant indicators increasingly available, including in some of the most highly polluted and data-poor regions.

Nevertheless, as highlighted by a recent UN publication, there is no common legal framework for Ambient Air Quality Standards (AAQS) globally and that effective enforcement of AAQS remains a significant legal challenge. In this sense the air quality legislation framework in Europe (e.g. National emission ceiling directive (2016/2284/EU)) represents a key regional legal instrument on air quality, which requires individual signatory countries to develop relatively robust legal systems of air quality control.

As a result, monitoring and modelling supported by CAMS data are essential tools for supporting the implementation of legislation as well as development of downstream applications for citizens (e.g. LQ-WARN-app).

New WHO Global Air Quality Guidelines (AQGs) provide clear evidence of the damage air pollution inflicts on human health, at even lower concentrations than previously thought.

The guidelines recommend new air quality levels to protect the health of populations, by reducing levels of key air pollutants, some of which also contribute to climate change.

The EU space programme contributes to public health

Added value brought by Galileo

From emergency caller location to the monitoring of elderly patients, Galileo has a substantial impact on our health and safety. New applications will only increase this importance in the future. The successful resolution of emergency situations is driven by one key information factor – the emergency caller's location. GNSS positioning enables individual patients, staff or equipment to be monitored and response teams to be directed more efficiently.

As illustrated by the recent pandemic, precise location is a key requirement when attempting to monitor and map the spread of a disease; GNSS is one of the main tools supporting this. Galileo also supports the development of telemedicine, medical transport (UAVs) and guidance for the visually and physically impaired. For many citizens, GNSS-enabled applications such as fitness trackers and wellbeing smartphone applications are already a natural part of a healthier lifestyle. Finally, satellite communication-based telemedicine solutions could address connectivity needs, bridging the digital gap of medical services affected by staff shortages: a common phenomenon to many global (including European) regions.

Added value brought by Copernicus

Atmosphere (CAMS) | Climate Change (C3S) | Emergency (CEMS)

In addition to the large quantity of satellite data delivered on a free, full and open basis by the Sentinels and likely to be used for health-related applications (e.g., satellite data on the atmospheric composition), Copernicus delivers a set of value-added services directly relevant to public health issues. Copernicus supports public health authorities in monitoring health-related environmental phenomena by supplying information pertinent to their activities such as air quality forecasts and UV forecasts. Copernicus can also help identify areas prone to the emergence and spread of epidemics, which depend on environmental factors such as water, sanitation, food and air quality.

The **Copernicus Atmosphere Monitoring Service (CAMS)** (delivering global and regional air quality products and harmful UV forecasts) and the **Copernicus Climate Change Service (C3S)** (providing information on the impacts of a changing climate on the health of European citizens) both illustrate Copernicus' contribution to public health. In turn, CAMS data and air quality forecasting enables the development of innovative services such as the PASYFO app which forecasts personal allergy symptoms due to pollen. Improved monitoring of airborne pollen is vital to ensure better prevention, diagnosis and treatment of allergy related health problems and can reduce associated costs.

The Copernicus Emergency Management Services (CEMS) plays a role in saving lives in emergency events and post-disaster recovery activities. Copernicus offers new opportunities for exploiting health data with the scope of the creation of comparable standardised maps, monitoring methods and integrated health statistics.

Start-ups using space data for saving lives

EUSPA is supporting new solutions that uses EU space data. Due to their social value, innovations in the area of health are especially important. EUSPA has recently organised three competitions that have supported development of prototypes with high potential to be introduced in the market. MyGalileoApp took place in 2019, MyGalileoDrone (more details on page 49) and MyGalileoSolution (more details on page 69) had their final rounds and announcement of winners in early 2021. Furthermore, MyEUSpace Competition will see its finalists in spring 2022. Below is an overview of some selected teams and their health-related solutions from the three competitions:

- **Allerayde SAB Oy** worked on an adrenaline auto-injector with built-in emergency device;
- **RigiTech** dealt with last-mile drone delivery for medical services;
- **Everdrone** developed a drone system delivering Automated External Defibrillators; and
- **ABZero** developed a system for autonomous delivery of medical goods carried in smart capsules using drones.

More information about the support EUSPA provides can be found in the start-up corner on the webpages.

Annex 1: Methodology

Methodology

The Market Report applies the EUSPA's Market Monitoring and Forecasting Tool (MMFT).

The model utilises advanced forecasting techniques applied to a wide range of input data, assumptions, and scenarios to forecast the size of the GNSS and EO markets. The GNSS market is quantified according to shipments, revenues and installed base of GNSS devices, and the EO market is defined by purchase of data and services. All revenues are measured from the demand point of view, i.e. in which part of the world the data, services, and devices are purchased.

The forecast methodology is applied to each application and depends on the availability of input data. For some applications, detailed data on the number of devices shipped or value of the market are available, others rely on the number of devices in the installed base, while others still use the number of potential users as a starting point or the revenues generated in the market. Key input assumptions are collected from market reports and studies to help inform the penetration of GNSS, the average lifetime of a devices, device prices, EO data and services sales, and more. Input assumptions and outputs are subject to internal and external validation with consortium and industry experts to ensure emerging trends are captured as soon as they are identified.

Where possible historical values are anchored to actual data in order to ensure a high level of accuracy. Application-level model results are cross-checked against the most recent market research reports from independent sources before being validated through an iterative consultation process with European and international sector experts and stakeholders.

NOTE: Quantitative data and forecasts throughout the Market Report are given for all applications listed in the charts of each market segment, carefully cross-checked in order to avoid double-counting of devices. That is why it is possible that the front page of each market segment provides a longer list of applications. In many cases, a single GNSS device contributes to a variety of applications.

Sources

The model makes use of publicly available information and additional data and reports purchased from private publishers. Primary sources include:

Euroconsult (EO For Agriculture, 2020); Euroconsult (EO Data & Services Market, 2020); ABI Research; Airbus; American Farm Bureau Federation; App Annie; appFigures; BCG; Berg Insight; BI Intelligence; Boeing; Bombardier; Broadcom; Cisco; Cubris; Deloitte; Digi-Capital; EU C-ITS Strategy; EGNOS Service Provider (ESSP); Embraer; Equasis; Eurocontrol; European GNSS Service Centre (GSC); Eurostat; European Commission; European Securities and Markets Authority; Farstad Shipping; Finnish VTT Research Centre; Food and Agriculture Organisation; FP7 and H2020 project websites; Federal Aviation Administration; Gartner; General Aviation Manufacturers Association (GAMA); General Aviation News; GE Transportation Signaling; Goodyear; Google; GPS World; Grand View Research; GSM Association; Gunter's Space Page; Harbor Research; Hitachi; IBM; IDC; Infomines; Infonetics; Informa Economics and Measure; Inside GNSS; International COSPAS-SARSAT Programme; International Council of Marine Industry Associations (ICOMIA); International Road Assessment Programme (IRAP); International Telecommunications Union (ITU); International Maritime Organization (IMO); International Convention for the Safety of Life at Sea (SOLAS); International Civil Aviation Organization (ICAO); Irish Health & Safety Authority; Juniper Research; Kapsch GPS World Receiver Survey; KPMG; London School of Economics; Lux Research; MarketsandMarkets; McKinsey; Ministère de l'Environnement, de l'Energie et de la Mer; Nanosats Database; NATS Jon King blog; Organisation Internationale des Constructeurs d'Automobiles (OICA); Pew Research Centre; Proxbook; Research and Markets; Rivers of the World Atlas; Rolls Royce; Royal Institute of Navigation; Sensors Magazine; SESAR Joint Undertaking; Siemens; Statista; Statistic Brain; Technavio; Thales Alenia Space; TTG Transportation Technology; Teal Group; The Verge; TrendForce; TNS/Google; UAVGlobal; UCS Satellite Database; UIC International Railway Statistics; United Nations Conference on Trade and Development (UNCTAD); United Nations public information; UseGalileo; US Bureau of Labor Statistics; US National Transportation Statistics; Vision Mobile; VTPI; World Bank; World Economic Forum; World Shipping Council; World Stock Exchange; Xinhua.

