2024 / ISSUE 2

EUSPA EO and GNSS Market Report

EDITOR'S SPECIAL

Resilient societies

#EUSpace

European Union Agency for the Space Programme

On the cover: Walcheren, Zeeland, The Netherlands. Contains modified Copernicus Sentinel data (2023), processed by EUSPA.

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EUSPA

European Union Agency for the Space Programme

The EU Space Programme: several components delivering a wealth of services to citizens and institutions

GALILEO AND EGNOS

The European Global Navigation Satellite System (EGNSS) 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 System (GNSS) 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 AND IRIS²

The EU GOVernmental SATellite COMmunication (**GOVSATCOM**) programme aims to ensure the long-term availability of reliable, secure, resilient and cost-effective satellite communication services for EU and national public authorities. The needs of targeted authorities include the management of emergency and security-critical missions, operations and infrastructures. These also include defence and public safety-related operations, as well as diplomatic communication.

The added value of GOVSATCOM is that it avoids the duplication of efforts between European Union Member States, thus overcoming the existing fragmentation of the secure SATCOM market.

A recent addition to the secured SATCOM* component of the EU Space Programme is the **IRIS²** initiative. IRIS² aims to further enhance EU satellite-based connectivity, to integrate and expand the GOVSATCOM portfolio and to offer additional services to both authorised government users and commercial users.

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

Space Situational Awareness (SSA) adopts a holistic approach toward supporting Europe's independent utilisation of and access to space, based on acquiring a comprehensive knowledge and understanding of space hazards, including collisions between space objects, fragmentation and re-entry of space objects into the atmosphere, space weather and near-Earth objects. SSA covers:

- **Space Surveillance and Tracking (SST):** a system of sensors and capabilities to survey and track space objects;
- **Near-Earth Objects (NEO):** capabilities to monitor the risk of natural space objects approaching the Earth; and
- **Space Weather Events (SWE):** capabilities to monitor space weather and solar activity.

Linked to SSA, **Space Traffic Management (STM)** encompasses the means and rules to access, conduct activities in, and return from outer space safely, sustainably and securely. To perform STM activities, it is necessary to observe space traffic continuously. EU Space Surveillance and Tracking (EU SST), with its network of sensors and capabilities, constitutes the operational pillar of the EU STM approach.

* Since this report focuses on the EO and GNSS market, the markets of SSA, GOVSATCOM and IRIS² are not presented in this report. A focus on the Secure SATCOM Market and User Technology Report can be found on page 24.

Dear Reader,

As the go-to-source for all things related to the EU Space Programme, EUSPA has a well-earned reputation for being a trusted provider of insightful information and expertise that policymakers, entrepreneurs and major corporations can rely on.

Our ever-growing library of publications includes such titles as the *GNSS User Technology Report*, the *GNSS Investment Report*, the *EU Space for Green Transformation Report* and the recently released *Secure SATCOM Market* and *User Technology Report*.

One title stands out on the EUSPA shelf: *The EO and GNSS Market Report*.

Published every two years, this flagship report is the most established reference document for information on the global Earth Observation and GNSS markets and I am thrilled to introduce our latest edition.

This new issue offers a comprehensive analytical overview of key GNSS and EO market segment trends and in-depth forecasts on how the market will evolve.

In the following pages you'll see how the GNSS and EO downstream market continues to grow and, with it, the EU's downstream sector. You will also learn that GNSS and EO combined global revenues are set to increase from more than €260 billion in 2023 to nearly €590 billion by 2033. Furthermore, it's worth noting that cumulative global GNSS downstream market revenues over the 2023 to 2033 period are expected to surpass €4.5 trillion.

As always, much of this information and data is presented via an array of insightful charts, graphs and case studies.

Beyond looking at the global market, the Report examines what's happening within 15 key market segments, most of which are synergetic by nature in that they include a balanced use of both EO and GNSS. We've also included a dedicated section on the main cross-segment market trends for EO and GNSS.

This year's Editor's Special explores how EU Space, particularly EGNSS and Copernicus, contribute to the building of a more resilient society – a timely topic considering today's global context of rapid technological advancement, climate-related changes and ongoing geopolitical tensions.

While challenges like these may look like lemons, I think they could be opportunities to make lemonade. In fact, one of the key takeaways from this report is how many of today's most pressing challenges represent a real opportunity for Europe – an opportunity to leverage the power of EO and GNSS to develop the innovative solutions that will have positive impact on society and define our collective future.

Rodrigo da Costa

Executive Director
European Union Agency for the Space Programme (EUSPA)
January 2024

How to read this report

The European Union Agency for the Space Programme (EUSPA) and the European Commission (EC) welcome all readers to the second issue of the EUSPA EO and GNSS Market Report, which 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 for the previous issue, covering 15 market segments.

The 15 market segments are the following: **Agriculture / Aviation and Drones / Climate, Environment and Biodiversity / Consumer Solutions, Tourism and Health / Emergency Management and Humanitarian Aid / Energy and Raw Materials / 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:

- **A general overview of the EO and GNSS market** that covers the downstream space application market, the role of EO and GNSS in the different segments, market size and revenues of both EO and GNSS (as well as shipments and installed base in the case of GNSS). It further includes a global industry overview, as well as a general description of Copernicus and EGNSS. Finally, it presents overarching market drivers and EO- and GNSS-specific market trends.
- **The market segments** form the core of the report. All segments, regardless of length, follow a common structure:
  - ✓ An overview of the EO and GNSS applications, alongside a segment description, to introduce the segment;
  - ✓ **Key** market segment **trends** illustrated with examples;
  - ✓ **A user perspective** that focuses on user needs and the utilisation of EO and GNSS in the segment;
  - ✓ The **industry value chains** including a non-exhaustive list of key stakeholders;
  - ✓ **Recent developments**, featuring market data on historical shipments or installed base of GNSS devices and EO data and service revenues by application or region over the past decade, complemented by initiatives and examples that have recently been implemented;
  - ✓ **Future market evolution** including GNSS shipment and EO revenue forecasts for the coming decade to 2033. 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** covering the current use of Galileo, EGNOS and Copernicus services and associated relevant projects within the specific segment; and
  - ✓ **Reference charts** that show 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 **'Resilient Societies'**, which refers to all (non-military) activities aimed at safeguarding people, their possessions, the environment, the economy and the organisation of our societies against hostile or rogue actors, as well as managing other threats, risks and hazards that could imperil life or belongings. Through several use cases is demonstrated how EO and GNSS contributes to those activities.
- **Annexes** conclude the report with a description of the methodology behind the data presented (Annex 1), a definition of key performance parameters (Annex 2), a list of application descriptions (Annex 3), a list of acronyms (Annex 4) and information about the authors (Annex 5).

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The second issue of the EO and GNSS Market Report provides a comprehensive assessment of the **use of EO and GNSS** across a range of **different applications**, grouped into **15 market segments**. The report also features an Editor's special on **Resilient Societies**.

As the global context rapidly changes, **overarching market drivers** such as the digital transition, climate change, growing population, energy demand and supply chain challenges, along with the rise of New Space entrepreneurship, **support the adoption of EO and GNSS solutions** within the segments and applications covered in this report.

As showcased throughout this report, the flagship components of the EU Space Programme covered in this report, **Galileo** and **EGNOS** for GNSS and **Copernicus** for EO are **key enablers in the downstream space application market**. The **added value and key differentiators** of European GNSS and EO are showcased across each market segment displayed in this report, both separately and in synergy with each other.

GNSS

The global **GNSS downstream market revenues**, generated by both the device sales and the added-value services supported by such devices, will **enjoy a growing trend,** from **€260 billion** in **2023** to around **€580 billion** in **2033**.

GNSS global revenues will rise from more than €260 billion in 2023 to around €580 billion in 2033

The market for the **devices**, expected to grow from around **€70 billion** in **2023** to almost **€120 billion** in **2033**, will progressively become more mature in the long term, while the **added-value service market** will experience **rapid growth** thanks to continuous innovation: revenues are foreseen to soar from around **€190 billion** in **2023** to **more than €460 billion** in **2033**.

The services enabled by GNSS devices will generate more than 80% of total GNSS revenues in 2033

The **annual shipments** of GNSS devices are forecasted to rise from 1.6 billion units in 2023 to 2.2 billion units in 2033, with the two dominating segments: **Consumer Solutions** (such as smartphones, fitness devices and tablets) and **Road** and **Automotive** (including in-vehicle systems and several types of on-board units), accounting together for the majority of the shipments by 2033.

While the market is becoming mature, the **stock of GNSS devices installed worldwide** will **continue to grow**. In particular, the installed base of GNSS devices is forecast to reach almost 9 billion units by 2033, with a slowdown vis-à-vis previous forecasts, connected to the increasing market maturity of mass-market applications.

While mass-market segments will also dominate revenues, **a significant contribution to the value of the market** will also be provided by **professional market segments** including **Agriculture, Urban Development And Cultural Heritage**, and **Infrastructure**.

Global GNSS shipments will hit 2 billion units per year by 2027, the installed base nearly 9 billion by 2033

From a **regional** perspective, **demand** will continue to be driven by economic and demographic growth in Asia-Pacific, with the region accounting for a growing share of the total revenues – up to around 45% in 2033. The established markets of North America and Europe (including both EU27 and non-EU27) will experience a **relative decline** in terms of global shares even though revenues **will grow in absolute numbers**, while the markets of South America & Caribbean, and the Middle East & Africa will grow in both value and share of total revenues.

Looking to the **supply side**, GNSS revenues are predominantly concentrated among companies based in the United States (around 30%) and in Europe (around 25%). Chinese, Japanese and Korean companies also retain a significant share of the market.

EO

Driven by the critical importance of improving the sustainability of human activity, improved service offering and increasing awareness on the potential use and added value of EO information, the EO market is expected to continue to grow rapidly from €3.4 billion in 2023 to almost €6 billion in 2033, including both **data revenues** and **value-added service revenues**.

EO global revenues expected to grow from €3.4 billion in 2023 to almost €6 billion in 2033

Value-added EO services represent the largest market and will grow to almost €5 billion in 2033

The **rise of the EO application market** is expected to be **fueled by added-value services**, which represent the largest market, with revenues estimated to account for **€2.8 billion in 2023** and expected to grow to almost **€5 billion by 2033**, experiencing a CAGR of 6%. Revenues from EO data sales amounted to around €600 million in 2023 and are set to increase to almost €1 billion in 2033.

Currently, nearly **half of the revenues are generated by the top three segments:** Climate, Environment and Biodiversity; Agriculture; and Urban Development and Cultural Heritage. The **Insurance and Finance** segment will grow to **become the leading contributor to global EO revenues**, reaching almost €900 million in 2033.

In 2023, looking to the geographical distribution of the **demand**, EO revenues have been generated primarily in **North America** (accounting for almost 50% of the value of sales), followed by Europe (above 20% including EU and non-EU countries) and Asia-Pacific, accounts for slightly less than 20%. In the future, it is expected that revenues in both Europe and Asia will grow faster than in North America, leading to a more balanced geographical distribution of sales in 2033.

Focusing on the **supply side** of the market, North America leads, with Europe chasing as close second. the EO value chain can be segmented along three stages: **data acquisition and distribution**, where North American companies lead with 50% of revenues, **data processing**, in which again North American suppliers dominate the market with around 55% of global sales, and **analysis, insights & decision support**.

North American EO industry is overall the most prominent, while Europe is leading in the analysis, insights & decision support category

In this last **stage of the value chain**, the **European industry is leading**, represented mostly by small and medium-size companies.

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 relies on the use of satellite-mounted payloads to gather data about Earth 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, often used in complementarity with in-situ measurements, can be assimilated into complex models to produce information and intelligence (e.g. forecasts, behavioural analysis and climate projections).

KEY EO PERFORMANCE PARAMETERS

Different types of sensors utilise 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.

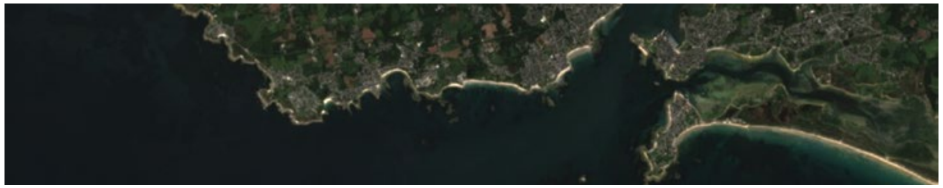
The essential parameters in EO include the sensor **resolution**:

- **Spatial resolution** defines the size of the pixels analysed by the sensors. EO satellites can be divided 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, while 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.
- **Radiometric resolution** expresses the sensitivity of the sensor. The finer the radiometric resolution, the more sensitive it is to small differences in the energy emitted or reflected by an object.

Additional key parameters are represented by the **geolocation accuracy**, the **spectral range**, and **latency**.

In-orbit infrastructures may offer a global coverage with a single spacecraft. Orbital geometry, however, limits the frequency of fly-by over the 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 to near real time.

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



©ESA, Copernicus Data Space

EO MARKET

This Market Report considers the EO market to encompass *activities where satellite EO-based data and value-added services enable a variety of applications across multiple segments*. It is noteworthy that the present report does not include applications belonging to the defence domain.

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 generated further along the value chain and stem from a transaction between an EO products and services provider, or information provider (that uses free and/or commercial input data) and an end-user*.

This report covers only the commercial EO market, meaning that the market quantification captures only activities based on commercial transactions. Therefore grant-funded activities in the EO domain are outside the scope 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 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.

ON CHARTS AND METHODOLOGY

Data contained within the charts starting from the year 2023 are estimated, forecast and subject to update in the next edition of the Market Report. These will only change if the number of applications is expanded in future reports.

Terminology used in charts:

✓ **Revenue:** The revenues from data/services sales in a given year.
✓ **Regions:** European Union (EU27), North America, Asia-Pacific, Russia & Non-EU27 Europe (Non-EU27 Europe), Middle East & Africa, and South America & Caribbean.

Revenues are presented from two different angles. First, EO demand indicates the region in which revenues are generated, similarly to the shipment of GNSS. Second, the market share shows the origin of supply – i.e. the headquarters of the company (or its ultimate parent) offering the product – as presented on the dedicated industry and market share pages. The difference between the EO demand data and the supply-driven market share analysis data thus gives an indication of the trade balance between regions.

For methodology and sources, and for abbreviations used within the report, please see **Annex 1** and **Annex 4**, respectively.

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

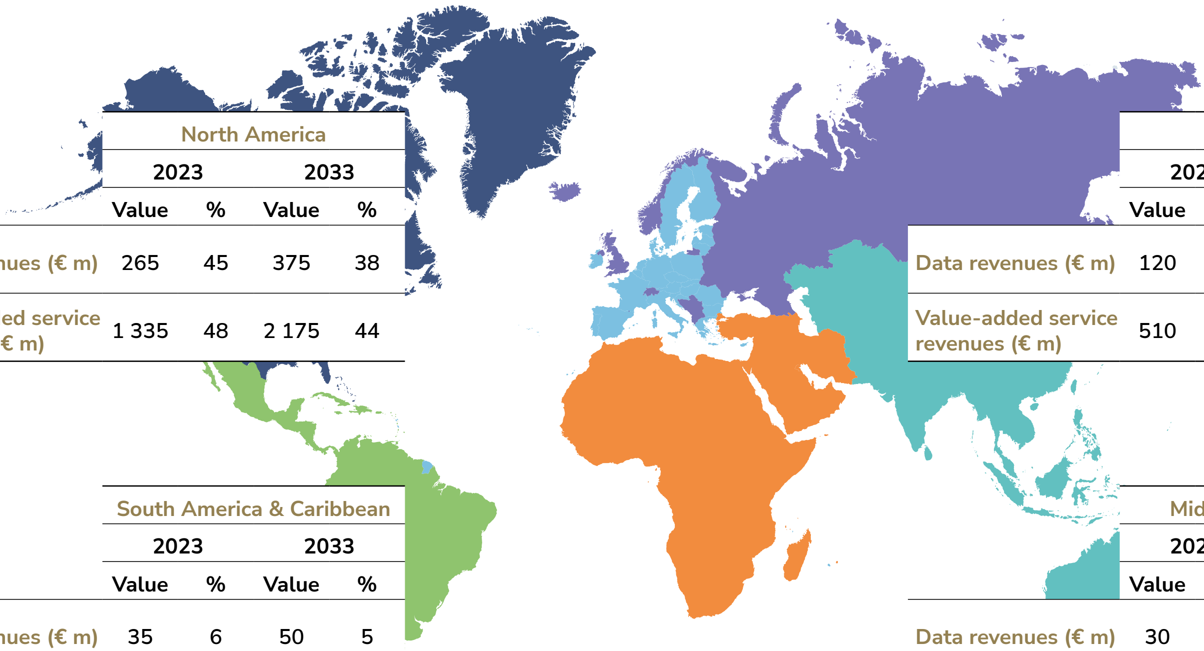
EO

EO demand world map

	European Union (EU27)			
	2023		2033	
	Value	%	Value	%
Data revenues (€ m)	100	17	195	20
Value-added service revenues (€ m)	415	15	760	15

	Global	
	2023	2033
	Value	Value
Data revenues (€ m)	595	980
Value-added service revenues (€ m)	2 775	4 960

	Russia & Non-EU27 Europe (Non-EU27 Europe)			
	2023		2033	
	Value	%	Value	%
Data revenues (€ m)	45	8	90	9
Value-added service revenues (€ m)	205	7	390	8



	North America			
	2023		2033	
	Value	%	Value	%
Data revenues (€ m)	265	45	375	38
Value-added service revenues (€ m)	1 335	48	2 175	44

	Asia-Pacific			
	2023		2033	
	Value	%	Value	%
Data revenues (€ m)	120	20	220	22
Value-added service revenues (€ m)	510	18	1 105	22

	South America & Caribbean			
	2023		2033	
	Value	%	Value	%
Data revenues (€ m)	35	6	50	5
Value-added service revenues (€ m)	155	6	265	5

	Middle East & Africa			
	2023		2033	
	Value	%	Value	%
Data revenues (€ m)	30	5	50	5
Value-added service revenues (€ m)	155	6	265	5

Role of EO across the market segments

Of the 15 market segments presented in this EO and GNSS Market Report, 14 have a strong or even dominant influence of EO applications. For each of these segments, a brief summary of the scope is presented below. More insight into segment-specific use of EO can be found in Annex 3. The Space segment does not include any EO content.

Agriculture – Modern farming relies on EO data and information for sustainable nutrient management, restoring soil health and the preservation of biodiversity. EO now plays a vital role in many day-to-day farming operations, such as vegetation health monitoring, field delineation and guiding the variable application of farming inputs such as fertilisers.

Aviation and Drones – EO has enabled monitoring of weather impact (e.g. volcanic ash clouds) and hazardous weather on Aviation and Drones. This helped stakeholders to carry out their operations safely and plan their maintenance effectively. On the other hand, EO data is also used to monitor Aviation's impact on the environment (e.g. contrail monitoring and mitigation), thus allowing stakeholders to reduce their footprint.

Climate, Environment, and Biodiversity – Various environmental parameters obtained by EO data contribute to an increasing number of international, regional and local policies related to, or impacting, the environment. The role of EO in climate services is well-established, contributing invaluable data for climate modelling. EO also improves our understanding of the health of ecosystems and existing and potential stressors therein.

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 fruition is enabled by EO by providing, for example, insights into wave conditions and water quality.

Emergency Management and Humanitarian Aid – EO is providing the 'full picture' needed for context-aware emergency responses, ranging from preparedness, prevention and mitigation to response and post-event recovery. EO provides comprehensive information over vast, remote and volatile areas, offering reliable and frequently updated documentation, assessments, and real-time monitoring of humanitarian situations.

Energy and Raw Materials – EO-powered solutions are widely used in the Energy segment to help renewable energy project developers estimate annual energy production, assess risks to energy assets, or nowcast near-term energy production to balance the electrical grid. In the Raw Materials segment, EO data helps monitor environmental impact, identify areas with high mineral resources potential, detect illegal mining activities, and increase safety by monitoring mine pit/tailings slope stability.