Disclaimer

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The information provided in the Report is based on the Agency's best estimates and forecasts at the time of publication. Although the Agency has taken utmost care in checking the reasonableness of assumptions and results, the Agency accepts no responsibility for the further use made of the content of the Report.

Any comments to improve the next issue are welcome and should be addressed to: **market@euspa.europa.eu**

Annex 2: Definition of GNSS performance parameters

The definitions given below are to explain the key performance parameters as referenced throughout the report. **Important notice: the definitions below are applicable to this report only, and are not meant to be used for any other purpose.**

Key GNSS performance parameters

Availability is the percentage of time the position, navigation or timing solution that can be computed by the user. Values vary greatly according to the specific application and services used but typically range from 95 to 99.9%. Two types of availability are considered:

- System availability: is what GNSS Interface Control Documents (ICDs) refer to.
- Overall availability: takes into account the receiver performance and the user's environment. Values vary greatly according to the specific use cases and services used.

Accuracy is the difference between true and computed solution (position or time). This is expressed as the value within which a specified proportion – usually 95% – of samples would fall if measured. This report refers to positioning accuracy using the following convention: centimetre-level: 0-10cm; decimetre level: 10-100cm; metre-level: 1-10 metres.

Calibration only relates GNSS Timing Receivers and is the process of measuring the different biases of the GNSS signal's propagation through the antenna cable and equipment hardware in order to characterise and consider them when computing the timing solution.

Continuity is ability of a system to perform its function (deliver PNT services with the required performance levels) without interruption once the operation has started. It is usually expressed as the risk of discontinuity and depends entirely on the timeframe of the application. A typical value is around 1*10-4 over the course of the procedure where the system is in use.

Integrity is a term used to express the ability of the system to provide warnings to users when it should not be used. It is the probability of a user being exposed to an error larger than the alert limits without timely warning. The way integrity is ensured and assessed, and the means of delivering integrity-related information to users are highly application dependent. Throughout this report, the "integrity concept" is to be understood at large, i.e. not restricted to safety-critical or civil aviation definitions but also encompassing concepts of quality assurance/quality control as used in other applications and sectors.

Robustness relates to spoofing and jamming and how the system can cope with these issues. It is a more qualitative than quantitative parameter that depends on the type of attack or interference the receiver is capable of mitigating. Robustness can be improved by authentication information and services.

Authentication gives a level of assurance that the data provided by a positioning system has been derived from real signals. Radio frequency spoofing may affect the positioning system, resulting in false data as output of the system itself.

Time To First Fix (TTFF) is a measure of time between activation of a receiver and the availability of a solution, including any power on self-test, acquisition of satellite signals and navigation data and computation of the solution. It mainly depends on data that the receiver has access to before activation: cold start (the receiver has no knowledge of the current situation and must thus systematically search for and identify signals before processing them – a process that can take up to several minutes.); warm start (the receiver has estimates of the current situation – typically taking tens of seconds) or hot start (the receiver understands the current situation – typically taking a few seconds).

Other performance parameters

Power consumption is the amount of power a device uses to provide a position. The power consumption of the positioning technology will vary depending on the available signals and data. For example, GNSS chips will use more power when scanning to identify signals (cold start) than when computing a position. Typical values are in the order of tens of mW (for smartphone chipsets).

Resiliency is the ability to prepare for and adapt to changing conditions and withstand and recover rapidly from disruptions; including the ability to recover from deliberate attacks, accidents, or naturally occurring threats or incidents. A resilient system will change its way of operations while continuing to function under stress, while a robust (but non-resilient) system will reach a failure state at the end, without being able to recover.

Connectivity refers to the need for a communication and/or connectivity link of an application to be able to receive and communicate data to third parties. Connectivity relies on the integration with both satellite and terrestrial networks, such as 5G, LEO satellites, or LPWANs.

Interoperability refers to the characteristic of a product or system, whose interfaces are completely understood, to work with other products or systems, in either implementation or access, without any restrictions (e.g., ability of GNSS devices to be combined with other technologies and the possibility to merge the GNSS output with the output coming from different sources).

Tracebility is the ability ability to relate a measurement to national or international standards using an unbroken chain of measurements, each of which has a stated uncertainty. For Finance applications, knowledge of the traceability of the time signal to UTC is essential to ensure regulatory compliance of the time-stamp.

Annex 2: Definition of EO performance parameters

The definitions given below are to explain the key performance parameters as as referenced throughout the report. **Important notice: the definitions below are applicable to this report only, and are not meant to be used for any other purpose.**

Key EO performance parameters

Spatial resolution relates to the level of detail that can be retrieved from a scene. In the case of a satellite image, which consists of an array of pixels, it corresponds to the smallest feature that can be detected on the image. A common way of characterising the spatial resolution is to use the Ground Sample Distance (GSD) which corresponds to the distance measured on the ground between the centres of two adjacent pixels. Thus, a spatial resolution of 1 meter means that each pixel corresponds to a 1 by 1 meter area on the ground.

Spectral resolution refers to the ability of a sensor to differentiate electromagnetic radiation of different wavelengths. In other words, it refers to the number and "size" of wavelength intervals that the sensor is able to measure. The finer the spectral resolution, the narrower the wavelength range for a particular channel or band. In remote sensing, features (e.g.,, water, vegetation) can be characterised by comparing their "response" in different spectral bands.

Radiometric resolution expresses the sensitivity of the sensor, that is to say its ability to differentiate between different magnitudes of the electromagnetic energy. The finer the radiometric resolution, the more sensitive it is to small differences in the energy emitted or reflected by an object. The radiometric resolution is generally expressed in bit, a resolution of 8 bit meaning that the "brightness" of the image is measured with a scale of 2^8=256 nuances.

Temporal resolution relates to the time elapsed between two consecutive observations of the same area on the ground. The higher the temporal resolution, the shorter the time between the acquisitions of two consecutive observations of the same area. In absolute terms, the temporal resolution of a remote sensing system corresponds to the time elapsed between two consecutive passes of the satellite over the exact same point on the ground (generally referred to as "revisit time" or "orbit cycle"). However, several parameters like the overlap between the swaths of adjacent passes, the agility of the satellites and in case of a constellation, the number of satellites mean that some areas of the Earth can be re-imaged more frequently. For a given system, the temporal resolution can therefore be better than the revisit time of the satellite(s).

Geolocation accuracy refers to the ability of an EO remote sensing platform to assign an accurate geographic position on the ground to the features captured in a scene. An accurate geolocation makes easier the combination of several images (e.g.,, combination of a Synthetic Aperture Radar image with a cadastral map and a vegetation map).

Other performance parameters

Agility corresponds to the ability of a satellite to modify its attitude and to point rapidly in any direction in order to observe areas of interest outside its ground trace. High agility can improve the temporal resolution compared with the revisit time of the satellite.

Swath corresponds to width of the portion of the ground that the satellite "sees" at each pass. The larger the swath, the bigger the observed area at each pass.

Off-nadir angle corresponds to the angle at which images are acquired compared with the "nadir", i.e. looking straight down at the target. In practice, objects located directly below the sensor only have their tops visible, thus making it impossible to represent the three-dimensional surface of the Earth. High resolution images are therefore generally not collected at nadir but at an angle. A large off-nadir angle enables a wider ground coverage at each pass and the identification of features not visible at nadir, but it reduces the spatial resolution. For optical imagery, typical off-nadir angles are in the range of 25-30 degrees.

Sun-elevation angle corresponds to the angle of the sun above the horizon at the time an image is collected. High elevation angles can lead to bright spots on the imagery while low elevation angles lead to darker images and longer shadows. The most appropriate angle depends on the type of application: a high sun elevation is appropriate for spectral analysis since the objects to be observed are well illuminated while a lower elevation angle is better suited to interpretation of surface morphology (e.g.,, the projected shadows can enable a better image interpretation).

Annex 3: List of applications

The applications for each market segment are listed below and accompanied with a definition, explaining the use of EO, GNSS or both. The list of segments follow the order of the report.

LEGEND: EO application / GNSS application / Synergetic application (combined use of EO and GNSS)

AGRICULTURE

ENVIRONMENTAL MONITORING

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

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

NATURAL RESOURCES MONITORING

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

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

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

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

OPERATIONS MANAGEMENT

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

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

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

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

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

Field definition: Both EO and GNSS allow for the precise measurement and definition of field boundaries.

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

Pastureland management: EO can monitor the growth and maintenance of grasslands. Mowing and grazing activities on grassland can be detected and verified using EO.

Precision irrigation: Similar to variable rate application, precision irrigation combines GNSS positioning with EO information to distribute the appropriate amount of water for irrigating crops.

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

WEATHER SERVICES FOR AGRICULTURE

Climate services for agriculture: Long term forecasting and monitoring of climate variables relevant to agriculture using remotely sensed data. Air quality and land temperature can be understood through the use of EO, which in turn can help in understanding how our climate could affect future harvests and yields.

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

Annex 3: List of applications

AVIATION AND DRONES

COMMUNICATIONS

ATM System Timing: the ground systems used by air traffic control are increasingly connected. The systems rely on precise and high integrity timing for synchronization of logs, communication and traffic handover at system level - all of which are dependent on GNSS derived timing.

ENVIRONMENTAL MONITORING

Aircraft Emission Measurement and Monitoring: enables monitoring of trace gas composition of the Earth's atmosphere at different altitudes to understand more accurately the impact Aviation has on the environment at those different altitudes.

Particulate Matter Monitoring: enables air traffic services to monitor particulates in airspace, enabling them to provide avoidance instructions (e.g., to avoid Volcanic Ash clouds) and allowing improved planning of routes and flight efficiency.

NAVIGATION

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

Performance Based Navigation (PBN): An umbrella term for navigation based on a specific standard. For simplicity, this is categorised as:

- Area Navigation: A fundamental requirement for IFR aircraft and certified category drones to be able to navigate along routes with a required accuracy. GNSS is a core capability that enables them to meet the requirements of PBN within the en-route and terminal phases of flight.
- Approach Navigation: The approach phase of flight is a critical phase where high performance is needed from GNSS. SBAS and GBAS are two solutions that are deployed, providing IFR aircraft and certified category drones with the capability to land in low visibility conditions down to 200ft. These performances are expected to be extended by incorporating Galileo and dual frequencies.
- Low Level Routing: An area navigation capability specified initially for helicopter operations but supporting light General Aviation and potentially drones in the future. The ceiling of the routes is low level (<4,000') and enables helicopters to transition busy TMA or areas of high terrain safety.

VFR complement: Use of uncertified GNSS receivers as a navigation complement to VFR piloted operations. This includes moving map displays on portable devices.

OPERATIONS MANAGEMENT

Aircraft Maintenance and Operation Optimisation: Identifies areas where aircraft have flown through large areas of particulate matter, and in turn require early or more maintenance actions helping airlines and manufacturers save costs. When combined with innovative digital and satellite-based solutions, it also supports new tools and traffic optimization mechanisms for multimodal access, passenger and freight flows into and out of the airport, as well as between airports, facilitating improved airport access and reducing traffic from / to the city or other key transport nodes.

Airport Capacity and Safety: EO is a valuable asset to support Advanced-Surface Movement Guidance and Control System (A-SMGCS) surveillance and safety support services as well as helping airport managers to maintain high quality and complete knowledge of their airport assets.

Monitoring Terrain Obstacles near an Airport: EO assists airport operators to monitor and manage potential threats to aviation safety from changes to airport surroundings and helping to secure safe flight take-off and landing.

SURVEILLANCE

Electronic Conspicuity: provides self-reporting of position from an aircraft or drone to other aviation actors providing a means to learn about position and speed vectors. The information from this is derived from GNSS and covers many certified (used mostly for Air Traffic Management) and non-certified solutions (used for situational awareness of the operator).

GADDS: The Global Aeronautical Distress and Safety System is a concept developed by ICAO which enhances the effectiveness and alerting of search and rescue services in the event of an aviation tragedy. It ensures that the aircraft is tracked and that the lasted known GNSS derived position is always recorded, maintaining an up-to-date record of aircraft progress. GADSS has three components: Aircraft Tracking; Autonomous Distress Tracking; and Post Flight Localization and Recovery. Aircraft Tracking is enabled through the on-board GNSS equipment (either the PBN or Electronic Conspicuity device), whilst the other components are provided by Emergency Locator Transmitters which are covered in the Emergency Management and Humanitarian Aid segment.

Infrastructure timing: Different solutions, such as radars, are used by air traffic services to track aircraft and provide services to facilitate conflict free traffic flows. All systems in use today rely on GNSS for timing, and often synchronization as well, for example in Wide Area Multilateration systems that use multiple sychronised receivers to calculate where an aircraft is.

WEATHER SERVICES

Hazardous Weather Identification: EO is used to identify and monitor hazardous weather conditions such as storms, enabling aircraft and air traffic management to detect and avoid these weather phenomena earlier. This leads a reduction in the number of safety incidents and increased flight efficiency.

Annex 3: List of applications

BIODIVERSITY, ECOSYSTEMS AND NATURAL CAPITAL

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

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

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

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

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

CLIMATE SERVICES

CLIMATE CHANGE MITIGATION AND ADAPTATION

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

CLIMATE MODELLING

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

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

CLIMATE MONITORING AND FORECASTING

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

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

Annex 3: List of applications

CONSUMER SOLUTIONS, TOURISM & HEALTH

CORPORATE

Billing: Payment processing based on location or activity duration for public transport, gyms, theme parks, parking.

Geo-advertising: Consumer preferences are combined with positioning data to provide personalised offers to potential customers. EO represents an additional layer of geospatial information contributing to better audience targeting.

Mapping & GIS: Smartphones enable users to become map creators as a result of the democratisation of digital mapping. Mapping services comprise all consumer applications that draw on EO information for map features, which includes location or navigational services, including navigation, tracking and local search & discovery applications.

SATCOM users: GNSS is typically used in Satellite Control Stations and Telecommunications Gateways, mostly for frequency control. When focusing on the user segment, we look into the end user markets that use handheld SATCOMs.

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

HEALTH & LIFESTYLE

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

Games: GNSS enables a wide range of location-based games on smartphones and tablets. Various uses are associated with EO including backdrop images for a game or gamification of EO crowdsourced in-situ information.

Geo-tagging: adding geographical metadata to online content with the purpose of identifying the physical location of where the content was posted from.