Fisheries and Aquaculture – Dedicated EO services and products bring value-added in the Fisheries and Aquaculture segment by providing insights in salinity, temperature and water quality, among others, and thus greatly improving Fisheries and Aquaculture outputs. EO also allows Fisheries to monitor and predict where fish may migrate and now plays a pivotal role in detecting illegal fishing activities at sea.

Forestry – EO is becoming an extremely valuable tool in monitoring and maintaining the sustainability of forests. Foresters can use EO to understand forest health and optimise operations. From carbon monitoring to battling deforestation and degradation, EO is contributing to conservation of forests all around the world.

Infrastructure – EO increasingly supports site selection and construction and post-construction monitoring through satellite-based ground deformation assessment. Thanks to its capacity to deliver information on risk exposure and the future impacts of climate change, EO can also help to design more resilient infrastructures and to optimise maintenance operations, in particular for large and/or linear 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 to 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 modes 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 – While the use of EO is rather new and innovative, applications such as congestion control and infotainment services have greatly benefited from global EO data, contributing to road safety.

Urban Development and Cultural Heritage – EO provides critical data for urban planning, helping cities manage growth, infrastructure, environmental sustainability and resilience. It further aids in monitoring cultural heritage sites, ensuring their preservation by tracking changes, threats and facilitating informed conservation efforts.

EO

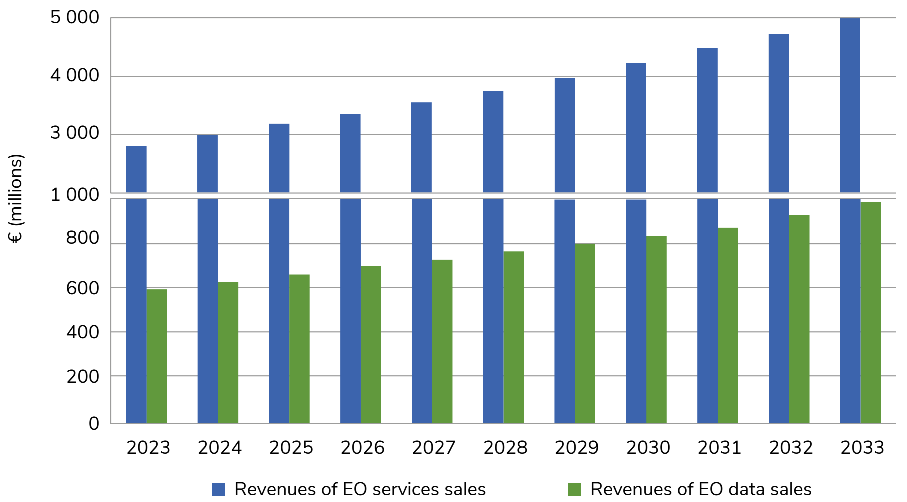
Revenues generated from EO data and service keep growing consistently

The global market for Earth Observation (EO) data and services, examined across 15 segments (with Space being the only segment not associated with the EO market in this report), has been categorised based on an analysis of over 100 market-based applications. Although various EO applications have been recognised within each segment, **only 12 of these EO segments presently have quantifiable data on revenue streams from data and value-added services**. Quantifiable EO data for the Aviation and Drones, and Rail segments is not available.

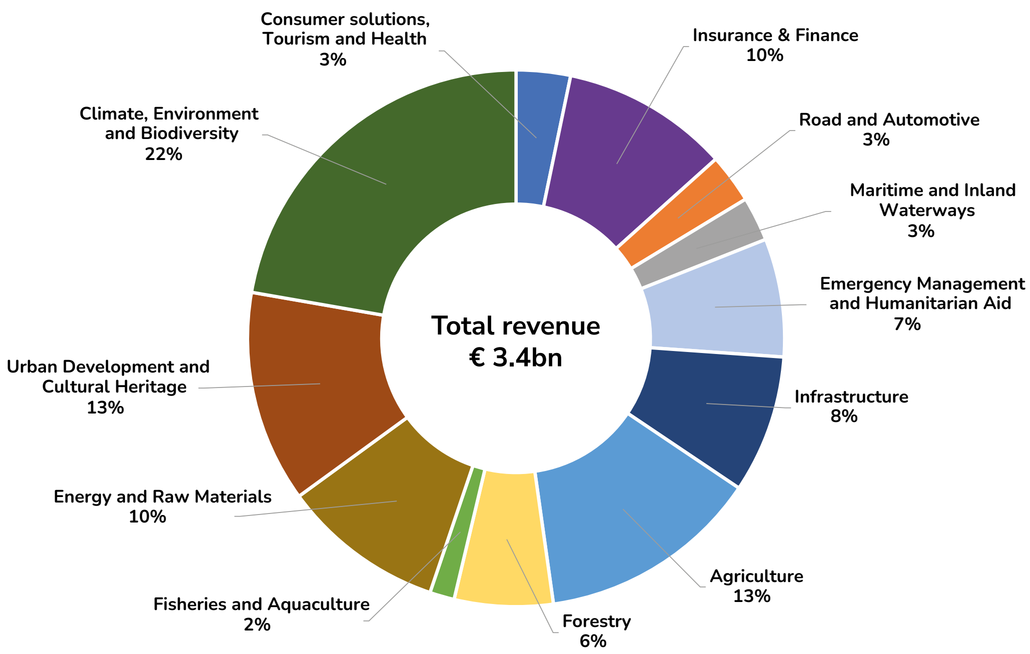
In 2023, the global revenues from EO data and value-added services amounted to €3.4 billion. Almost half of this total is generated by the top three segments: Climate, Environment and Biodiversity, Agriculture, and Urban Development and Cultural Heritage. However, projections suggest significant growth in the Insurance and Finance segment, with an expected increase from around €340 million in 2023 to becoming the leading contributor to global EO revenues in 2033, reaching almost €900 million. **By 2033, the overall revenues of the global EO data and value-added services market are projected to reach nearly €6 billion**.

The **forecasted growth of EO data and service revenues** can be attributed to multiple **drivers** in multiple segments. EO value-added services provide insights into production in the Agriculture and Forestry segments, **saving time and money** for those working in these sectors. With the effects of climate change being felt more harshly each year, EO services are invaluable to these segments, not to mention the value EO observation brings to the Climate, Environmental and Biodiversity sector through **continuous and complete information** hard to obtain through other systems. EO data is used to feed risk assessment in Insurance and Finance with information not available otherwise or available but with a not comparable level of **accuracy and update frequency**. Also, EO provides critical data for urban planning, supporting **sustainable development**.

Global revenue of EO data and services sales



Distribution of revenue by segments (€m, 2023)



As depicted in the chart on the left, showcasing the EO global revenues between 2023 and 2033, both value added services and EO data are forecasted to rapidly expand in the coming decade.

Revenues generated from **EO data alone** in 2023 amounted to almost **€600 million** across all segments. The EO data market is expected to see a CAGR of 5% by 2033, resulting in total revenues of almost **€1 billion**.

The **EO value-added services** market, on the other hand, is considerably larger than the EO data market. EO value added services generated globally a **total of around €2.8 billion in 2023**. Starting in 2023, the EO value-added services market is expected to experience a CAGR of almost 6%, achieving total revenues of almost **€5 billion** by 2033.

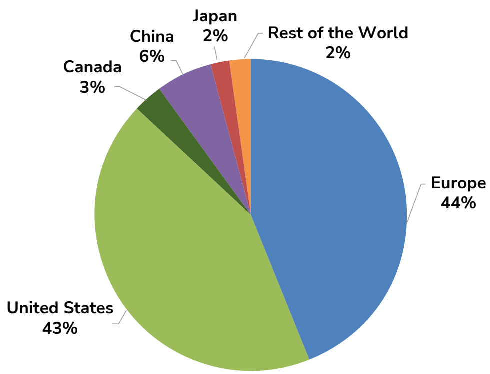
EO industry overview

Europe[1] and the **United States** generate the most revenues[2] from **EO data** and **value-added services**. The pie chart below illustrates the revenues from the supply perspective, delineating the sources of EO data and services. This is different from **the EO demand world map**, which indicates the regions in which EO data and services revenues are generated (page 10).

Collectively, US and European companies account for a market share of more than 85%, with each being responsible for over 40%. **Chinese** companies represent 6% of the market, while **Canada** and **Japan** generate 3% and 2% of global revenues, respectively.

The downstream EO industry is organised into three categories: **data acquisition and distribution, data processing,** and **analysis, insights & decision support**. The table in the top right corner highlights the leading 10 companies in each of these value chain categories. Notably, top companies often vary across the value chain, although major players, such as Maxar, Airbus and Amazon, have a presence in more than one category.

Geographical split of revenues in the EO industry 2021



Top 10 companies across the value chain based on 2021 revenues

Data acquisition and distribution		Data processing		Analysis, insights & decision support		Users
Alphabet (Google)	US	Alphabet (Google)	US	21AT	CN	Users of EO products and services across the different market segments
Airbus	NL	Airbus	NL	Airbus	NL	
Amazon	US	Amazon	US	BASF	DE	
ESRI	US	CGI	CA	Beijing Piesat	CN	
KSAT	NO	ESRI	US	CGI	CA	
Leonardo	IT	Garmin	US	NEC Corporation	JP	
Maxar	US	Leonardo	IT	Leonardo	IT	
Planet	US	Maxar	US	Maxar	US	
Thales	FR	Oracle Corp	US	Trimble	US	
Verisk	US	Trimble	US	VITO	BE	

The top 10 companies mentioned above are listed in alphabetical order

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

[2] A different methodology was used to calculate EO revenues compared to rest of the report. 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 around 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), which indicates the regions in which the revenues deriving from EO data and services are generated. 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 European share of the EO market presented on this page is a methodologically different statistic to the share of revenues presented for EU27 in the map on page 10. For further information on the methodology, please refer to Annex 1.

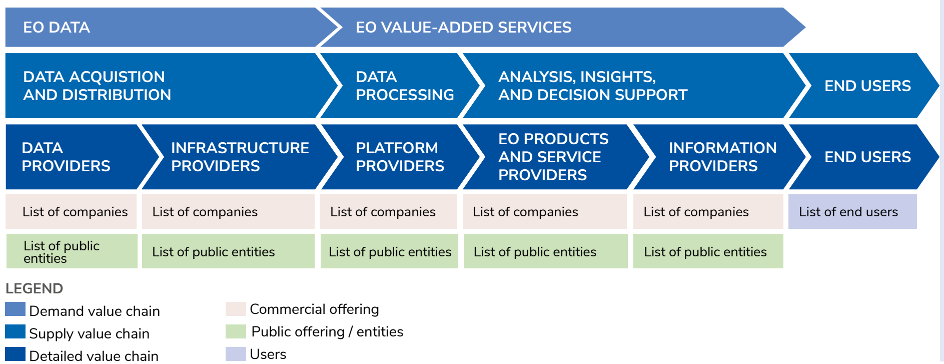
The EO value chain

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 (blue), 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:

- **Data providers:** Providers of unprocessed or pre-processed EO data from multiple sources (i.e. satellites and in-situ (non-space) measurements). Typically operating a data-as-a-service business model.
- **Infrastructure providers:** Providers of various types of computing infrastructure upon which EO data can be accessed, stored, distributed or manipulated. Typically operating an infrastructure-as-a-service business model.
- **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. Typically, operating platform-as-a-service and/or software-as-a-service business models.
- **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. Typically operating an analytics-as-a-service business model.
- **Information providers:** Providers of sector-specific information that incorporates EO data along with non-EO data. Typically operating an insights-as-a-service business model.
- **End Users:** Final users benefitting in their decision making or operations from the solutions offered by EO services and/or information providers.

The entities listed in the value chains of the different segments are to be considered as representative examples and non-exhaustive of the entire market.

Example of a generic EO value chain



The European EO industry covers more than a third of the global processing market

European EO market share by value chain categories

The EO value chain starts with companies involved in **data acquisition and distribution**, which provide raw, unprocessed or pre-processed data from EO constellations. North America leads with around 50% of shares, with Europe following and retaining around 40% of the market.

Subsequently, **data processing** companies perform the systematic review of data with the purpose of extracting any potential valuable knowledge. In the EO data market, entities that work at this step in the value chain leverage EO data to **provide online platforms** or **digital services** through which users can utilise tools and capabilities to analyse EO data, develop algorithms and build applications. In 2021, North American companies led with around 55% of the market. This large share is due to the presence of very large companies including AWS, Alphabet (Google) and Maxar. **Europe** accounted for around **35% of the market in data processing** and had significant market shares in the Aviation, Climate, Environment, and Biodiversity, and Insurance and Finance segments. Over 200 European companies had EO data processing related activities across all market segments, more than double the number of North American companies.

The EO value chain category following data processing is **analysis, insights and decision support**; Europe has more than a **50% share** of this global market, while North America has nearly a quarter. In this stage of the value chain, European service providers, mostly SMEs, have successfully specialised in addressing their need of their clients for customised solutions.

Please note the changes in market share are driven by general market trends, mergers and acquisitions, and exchange rate fluctuations.

NOTES
The footnotes presented on page 13 also apply to this page. For further information on the methodology, please refer to Annex 1.

EO Regional market shares in data processing, by market segment - 2021

	Europe	North America	Asia+Russia
	30%	50%	20%
	85%	10%	5%
	65%	20%	15%
	10%	75%	15%
	35%	40%	25%
	50%	25%	25%
	70%	30%	0%

	Europe	North America	Asia+Russia
	30%	60%	10%
	30%	60%	10%
	80%	20%	0%
	65%	20%	15%
	30%	5%	65%
	30%	70%	0%
	35%	55%	10%

Note: Segment share for the 'rest of the world' is not shown nor accounted for in this table. Rounding is performed to the level of 5%.

Focus on Europe – The EARSC Industry Survey 2023

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 27 countries and include over 140 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. Please note that the industry survey also covers defence in its scope.

Based on outcomes from its eighth edition, the EO services sector comprised of 772 Companies (an increase of 3.5% compared to the 2022 survey) across 34 countries (comprising EU and ESA member states). **Companies offering services or supplying (selling) data or information using satellite data** generated a total of **€1.7 bn revenues** (driven by Copernicus data and information) in 2022 (an increase of +10.9% compared to the previous year).

Considering around 14 000 employees estimated in the sector, the European EO industry results to still be largely dominated by micro and small companies. The 2022 Survey shows that, similarly to the previous year, approximately **96%** of the companies covered **have less than 50 employees**, whereas 66% have less than 10 employees.

More information available at: EARSC Industry Survey 2023 - EARSC and EARSC website

A growing number of segments and users count on reliable Copernicus data and services

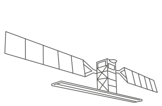
Copernicus is the European Union's Earth Observation and Monitoring EU Space Programme component

Copernicus delivers **accurate, consistent and reliable information** in the field of **environment and security** and **supports a wide range of Union policies** in domains such as Agriculture, Climate, Environment, Energy, Fisheries and Aquaculture, Forestry and Infrastructure. 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 other Copernicus Contribution Missions (CCM); an In-Situ Component which collects data acquired by a multitude of sensors at air-, sea- and ground-level, and includes a specific category of information known as geospatial reference data; and a Service Component which transforms the various data into timely and actionable information products.

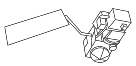
The programme is managed by the European Commission and implemented in partnership with the Member States, European Space Agency (ESA), European Organisation for the Exploitation of Meteorological Satellites (EUMETSAT), European Centre for Medium-Range Weather Forecasts (ECMWF), Mercator Ocean International, the European Environment Agencies (EEA), the Joint Research Centre (JRC), FRONTEX, the European Maritime Safety Agency (EMSA), the EU Satellite Centre (SatCen), which jointly represent the entrusted Entities.

Six Sentinel families are designed to serve a wide range of users

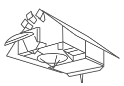
The **Sentinels** are the **Earth Observation satellites** dedicated to the **Copernicus programme** and are designed to meet the needs of the Copernicus services and their users. The six Sentinel families, presented below, ensure an independent and autonomous Earth Observation capacity for Europe with global coverage. The satellites provide observations which serve a wide range of users for a multitude of applications in the areas of climate, land and ocean services, emergency management, atmosphere and air quality, among others.



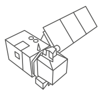
Sentinel-1A provides all-weather, day and night radar imagery for land and ocean services. Sentinel 1-B was retired in December 2021.



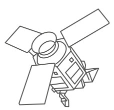
Sentinel-3A & -3B provide optical, radar and altimetry data for marine and land services.



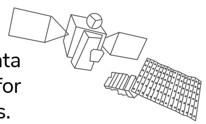
Sentinel-6 provides radar data to measure sea-surface height, for oceanography and climate studies.



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



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



Launch 2024

Sentinel-4 & Sentinel-5 are payloads to fly aboard EUMETSAT MTG-S and Metop-SG satellites, to provide atmospheric composition data.

Copernicus Sentinel expansion missions

Currently, **six Sentinel expansion missions** are being studied **to address foreseen gaps in Copernicus user needs**. CHIME would provide hyperspectral data to support sustainable agricultural and biodiversity management, as well as soil property characterisation. CIMR would provide observations of sea-surface temperature, sea-ice concentration and sea-surface salinity for Arctic user communities. The CO2M mission would measure atmospheric carbon dioxide produced by human activity, providing the EU with a unique and independent source of information to assess the effectiveness of policy measures. CRISTAL would measure and monitor sea-ice thickness and overlying snow depth in support of maritime operations. LSTM would provide observations of land-surface temperature to aid the agricultural user community. ROSE-L's radar data would be used in support of forest management, to monitor subsidence and soil moisture and to discriminate crop types for precision farming and food security.

Copernicus Contributing Missions

The Copernicus Contributing Missions (CCM) play a **vital role in meeting user needs**, delivering **data** that **complements the output of the Copernicus Sentinel** missions. The complementary data comes from Contributing Missions from ESA, Member States, EUMETSAT and other third-party operators. There are around 30 existing or planned contributing missions, encompassing various technologies like SAR, optical sensors, spectrometers and altimetry systems. These missions are essential to ensure that the full range of user observational requirements is satisfied.

Recently, ESA started working with European Emerging CCM data providers, which are part of the European New Space ecosystem and will progressively become part of the data offering. Currently, nine such data providers (a mix of start-ups, scale-ups and SMEs) are under contract with ESA to supply multispectral and hyperspectral images, thermal infrared and atmospheric composition data. They include Aerospacelab, Endurosat, Kuva Space, Absolut Sensing, Prométhée, ConstellR, Orora Technologies, Aistech, and Satlantis.

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

Atmosphere	Climate	Emergency	Land	Marine	Security*
CAMS	C3S	CEMS	CLMS	CMEMS	CSS

*Serves registered Public users only

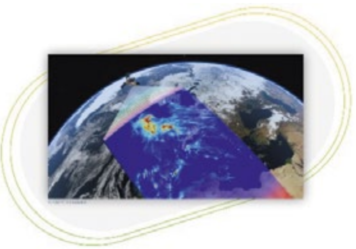
EU continues to ensure Copernicus data is easily accessible and usable

Access to Copernicus Data

The massive amount of data and information produced in the context of the **Copernicus programme** – representing petabytes – are made freely available and accessible to any citizen and any organisation around the world. As the data archives grow, it becomes more convenient and efficient to analyse data where they are originally stored, instead of downloading the data locally.

Cloud technologies allow this versatility, while offering users a large choice of options to benefit from the data generated by Copernicus – i.e. they can search, visualise and further process the data in a fully maintained software environment, while still having the possibility to download the data to their own computing infrastructure.

Being able to **easily access this data** is crucial for EO companies, as indicated in the EARSC 2022 survey; **58% of the companies** indicated ease of **access as the most important reason for using certain platforms**.



© ESA, Copernicus Data Space Ecosystem

Data Access Hubs

Copernicus data and services can be accessed through various hubs, some of which are managed by ESA, such as the new Copernicus Data Space Ecosystem (see right side of page), and the Copernicus Contributing Missions Online gateway. Furthermore, two access hubs are managed by EUMETSAT: EUMETCast and the Data Store.