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

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

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

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

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

NAVIGATION & TRACKING

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

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

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

ROBOTICS

Consumer robotics: GNSS signals are used along with other sensors integrated in consumer electronics for localisation and navigation purposes. e.g., Gardening robots, Delivery robots, Security and surveillance robots, Personal assistant robots, Painting robots, Automated guided vehicle/logistics.

Enhanced human: Human enhancement refers to methods for altering the human body to enhance mental or physical performance. The most developed examples are untethered mixed reality devices: in the future, GNSS position could be combined with optical feedback and 3D mapping to give users full situational awareness and the most accurate navigation.

TOURISM

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

Annex 3: List of applications

EMERGENCY MANAGEMENT & HUMANITARIAN AID

EARLY WARNING

Early warning: The Early Warning sub-segment comprises all applications related to forecasting the likelihood of a disaster event using EO sensor data, including disaster prediction tools, risk indexes and early warning mass notification systems in combination with location (GNSS) intelligence. Early warning is available for both natural and man-made disasters.

GNSS-enabled ocean monitoring buoys: This application consists of multiple type of buoys, deployed at sea and in oceans, to provide early warning for natural events following seismic activities (e.g., volcanoes, earthquakes, tsunamis, floods, etc.).

MIGRATION AND SETTLEMENT

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

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

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

Telematics for Humanitarian Aid: real-time satellite geo-positioning and fleet-management solutions used by humanitarian organisations, NGOs and UN (United Nations) agencies, as well as national or EU agencies for their safety and security.

POST-EVENT ANALYSIS

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

PREPAREDNESS

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

RAPID MAPPING

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

SEARCH AND RESCUE

Beacons for Aviation: Aircraft should be equipped with Emergency Locator Transmitters (ELTs) or a PLB that help Search and Rescue operations in the event of an incident. In line with requirements in ICAO Annex 10 (and standards set in ICAO Annex 6) as well as the implementation of the Global Aeronautical Distress and Safety System (GADSS), many ELTs utilise GNSS to report their position when triggered.

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

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

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

Annex 3: List of applications

ENERGY AND RAW MATERIALS

ENERGY NETWORK FIDELITY

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

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

ENVIRONMENTAL IMPACT MONITORING

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

MARKET INTELLIGENCE

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

RAW MATERIALS

Illegal mining monitoring: Due to its capacity to detect landscape changes through the analysis of satellite imagery, EO can support the detection and monitoring of the evolution of illegal mining activities (including in remote areas).

Mining Machinery Guidance: Augmented GNSS solutions enable the accurate guidance of heavy mining machinery.

Mining Surveying: EO and GNSS can provide mine site surveying. This is particularly important for dangerous, remote or topographically-challenging sites, as acquiring satellite data requires no on-site presence, supervision, or permitting. GNSS significantly accelerates all surveying activities (such as monthly measurements for evaluation of excavated mass, establishment of ground control points and stakeout of mining features) and decreases the time surveyors are in the field. Apart from surveying, high-accuracy GNSS in mining is utilised for tasks such as machine guidance, grading, dozing, drilling, collision avoidance and fleet management. In machine guidance, a critical GNSS application is the determination of excavator bucket wheel position.

Site selection, planning and monitoring: EO and GNSS can provide a large variety of products and information supporting the identification of the most suitable areas for the exploitation of mineral resources. Products and information include geological evaluation, topography mapping, etc.

RENEWABLE ENERGY

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

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

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

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

Annex 3: List of applications

ENVIRONMENTAL MONITORING

ENVIRONMENTAL AUDITING

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

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

ENVIRONMENTAL RESOURCES MANAGEMENT

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

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

IMPACT STUDIES AND ENVIRONEMNTAL, SOCIAL, AND CORPORATE GOVERNANCE (ESG)

EO monitors parameters necessary for the elaboration of **impact studies** and for the **implementation and monitoring of ESG** policies across four different environments:

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

Annex 3: List of applications

FISHERIES AND AQUACULTURE

AQUACULTURE

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

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

FISHERIES

Catch Optimisation: EO data contributes to habitat mapping for fish species. Combined with weather data and data on other relevant parameters (e.g. bio-geochemical analyses and forecasts for global and regional seas, topography, bathymetry, ocean colour, sea-surface temperature and ocean currents), the catch optimisation application provides relevant information which allows for the selection of the optimal timing, location, and means for fishing activities.

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

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

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

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

FORESTRY

ENVIRONMENTAL MONITORING

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

Deforestation/degradation monitoring: EO helps in remotely detecting forest degradation and/or deforestation. Optical and radar data can be used to measure forest vegetation intensity (through the generation of various indices such as NDVI), forest canopy cover and land use changes associated with deforestation/degradation.

NATURAL RESOURCE MONITORING

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

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

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

OPERATIONS MANAGEMENT

Automatic steering: Automatic steering completely takes over steering of the forestry machinery from the driver allowing the operator to engage in core forestry tasks.

Forestry asset management: GNSS provides insightful telematics data from forestry assets to help increase traceability/efficiency, monitor workforces and reduce costs.

Forest exploitation certification: EO can help in the verification and certification of forestry management and production activities.

Forestry machinery guidance: GNSS positioning can assist drivers of forest machinery in following the optimal path when conducting activities, thus minimising risks of overlaps.

Annex 3: List of applications

INFRASTRUCTURE

ENVIRONMENTAL MONITORING

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

INFRASTRUCTURE PLANNING

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

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

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

INFRASTRUCTURE CONSTRUCTION AND MONITORING

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

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

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

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

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

TIMING & SYNCHRONISATION OF TELECOMMUNICATIONS NETWORKS

Data centre: A Data Centre is a dedicated space within a building, or a group of buildings used to house computer systems and associated components, such as telecommunications and storage systems. GNSS is used as a time source for network synchronization of computing resources.

Digital Cellular Network (DCN): Telecom operators require accurate and consistent time and frequency at distant points of their networks to meet increasingly demanding broadband requirements. GNSS is used to provide consistent frequency and time alignment between all base stations within the network.

Professional Mobile Radio (PMR): Telecom operators require accurate and consistent time and frequency at distant points of their networks to meet increasingly demanding broadband requirements. GNSS is used for synchronisation of time slots and handovers between base stations.

Public Switched Telephone Network (PSTN): Telecom operators require accurate and consistent time and frequency at distant points of their networks to meet increasingly demanding broadband requirements. Originally a network of fixed-line analog telephone systems, the PSTN is now almost entirely digital in its core network and in this report it consists in fixed telephones networks. GNSS is usually a back-up to atomic clocks to provide time slot management.

Satellite Communication (SATCOM): Telecom operators require accurate and consistent time and frequency at distant points of their networks to meet increasingly demanding broadband requirements. GNSS is typically used in Satellite Control Stations and Telecommunications Gateways, mostly for frequency control.

Small cells: Telecom operators require accurate and consistent time and frequency at distant points of their networks to meet increasingly demanding broadband requirements. GNSS is used to provide frequency and phase alignment in small cells networks.

Annex 3: List of applications

INSURANCE AND FINANCE

FINANCE

Commodities trading: EO can contribute to the calculation of indicators which can be used by the organisation exploiting natural resources (e.g., oil & gas, mineral resources) to develop their logistics strategies and by investors interested in these natural resources to develop their financing strategies. Beyond natural resources, there is a growing interest in the food commodity market for which earth observation can provide vital information on crop conditions (e.g. the AMIS tool by the FAO).

Risk assessment: Any investment decision is subject to some uncertainty and before embarking on a new business, investors need to better understand and assess the risks associated to this new business and to quantify the potential for losses. Combined with other relevant data, EO data can help investors and asset managers to better understand current and future risks to their investments (e.g., flood risks, subsidence risk). Similarly, financial institutions increasingly need to consider climate risks in their assessments. EO constitutes a major source of data to feed their screening processes.