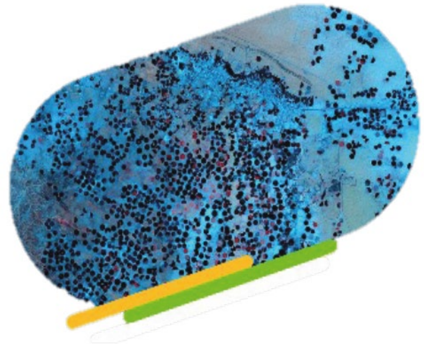
In addition to the above platforms, each Copernicus Service has developed its own online platform which provides users with access to information products, associated documentation and support services for their use (1000+ Copernicus products are available to users in total).

Additionally, the European Commission has funded the deployment of cloud-based platforms, providing centralised access to Copernicus data and information, as well as to processing tools. These platforms are known as **Data and Information Access Services (DIAS)**, allowing users to discover, manipulate, process and download Copernicus data and information.

Furthermore, the **Copernicus Thematic Hubs** were launched in 2023. These are single entry points for the ensemble of data, products and information generated by the Copernicus services and components for specific thematic or geographical areas. The Hubs correspond to specific EU policy needs and provide simplified access to key information on selected areas for various stakeholders, policy makers and users. In 2023, Copernicus has launched four Thematic Hubs; Health, Coastal, Energy and Arctic. Each Hub is operated by a Copernicus Entrusted Entity.

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 basis for the development of value-added products while stimulating 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 presented in this market report.

Copernicus Data Space Ecosystem

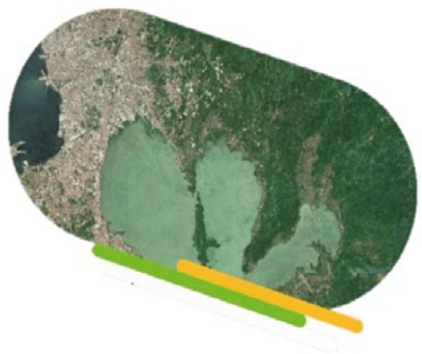


© ESA, Copernicus Data Space Ecosystem

Building on the experience gained with the Copernicus DIAS-es launched in 2017, the European Commission has recently procured a **new data access service** from a consortium led by T-Systems, which has become operational in July of 2023: the **Copernicus Data Space Ecosystem (CDSE)**.

The CDSE means a significant leap forward in the way users can access and work with Earth Observation data.

The platform provides access to a **large repository of open and free Earth Observation data** from the Copernicus Sentinel satellites, including new and historical Sentinel images, as well as Copernicus Contributing Missions. The CDSE works towards supporting users in accessing, viewing, using, downloading and analysing data, with the aim of improving access and exploitation of the EU's Copernicus satellites data. It is designed to be flexible and adaptable to the needs of different users, while ensuring continuity of the existing distribution services and DIAS-es.



© ESA, Copernicus Data Space Ecosystem

The Copernicus Data Space Ecosystem offers:

- Largest EO data offering in the world, with discovery and download capabilities;
- Set of data processing tools to extract objective information and conduct public, private or commercial activities;
- An ecosystem to offer data, services and applications from public, commercial and scientific service providers;
- A service to benefit institutional users, research, commercial sector and citizens.

Understanding user needs is crucial for the EU Space Programme

Copernicus is a user-driven programme

From the start, **users** have been **at the centre of the design and implementation of Copernicus** and have driven the implementation and validation of the service-related requirements. The programme governance differentiates between core[1] and other users. Copernicus core users can be policymakers and public authorities that can use the information as a basis to act or develop policies and legislation, such as in the environmental field or in the civil protection area in the event of a natural disaster or humanitarian crisis. **Other users** include research, commercial and private users.

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 observes the permanent involvement of users, with the **Copernicus User Forum** established to assist the programme committee in identifying core user requirements, verifying service compliance and coordinating public sector users. For non-core users, EUSPA organises the annual **User Consultation Platform (UCP)**, where users from different market segments meet to discuss their needs and application-level requirements relevant for Earth Observation (EO), along with GNSS and secure telecommunications.

[1] See STAFF_WORKING_PAPER_2019-394-Expression_of_User_Needs_for_the_Copernicus_Programme.pdf

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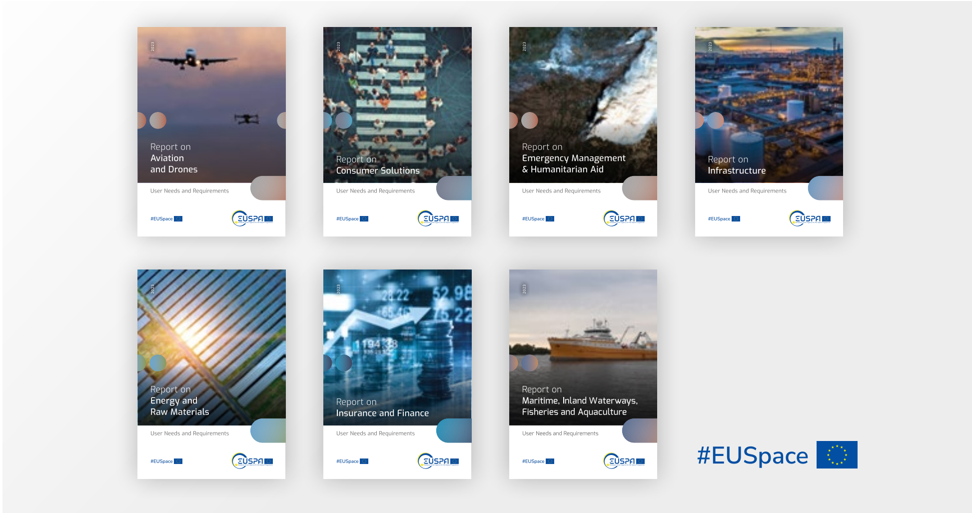


The latest editions of the User Consultation Platform for the European Space Programme

The User Consultation Platform (UCP) engages 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. The last two editions of the UCP also addressed EO, exploring the use case of EO and investigating associated user requirements.

The UCP of **2022**, which was held during the EU Space Week in Prague, attracted over 300 attendees from seven different market segments including Infrastructure, Energy and Raw Materials, Consumer Solutions, Aviation and Drones, Maritime and Fisheries, Emergency Management and Humanitarian Aid, and Insurance and Finance. During the **2023** EU Space Week in Seville, users were grouped in seven sessions: Agriculture and Forestry, Environmental Climate & Biodiversity, Rail, Public Transport, Road and Automotive, Space, and Resilient Societies. Both events represented unique opportunities for the **EO community** to gather and discuss about needs, challenges and opportunities.

The 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 user needs and requirements of the application domains. At the same time, these reports serve as a key input to the UCP enabling the main included outcomes to be validated and subsequently updated.

The full reports of the UCP 2022 and 2023 are available at the following link:
https://www.euspa.europa.eu/media-library/publications

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 include:

- **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).
- **Calibration:** 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 (only relates GNSS Timing Receivers).
- **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.
- **Robustness:** Relates to spoofing and jamming and how the system can cope with these issues
  - **Robustness to jamming** is the ability of the system to mitigate radio frequency (RF) interference and continue operations within stated service performance limits.
  - **Robustness to spoofing** is 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.
- **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.

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**.

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** and **service** revenues. The latter include revenues derived from **commercial augmentation services** and **other services** attributable to GNSS.

Commercial augmentation services include GNSS augmentation subscriptions (PPP, RTK, PPP-RTK and DGNSS). Revenues deriving from **other services** include software products and content such as digital maps for portable navigation devices (PNDs) and in-vehicle systems (IVS), as well as 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 revenues, advertisements and in-app purchases), subscription revenues from asset management services, drone service revenues across a range of industries. 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 2023 are estimated, forecast and updated in the next edition of the Market Report.

Terminology used in charts:

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

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

➜ **Revenues:** The revenues from device/service sales in a given year.

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

The chart data are presented from two angles. First, GNSS demand shows the regions in which shipments are sold, devices are used and revenues are generated (accounting for most of the chart material presented in the report). Second, the market share analysis looks at the origin of supply – where a company (or its ultimate parent) offering the product is headquartered – as presented on the dedicated industry and market share pages. The difference between the GNSS demand data and the supply-driven market share analysis data thus gives an indication of the trade balance between regions.

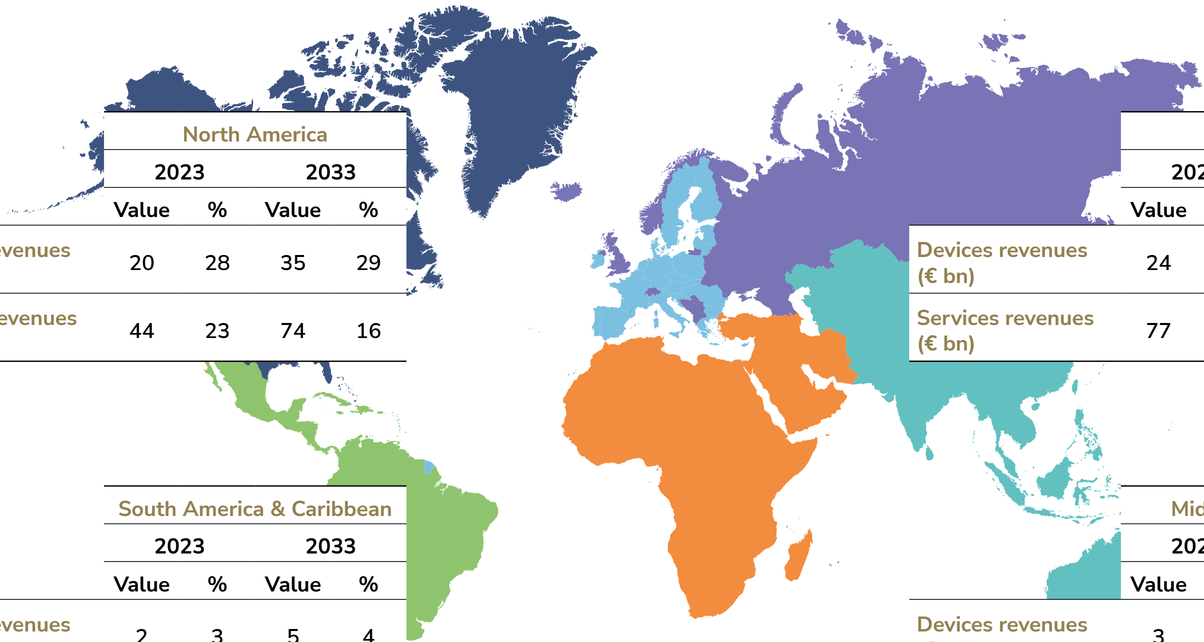
For methodology and information sources see **Annex 1** and for any abbreviation used within the report, please refer to **Annex 4**.

GNSS demand world map

European Union (EU27)	2023 Value	2023 %	2033 Value	2033 %
Devices revenues (€ bn)	16	23	27	23
Services revenues (€ bn)	32	17	54	12

Global	2023 Value	2033 Value
Devices revenues (€ bn)	71	119
Services revenues (€ bn)	191	463

Russia & Non-EU27 Europe (Non-EU27 Europe)	2023 Value	2023 %	2033 Value	2033 %
Devices revenues (€ bn)	6	8	13	11
Services revenues (€ bn)	9	5	23	5



North America	2023 Value	2023 %	2033 Value	2033 %
Devices revenues (€ bn)	20	28	35	29
Services revenues (€ bn)	44	23	74	16

Asia-Pacific	2023 Value	2023 %	2033 Value	2033 %
Devices revenues (€ bn)	24	34	34	29
Services revenues (€ bn)	77	40	218	47

South America & Caribbean	2023 Value	2023 %	2033 Value	2033 %
Devices revenues (€ bn)	2	3	5	4
Services revenues (€ bn)	10	5	29	6

Middle East & Africa	2023 Value	2023 %	2033 Value	2033 %
Devices revenues (€ bn)	3	4	5	5
Services revenues (€ bn)	19	10	65	14

Role of GNSS across the market segments

GNSS applications have a dominant influence in all the 15 market segments presented in this EO and GNSS Market Report. For each of these segments, a brief summary of the scope is presented below. More insight into segment-specific use of GNSS can be found in Annex 3. The Climate, Environment, and Biodiversity segment cover GNSS to only a limited extent.

Agriculture – New technologies are pushing the Agriculture sector to new frontiers. GNSS allows for the efficient guidance of farming machinery and the implementation of smart farming practices. Enabling growing automation and improved monitoring of the different operations, use of GNSS leads to increased yield and reduced environmental impact.

Aviation and Drones – Standardisation and certification of GNSS makes operations safer and gives access to smaller regional airports without costly investment into ground-based navaids. GNSS is an indispensable asset that supports all aspects of Aviation. GNSS is also the only viable means of navigating and tracking drone traffic. The latest U-space regulation heavily relies on GNSS-based services.

Climate, Environment, and Biodiversity – GNSS has limited but important application in the climate services domain as the technology supports a range of geodetic applications that measure properties of the Earth (magnetic field, atmosphere). In the domain of biodiversity, GNSS-beacons are used to geolocate animals for the purposes of monitoring migrations, habitats and behaviours.

Consumer Solutions, Tourism and Health – GNSS is ubiquitous in our everyday life. A very wide array of apps supported by smartphones and wearables enhance individual fitness and healthcare, on top of navigation, contactless deliveries and much more.

Emergency Management and Humanitarian Aid – GNSS is vital for search and rescue beacons. It allows the transmission of the accurate positioning of somebody (e.g. mariner overboard, hiker) or something (e.g. aircraft, vessel) in distress towards the emergency response teams, enhancing the effectiveness of emergency response efforts in case of manmade or natural emergencies (e.g. landslides, droughts, earthquakes and floods).

Energy and Raw Materials – Electricity grids rely heavily on timing and synchronisation enabled by GNSS, balancing supply and demand to ensure safe operations. In the Raw Materials segment, GNSS supports mining site monitoring, tracking of assets and mining machinery guidance and is a key enabling technology for various autonomous systems.

Fisheries and Aquaculture – GNSS significantly contributes to Illegal, unreported and unregulated fishing detection with its traditional use in the field, namely tracking the location of vessels through Automatic Identification System (AIS) and Vessel Monitoring System (VMS). It also improves safety at sea of fishing vessels.

Forestry – GNSS plays a crucial role in the effective management and long term sustainability of forests. In particular, GNSS is used to help monitor the health of trees with on-tree devices, as well as the tracking of timber supply chains.

Infrastructure – GNSS contributes to the proper functioning of Infrastructures operations. The high accuracy services it offers allow a safe and on-time completion of construction work and support preventive maintenance operations. The GNSS timing and synchronisation function is expected to play an increasingly critical role in mobile telecommunication networks and in the provision of a secure environment for data centres and cloud services.

Insurance and Finance – The financial world relies on GNSS timing and synchronisation for the accurate timestamping of financial transactions.

Maritime and Inland Waterways – GNSS, on top of being a fundamental tool for navigation information, is supporting the transition towards digitalisation and more autonomous vessels. This, coupled with smart ports, paves the way for increased safety and a more sustainable blue economy.

Rail – GNSS is increasingly becoming a fundamental pillar not only for non-safety applications (e.g., asset management), but also for improved maintenance, train driving optimisation, and for safety-related applications, including Enhanced Command & Control Systems. All this together, will increase capacity, efficiency and safety of railways.

Road and Automotive – GNSS plays a crucial role in ensuring safety and efficiency of road transport, while also reducing congestions and the related emissions. All this is deployed through enabling emergency assistance, allowing connected and autonomous cars, supporting asset management, including tracking of dangerous gods, empowering road user charging and smart tachograph.

Space – GNSS provides benefits that, undoubtedly, can be exploited in Space: from using real-time GNSS data for absolute and relative spacecraft navigation, to deriving Earth Observation measurements from it. Firstly used by Low-Earth Orbit (LEO) satellites, the use of GNSS has extended to higher regions of the outer space, including GEO orbits and the cislunar space. Such diversification and proliferation of space users, driven largely by the New Space paradigm, leads to an increasing need for spaceborne GNSS-based solutions.

Urban Development and Cultural Heritage – GNSS enables precise location-based data for urban planning, facilitating the deployment of efficient transport networks and infrastructure development. Additionally, it aids in mapping and preserving cultural heritage sites, ensuring accurate documentation and restoration efforts.

The GNSS market will continue growing towards long-term maturity

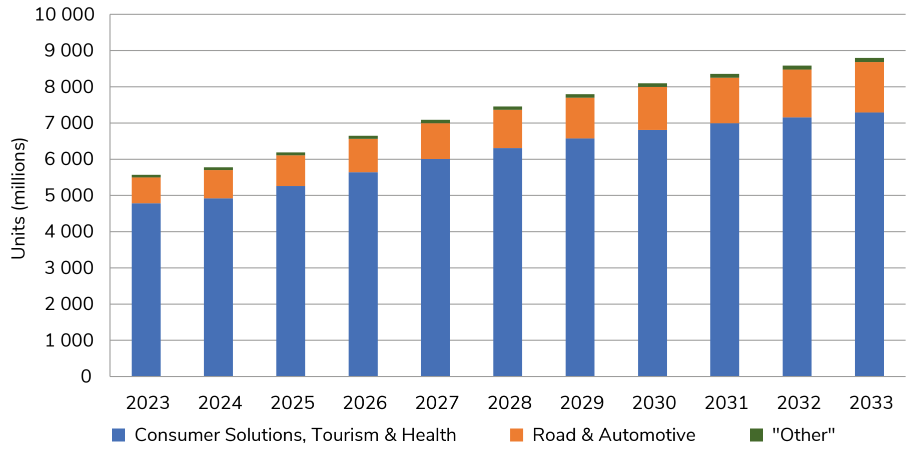
Yearly global GNSS devices shipments (graph below) is forecast to continue growing over the next decade, reaching more than 2.2 billion units in 2033 from nearly 1.6 bn units in 2023. The **Consumer Solutions, Tourism and Health** segment accounts for **90% of all global annual shipments**, mainly due to the significant number of sales of smartphones and wearables. Asia-Pacific is expected to maintain the largest market share with almost 50% of the global market expected by 2033.

The **overall installed base of GNSS devices** (upper-right graph) **is projected to grow from 5.6 billion units in 2023 to almost 9.0 billion units in 2033**. Similar to global shipments, Consumer Solutions will continue to dominate, maintaining almost 90% of global GNSS devices in use in 2023, but slowly decreasing to below 85% by 2033 due to the increasing maturity of consumer devices, increased attention to sustainability (i.e. longer lifetimes), and disruptions to the supply chain due to international crises, which significantly affect smartphones.

In parallel, the **Road and Automotive** segment is increasingly adopting and integrating in-vehicle systems into new car shipments, with its share of the global installed base of GNSS devices expected to grow from over 10% in 2023 to over 15% in 2033.

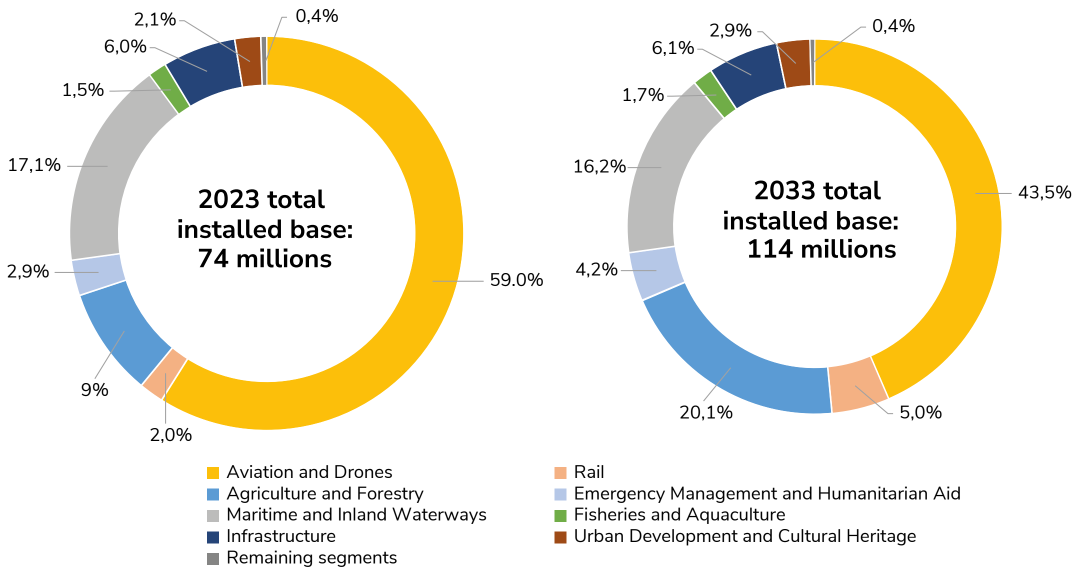
As for other segments (bottom-right graphs), **Aviation and Drones** will continue to grow, rising from 44 million units in 2023 to almost 50 million units in 2033. **Maritime**, the second largest market in 2023, will see its global share of over 17% (corresponding to 13 million units) drop to 16% (18 million) in 2033. **Agriculture** will take over as the second largest segment, reaching 20% of the global market in 2033, with around 23 million units, up from less than 7 million in 2023.