Timing and synchronisation for finance: Financial institutions are legally required to trace operations within a consistent and accurate time scale. GNSS is therefore used across network operations of both banks and stock exchanges.

Bank Network Operations: GNSS equipment is used for Time Stamping functions, to log events in a chronologic manner and therefore be able to recreate causal links. Usually a GPS antenna is deployed on a roof and it is connected to a PTP or NTP server.

Stock Exchange Network Operations: All stock exchanges are equipped with large data centres holding the exchanges' matching engines in racks of interconnected servers using GNSS receivers as timing and synchronisation sensors.

INSURANCE

Event footprint: EO serves as a complementary source to support existing processes in assessing damage. Event footprint involves comparing the claims received from clients with the actual material damages that occurred in the field in order to determine the amount of compensation that should be paid. EO data provides a visualisation of the extent of the damage (production of delineation maps) and helps optimise intervention, reducing costs for insurers. Responsiveness and high resolution can be important factors in the choice of EO source.

Index production: Computation of numerical indexes (part of parametric insurance products) based on image analyses. Using regular monitoring of areas to compute a numerical index, the application is particularly useful for crops and livestock insurance. These products are an alternative to traditional insurance approaches, and allow new markets (farmers and pastors) to be addressed, especially in remote areas.

Risk modelling: EO can be used for calibration of risk models and refinement of hypotheses as well as an input for digital models. Risk modelling involves the evaluation of potential losses that could arise due to natural disasters through a probabilistic assessment of events. By improving the accuracy of the predictions, (re)insurers are able to better forecast cash out-flows and reduce the financial risks, eventually reducing premiums. EO data is used as a complementary source of information to meteorological and geological data, and generates a moderate added value.

MARITIME & INLAND WATERWAYS

ENVIRONMENTAL MONITORING

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

INLAND WATERWAYS

Inland waterways navigation: EO data is used to detect periods of flood or low flow which may cause disruptions to waterway traffic, allowing the bodies responsible for the inland waterways to make informed decisions about traffic flows. GNSS is also used to ensure safe navigation in inland waterways (rivers, canals, lakes and estuaries).

MARINE ENGINEERING

Dredging: Satellite-derived turbidity data (stirred-up sediment from anthropogenic activities such as dredging) provide a reliable and cost-effective overview without the need for field deployment. GNSS in combination with PPP/RTK Positioning Techniques supplies high accuracy real-time positioning needed for dredging operations.

Marine surveying and mapping: Encompasses a wide range of GNSS-enabled activities (seabed exploration, tide and current estimation, offshore surveying, etc.), and their outcomes are important for maritime navigation. Satellite technology using radar and multi-spectral contributes to surveying and mapping with data on ocean heights and, as a result, helps to interpret gravity and bathymetry for the Earth's oceans. Satellite-derived bathymetry in particular, is the most recently developed method of surveying shallow waters. In contrast to other survey methods, satellite-derived bathymetry requires no mobilisation of persons or equipment, provides rapid access to bathymetric data and saves costs.

MERCHANT VESSELS

Collision avoidance: Alongside the receivers for navigation, merchant vessels above 300GT are required through the IMO SOLAS regulation to be equipped with an Automatic Identification System (AIS). Similar to a radar, through the AIS, nearby vessels communicate their position and heading with each other as well as with shore-based infrastructures (e.g., near ports) to improve the traffic management and safety of navigation.

GNSS vessel engine management systems: GNSS supports remote monitoring of ship's condition (e.g., engine diagnostics). This provides the vessel operators with the necessary information to perform routine check on the engine and improves the overall maintenance of vital elements of the vessel.

Merchant navigation: GNSS is the primary source of positioning information in sea navigation. In the case of Safety of Life at Sea (SOLAS) vessels: all passenger ships, cargo ships larger than 500 gross tonnage or larger than 300 tons if engaged on international voyages are regulated and rely heavily on GNSS to support navigation activities. At least 3 devices are typically fitted on vessels for redundancy reasons.

Annex 3: List of applications

Navigation through sea ice: In combination with GNSS positioning information, ice maps generated using EO data enable navigation applications which automatically avoid waters with high iceberg concentrations, allowing ships to sail faster and more safely through open waters. Reflections of satellite navigation signals collected in space can be used to accurately map the extent of the sea ice in the Arctic and Antarctic.

Ship route optimisation: Real-time or near real-time monitoring of water depth, winds, waves and currents using EO data enables navigation applications to chart the best routes taking into consideration current ocean conditions, leading to time and fuel savings. GNSS positioning information constitutes an essential layer of information for the efficiency, safety and optimization of maritime transportation.

PORTS

GNSS automated port operations: GNSS positioning supports automation of operations at ports and intermodal hubs.

Piloting assist at ports: EO data on port traffic and metocean conditions is used to complement in situ data to support Vessel Traffic Management, enabling safer and more efficient piloting of vessels in busy port environments. Real-time navigation information (based on GNSS) provides pilots with greater control, safety and accuracy during port approach and manoeuvres.

Port navigation devices: Transit progress, docking and loading-unloading operations are monitored through GNSS-based technologies.

Portable Pilot Units (PPUs): PPUs are professional, portable devices used by maritime pilots to navigate vessels through narrow passages such as locks and ports. Used together with the vessel's bridge and interfaced with high-accuracy GNSS, PPUs make docking of large marine vessels by pilots safer and more time and fuel efficient.

Port safety: EO data provides an overview of port traffic and berth estimations, allowing for risk models to be created. These assess the risk of damage at the port cause by adverse events such as extreme weather, congestion or oil spills. This enables port officials to take risk mitigation measures and to plan for safety when developing port infrastructures. The safety of port terminal operations is ensured by GNSS positioning information.

Port security: EO data contributes to enhanced situational awareness with the goal to prevent crime or any illicit good entering or exiting the country. High resolution SAR data for instance enables port authorities to access most recent information on changes in cargo and passenger ports, tracking vessels, estimating amount of stored goods.

Vessel docking: With the necessary centimetre positioning/speed accuracy (covering the complete port/ harbour zone), docking assist systems provide efficient and safe manoeuvring within the entire port area. This enhances vessel trajectory and facilitates the constant monitoring for moored/docked vessels.

OCEAN SERVICES

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

RECREATIONAL CRAFT

Recreational navigation: GNSS-based systems for maritime navigation are widespread not only across commercial, but also recreational vessels. They are used both for overseas and high traffic areas.

VESSEL TRACKING

Dark vessel monitoring: GNSS-enabled Long-Range Identification and Tracking (LRIT) as well as AIS or VMS provide the means to monitor and track suspicious vessels. When those vessels turn off or disable their own AIS or VMS, EO data is able to provide enhanced situational awareness that can be used by dedicated maritime authorities to monitor and track 'dark vessels' through EO imagery and SAR data.

Annex 3: List of applications

RAIL

ATTRACTIVENESS ENHANCEMENT

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

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

MAINTENANCE IMPROVEMENT

Condition-based maintenance: Continuous monitoring of assets movement, performance and potential damage is used to detect when specific item maintenance is needed based on the defined conditions. GNSS is increasingly seen as a standard source of location and timing information in these systems.

Infrastructure monitoring: Very high resolution EO satellites data are used in order to detect encroaching vegetation, landslides or track deformation.

Predictive maintenance: Models relying on continuous location and asset performance monitoring are developed in order to fine-tune maintenance schedules. GNSS is increasingly seen as a standard source of location and timing information in these systems.