Installed base of GNSS devices by segment

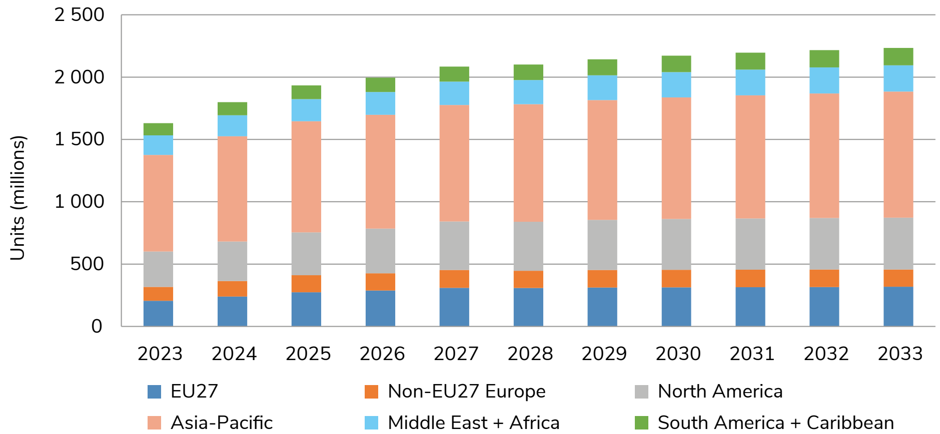


Installed base of "Other" by segment (2023)

Installed base of "Other" by segment (2033)



Shipments of GNSS devices by region



* Remaining segments includes Space, Insurance and Finance, Energy and Raw Materials

The GNSS cumulative revenues are forecast to reach €4.6 trillion in the next decade with services accounting for almost 80% in 2033

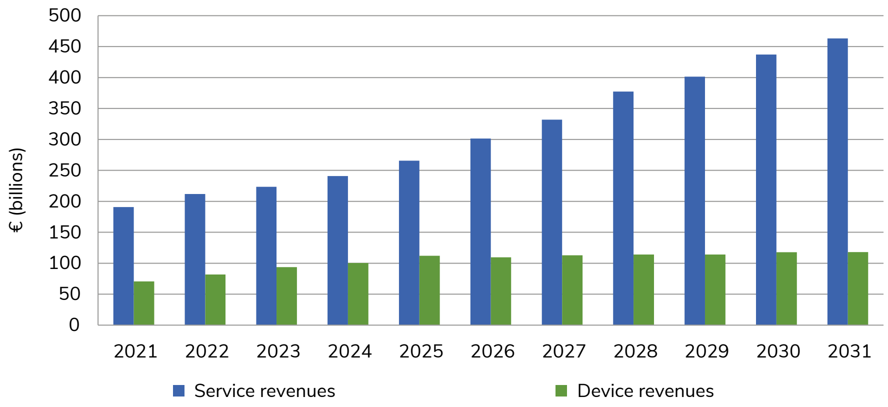
The **global GNSS downstream market revenues from both device and service sales are expected to grow from around €260 billion in 2023 to around €580 billion in 2033** with a CAGR of over 8%.

Revenues from services* are driving the growth. Overall, service revenues (i.e. both augmentation services and other services attributable to GNSS) will account for **around €460 billion in 2033** or almost **80% of the total global GNSS downstream market revenues**. This is in line with expectations, since the more the GNSS market matures, the more services become relevant compared with devices.

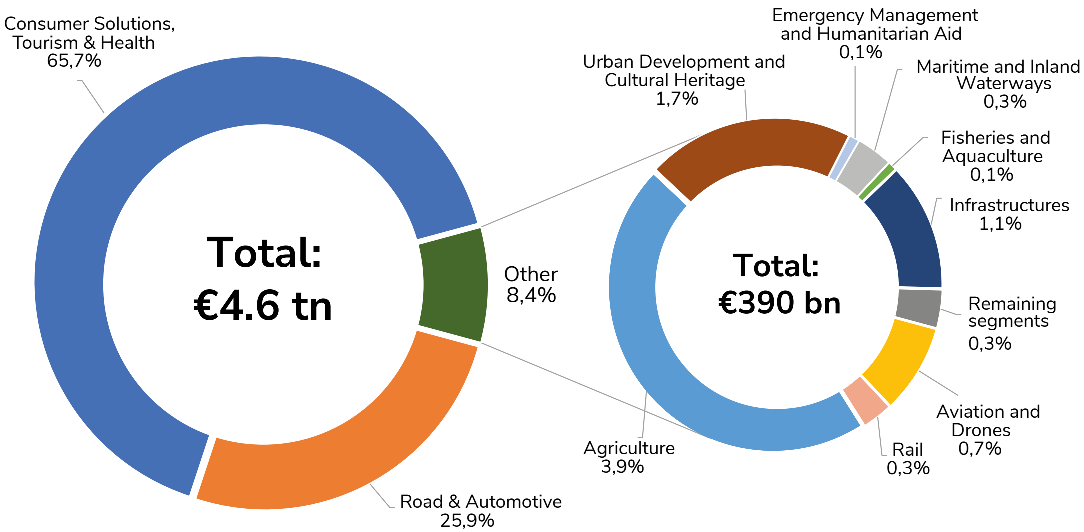
Revenues from **smartphone apps** represent an important component, amounting to over 60% of added-value services, and over 40% of the total revenues. This is due to increasing digitalisation and the growing uptake of user-friendly solutions which have transformed the most common smartphone apps into unmissable platforms for our daily live such as personal banking, the use of various ride-hailing apps, tourism applications and a plethora of in-app purchases for games and social media applications which all rely on GNSS for their functionalities.

*Please refer to page 18 for a more detailed definition

Revenue from GNSS devices sales and services



Cumulative revenue by segment 2023-2033



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

The **market segments Consumer Solutions and Road continue to dominate in terms of cumulative revenues** with a combined total of over 90% for the forecasting period 2023-2033.

Within the Road and Automotive segment, most of the revenues are generated from devices used for navigation, such as Connected and Automated Driving (CAD), navigation apps and mapping software updates, In-Vehicle Systems (IVS) and asset management applications including insurance telematics. Meanwhile, revenues from Consumer Solutions mainly come from revenues related to GNSS-enabled apps and GNSS-enabled data revenues from smartphones and tablets.

For the remaining revenues, almost 80% will be generated by Agriculture (46%), Urban Development (20%) and Infrastructure (13%). In Agriculture and Urban Development, revenues are predominantly generated by commercial augmentation services (and automatic steering equipment for agriculture), while the primary sources of revenues in Infrastructure are linked to mapping and surveying, construction operations and site selection or monitoring.

GNSS

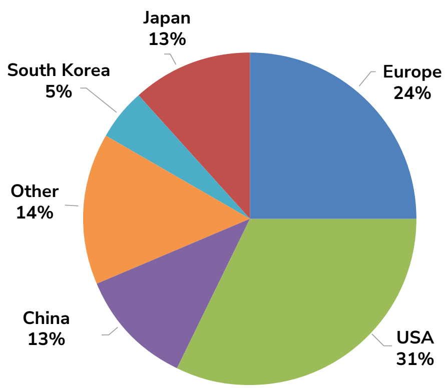
GNSS industry overview

Revenues[1] from **GNSS components and receivers, system integrators** and **software / added-value services** are predominantly generated by companies based in **the US and Europe**[2]. The US maintains the largest portion of the market (over 30%), followed closely by Europe (almost 25%).

By contrast, **Japan, China and South Korea** combined account for 30% of the global market.

The downstream GNSS industry is split into three categories: **components and receivers manufacturers, system integrators, and added-value service providers**. The top-right table displays the top 10 companies in each value chain category. **Components and receiver manufacturers**' ranking is dominated by US companies (five out of 10). **System integrators**, although more geographically diverse, are dominated by automotive or smartphone companies. Lastly, tech giants such as Alphabet, Tencent and Microsoft appear on the list for **added-value service providers**, together with augmentation service providers like Trimble.

Geographical split of revenues in the GNSS industry 2021



Top 10 companies across the value chain based on 2021 revenues

Components & Receivers Manufacturers		System integrators		Added-Value Service Providers		End users
Avago (Broadcom)	US	Apple	US	Alphabet (Google)	US	Users of GNSS-based solutions across the different market segments
Beijing Bdstar Navigation	CN	China First Automobile Group Corporation	CN	Denso	JP	
Garmin	US	Ford	US	ESRI	US	
Hexagon	SE	Garmin	US	Facebook	US	
Kongsberg Maritime	NO	General Motors	US	Garmin	US	
Mediatek	CN	Oppo	CN	Hexagon	SE	
Qualcomm	US	Samsung Electronics	KR	HERE International	NL	
Trimble Navigation	US	Stellantis	NL	Microsoft	US	
United Technologies Corporation	US	Toyota	JP	Tencent	CN	
VALEO	FR	Volkswagen	DE	Trimble Navigation	US	

The top 10 companies mentioned above are listed in alphabetical order.

[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 1 000 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), which indicates the regions in which the revenues deriving from GNSS equipment and services are generated. In contrast, the methodology in the rest of the report attributes the size of the GNSS market to the region where equipment or services are sold and used. Specifically, this means that the European share of the GNSS market presented in this table is a methodologically different statistic to the share of the revenues presented for EU27 in the map on page 19. For further information on the methodology, please refer to Annex 1.

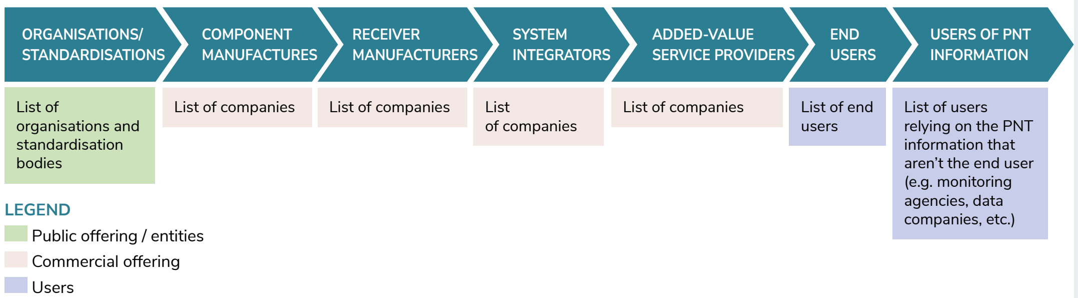
[2] In the market share analysis, Europe is defined as EU27 plus Norway, Switzerland, and the United Kingdom.

The GNSS value chain

Across the different market segments, the core of the GNSS industry value chain is centralised around the three categories as explained above. Nonetheless, every market segment has its own specific value chain and, therefore, we strongly recommend you explore these per segment. In general, each value will most probably contain all the following categories of stakeholders:

- **(Inter)national organisations and standardisation bodies:** regulated segments, such as Maritime and Aviation, will present a first link in their value chain dedicated to bodies setting GNSS standards and requirements (not present in each segment).
- **Component manufacturers:** these support the industry by producing chips, antennas and other inputs for GNSS receivers.
- **Receiver manufacturers:** added value and market specificities are conferred by device/product manufacturers specialised across segments.
- **System integrators (and design consultancies):** these are 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 (augmentation providers have different relevance across segments; they are not present in some segments, while they are covered by a dedicated stage of the value chain if they are of key importance in other segments).
- **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 leading in several transport applications, Finance and Space

European GNSS market share by vale chain categories

The adjacent table presents the regional market shares for components and receivers manufacturers for each market segment in 2021.

European companies are found to hold **30% of the global GNSS components and receivers market in 2021**. Europe's market share varies across market segments. European companies are leading in segments such as **Maritime (45%), and Finance (70%)**, but trailing behind the average market shares in segments such as **Consumer Solutions (5%), Aviation and Drones (15%), and Urban Development (5%)**.

Europe accounts for over 25% of the system integrators global market share and almost 20% in added-value service providers in 2021.

Please note that changes in market share are driven by general market trends, mergers and acquisitions, and exchange rate fluctuations.

NOTES
The footnotes presented on page 23 also apply to this page. For further information on the methodology, please refer to Annex 1.

GNSS Regional market shares of Components & Receivers Manufacturers, by market segment - 2021

	Europe	North America	Asia+Russia
	15%	45%	40%
	15%	75%	10%
	5%	50%	45%
	45%	45%	10%
	35%	25%	40%
	70%	30%	0%
	45%	40%	15%

	Europe	North America	Asia+Russia
	15%	55%	30%
	25%	40%	35%
	45%	35%	20%
	25%	25%	50%
	40%	25%	35%
	5%	35%	60%

Note: Segment share for the 'rest of the world' is not shown nor accounted for in this table. Rounding is performed to the level of 5%. The reader should be aware that, unlike the approach adopted for the previous issue of this report, some companies active in the Road and Automotive segment that used to be considered manufacturers, are now categorised as system integrators, as this approach is considered more appropriate and representative. This aspect needs to be considered by the reader especially when comparing the new findings with the ones presented in the previous issue of this report.

Must read space reports

Secure SATCOM Market and User Technology Report

Secure Satellite Communications (SATCOM) is essential for the resilience and strategic autonomy of the European Union and its Member States. It's the basis for security- and safety-critical missions and operations, supports **crisis management, surveillance missions, the protection of critical infrastructure and situational awareness**. Secure SATCOM services are also widely used in a variety of applications, ranging from the response to natural disasters, telemedicine and telehealth services in remote locations, maritime emergencies and key infrastructure, including air traffic management.

In this context, and with **GOVSATCOM** and **IRIS²** underway, experts at EUSPA produced the first ever Secure SATCOM Market and User Technology Report. The long study aims to help relevant public and private actors identify business opportunities, set the basis for developing the market and enable the realisation of benefits from satellite communications, both in the EU and worldwide. The report consists of two parts: (i) the secure SATCOM market and (ii) the secure SATCOM user technology chapter. The secure SATCOM market chapter offers a comprehensive review of various relevant SATCOM use cases, the forecasted capacity demand and an overview of the supply side as well. The user technology chapter provides an overview of the technologies currently shaping the downstream industry. It identifies key trends such as the increased capacity offered by High-throughput Satellite Systems (HTS), the deployment of multi-orbit and multi-band terminals, optical communications, interoperability, and standards.

EUSPA-UNOOSA Report, contributing to the Space 2030 Agenda

In support to the **implementation of the Space2030 Agenda, EUSPA** in partnership with the United Nations Office for Outer Space Affairs (**UNOOSA**) produced the report "Contribution to the Space2030 Agenda – The European Union Space Programme "EU Space" Supporting a world with a global population of 8 Billion people". The report aims to **raise awareness about the contribution of space**, and, thus, the European Union Space Programme components **to the achievement of global agendas**.

More specifically, the EUSPA-UNOOSA work sheds light on the challenges **to the sustainable development of humankind**, by identifying **eight global demographic challenges**, including food security, climate change and environmental impacts among others. Finally, the report provides **examples of how space applications** can **support the solution** to the identified challenges and presents relevant European case studies.

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 is designed to provide 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 free-of-charge, high-accuracy Precise Point Positioning (PPP) corrections through the E6-B frequency band. HAS has been offering, since January 2023, real-time user positioning performances with accuracy down to a decimetre level in nominal conditions.
- **Public Regulated Service (PRS):** A service that will be restricted to government-authorised users, designed for sensitive applications that require a high level of service continuity.
- **Commercial Authentication Service (CAS):** A service that will provide 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**.

Furthermore, other services, such as Emergency Warning Satellite Service (EWSS) that will communicate warning messages to populations facing the threat of natural disasters or other emergencies in affected regions, are being prepared.

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The Galileo infrastructure will evolve with the arrival of the **second generation of Galileo satellites**. With a gradual introduction of cutting-edge new generation satellites in the current fleet, several significant innovations will be made available to Galileo users: diversification of navigation services, by enlarging the already excellent Galileo portfolio with innovative services; strengthened robustness of the satellite navigation services, by including frequency diversity, increased power levels, various levels of authentication; increased accuracy in time and position, relying on a new generation of atomic clocks and an innovative on-board time generation approach; use of state-of-the-art satellite technology, including inter-satellite links and full electric propulsion systems.

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 (OS):** free and open to the public, the Open Service is used for general-purpose and non-safety critical applications users;
- **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 and Rail;
- **EGNOS Data Access Service (EDAS):** offered on a controlled access basis, it 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. The system is evolving to provide a dedicated service for maritime users. The next EGNOS version (EGNOS V3) will also augment Galileo signals, allowing the use of DFMC (Dual-Frequency Multi-Constellation) receivers.

For more information, please refer to the European GNSS Service Centre (GSC), which is set to be an integral part of the European GNSS infrastructure and provides the single interface between the Galileo system and the users.

The majority of receivers entering the market are Galileo compatible

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 with considerable benefits.

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

GNSS

EGNSS performances keep matching evolving user needs

The bottom-up nature of Galileo and EGNOS programmes

Although one of **Galileo**'s main aims is to **ensure European independence in terms of satellite navigation, positioning and timing services**, the programme is continually developing to respond to **user needs**. Ultimately, it is helping ensure that Europe keeps up with the fast-paced GNSS global landscape and provides high performances to users.

The programme was originally designed to be compatible and interoperable with GPS, GLONASS and BeiDou. Moreover, Galileo and **EGNOS** are able to enhance the operational domain through more accurate and reliable positioning information, while also ensuring seamless availability and continuity of the signal.

For these reasons, Galileo and EGNOS continue to generate added value to European industry, its economy and citizens. In particular, the **increased accuracy** they offer through the Galileo High Accuracy Service (**HAS**) provides free of charge high accuracy Precise Point Positioning (PPP) corrections through the Galileo signal (E6-B) and by terrestrial means (Internet), offering real-time improved user positioning performances down to decimetre level. Increased accuracy can be leveraged in a wide array of **market segments**, for both products and services, as well as for **research and development** purposes. Another important differentiator is represented by the Open Service Navigation Message Authentication (**OSNMA**), the data authentication function for Galileo Open Service users worldwide, freely accessible to all. Authentication is very relevant for many applications, including transport, for autonomous vehicles in particular, and for activities with legal implications, e.g., support to the CAP in Agriculture.

User Consultation Platform (UCP) for the European Space Programme continues focusing on GNSS User needs and requirements

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.

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.

The fourth edition in 2022, explored, related to GNSS, the requirements of users from across seven market segments, namely **Infrastructure, Renewable Energy and Raw Materials, Consumer Applications, Aviation and Drones, Maritime and Fisheries, Emergency Management and Humanitarian Aid**, and **Insurance and Finance**. During these sessions, a range of different topics were addressed including the exploration of GNSS applications and related operational scenarios, user requirements, synergies with other components of the EU Space Programme, main market trends and the evolution of the EU Space Research and Innovation.

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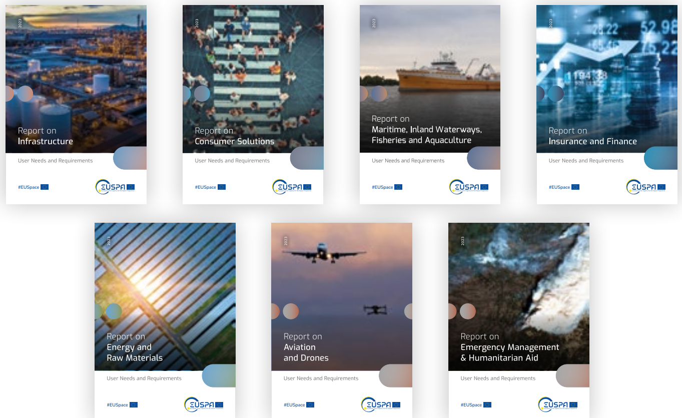
Additionally, during the **2023** EU Space Week in Seville, the fifth edition of the User Consultation Platform (UCP) for the European Space Programme has taken place and hosted seven parallel sessions: **Agriculture and Forestry, Environmental Climate & Biodiversity, Rail, Public Transport, Road and Automotive, Space, and Resilient Societies**.

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 serve as a key input to the UCP, allowing the main included outcomes to be validated and subsequently updated.

The full reports of the UCP User needs and requirements 2022 and 2023 are available at:
https://www.euspa.europa.eu/media-library/publications



Market drivers: digital transition and climate change

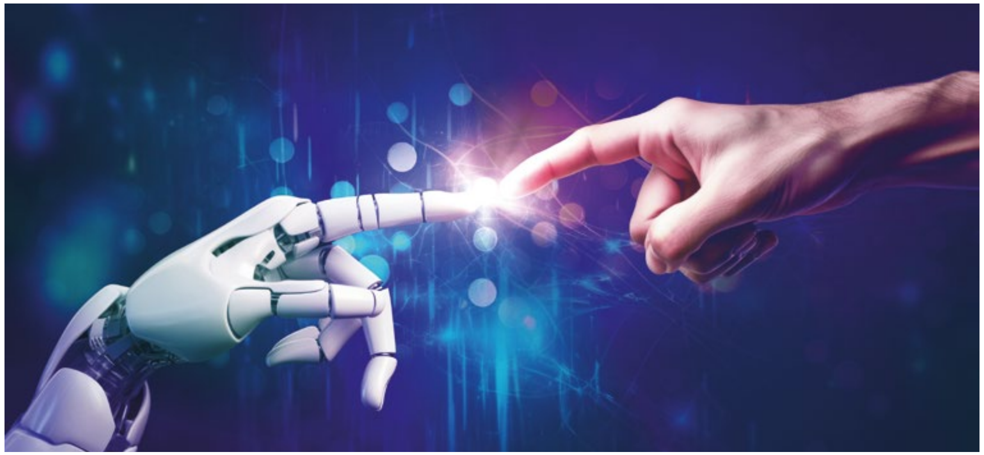
The market drivers presented in this section are the underlying forces behind relevant changes in the social, political, technological, economic, and cultural environment. Ultimately, they can affect demand and consumption. Therefore, even if they might not be explicitly mentioned in the chapters dedicated to segments, they affect, to different extents, the uptake of EO and GNSS solutions within the segments and applications covered in this report.

The digital transition increasingly relies on EO and GNSS as enablers

The digital transformation increasingly forms the backbone of policymaking. This ongoing data revolution increasingly relies on EO and GNSS. On the **consumer** side, we are witnessing the rise of **digital twins**, the use of satellite images for **game development** and in support of **leisure activities**. In the **professional domain**, uptake of **AI and advanced analytics is increasing**. **Finance and Insurance**, among others, are good examples, as EO supports traders in better understanding and forecasting the markets, while **parametric insurance** is expanding with the help of new digital applications. Also in the area of **transport**, the ubiquitous presence of GNSS for asset management is necessary to support micromobility schemes and the emerging **mobility-as-a-service** concept. More recently, GNSS and EO became useful tools for a closer collaboration within the Forestry value chain, also in relation to the EU Deforestation Regulation.

Ultimately, **EO and GNSS** help to meet the **expectations of more aware and demanding users**, who increasingly value experiences over products.

The growing digitalisation and the use of space technologies come with challenges that cannot be neglected, such as the need to ensure **cybersecurity**, for both space and ground infrastructure. Cybersecurity is a must for both professionals, who need to ensure a smooth and safe deployment of their activities, and individual consumers, who want to rely on safe tools for accessing information and content while maintaining their privacy.



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Climate change drives environmental awareness and increases the need for sustainable practices across all market segments

Space technology can support a strong and effective wake-up call for environmental and climate action. **EO** and **GNSS** have a dual function in this context.

First, they offer **valuable tools for the green transition** of many domains – for example, the growing focus on sustainability by the tourism sector, especially taking advantage of the user-friendliness of smartphone apps which make satellite-derived information simple and accessible; the **planning and management of urban areas** made more efficient by EO maps; the spread of **regenerative agriculture** and a more sustainable production of protein, especially from the seas; and the support to the deployment of the **circular economy** providing measurements and evidence to prove that an asset is being managed sustainably, monitoring emissions and natural capital.

Second, EO and GNSS, often combined, allow for effective **assessment of the natural environment and the anthropogenic impact on it**; they support **evidence-based decision making** on the design of new green policies and can be used as **tools to monitor** the **progress** of those policies. In fact, satellite-derived data, as per the Copernicus Atmosphere Monitoring Service (CAMS), can address a range of crucial climate variables to be closely monitored.

EUSPA has published in January 2023 the EU Space for Green Transformation report, which showcases how applications leveraging EU space data from **Copernicus, Galileo and EGNOS can help companies become more sustainable**.

Performing the green transformation requires that a company takes a deep look through their internal operations, as well as their supply chain to understand where and how pollution and waste occur. In that regard, the slew of tools, including remote sensing, location-based services, artificial intelligence and many others makes **monitoring, tracking, evaluating and implementing sustainable operations not just possible, but long-term profitable**.

The report explains the implications of the Green Deal for companies. It also presents detailed **examples of how** various **industries**, including energy, road transport, aviation, agriculture, forestry and mining, are **leveraging the power of EU Space** to drive their sustainability journeys.

Market drivers: growing population, energy demand and supply chain challenges

Economic and population growth boosts demand of space-related downstream services

The **demographic and economic growth** taking place at regional level is an important driver for the uptake of downstream space solutions.

The **demographic growth**, with time, will have a straightforward effect in **enlarging the addressable market** for GNSS and EO solutions, directly because of the larger user base of Consumer Solutions, as well as indirectly by boosting the demand for products and services that make use of GNSS or EO.

Even more importantly, the use of **space** represents an opportunity to **help address the challenges posed by demographic and economic growth** (for more information on the EUSPA-UNOOSA report please refer to page 24).

For example, population continues to increase, along with the environmental impact of human activity. This poses **challenges for food security** and **agriculture**. **GNSS and EO contribute in multiple ways** to improvements in food security, from precision farming to monitoring livestock, including fishing areas, and thanks to the provision of early warning for famine.

Moreover, these challenges affect **water management** and aquatic ecosystems, as well as various aspects related to sanitation and hygiene services. **Space** can **contribute** to water management in many ways, such as in supporting the mapping and **management of water resources** and in **monitoring infrastructure**.

Additionally, growing **population and urbanisation** go hand in hand. While urbanisation can be a catalyst for economic growth and social and cultural development, if **unmanaged** it can **lead to congested cities** lacking green and open spaces, and without appropriate public transport. **Space can** help to **support urban planning** and **vehicle traffic management.**

Finally, **population and economic growth** directly **impact energy demand**, potentially contributing to future carbon emissions. **GNSS** and **EO** can **support** in **planning** renewable **energy plants**, enabling **smart grid management** and help individual users to adjust their habits with **renewable energy forecasts**.

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Energy demand, supply chain challenges and their impact on space technologies

As the global population has grown, the use of energy has increased. However, this increase is not commensurate since modern societies are increasingly dependent on electricity. In turn, the use of electric power has enabled accelerated economic development, as reported by EUSPA and UNOOSA. Currently, 91% of the world's population has access to electricity, but only 18% of the total energy consumption derives from renewable sources, which means that **the global economy is still heavily dependent on fossil fuels**.

Events with global impact, such as the COVID-19 pandemic and Russia's invasion of Ukraine, drove up energy prices amid shortages and uncertainty about the future, leading to higher production prices and reduced profitability in all markets, while also limiting consumer spending.

Also, the global supply chains of raw materials and components, including **semiconductors**, (and consequently GNSS chipsets), suffered major disruptions stemming from the aforementioned events. The EU is undertaking concrete initiatives to cope with these crises. All economic domains have been suffering from this **disruption**, including the **Automotive sector**: while the demand for cars has been on the rise, resulting in a higher chipset demand, supply in Europe has stagnated, slowing down growth. This is also the case for many other market segments.

The supply chain disruption, combined with low consumer consumption and market confidence, makes it difficult to forecast the speed at which future demand will return to pre-pandemic and pre-war levels.

EO and GNSS are vital resources in **identifying optimal sites for renewable energy**, assessing the energy output potential of solar and wind power plants, and assisting governmental authorities, energy and utility companies, energy traders, supply chain managers and mining companies in undertaking many energy-related tasks and analyses. Therefore, **space-based technology** can and is already **supporting the transition to renewable energy sources**, which at the same time paves the way for energy independence from geo-political dynamics. The green transition and decreased dependence on fossil fuels are expected, in turn, to support the growth of space downstream in the long run, leading to a virtuous cycle of market growth and increased energy sustainability.

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Market drivers: new space entrepreneurship

New Space entrepreneurship on the rise

The **commercialisation of the Space sector**, called New Space, refers to private actors playing an increasingly important role, rather than the state monopolies of the past. **Private companies** are transitioning from being simply contractors to national governments to becoming **central players**, increasingly gaining the capacity and influence to actively shape the trajectory of the Space sector.

Traditionally, investors have considered the commercial opportunities of Space to be high risk and high cost, with long payment periods. However, the barriers to entry into the Space sector have dramatically reduced thanks to technological and commercial breakthroughs. First, **standardisation, digitalisation and miniaturisation of technology** allowed for the **reduction of size, weight and production costs of satellites**, which are the key drivers of launch costs. Following this increased efficiency, the Space sector began to have a deeper impact on the whole economy, encouraging companies to build upon existing space-based systems to develop new capabilities serving an **ever-expanding array of commercial downstream markets**.

With the growing presence of **smaller entities** in the sector, innovation will occur at a more rapid pace as these companies are **more agile and innovative** than traditional players. They are therefore challenging the status quo and fostering even more technological breakthroughs, especially in terms of sustainability. In fact, these smaller ventures are leading the shift towards **greener space technologies and more environmentally friendly space solutions**.

With a strong legacy of space excellence, **Europe has the potential to become a centre for New Space companies**. European countries have already started rolling out strategies not only to attract private European companies but also foreign ones. Moreover, similar to the US, venture capital firms are also prominent investors in the European New Space segment.

In addition, the **CASSINI initiative** is also boosting the EU entrepreneurial fabric in many ways. The following box offers further details.

Enhancing collaboration between space technologies and the media

In line with the technological advancements in the Space sector, information deriving from space technology is becoming increasingly accessible and visible to the wider public. On top of the efforts made by national and regional space agencies in maintaining webpages to report on their activities and breakthroughs, a new emerging trend concerns the **use of satellite products by the news**. Therefore, citizens are becoming increasingly familiar with satellite images, and this **new line of business** is offering opportunities for private companies that can **support journalists and publicists** with effective communication tools.

Many companies are taking this chance to expand their portfolios and differentiate their clients. For example, Maxar has launched the Maxar News Bureau, which combines space technology and journalism under a **partnership programme with trusted media organisations**. As a leading provider of satellite imagery and space-based analytics, the Maxar News Bureau leverages Maxar's position in the sector to provide a wide range of geospatial coverage to the general public. In turn, this allows the reporting of detailed and up-to-date information on various topics, such as natural disasters, geopolitical crises and climate change.

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Other space companies are also engaging in such partnerships. For instance, Planet Labs, as shown on its News and Press webpage, often collaborates with large news outlets by providing insights from its satellite imagery capabilities, covering diverse topics and areas. Similarly, BlackSky also supplies its satellite imageries to media companies, providing more context and enriching news reporting.

Space entrepreneurial initiative: CASSINI

CASSINI is the European Commission's **initiative to support entrepreneurs, start-ups and SMEs in the Space industry**, including New Space, during 2021-2027. The initiative is open to all areas of the EU Space Programme and covers both upstream (i.e. nanosats, launchers, etc.) and downstream (i.e., products/services enabled by space data, etc.). CASSINI comprises a €1 billion EU **seeds and growth fund, hackathons** and **mentoring, prizes, a business accelerator, partnering** and **matchmaking**, empowering entrepreneurs to grow their businesses and reach new heights.

In more detail, the CASSINI Hackathons facilitate participants to apply their skills to address global challenges using EU space technologies; the CASSINI Matchmaking offers a platform for start-ups, scaleups, and SMEs to connect with corporates and investors to solve business challenges and address global needs; and the CASSINI Business Accelerator provides intensive acceleration programmes for top space start-ups and scale-ups to boost their commercial growth. Lastly, the EU Space Academy serves as a go-to source of know-how on space for entrepreneurs.

The **CASSINI Challenges** (formerly #myEUspace Competition) are another example of the provision of **support** to **creative innovators** in developing groundbreaking commercial solutions leveraging on Galileo and Copernicus, providing resources to scale up their businesses and launch their products globally.

For more information and open opportunities, please refer to the official webpage or sign up via the QR code below.

EO cross-segment market trends: while environmental priorities drive the demand, the industry undergoes vertical integration and improves its data offering

Key market trends in Earth Observation

- Stakeholders across all segments are taking steps to reduce their environmental impact, driving the use of EO for measuring, monitoring and reporting needs.
- A growing number of satellite data providers is acquiring data platform companies, increasing the vertical integration in the downstream part of the market, including non-space companies investing in EO capabilities.
- Satellite sensor capabilities and diversity continues to increase improving and expanding their satellite data offerings through increased spatial resolution and sensors diversity.

Environmental, Climate and Biodiversity considerations drive measuring, monitoring and reporting needs in most segments

Stakeholders in all segments are taking steps to **reduce their impact on the Environment**, Climate and Biodiversity, and to account for climate risks. Various actors across the value chain have committed to climate neutrality goals, often accelerated by legislation and regulation, while others started reporting on climate risk assessments.

Measuring, monitoring and reporting on various **Environmental, Climate and Biodiversity indicators** can leverage insights generated by **satellite imagery**. Upcoming satellite missions such as CHIME and CO2M will generate data that are particularly useful for this purpose.

Today in-orbit sensors already provide important **emission-related insights**, for example by enabling the comparison of actual methane emissions with those reported nationally. It is these kinds of insights that allow stakeholders in various segments to **monitor performance of supply chains against legal or quality standards, assess total carbon footprint, or evaluate the effectiveness of climate policies**.

Additionally, it is foreseen that **multiple segments will increasingly rely on EO data** to provide important information on biodiversity indicators. For example, EO insights such as habitat identification and wetland classification can support ecosystem conservation efforts. Such insights are also useful for the selection of sites for new renewable energy projects, with a view to minimising impact on the environment.

The industry sees increased vertical integration in the downstream segment, including non-space companies investing in EO capabilities

Vertical integration is becoming increasingly common in the EO industry. It has been prevalent primarily in the **upstream segment**, where companies choose to control the entirety of the Space segment, including the **design, manufacturing, launch and operations of satellite constellations**.

More recently, vertical integration has been applied in the **downstream segment**, where **satellite data providers** choose to **acquire data platform companies** to improve their product delivery (e.g. Maxar's 2022 acquisition of Wovenware to increase its 3D production capabilities) or go a step further and acquire **analytics companies** serving specific segments to immediately get a foothold in the market (e.g. Planet's acquisition of Vandersat and Salo Sciences).

Additionally, backward integration, in which companies choose to **invest in EO capabilities to address specific needs within the organisation**, is an emerging trend. Examples include Hitachi's Vegetation Manager and Husqvarna's Intellion, both vegetation monitoring tools. ExxonMobil and Tomorrow.io have announced similar plans to develop EO capabilities.

In-orbit sensor capabilities and diversity continue to increase, improving EO data-enabled service offerings in various segments

Satellite data providers, old and new, continue to dedicate significant resources to improving and expanding their satellite data offerings.

Such improvements include **increased spatial resolution**, such as Airbus Pléiades Neo constellation and the Maxar's new Legion constellation targeting a 30cm ground sampling distance (GSD), while others focus on **increasing sensor diversity**, such as Planet, Wyvern, PIXXEL, OroraTech, or on launching satellites equipped with **novel hyperspectral and thermal infrared sensors**. Similarly, public missions such as EnMap (and future CHIME) significantly **increase the amount of hyperspectral data available** for various applications.

The increased availability of hyperspectral data enables multiple applications in different segments. In the **Raw Materials** segment, such data sources will greatly benefit **mineral exploration** activities. In Forestry, tree species can be classified more accurately. In **Agriculture**, hyperspectral data is better suited for the early detection of diseases than (traditionally more ubiquitous) multispectral data, while in the **Urban Planning and Environment** segments, hyperspectral data can play an important role in the monitoring of air quality (particulate and gaseous). The **Emergency Management and Humanitarian Aid** segment equally benefits from new sensors, such as thermal infrared, which can support the early detection of forest fires.

GNSS cross-segment market trends: automation, growing attention to health and new safety requirements trigger the demand for more and better GNSS solutions

Key market trends in GNSS

- Advancements in automation boost the relevance of GNSS solutions, offering increased efficiency and safety.
- Increased attention to healthier lifestyle is pushing the demand of digital technologies and GNSS, especially concerning physical activity and food quality and traceability.
- Safety is an important driver of innovation in GNSS, both at application and service level, involving both both commercial and public providers of satellite services and solutions in transport, across air, sea and land.

The rise of automation strengthens the role of GNSS

The past few years have seen the spread of **automation** into nearly every industry and sector. Industry analysts say that this trend will continue, if not accelerate, enabled by the increasing maturity of technological enablers such as Artificial Intelligence, robotics and innovations in computing.

The upscaling of automation is due to its vast potential to transform these industries by making them **smarter, more efficient and sustainable**. The rise of automation is affecting nearly every industrial sector, including **transport**, via unmanned road vehicles, vessels, trains and drones; and **Agriculture**, **Logistics** and **Construction** and **Urban Development.**

As autonomous vehicles, robots and machinery interact with the environment and with humans, the **safety** of their operation is essential. This in turn impacts the demand and requirements for satellite navigation technologies, in terms not only of higher accuracy but also increased robustness and availability.

Such a trend has been driving a new wave of innovation in the provision of augmentation services, with the industry developing new networks and signing partnership agreements to make **turnkey solutions** available for their customers.

GNSS Investment Report by EUSPA and EIB highlights the role of investment funding to sustain industry growth

The EU Agency for the Space Programme (EUSPA) and the European Investment Bank (EIB) have published the first issue of the GNSS Investment Report. The report features a comprehensive **investment analysis of the GNSS market**, complemented by the analysis of the dynamics of the sector overall. The report also outlines the current state of play regarding available public and private funding and identifies **needs and funding gaps** for GNSS companies and start-ups in the European Union.

The report suggests that, while Europe still holds a competitive position in the global landscape of downstream GNSS-enabled products and services, **significant public and private investment will be necessary** over the next 10 years to enable European manufacturers and providers to remain competitive and afford relying on domestic suppliers.

As well as analysing the landscape and trends on investment funding from the demand and supply perspectives, the report provides **recommendations on supporting future EU competitiveness in the GNSS downstream market**.

Healthy lifestyle boost the demand for GNSS solutions

From a societal and global perspective, the increase in population age presents both challenges and opportunities. In addition to longevity alone, **the COVID-19 pandemic** alerted many citizens across the globe of the **importance of healthier lifestyles**.