SAFETY RELATED

Enhanced Command & Control Systems (CCS): In main lines with high traffic density, GNSS can be an additional source of data to improve train command and control systems such as the European Train Control System (ETCS) and the Positive Train Control (PTC). In low density lines, GNSS can support the provision of a signalling system. For both, it allows cost saving which can be vital to ensure the viability of the rail service.

Trackside personnel protection systems: Workers must be warned of an approaching train. GNSS location information is used as a complement to existing procedures for enhanced tools deployed alongside the train tracks or added information provided to the stakeholders.

TRAIN DRIVING OPTIMISATION

Driver Advisory Systems (DAS): The real-time location provided by GNSS is used to help drivers operate their trains. The goal of DAS is to enable train operation optimisation by providing driver assistance.

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

ROAD & AUTOMOTIVE

FLEET MANAGEMENT SYSTEMS

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

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

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

LIABILITY

Insurance telematics: Black boxes rely on GNSS data to increase the fairness of motor insurance for both insurers and subscribers. The basic idea behind such schemes is that in combination with other car sensor data, GNSS positioning information is used by insurance companies to monitor a driver's behaviour and assess the risk (e.g., of having an accident) in order to calculate the insurance premium that should be charged to each individual.

Road User Charging (RUC): GNSS-OBUs support toll operators in charging levies for the use of roads and for congestion control. GNSS-based solutions are designed to charge motorists for the actual distance travelled, without barriers or gantries, and provide interoperability between national cross-border schemes.

Smart tachograph: Smart tachographs leverage GNSS positioning to support road enforcers by recording the position and time of the vehicle at different points during the working day.

SAFETY RELATED

Advanced Driver Assistance Systems (ADAS): ADAS are developed to adapt vehicle systems for safety and eco driving. Safety features are designed to avoid collisions and accidents by offering technologies that alert the driver to potential problems, or to avoid collisions by implementing safeguards and taking over control of the vehicle.

Connected and Automated Driving (CAD): CAD enabled by GNSS positioning information feeds technologies allowing road vehicles to exchange information between other vehicles and their surroundings. This contributes to the creation of integrated connected platforms supporting mobility services. In the upcoming years, these will become automated, removing the driver from the driving seat and having a set of technologies including GNSS to guide and operate the vehicle.

Annex 3: List of applications

Emergency assistance: The pan-European eCall and other systems, such as the ERA-GLONASS in Russia, send a message including location to emergency response centres in case of accident, accelerating assistance to drivers.

SMART MOBILITY

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

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

Driving comfort: Mobility platforms combining various data sources to provide real-time information (i.e. ground sensors, remote sensing data, historical data) , as well as predictions e.g., meteorological forecasts for end users on road conditions ahead. This information will enable users (through the vehicle navigation system) to plan and navigate most optimal routes.

URBAN DEVELOPMENT AND CULTURAL HERITAGE

ENVIRONMENTAL MONITORING

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

Light pollution: Night-time light observations can be performed using EO, e.g., to measure human activities, indicators of urbanisation and electrification, as well as health effects coming from light pollution.

Thermal auditing: EO provides thermal imagery allowing to measure buildings' efficiency and to detect thermal defects in these, both during construction (for acceptance of works) as well as for thermal audits of existing buildings.

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

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

SMART CITIES OPERATIONS

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

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

URBAN PLANNING AND MONITORING

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

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

Real estate: EO data are enabling increased situational awareness for real estate actors as part of the planning or monitoring phases. This includes supporting valuation of land or property, monitoring the evolution or real estate property projects or developing analyses and risk assessments for hazard-prone locations.

Annex 3: List of applications

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

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

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

SPACE

Though GNSS was originally designed to serve terrestrial users, it has also proven its worth as a valuable tool for in-space applications. From using real-time GNSS data for spacecraft navigation to deriving EO measurements from it, in-space applications are numerous.

ACTING/SUPPORTING MISSION PAYLOADS

Scientific & Operational Missions (SOM): In the case of scientific missions, GNSS receivers can be used as a mission payload, providing input to study physical elements, through characteristics of the GNSS SIS measurements (e.g., radio occultation, altimetry analyses, TEC assessment). In the case of operational missions, GNSS receivers can be used to support the acquisition of information for commercial purposes (e.g., taking and selling Earth Images/Observation Data).

Technology Demonstration (TechD): Using GNSS aboard a spacecraft to demonstrate its scientific interest is the first step to assess its potential use with respect to other conventional technologies. An example of this type of use is the so called GNSS Reflectometry (GNSS-R), which consists of making measurements of the reflections of navigation signals from GNSS from the Earth.

DEEP SPACE APPLICATIONS

Lunar Transfer Orbit (LTO): Beyond the GEO orbits (e.g.,, translunar trajectories), the use of multi-constellation capabilities aboard spacecraft may allow the user to cope with limited visibility and availability, taking advantages of GNSS signals coming from the opposite side of the Earth.

NAVIGATION AND CONTROL SUBSYSTEM

Attitude Determination (AD): Space missions' success often rely on the pointing accuracy and the stability of its payloads. Being accurately aware of the vehicle's orientation in space allows to apply – if needed – the necessary torques to obtain the desired attitude. Furthermore, several small satellites rely on passive attitude control, and the GNSS-based attitude information – in support to other sensors – is important for the mission (e.g., precise communication data link among satellites, precise pointing direction of a camera to acquire images of a determined area, etc.).

Precise Orbit Determination (POD): Accurate and autonomous determination of the absolute Position, Velocity and Time (PVT) of the vehicle, whose initial position is unknown, allows potential correction of its orbital trajectory. GNSS POD has grown in importance and established itself as one of the common techniques to determine the trajectories of satellites in LEO. Such GNSS-based information can also be used to perform "Rendezvous & Docking", "Formation Flying" or "GEO Station keeping".

Space Timing and Synchronisation (S-T&S): The need for highly precise timing information obtained through GNSS is relevant in space both for data time stamping (providing a direct and accurate access to the UTC) and synchronisation (e.g., between receivers at different locations) – reducing dependency on very expensive on-board clocks. These two applications serve as core of data collection in most satellite missions, including EO or communication. Similar to positioning information, timing can be used both independently and in conjunction with other data to support more complex tasks.