The health, fitness and wellbeing and food sectors, among others, have been impacted by this trend – consumers are making **more educated choices on what they eat** – in terms of healthy products, based on environmental and treatment practices – **where they live** – becoming more sensitive to pollution – and how, by changing their lifestyle, to remain active.

While the increased attention to **food quality and traceability** is pushing the demand of digital technologies – including GNSS – along the relevant value chains in **Agriculture and Aquaculture**, higher awareness of the consequences of pollution has increased social acceptance of climate-friendly policies in mobility, energy and transport, which supported by space technologies including satellite navigation.

Finally, the demand for **fitness** devices and wearables has supported innovation and market growth in **Consumer Solutions** and driven industry convergence on wearables, with GNSS specialist companies now competing with wellbeing device specialists, mobile phone manufacturers and sportswear giants.

Safety needs and requirements drive GNSS adoption and innovation

Safety considerations have a multifaceted impact on GNSS adoption and innovation. First and foremost, the need to save lives across different domains has been supporting the **development of dedicated GNSS applications** to accurately locate emergency calls (E112), help mitigate the consequences of road incidents (eCall), and locate people in distress through several types of GNSS-enabled locator beacons.

Second, the demanding **performance requirements** of **several safety critical GNSS applications** are **driving innovation** by both commercial and public providers of satellite services and solutions in transport, across air, sea and land.

Leading GNSS players have started offering **end-to-end safe GNSS solutions**, from correction services to on-board positioning engines, in order to meet the safety performance requirements established by relevant transport standards.

At the same time, **public GNSS providers and operators**, led by the EU, are **upgrading their services** to meet segment specific requirements. This is true for the unique Return Link Service that was developed as part of Galileo SAR service (see page 86 and 89), as well as for the upcoming EGNOS maritime service, which was designed to meet the integrity requirements of the maritime community (see page 148).

What you should not miss in this report...

CLIMATE, ENVIRONMENT AND BIODIVERSITY

Demand for specialised risk modelling and climate resilience is driving the uptake of climate-related EO products (pages 60 and 61)

AGRICULTURE

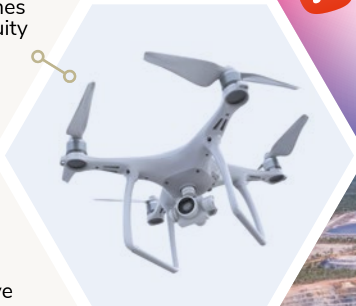
GNSS automatic steering is growing in popularity, paving the way for the advent of robotics (pages 35, 38 and 39)

AVIATION AND DRONES

U-space regulation will boost GNSS adoption in drones via Electronic Conspicuity devices (pages 49 and 50)

FISHERIES AND AQUACULTURE

GNSS and EO improve the productivity of the industry and the monitoring capabilities of authorities (pages 107 and 108)



CONSUMER SOLUTIONS, TOURISM AND HEALTH

As the smartphone device market becomes more mature, space-enabled apps will drive market growth (pages 74, 75 and 76)

EMERGENCY MANAGEMENT AND HUMANITARIAN AID

Galileo differentiators and Copernicus services improve emergency management (pages 86, 87 and 89)

ENERGY AND RAW MATERIALS

The digitalisation of the mining business is driving adoption of GNSS and EO (pages 98 and 101)

FORESTRY

Forest monitoring, preservation and regeneration needs, along with trafficability assessment, strengthen the demand for EO (pages 118 and 119)

MARITIME AND INLAND WATERWAYS

GNSS and EO will support autonomous vessels introduction across oceans, seas and rivers (pages 149 and 150)

INFRASTRUCTURE

Increasing awareness of how EO can support the infrastructure lifecycle will increase market size (pages 129 and 131)

INSURANCE AND FINANCE

From green bonds to ESG, EO supports the green transition in Insurance and Finance (page 138)

URBAN DEVELOPMENT AND CULTURAL HERITAGE

EO is supporting both urban development and cultural heritage management (pages 183 and 184)

RAIL

Asset management solutions drive GNSS growth in Rail (pages 160 and 161)

ROAD AND AUTOMOTIVE

The race of the Automotive industry toward automation is driving innovation in GNSS positioning (pages 165 and 166)

SPACE

Mega constellations deployment means larger demand for GNSS positioning (page 178)

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 an individual level, EO allows farmers to remotely monitor crop performance and reduce their usage of inputs such as fertilisers. 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 to 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:** FAO's Global Information and Early Warning System, Regenerative Agriculture and GNSS-enabled robots delivering value to the agricultural sector.
- **User perspective:** Significant progress has been made on converging EO and GNSS value propositions to user needs.
- **Industry:** Agriculture Value Chains.
- **Recent developments:** Eco-schemes and Artificial Intelligence shaping how we produce food.
- **Future market evolution:** Frontier tech continuing to disrupt the market.
- **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.

FAO's Global Information and Early Warning System, Regenerative Agriculture and GNSS-enabled robots delivering value to the agricultural sector

Key market trends

- FAO's Global Information and Early Warning System on Food and Agriculture (GIEWS) is providing valuable information to agricultural stakeholders all around the world
- Regenerative Agriculture is a holistic approach to sustainable farming practices and is growing in popularity, with several relevant EO and GNSS applications
- Autonomous robots in farming applications are an increasingly common sight thanks to GNSS

FAO's GIEWS – Continual integration of Earth Observation data into globally significant early warning system

Established as a response to the food crises in the early 1970s, the Global Information and Early Warning System on Food and Agriculture (GIEWS) plays a vital role in safeguarding global food security. Its mission revolves around the continuous monitoring of crucial indicators, such as food supply and demand around the world. GIEWS issues regular and unbiased reports, shedding light on prevailing conditions and providing early warnings of potential food crises at regional and country levels. **Recently, GIEWS has embraced cutting-edge Earth Observation data and revolutionary technologies, crucially including Copernicus data.** This has led to enhanced services, facilitating more robust monitoring of major food crops worldwide and enabling precise assessments of production prospects. This invaluable resource provides insights into critical aspects, such as water availability and vegetation health during essential cropping seasons. **Key data sets, such as rainfall estimates and the widely recognised Normalized Difference Vegetation Index (NDVI), bolster its monitoring and forecasting capabilities.** A significant milestone in this journey of improvement has been the collaborative development of the Agricultural Stress Index (ASI) alongside FAO's OCB Division. The ASI serves as a quick-look indicator, enabling early identification of agricultural areas vulnerable to dry spells and severe droughts. Prompt recognition empowers stakeholders to intervene in a timely manner, implementing measures to mitigate the impact on agricultural productivity and overall food security.

GNSS-enabled autonomous harvesting, weeding and planting robots and drones becoming a more common sight

GNSS technology is ushering in a new era where drones and robots are taking on increasingly complex tasks in agriculture. Autonomous machines are gaining adoption in the sector. **In many developed countries,** particularly within the horticulture sector, **these robots are increasingly used for harvesting activities, such as fruit or vegetable picking.** Weeding has long been a strenuous task for farmers, and here, too, robots offer a compelling alternative to manual labour. Robots can efficiently manage weed control, reducing the physical burden on farmers. In recent years, engineers have pushed the boundaries of robotics even further, enabling machines to undertake intricate tasks like planting and seeding.

Several companies have developed sophisticated robots and drones that harness the power of AI and machine learning to perform these activities with precision and efficiency. Robots and drones are also proving their worth in crop management by applying farming inputs such as pesticides and herbicides. Coupling robots and drones with smart and selective application methods can help reduce the overall use of these inputs, promoting more sustainable farming practices. According to Mordor Intelligence's 2023-2028 outlook, the future looks promising for the agricultural robotics market, **with an estimated valuation of €12.3 billion in 2023, set to surge to €22.8 billion within the next five years**. This growth underscores the transformative potential of technology in modernising and enhancing agriculture.

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Monitoring Regenerative Agriculture using Earth Observation

Regenerative agriculture is a term that is becoming increasingly common. It represents a holistic approach to how we produce our food that encompasses several key principles, **including minimising soil disturbance, enhancing crop diversity, maintaining soil cover, and integrating grazing animals into the agricultural landscape.** The role of satellite imagery in validating various aspects of regenerative farming is both vital and multifaceted. Firstly, by analysing spectral characteristics, satellites can identify different types of cover crops, offering valuable insights into their presence and health. EO data also possess the capability to identify tillage practices by observing the presence or absence of plant residue on the soil's surface. They can also pinpoint abrupt **changes in soil texture and roughness, providing a means of monitoring soil disturbance and conservation efforts**.

Moreover, crop rotation, a fundamental component of biodiversity in regenerative agriculture, can be verified using satellite imagery. The technology allows for the differentiation of various crop types based on their unique spectral signatures, facilitating the assessment of crop rotation practices. Finally, the presence of grazing cattle on cropland can be discerned through satellite observations. Their direct impact on vegetation status, especially following intensive or rotational grazing, is evident in changes detected in vegetation cover. Incorporating EO data into regenerative farming practices enables a comprehensive, data-driven approach to assessing and enhancing the implementation of regenerative principles, contributing to a sustainable and thriving future for agriculture.

Significant progress has been made on converging EO and GNSS value propositions to user needs

Sources of key EO and GNSS user requirements

The key EO and GNSS user requirements for the different application groups within the **agriculture** segment are collected using a harmonised procedure at EU level.

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 and Forestry user needs and requirements. User requirements for Earth Observation services and products – as well as their evolution – are now also collected through the UCP. The process covers the EO user needs and requirements of commercial users based on inputs from industry experts and user groups, mirroring the existing process implemented for GNSS. The report featuring EO user requirements was validated in 2023 and will be available in early 2024. The report also includes the user requirements for **Forestry** applications.

Moreover, the collection of specific requirements for Copernicus services and products is supported by 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; and (iii) regular and structured exchanges among representatives of the Copernicus governance structure and Member States through the Copernicus User Forum.

Farm Management Systems – an all-in-one solution for farmers

Simultaneously managing all farm operations can be an extremely demanding job, but a Farm Management System (FMS) can ease the burden on farmers. An FMS is a digital tool or software package designed to comprehensively optimise and oversee farm operations and production activities.

This software **automates various farm tasks, including record-keeping, financial management, data storage and various types of operational analysis relating to farming activities**. It also helps streamline production processes and work schedules. FMS solutions are tailored to meet the specific requirements of individual farms, as each operation has its unique set of activities.

Most FMSs incorporate EO and/or GNSS data into their workflows. This integration allows farmers to visualise and track various aspects of farm processes, such as crop growth and input usage. FMS is gaining popularity among farmers, with numerous commercial options available on the market. **Nevertheless, the interoperability of farming equipment with these systems is a common challenge due to the different digital standards applied.**

This lack of interoperability can sometimes obstruct the adoption of FMS, which limits increases in production efficiency through smart farming methods. However, when implemented correctly, FMS can deliver a range of benefits, including cost reduction, increased yields, improved yield quality, enhanced profitability and decreased operational risks.

Integrated Pest Management key to farmers reducing pesticide use

It is an ongoing challenge for farmers to deal with the threat that pests pose to their crops while simultaneously trying to manage pesticide use efficiently. Integrated Pest Management (IPM) is a farming approach which aims to address pest issues, while minimising potential risks to both people and the environment.

IPM takes an ecosystem-centred strategy that focuses on preventing damage from pests over the long term. This prevention is achieved through a combination of techniques, including biological control, altering habitats, adjusting cultural practices and employing resistant crop varieties. In respect of the application of pesticides, IPM ensures that they are selected and used in a manner that reduces any potential harm to humans, non-target organisms and the environment.

The integration of EO and GNSS technologies is therefore crucial. By combining EO data with GNSS solutions for variable-rate pesticide application, farmers can create detailed crop maps and precisely position their spraying equipment, leading to reduced pesticide usage.

In Europe, as part of the Green Deal initiative, **the European Commission has set a goal to cut pesticide usage in half by 2030**. Farmers face the challenge of maintaining agricultural output while decreasing the use of certain farming inputs. The adoption of IPM practices and the incorporation of EO and GNSS solutions can be instrumental in helping farmers achieve this challenging but environmentally responsible objective.

Agriculture Value Chains[1]

EARTH OBSERVATION

DATA PROVIDERS

- AIRBUS*
- BLACKSKY
- CAPELLA SPACE
- GEOSAT*
- E-GEOS*
- EARTH-I*
- EOS DATA ANALYTICS*
- ICEYE*
- MAXAR
- PLANET
- SATELLOGIC*
- UMBRA

- COPERNICUS SENTINELS*
- LANDSAT (USGS)
- METEOSAT (EUMETSAT)*
- RADARSAT (CSA)
- RELEVANT EUROPEAN NATIONAL MISSIONS
- RELEVANT IN-SITU NETWORKS

INFRASTRUCTURE PROVIDERS

- AWS
- CLOUDFERRO*
- GOOGLE CLOUD PLATFORM
- IBM CLOUD
- MICROSOFT AZURE
- T-SYSTEMS*

- FEDERATED INFRASTRUCTURE (E.G. GAIA-X)*
- SENTINEL COLLABORATIVE GROUND SEGMENT*

PLATFORM PROVIDERS

- ADAM*
- CLOUDEO*
- CREODIAS*
- EARTH-I*
- EDS CEODE
- EURODATACUBE*
- GOOGLE EARTH ENGINE
- NORTH.IO*
- OPEN DATA CUBE
- PLANET EXPLORER
- SENTINEL-HUB* (SINERGISE)
- TERRADUE*
- UP42*

- COPERNICUS DATASPACE ECOSYSTEM*
- FOOD TEP*
- WEKEO*

EO PRODUCTS AND SERVICE PROVIDERS

- AGRICOLUS*
- BASF*
- CLEVERFARM*
- DESCARTES LABS
- DIGIFARM*
- E-GEOS*
- EARTH DAILY
- EOS DATA ANALYTICS
- FARMSTAR
- FIELDSENSE*
- GAF*
- GEOVILLE*
- GMV*
- KAPPAZETA*
- ONESOIL*
- PESSL INSTRUMENTS*
- PLANETEK*
- SATAGRO*
- SATELLIGENCE*
- SENCROP*
- SINERGISE
- TALKINGFIELDS*
- TRIMBLE
- VITO*
- VULTUS*

- COPERNICUS CLIMATE CHANGE SERVICE (C3S)*
- COPERNICUS LAND MONITORING SERVICE (CLMS)*

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

GNSS

AUGMENTATION SERVICE PROVIDERS

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

- NATIONAL AND REGIONAL RTK NETWORK PROVIDERS

COMPONENT AND RECEIVER MANUFACTURERS

- AG LEADER TECHNOLOGY
- AGJUNCTION
- ANALOG DEVICES
- ANTCOM
- ARAG*
- AVMAP*
- BEIJING BDSTAR NAVIGATION
- CAMPBELL SCIENTIFIC
- CHCNAV
- CNH INDUSTRIAL*
- COMNAV TECHNOLOGY
- DEERE
- HARXON
- HEXAGON*
- MEINBERG*
- RAVEN INDUSTRIES
- SEPTENTRIO*
- TOPCON CORPORATION
- TRIMBLE NAVIGATION
- UNISTRONG GNSS
- YAGEO

SYSTEM INTEGRATORS DESIGN CONSULTANCIES TESTING & MAINTENANCE

- AG LEADER TECHNOLOGY
- AGCO CORP
- AMAZONEN-WERKE*
- ARAG*
- AVMAP*
- CLAAS KGAA*
- CHCNAV
- CNH INDUSTRIAL*
- DAEDONG INDUSTRIAL
- DEERE
- HEXAGON*
- ISEKI & CO
- JCB*
- KRONE*
- KUBOTA CORPORATION
- MAHINDRA
- MILLAT TRACTORS
- SDF GROUP*
- TONGYANG MOOLSAN
- YANMAR

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

LEGEND

- Commercial offering
- Public offering / entities
- User segments

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

While North America dominates the EO data processing and analysis market, European companies account for around half of the analysis, insight and decision support global market share. The biggest European companies across the value chain are BASF and Leonardo (e-GEOS).

European companies such as Hexagon, CNH, Septentrio, Arag and Avmap have a combined total of around one tenth of the total agriculture GNSS component and receiver market, the vast majority of which is held by Hexagon alone.

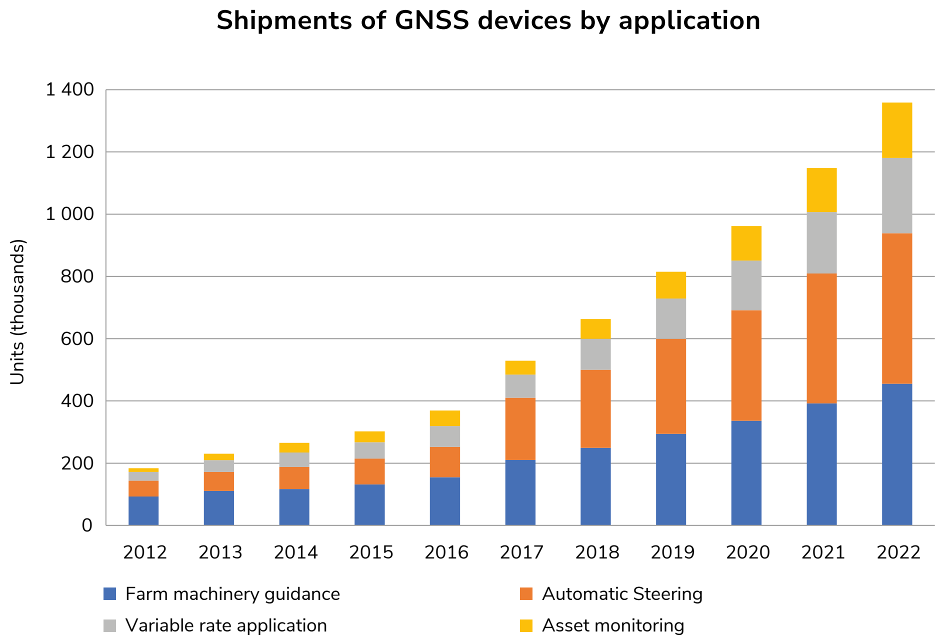
NOTES

[1] The value chain considers the key global and European companies involved in GNSS and EO downstream activities. Please note that enterprises listed in the data providers step of the value chain often provide platforms as a service. For the sake of simplicity the data providers are not repeated in other stages of the value chain in which they are active.
[2] In the market share analysis, Europe is defined as EU27 plus Norway, Switzerland and the UK.

Please refer to page 13 and 23 for a comprehensive description of value chains and how to interpret them at segment level.

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

Eco-schemes and Artificial Intelligence shaping how we produce food



Shipments of GNSS receivers have grown continually and strongly over the past decade, rising **from almost 200 000 units shipped across all applications in 2012 to close to 1.4 million units shipped annually**.

While farm machinery guidance was the dominant application until 2016, automatic steering has now the largest market share due to the increasing popularity of advanced steering systems. **In 2021 and 2022, automatic steering accounted for over 400 000 units shipped worldwide annually**.

The growing appeal of automated steering systems can be attributed to their ability to enhance machinery control and support the efficient application of farming inputs like fertilisers and pesticides.

Farm machinery guidance accounted for over 400 000 shipments worldwide in 2022, with variable rate application shipments accounting for just over 200 000 units. In the same year, shipments for asset management reached just under 100 000 units.

CAP Strategic Plans define how eco-schemes ensure agriculture remains green

The new Common Agricultural Policy (CAP) embraces a performance and results-based approach, offering increased flexibility while considering local conditions and needs. EU Member States must draw up their own CAP Strategic Plan under this approach. **One noteworthy addition to the CAP is the introduction of eco-schemes, which are strategically designed to align with Europe's climate objectives.**

These eco-schemes constitute an integral part of each CAP Strategic Plan and are defined by each Member State. The implementation of EO and GNSS technologies plays a pivotal role in simplifying the monitoring, reporting and verification of eco-schemes.

Eco-schemes encompass a variety of initiatives, including the rewetting of wetlands and peatlands, the development of nutrient management plans employing innovative methods to reduce nutrient release, optimising pH levels for nutrient uptake and fostering circular agriculture. Additionally, they involve precision crop farming to minimise inputs like fertilisers, water and plant protection products, as well as the creation and enhancement of semi-natural habitats.