Annex 4: List of acronyms

2D	Two Dimensional	B2B	Business-to-Business	COTS	Commercial Off-The-Shelf
3D	Three Dimensional	BDPS	Beacon Distress Positioning Sharing Service	COVID19	Coronavirus disease
3GPP	3rd Generation Partnership Project	BIM	Building Information Modelling	CSCDA	Copernicus Space Component Data Access system
4D	Four Dimensional - Temporal Dimension	BVLOS	Beyond Visual Line of Sight	CSS	Copernicus Security Service
5D	Fifth Dimensional - Real-time extraction in virtual model	C3S	Copernicus Climate Change Service	DAA	Detect and Avoid
5G	Fifth-generation of mobile telecommunications technology	CAGR	Compound Annual Growth Rate	DCN	Digital Cellular Network
A4E	Airlines for Europe	CAMS	Copernicus Atmosphere Monitoring Service	DFMC	Dual Frequency Multi Constellation services
AAQS	Ambient Air Quality Standards	CANSO	Civil Air Navigation Services Organisation	DIAS	Data and Information Access Services
AD	Attitude Determination	CAP	Common Agricultural Policy	DLT	Distributed Ledger Technology
ADS	Autonomous Driving System	CAS	Commercial Authentication Service	DO	Drought Observatory
ADS-B	Automatic Dependent Surveillance–Broadcast	CASA	Centre for Advanced Spatial Analysis	DSM	Digital Surface Model
AED	Automated External Defibrillator	CCO	continuous climb operations	DSRC	Dedicated Short-Range Communications
Agtech	Agricultural technology	CDO	continuous descent operations	DTSC	Digitial Twins of Smart Cities
AI	Artificial Intelligence	CEMS	Copernicus Emergency Management Service	E112	GNSS-supported emergency call
AIRE	Airlines International Representation in Europe	CEN	European Committee for Standardisation	EARSC	European Association of Remote Sensing Companies
AIS	Automatic Identification System	CENELEC	European Electrotechnical Committee for Standardisation	EASA	European Union Aviation Safety Agency
AIS-MOB	AIS-Man Overboard	CI	Critical Infrastructure	EC	European Commission
AIS-SART	AIS-Search and Rescue Transmitter	CIMR	Copernicus Imaging Microwave Radiometer	EC	Electronic Conspicuity
AMIS	Agricultural Market Information System	CIS	common information services	ECA	European Compliance Assurance
AQGs	Air Quality Guidelines	CLMS	Copernicus Land Monitoring Service	ECMWF	European Centre for Medium-Range Weather Forecasts
AR	Augmented Reality	CMEMS	Copernicus Marine Environment Monitoring Service	EDAS	EGNOS Data Access Service
ARAIM	Advanced Receiver Autonomous Integrity Monitoring	CNS	Communication, navigation and surveillance	EDO	European Drought Observatory
ASC	Aquaculture Stewardship Council	cOBC	Constellation On-Board Computer	EEA	European Environment Agency
ATC	Air Traffic Control	CODA	Copernicus Online Data Access	EFAS	European Flood Awareness System
ATIS	Alliance for Telecommunications Industry Solutions	COSPAS-SARSAT	Cosmicheskaya Sistyema Poiska Avariynich Sudov/Search And Rescue Satellite Aided Tracking	EFCA	European Fisheries Control Agency

Annex 4: List of acronyms

EFFIS	European Forest Fire Information System
EGMS	European Ground Motion Service
EGNOS	European Geostationary Navigation Overlay Service
EGNSS	European Global Navigation Satellite System
EHA	European Helicopter Association
ELT	Emergency Locator Transmitter
ELT-DT	ELT Distress Tracking
EMSA	European Maritime Safety Agency
ENVISAT	ENVIronmental SATellite
EO	Earth Observation
EO4EA	Earth Observation for Ecosystem Accounting
EO4SD	Earth Observation for Sustainable Development
EPIRB	Emergency Position Indicating Radio Beacon
ERA	European Regions Airline Association
ERTMS	European Railway Transport Management System
ESA	European Space Agency
ESG	Enviroonmantal, Social, and Governance
ESMA	European Securities and Markets Authority
ETC	Electronic Toll Collection
ETC/CCA	European Topic Centre on Climate Change Impacts, Vulnerability and Adaptation
ETCS	European Train Control System
EU	European Union
EU SatCen	European Union Satellite Centre
EUMETSAT	European Organisation for the Exploitation of Meteorological Satellites
EUROCAE	European Organisation for Civil Aviation Equipment
EUSPA	European Agency for the Space Programme
FAO	Food and Agricultural Organisation of the United Nations
FCC	Federal Communications Commission
FFO	Full, Free and Open
FINRA	Financial Industry Regulatory Authority
FIs	Financial Institutions
FLARM	flight alarm'
FMC	Fishing Monitoring Centre
FP6	Sixth Framework Programme
FRONTEX	European Border and Coast Guard Agency
GADSS	Global Aeronautical Distress & Safety System
GAGAN	Indian SBAS
GAST-D	GBAS Approach Service Type D
GAST-F	GBAS Approach Service Type F
GBAS	Ground Based Augmentation System
GDO	Global Drought Observatory
GEF	Global Environment Facility
GEO	Geosynchronous Equatorial Orbit (geostationary orbit)
GEOSAR	Geostationary Orbit Search and Rescue
GHG	Greenhouse Gases
GIS	Geographic Information System
GloFAS	Global Flood Awareness System
GLONASS	Global'naya Navigatsionnaya Sputnikovaya / GNSS by the Russian Federation
GMES	Global Monitoring for Environment and Security
GNSS	Global Navigation Satellite System
GNSS-RO	GNSS Radio Occultation
GOFC-Fire IT	Global Observation of Forest Cover - Fire Implementation Team
GOFC-GOLD	Global Observation of Forest Cover - Global Observation of Land Dynamics
GOVSATCOM	governmental satellite communications
GPR	Ground Penetration Radar
GPS	Global Positioning System
GTOS	Global Terrestrial Observing System
GWIS	Global Wildfire Information System
H2020	Horizon 2020 (Research and Innovation Programme by the European Commission
H2H	Hull-to-Hull
HAB	Harmful Algae Bloom
HAS	High Accuracy Service
HEMS	Helicopter Emergency Medical Services
HERA	Health Emergency Response Authority
HPC	High Performance Computing
HQ	Headquarters
HR	High Resolution
IADC	Inter-Agency Space Debris Coordination Committee
IATA	International Air Transport Association
ICAO	International Civil Aviation Organization
ICT	Information and Communication Technology
IGS SSR	International GNSS Service standards
IISD	International Institute for Sustainable Development
IMO	International Maritime Organisation
IMPEL	Implementation and Enforcement of Environmental Law

Annex 4: List of acronyms

IMU	Internal Measurement Unit	MiFiD II	Markets in Financial Instruments Directive	PMR	Professional Mobile Radio
INI	Own-Initiative Procedure	ML	Machine Learning	PMU	Phasor Measurement Unit
InSAR	Interferometric Synthetic Aperature Radar	MODIS	Moderate Resolution Imaging Spectroradiometer	PND	Personal Navigation Device
IOC	Initial Operational Capability	MOPS	minimum operational performance specifications	PNT	Positioning, Navigation and Timing
IoS	In-Orbit Satellite	MSAS	Japanese Satellite Based Augmentation System	POCs	Proof-of-Concepts
IoT	Internet of Things	MSC	Maritime Safety Committee	POD	Precise Orbit Determination
IPCC	Intergovernmental Panel on Climate Change	MTG-S	Meteosat Third Generation (Sounding)	PPP	Precise Point Positioning
ITU	International Telecommunications Union	MTO	Translunar Trajectory	PPPs	Public-Private Partnerships
IUU	Illegal, Unreported and Unregulated fishing	NASA	National Aeronautics and Space Administration	PRC	People's Republic of China
IVS	In-Vehicle Systems	NavIC	Navigation with Indian Constellation/Indian Regional Navigation Satellite System	PRS	Public Regulated Service
KIC	Knowledge and Innovation Community	NBS	Nature-based Solutions	PSD2	Directive of Payment Services
LDACS	L-band Digital Aeronautical Communications System	NEO	Near-Earth Objects	PSTN	Public-Switched Telephone Network
LEO	Low Earth Orbit	NFMS	National Forest Monitoring System	PVs	Photovoltaics
LEOSAR	Low Earth Orbit Search and Rescue	NG112	New Generation of E112	PVT	Position Velocity Time
LiDAR	Light Detection and Ranging	NGO	Non-Governmental Organisation	QNH	Question Nil Height (measurement; pressure at sea-level; aviation)
LPV	Localiser Performance with Vertical Guidance	NOAA	National Oceanic and Atmospheric Association	QZSS	Quasi-Zenith Satellite System/regional navigation satellite system commissioned by the Japanese Government
LTE	Long Term Evolution	NSP	Navigation System Panel	R&D	Research and development
LUCAS	Land Use/Cover Area frame Survey	NTRIP	Networked Transport of RTCM via Internet Protocol	R&I	Research and Innovation
MaaS	Mobility-as-a-Service	OCHA	United Nations Office for Coordination of Humanitarian Affairs	RACE	Rapid Action on COVID-19 and EO
MASS	Maritime Autonomous Surface Ships	ODA	Oracle Database Appliance	RBA	Remote Beacon Activation
MBDs	Mosquito-Borne Diseases	OS	Open Service	RF	Radio Frequency
MEO	Medium Earth Orbit	OSNMA	Open Service Navigation Message Authentication	RFI	Radio Frequency Interference
MEOLUT	Medium Earth Orbit Local user Terminal	PBN	Performance-based navigation	RIN	Royal Institute of Navigation
MEOSAR	Medium Earth Orbit Satellites Search and Rescue System	PinS	Point in Space	RLM	Return Link Message
Metop-SG	Meteorological Operational Satellite - Second Generation	PLB	Personal Locator Beacon	RLS	Return Link Service