The integration of EO and GNSS solutions into the management of eco-schemes not only enhances their efficiency but also contributes to the advancement of sustainable agricultural practices, aligning with the overarching objectives of the CAP.

EO and GNSS empowering Artificial Intelligence developments in agri-food

Both EO and GNSS offer a wealth of valuable datasets for the agricultural sector. There is a growing interest in harnessing the power of Artificial Intelligence (AI) within the agri-food sector to extract and leverage the insights contained within these datasets.

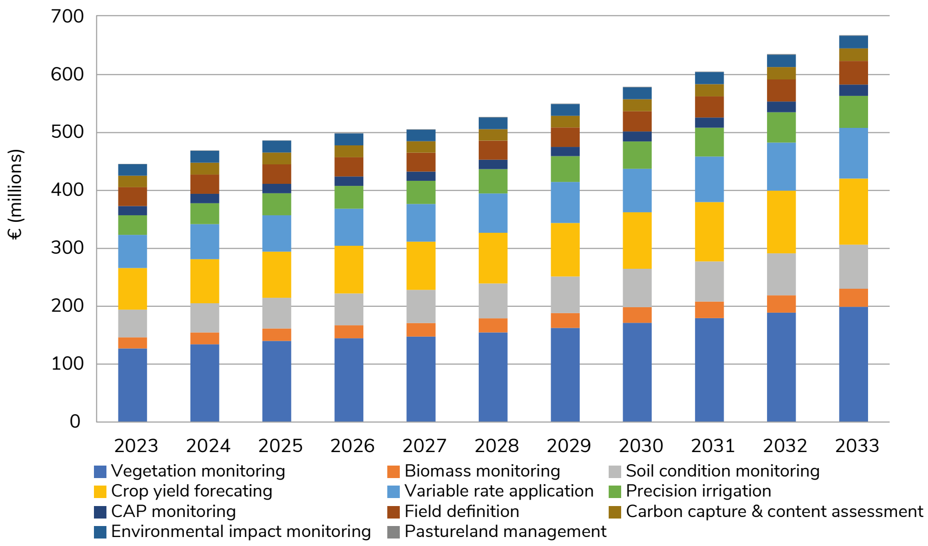
For example, AI can enhance predictions of crop yields by analysing data collected from EO and/or GNSS sources and integrating it into other datasets.

AI can simplify plant phenotyping, automate the detection of pests or pathogens, ensure consistent product quality throughout the production cycle, and support strategic decisions on time-to-market planning**.**

Consequently, AI has the potential to optimise farm operations, boost economic returns for growers and promote sustainable agricultural practices.

Frontier tech continuing to disrupt the market

Revenue from EO data & services sales by application



"Swarm" robotics could change the face of precision agriculture

Recent developments in smart agriculture, which have primarily revolved around the adoption of large machinery, have aimed to maximise output while minimising costs. However, this approach has raised both economic and environmental concerns.

A potentially transformative future trend involves the deployment of "swarms" of smaller, GNSS-enabled drones, robots and UAVs to optimise agricultural operations. By applying swarm intelligence approaches within agricultural robotics, the synchronised efforts of multiple robots working in cooperation can produce impactful operational efficiencies. This approach holds particular promise for agricultural activities that are labour and time intensive. **Swarm robotics has the potential to automatically divide and delegate tasks among the swarm**, thereby performing several tasks in parallel and reducing the need for human planning and labour.

Furthermore, for the likes of harvesting activities, these robots can be programmed to discern and avoid harvesting unripe plants, thereby enhancing efficiency and overall yield. Another critical aspect of agriculture that can benefit from swarm robotics is soil monitoring. These robots can be programmed to measure crucial parameters such as soil temperature, moisture levels and nutrient content. Subsequently, they can relay this data back to farmers, enabling them to make more informed decisions about crop management strategies.

Revenues from EO data and service sales across all agricultural applications are expected to increase from **almost €450 million in 2023 to around €670 million in 2033.**

In this new edition of the report two new applications have been quantified: carbon capture and content assessment; and environmental impact monitoring of farming. These inclusions reflect the increasing focus on the impact of agricultural activities on the environment.

Currently, the three largest applications in terms of market share are vegetation monitoring, crop yield forecasting and variable rate application. **Combined, they were forecast to achieved revenue of over €256 million in 2023 and are projected to reach more than €400 million by 2033**. Soil condition monitoring and precision irrigation also boast substantial market shares across the decade.

Vegetation monitoring is expected to **retain the largest market share** over the next decade, not only due to the value it can bring to farmers, but also due to the rich information it can provide to other stakeholders in the agricultural value chain, including governmental bodies and economists concerned with the maintenance and monitoring of food supply chains.

Digital twins in agriculture

A 'digital twin' is a digital replica of a real-world object that mirrors its behaviour and states throughout its lifecycle within a virtual environment. **Leveraging digital twins within farm management allows the separation of physical processes from their planning and control.**

Consequently, activities can be remotely overseen and based on real-time or near-real-time digital data rather than relying solely on direct on-site observation and manual tasks. Although still very much in its early phases, this capability could empower farmers to respond promptly to expected or unexpected deviations and to simulate the outcomes of interventions using real-world data. EO and GNSS data are considered invaluable sources of information for creating these digital replicas with the highest possible accuracy.

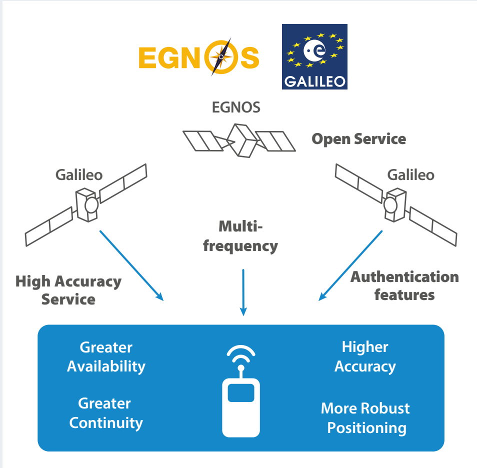
The application of digital twins within the livestock farming sector also has the potential to be used to improve large-scale precision livestock farming practices. In this approach, the health, behaviour, distress and disease control and prevention of a variety of farm animals can be better understood. In a broader context, comprehensive digital twins, encompassing greenhouse replicas, the physical environment and crop replicas, serve as valuable tools for making operational and tactical management decisions, shaping strategic design choices, and providing insights for predictive maintenance.

By simulating and evaluating preventive and corrective actions within the digital environment before implementing them in the physical world, these holistic digital twins could, in the future, offer a robust framework for capturing existing knowledge and generating artificial training datasets to inform future system design and operation.

The European space programme supports R&D activities in agriculture

Current usage of EGNSS

Galileo High Accuracy Service (HAS) delivers horizontal accuracy down to 20 cm and vertical accuracy of 40 cm, which is crucial for precise positioning and guidance in agricultural practices such as planting seeds, applying fertilisers and pesticides, and harvesting crops. **Farmers can leverage this accuracy to minimise overlaps, reduce costs and maximise productivity.** This level of accuracy is vital in agricultural applications that require high precision, such as autonomous farming equipment, variable rate application of inputs, land surveying and mapping.



The **Open Service Navigation Message Authentication (OSNMA)** provides a high level of data trustworthiness and protection against malicious signal spoofing. This ensures that farmers can rely on the GNSS signals for accurate navigation and positioning, enhancing safety and preventing disruptions in operations.

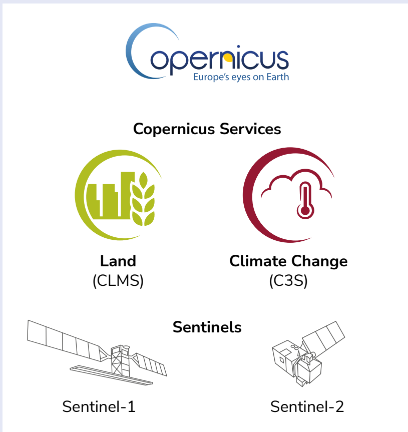
These Galileo-specific differentiators make the system suitable for various agricultural activities, empowering farmers with **accurate positioning, reliable signals and enhanced capabilities for optimal decision-making and efficiency**.

Current usage of Copernicus

Copernicus Sentinels 1 and 2 have changed 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 variable rate application, CAP monitoring and carbon content assessment services.

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.



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

Horizon Europe, a programme of the European Union

MAGDA

Weather and irrigation information for farmers - MAGDA

MAGDA will improve **farm-specific weather forecasts** as well as **irrigation advisories** which will proactively contribute to protecting crops from severe weather impacts, decreasing both food production losses due to adverse weather, but also water consumption due to mismanaged irrigation.

MAGDA is contributing to the **Sustainable Development Goal 12** ("Ensure sustainable consumption and production patterns") and 13 ("Climate Action"), as well as to the EU´s **Common Agricultural Policy** (CAP).

More information available at: https://www.magdaproject.eu

HORIZON 2020

PestNu

Digital platform for agro-advisory and business services - PestNu

PestNu aims to revolutionise **novel, digital and space-based technologies** (DST) with **agro-ecological and organic practices** (AOP) in a systemic approach which can be applied in novel circular economy food production – e.g. aquaponics, hydroponic greenhouses and open-field vegetable cultivation.

It aims to **reduce the dependence on hazardous pesticides**, reduce the loss of nutrients from fertilisers and progress towards zero pollution of water, soil and air.

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

Horizon Europe, a programme of the European Union

SPACE4GREEN

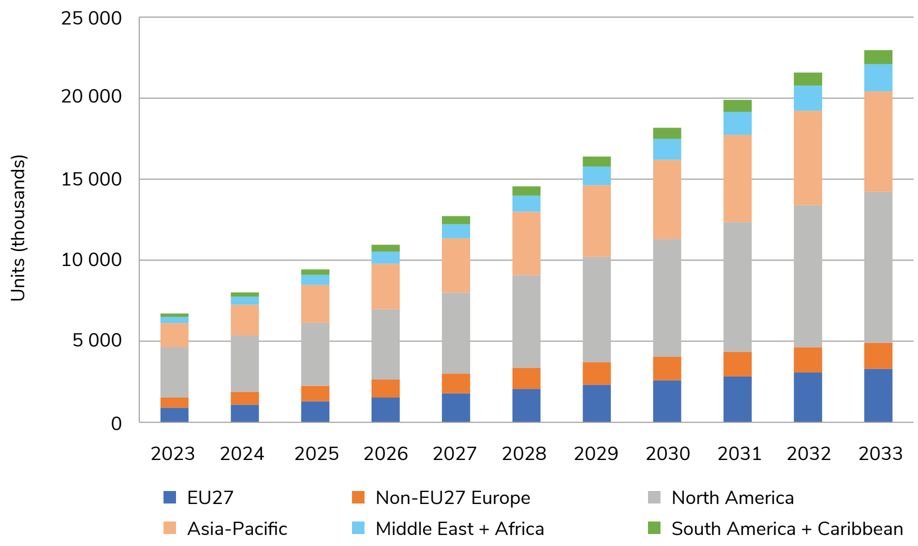
Trusted and green traceability through EU space technologies - SPACE4GREEN

The **SPACE4GREEN project** will develop a **technological** solution that **does not require human certification** for food products.

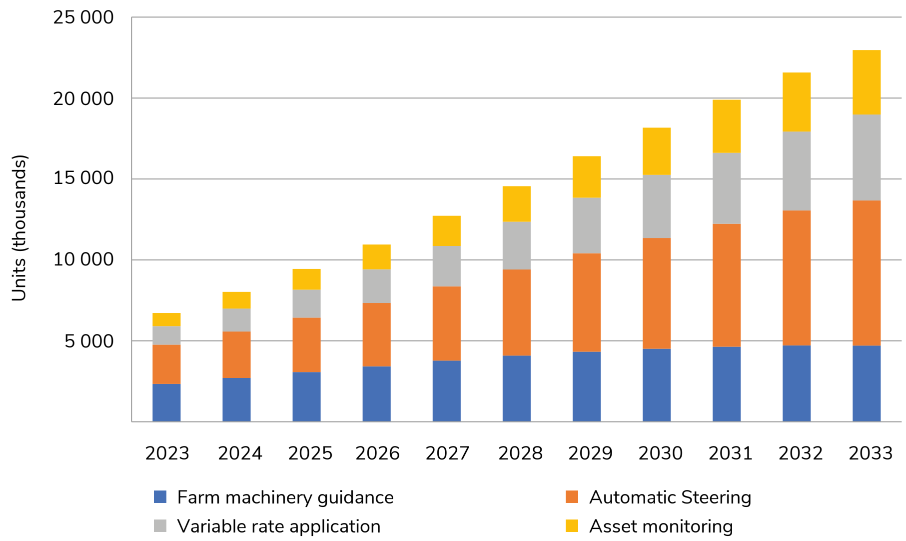
The solution is based on the **integration of space technologies** (Galileo Open Service Navigation Message Authentication) **and blockchain with smart devices and mobile platforms**. The project will develop a trusted platform for use among various stakeholders for the automated certification of activities without requiring third-party, human certification.

More information available at: https://www.space4green.eu

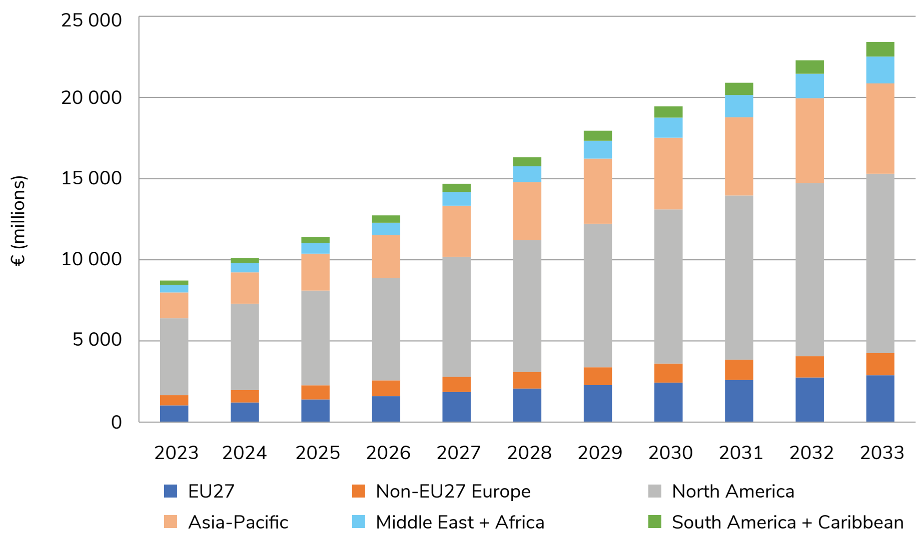
Installed base of GNSS devices by region



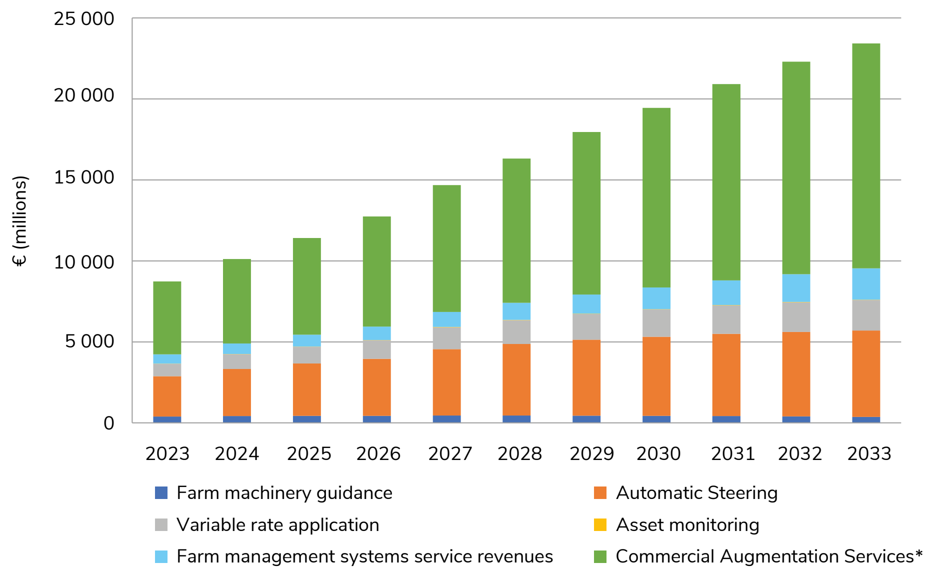
Installed base of GNSS devices by application



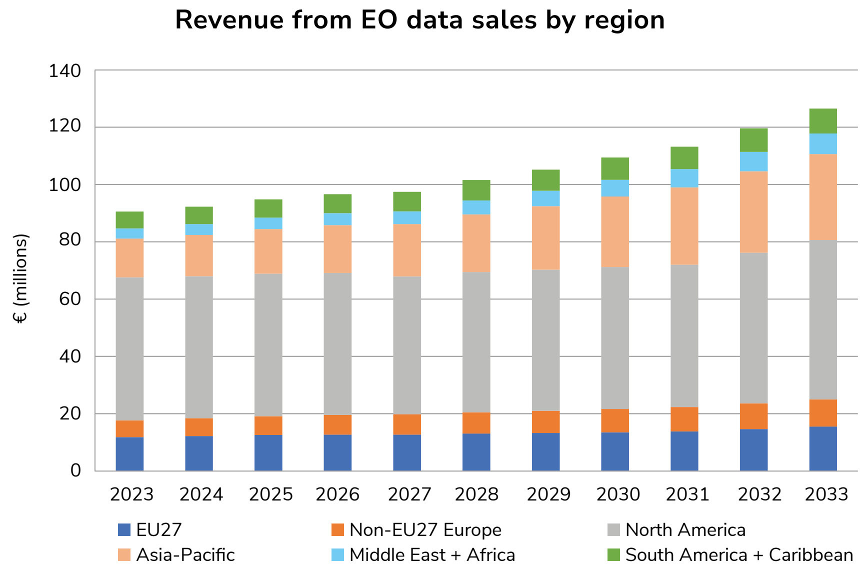
Revenue from GNSS device sales and services by region

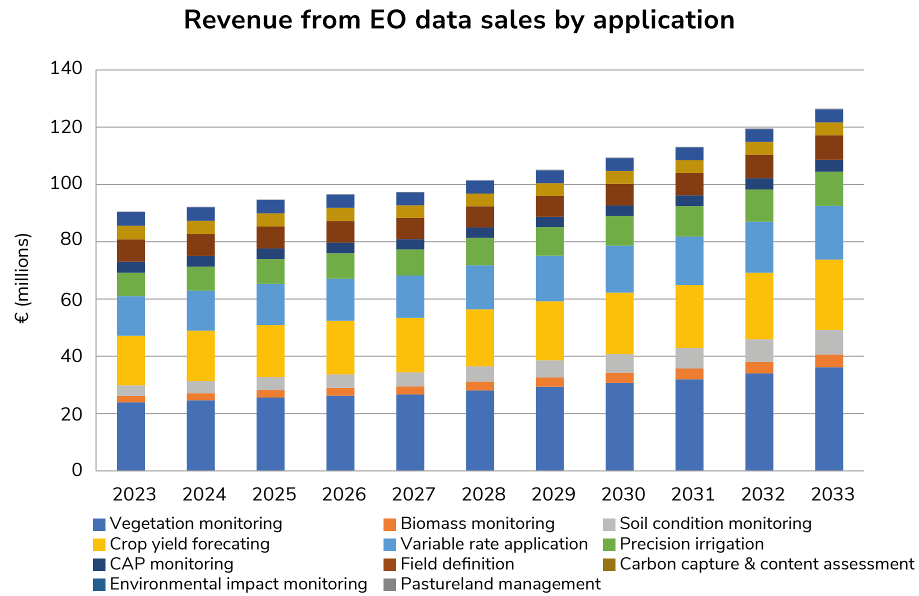


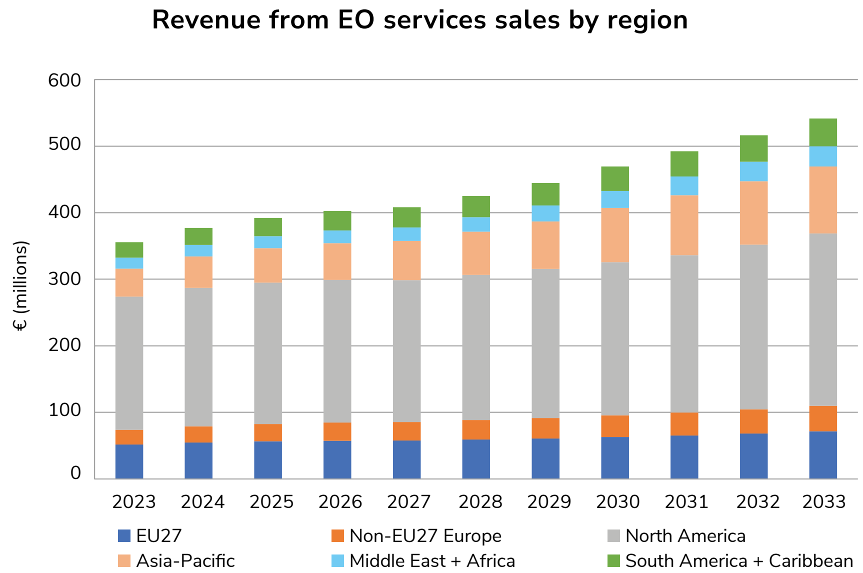
Revenue from GNSS device sales and services by application