Annex 4: List of acronyms

RNSS	Radio Navigation Satellite Services	SST	Space Surveillance and Tracking	UNIDO	United Nations Industrial Development Organisation
RNTF	Resilient Navigation and Timing Foundation	S-T&S	Space Timing and Synchronisation	USA	United States of America
RTCM	Radio Technical Commission for Maritime Services	STM	Space Traffic Management	USGS	United States Geological Survey
RTK	Real-Time Kinematics	SUGUS	Solution for EGNSS U-Space Service	USSP	U-Space Service providers
RUC	Road User Charging	SVS	Synthetic Vision Systems	UTC	Coordinated Universal Time
SaaS	Synchronisation-as-a-Service	SWE	Space Weather	UTM	Unmanned Aircraft System Traffic Management
SAE levels	Society of Automotive Engineers setting levels for autonomous driving	T&S	Timing and Synchronisation	UV	Ultraviolet (UV) radiation
SAR	Search and Rescue Service	TaaS	Time-as-a-Service	V2X	Vehicle to everything
SAR	Synthetic Aperture Radar	TAWS	Terrain Awareness Warning Systems	VAAC	volcanic ash advisory centres
SATCOM	Satellite communications	TechD	Technology Demonstration	VAS	Value-added Service
SBAS	Satellite-Based Augmentation Systems	TEWS	Tsunami Early Warning Systems	VBDs	Vector-Borne Diseases
SCADA	Supervisory Control and Data Acquisition	TGV	High-Speed Train	VDES	VHF Data Exchange System
SDCM	System for Differential Corrections and Monitoring (Russian SBAS)	TSI	Technical Specifications for Interoperability	VFR	Visual flight rules
SDG	Sustainable Development Goals	TTFF	Time To First Fix	VHF	Very High Frequency
SDI	Spatial Data Infrastructures	TWC	Two-Way Communication	VHR	Very High Resolution
SESAR	Single European Sky ATM Research	UAM	Urban Air Mobility	VIIRS	Visible Infrared Imaging Radiometer Suite
SIS	Sectoral Information System	UAS	Unmanned Aircraft Systems	VLL	Very Low Level
SiS	Signal-in-Space	UAT	Universal Access Transceiver	VMS	Vessel monitoring system
SLAM	Simultaneous Localisation and Mapping	UAV	Unmanned aerial vehicle	WAAS	Wide Area Augmentation System
SME	Small and Medium-sized Enterprise	UCP	User Consultation Platform	WFD	Water Framework Directive
SNAS	Satellite Navigation Augmentation System (PRC)	UHI	Urban Heath Island	WG	Working Group
SoL	Safety of Life Service	UITP	International Association of Public Transport	WHO	World Health Organisation
SOM	Scientific and Operational Missions	UK	United Kingdom	Wi-Fi	Wireless Fidelity
SRTM	Shuttle Radar Topography Mission	UN	United Nations		
SSA	Space Situational Awareness	UNESCO	United Nations Educational, Scientific and Cultural Organisation		

Annex 5: About the authors

The European Commission

The European Commission (EC) and more specifically the Directorate-General for Defence Industry and Space (DG DEFIS) has overall responsibility for the implementation of the Union Space Programme and its components (Galileo, EGNOS, Copernicus, GOVSATCOM and SSA).

This includes:

- Overseeing the implementation of all activities related to the programme;
- Defining its priorities and long-term evolution;
- Managing the funds allocated to the programme;
- Ensuring a clear division of responsibilities and tasks, in particular between the EU Agency for the Space Programme and the European Space Agency;
- Ensuring proper reporting on the programme to the Member States of the EU, the European Parliament and the Council of the European Union.

The EU Space Programme is fully financed by the European Union.

DG DEFIS further contributes to shaping the EU space policy and fostering a strong, innovative and resilient EU space ecosystem. It supports the emergence of New Space in the EU, including SMEs and new entrants, fosters entrepreneurship and access to finance, and contributes to the growth of the EU space industry.

DG DEFIS promotes EU space research fostering a cost-effective, competitive and innovative space industry and research community. It ensures that space technology, services and applications meet EU policy needs, and the R&I needs of the EU Space Programme. It also ensures that the EU can access and use space with a high level of autonomy.

The EU space policy addresses some of the most pressing challenges facing the EU today, such as fighting climate change, supporting EU's priorities, whilst strongly contributing to the green and digital transitions and to the resilience of the Union.

The European Union Agency for the Space Programme

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

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As a body of the EU, the Agency contributes to EU´s priorities: Green Deal and digital transition, the safety and security of the Union and its citizens, while reinforcing its autonomy and resilience.

EUSPA:

- Delivers safe, state-of-the-art, European satellite-based services to a growing group of users in Europe and around the world.
- Promotes the use of space data and services from Galileo, EGNOS, Copernicus and GOVSATCOM.
- Ensures the safety and security of the EU Space Programme assets both in space and on the ground.
- Supports innovation along the whole value chain of business development for companies, start-ups, innovators and academia.

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EUSPA Mission Statement

The mission of the European Union Agency for the Space Programme (EUSPA) is defined by the EU Space Programme Regulation. EUSPA's mission is to be the user-oriented operational Agency of the EU Space Programme, contributing to sustainable growth, security and safety of the European Union.

Its goal is to:

- Provide long-term, state-of-the-art safe and secure Galileo and EGNOS positioning, navigation and timing services and cost-effective satellite communications services for GOVSATCOM, whilst ensuring service continuity and robustness;
- Communicate, promote, and develop the market for data, information and services offered by Galileo, EGNOS, Copernicus and GOVSATCOM;
- Provide space-based tools and services to enhance the safety of the Union and its Member States. In particular, to support PRS usage across the EU;
- Implement and monitor the security of the EU Space Programme and to assist in and be the reference for the use of the secured services, enhancing the security of the Union and its Member States;
- Contribute to fostering a competitive European industry for Galileo, EGNOS, and GOVSATCOM, reinforcing the autonomy, including technological autonomy, of the Union and its Member States;
- Contribute to maximising the socio-economic benefits of the EU Space Programme by fostering the development of a competitive and innovative downstream industry for Galileo, EGNOS, and Copernicus, leveraging also Horizon Europe, other EU funding mechanisms and innovative procurement mechanisms;
- Contribute to fostering the development of a wider European space ecosystem, with a particular focus on innovation, entrepreneurship and start-ups, and reinforcing know-how in Member States and Union regions.

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