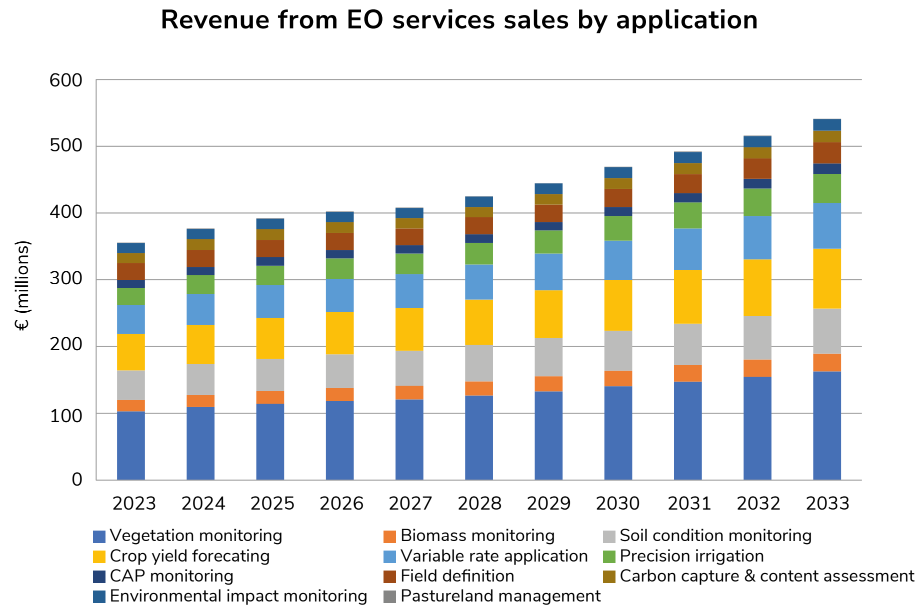


* Commercial Augmentation Services only include revenue from applications in Agriculture. Commercial Augmentation Services from applications in Infrastructure, Energy and Raw Materials and Urban Development and Cultural Heritage segments are captured in the chart for Urban Development and Cultural Heritage.


Revenue from EO data sales by region
140
120
100
80
60
40
20
0
€ (millions)
2023
2024
2025
2026
2027
2028
2029
2030
2031
2032
2033
EU27
Non-EU27 Europe
North America
Asia-Pacific
Middle East + Africa
South America + Caribbean


Revenue from EO data sales by application
140
120
100
80
60
40
20
0
€ (millions)
2023
2024
2025
2026
2027
2028
2029
2030
2031
2032
2033
Vegetation monitoring
Biomass monitoring
Soil condition monitoring
Crop yield forecating
Variable rate application
Precision irrigation
CAP monitoring
Field definition
Carbon capture & content assessment
Environmental impact monitoring
Pastureland management


Revenue from EO services sales by region
600
500
400
300
200
100
0
€ (millions)
2023
2024
2025
2026
2027
2028
2029
2030
2031
2032
2033
EU27
Non-EU27 Europe
North America
Asia-Pacific
Middle East + Africa
South America + Caribbean


Revenue from EO services sales by application
600
500
400
300
200
100
0
€ (millions)
2023
2024
2025
2026
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2028
2029
2030
2031
2032
2033
Vegetation monitoring
Biomass monitoring
Soil condition monitoring
Crop yield forecating
Variable rate application
Precision irrigation
CAP monitoring
Field definition
Carbon capture & content assessment
Environmental impact monitoring
Pastureland management

AVIATION AND DRONES

Legend

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

* Applies also (or exclusively) to drones

Communication

- ATM system timing

Environmental Monitoring

- Aircraft emission measurement and monitoring
- Particulate matter monitoring

Navigation

- Drone navigation (uncertified)*
- Performance Based Navigation (PBN)
- Performance Based Navigation (PBN) for drones*
- VFR complement[1]

Operations Management

- Aircraft maintenance and operations optimisation
- Airport capacity and safety
- Drone operations planning*
- Monitoring terrain obstacles
- U-space services*

Surveillance

- Electronic Conspicuity (certified)*
- Electronic Conspicuity (uncertified)*
- 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 a mature user of GNSS technologies that have enabled continuous growth in traffic and connectivity to all regions of the world. This continued growth has increased dependency on GNSS and ensured a continuous revision and assessment of the performance needed to support traditional and emerging users, such as drones and urban air mobility. Now, GNSS is essential in the aviation domain, a leading and indispensable asset, supporting all aspects of aviation; Performance Based Navigation, flight planning, operations, airspace design, and service provision to airlines, pilots, airports and air navigation service providers. The publication of EGNOS based procedures is also mandatory for all instrument runways in Europe, and projects are ongoing to build EGNOS-based instrument flight procedures for non-instrument runways.

ICAO coordinates new international developments in aviation, standardised through industry groups such as EUROCAE/RTCA. The current focus on the new range of Dual Frequency Multi Constellation (DFMC) receivers aims to further improve the resilience of GNSS given its criticality to aviation.

Unmanned aviation has experienced significant growth in recent years and GNSS is key for positioning and to enable integration with manned aviation; safe, efficient and conflict-free operations rely on GNSS as the primary PNT source. Together with position augmentation through SBAS, this benefits applications requiring high precision positioning, i.e. autonomous flights or Beyond Visual Line of Sight (BVLOS) operations.

Earth Observation (EO) data is also used by both manned and unmanned aviation. Services utilising EO data support the prediction of ash cloud dispersion and enable aircraft operators, airports and Aeronautical Information Service providers to plan adjustments to flight routes that minimise environmental impacts. Coupled with other data sources, such as elevation models and population density, EO data also becomes intrinsic to the assessment of ground risk for specific category operations (SORA) for unmanned operations.

Note: Topics mainly related to the **aviation** sub-segment are indicated with an **orange circle**, while the **drones** sub-segment topics are indicated with a **blue circle**.

What you can read in this chapter

- **Key trends:** GNSS and EO supporting aerodrome accessibility, enabling new modes of transportation and monitoring environmental impact of aviation.
- **User perspective:** The dependency on GNSS and integration with EO is increasing.
- **Industry:** Aviation and drones value chains.
- **Recent developments:** GNSS assurance and integrity critical for aviation growth & Electronic Conspicuity as the key U-space enabler.
- **Future market evolution:** Unlocking the drones' potential.
- **European Systems:** EGNSS and Copernicus current usage.
- **European Projects:** Research and Innovation Projects in Aviation and Drones segment.
- **Reference charts:** Yearly evolution of installed base of GNSS devices and revenues by application and region.

GNSS and EO supporting aerodrome accessibility, enabling new modes of transportation and monitoring environmental impact of aviation

Key market trends
- GNSS Augmentation and DFMC Standardisation promises improved performance for airspace users globally
- GNSS and EO supporting airport accessibility, enabling new modes of transportation and monitoring environmental impact of aviation
- Innovative Air Mobility operations expected to begin from 2024

GNSS augmentation continuing to unlock benefits for aviation

The augmentation of GNSS signals has been implemented in several regions of the world to address **the integrity needs of aviation in critical phases of flight such as approach and landing**.

Satellite-Based Augmentation Systems (SBAS) (such as EGNOS) enable several GNSS applications that would not be possible to the same minima without augmentation. Examples include LPV approaches at instrument runways, including CAT I precision approach, instrument flight procedures at non-instrument runways, approach procedures to offshore platforms or helicopter medical emergency operations. These are described further within the recent developments section of this chapter.

The simplicity of utilising SBAS to provide the integrity without any dependency on terrestrial infrastructure means the benefits can be provided to small aerodromes or airfields **improving safety and accessibility** while avoiding the costly installation and maintenance of ground infrastructure. Such use of SBAS is worldwide and best practices and lessons learnt are shared between Europe, Australia, New Zealand and the United States.

EO supporting aviation operations and mitigating aviation environmental impact

GNSS and EO are two key enablers supporting aviation's efforts to **reduce its environmental impact**. Together, they ensure that the most efficient routes are flown safely, with due regard for reducing flight time whilst maximising fuel efficiency by taking advantage of accurate track keeping, adjusting routes to take advantage of meteorological conditions whilst also minimising noise disturbance to the general population living close to aerodromes.

SATAVIA uses EO data to monitor **contrail formation**, which is estimated to cause up to 60% of all aviation's climate impact, accounting for 2% of the overall human-caused climate impact. This is a widely recognised issue, with efforts being undertaken globally to identify solutions as to how this can be reduced. Within Europe, EUROCONTROL and CANSO organised an event on the 7th of November 2023, to improve the understanding about contrails, together with their impact on climate and to explore potential mitigation measures to minimise their occurrence. Similarly, the FAA and NASA are active contributors to the debates on contrail topics. The industry, meanwhile, is developing its own **solutions and tools supported by EO data** to help airlines to avoid areas most likely to contribute to contrail formation.

EO also supports aerodrome planning through monitoring of hydrogeological hazards and subsidence at aerodromes, long term meteorological observations and changes in land use proximate to aerodromes. This data enables master planning for future development and site assessments for new airports and ancillary infrastructure. Other examples include EO data used to monitor and **forecast volcanic ash and dust clouds** which have potentially catastrophic consequences for civil aviation.

Innovative Air Mobility taking-off

In August 2023, EASA Opinion No. 03/2023 proposed updates to the EU drone regulatory framework and introduced novel terminology for Unmanned Aircraft Systems (UAS) and Vertical Take-Off and Landing (VTOL) capable aircraft (VCA) operations under the umbrella of Innovative Aerial Services (IAS), which includes both Aerial Operations and Innovative Air Mobility (IAM). The IAM is defined as "safe, secure, and sustainable air mobility of passengers and cargo enabled by new-generation technologies integrated into a multimodal transportation system". The EASA Opinion No. 03/2023 scheme as shown below outlines the new categorisation and taxonomy of the Innovative Aerial Services.

IAM concepts are globally entering a phase of **real operational trials**. The 2024 Olympic Games in Paris plan to trial IAM transporting passengers between stations, airports and Olympic stadiums. While these will most likely be with a pilot onboard (EASA Opinion No. 03/2023 does not provide details on the PBN capabilities), companies like EHang in China and Wisk in the US are planning autonomous operations to commence service within the next two to three years with EHang having achieved Type Certification in October 2023.

The supporting infrastructure is being developed just as quickly with a number of **vertiports** scheduled to **enter service in 2024**, including in Paris (four locations), Singapore, Orlando, Italy, Germany, Spain and Sweden according to the AAM Infrastructure Index. The electrical requirements for vertiports are also being addressed with a recent study by the FAA/NERL in the US estimating the demand per site will be between 900 kW and 13.3 MW.

With social acceptance of IAM still being a concern, the industry is focusing on the **certification and standardisation** of the technology and supporting systems (like DAA or UTM) throughout the work in **EUROCAE WG-105 UAS and WG-112 VTOL**.

EASA Opinion No 03/2023: Domains of UAS and VCA operations

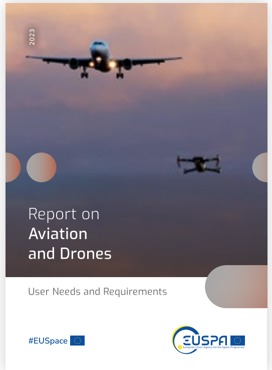
The dependency on GNSS and integration with EO is increasing

Sources of key EO and GNSS user requirements

The key EO and GNSS user requirements for the different application groups within the **aviation and drones** segment are collected using a harmonised procedure at EU level.

Information is collected through extensive interactions with user groups, providers and experts in a continuous process culminating at the User Consultation Platform (UCP). All relevant requirements are documented in detail and updated regularly within the Report on Aviation and Drones user needs and requirements. User requirements for EO services and products – as well as their evolution – are now also collected through the UCP. The process covers the EO user needs and requirements of commercial users based on inputs from industry experts and user groups, mirroring the existing process implemented for GNSS.

Moreover, the collection of specific requirements for Copernicus services and products is supported through an integrated process 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; and (iii) regular and structured exchanges among representatives of the Copernicus governance structure and Member States through the Copernicus User Forum.



EO supporting navigation, safety and sustainability

As aviation benefited from GNSS, the **integrity of geospatial data** defining runways, taxiways and obstacles have also become more critical. Requirements defining the quality of this data have been documented for several years and utilising EO is a natural and cost-effective solution when needing to assess the obstacles. Utilising EO data effectively supports planning and safety applications for aerodromes such as **procedure design, runway and route analysis for airlines, monitoring of terrain obstacle or airport planning**. One of the critical challenges with utilising EO data is its recency since all aviation data adheres to a strict update cycle of 28 days. Within this period, changes that impact navigation data or are operationally significant are communicated to all stakeholders. Within the UCP, the analysis of user requirements showed a preference for EO services supporting **critical identification of terrain and obstacles**, even with the challenge of having higher data resolution, and increased update frequency rates.

EO also helps monitoring and forecasting of **volcanic ash, atmospheric pollutants and contrails**. During the UCP 2022, users discussed the update rates and data resolution needed to support the use cases presented. The standards for meteorological data are established by ICAO and the new services that can be enabled utilising EO have the potential to provide better precision supporting more environmentally efficient operations but require further standardisation. EO data coupled with urban data can also be utilised for land-use planning to monitor the population living around airports, exposure to noise levels, third party risk exposure and impact on biodiversity.

Data-driven drone operations risk assessment

The current regulatory framework (EU) 947/2019 requires drone operators within the EASA specific category to carry out a **risk assessment** but does not specify the methodology and data to be used. In response to this, an international organisation, JARUS, developed a Specific Operations Risk Assessment (SORA) methodology that is widely used in and out of Europe. However, operators have at times struggled to provide detailed ground risk analysis due to missing population data, while regulators have not always approved applications in a timely manner due to the **lack of standardisation on data** used. This was explored at UCP 2022, noting the challenges and opportunities of EO data to support this standardisation. Several approaches are being explored, including the use of richer geospatial inputs, such as a building layer to identify if locations are sheltered or not. In parallel, EASA and JARUS have introduced an updated version of **SORA 2.5** (still under consultation), which facilitates the shift from a qualitative to a quantitative assessment.

Several options to complement the quantitative assessments exist, including applications of **AI, big data** or **digital twin models** or incorporating data derived from cellular networks. These pose additional challenges, including being costly and raising questions on privacy.

The increased accuracy provided by EGNOS enables safer drone operations at minimal cost in densely populated areas. The latest EGNOS receivers for UAS provide upper bounds of the position uncertainty, which is expected to enable an integrity concept currently being tailored to drone operations. This includes the work within EUROCAE **WG-105 SG-6 SORA** to develop guidelines for the use of multi-GNSS solutions for medium risk drones.

Together, EO and GNSS data can also support the future U-space environment including **U-space services** like remote ID or geo-awareness that rely on precise positioning. EO geospatial (population/housing) data already supports flight planning and ground **population risk assessments**, and the frequency of these updates will become more important as it is relied on to support strategic and tactical flight planning, moving maps and terrain avoidance systems.

Aviation and drones GNSS value chain[1]

LEGEND
- Drones
- Manned Aviation

COMPONENT & RECEIVER MANUFACTURERS

Drones
- DJI BAIWANG
- GMV*
- HEXAGON*
- INFINEON*
- QASCOM*
- SEPTENTRIO*
- ST MICRO
- TRIMBLE NAVIGATION
- U-BLOX*

Manned Aviation
- BEIJING BDSTAR NAVIGATION
- CHCNAV
- COBHAM*
- COLLINS AEROSPACE
- FINMECANICA*
- GARMIN
- HONEYWELL
- LEONARDO
- NORTHROP GRUMMAN
- NUVOTON
- RTX
- SABCA*
- SAFRAN*
- SBG SYSTEMS*
- TECHTEST*
- THALES AVIONICS*
- TRANSDIGM GROUP
- TRIG AVIONICS*
- UNITED TECHNOLOGIES

AIRCRAFT & DRONE MANUFACTURERS

Drones

FIXED WING
- ATMOS*, AUTEL ROBOTICS, AVY*, DJI, ETRA AIR*, WINGTRA, ZIPLINE;

MULTI-ROTOR
- AUTEL ROBOTICS, DJI, EHANG, ETRA AIR*, FLYING BASKET*, PARROT*, PRECISIONHAWK;

SINGLE ROTOR
- BABCOCK*, SCHIEBEL*;

VTOL FIXED WING
- MANNA*, QUANTUM SYSTEMS*, RIGITECH, UKREPECSYSTEMS, WING;

IAM
- AIRBUS*, ARCHER, CRISALION*, EHANG, HYUNDAI, JOBY AVIATION, LILIUM, VERTICAL AEROSPACE, VOLOCOPTER*

Manned Aviation
- AIRBUS*
- BEECHCRAFT
- BOEING
- BOMBARDIER
- COMAC
- DASSAULT*
- EMBRAER
- GULFSTREAM AEROSPACE
- PILATUS AIRCRAFT*
- PIAGGIO AEROSPACE*
- TEXTRON
- UNITED AIRCRAFT CORPORATION
- VULCANAIR*

DRONE OPERATORS & AIRLINES / AIRCRAFT OWNERS AND OPERATORS

Drones
- CYBERHAWK
- EHANG
- HEMAV*
- LILIUM*
- MANNA*
- NASA
- SKYFUTURES*
- SKYPORTS*
- VOLOCOPTER*
- WING
- ZIPLINE

Manned Aviation

MAIN AIRLINES ALLIANCES
- ONEWORLD
- SKYTEAM
- STAR ALLIANCE

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

UTM SERVICE PROVIDERS & ATM DATA SERVICE PROVIDERS & AIR NAVIGATION SERVICE PROVIDERS & REGULATORS AND MAIN ORGANISATIONS

Drones
- DRONE ALLIANCE EUROPE (DAE)*
- EUROCAE*
- EUROCONTROL*
- GLOBAL UTM ASSOCIATION
- HAPS ALLIANCE
- INTERNATIONAL CIVIL AVIATION
- ORGANISATION (ICAO)
- JOINT AUTHORITIES FOR RULEMAKING ON UAS (JARUS)
- RADIO TECHNICAL COMMISSION FOR AERONAUTICS (RTCA)
- USSPS (D-FLIGHT, DRONIQ, SKEYDRONE)
- UTM (AIRMAP, ALTITUDE ANGEL, UNIFLY)

Manned Aviation
- CIVIL AIR NAVIGATION SERVICES ORGANISATION (CANSO)
- EUROPEAN UNION AVIATION SAFETY AGENCY (EASA)*
- EUROCAE*
- EUROCONTROL*
- INTERNATIONAL CIVIL AVIATION ORGANISATION (ICAO)
- RADIO TECHNICAL COMMISSION FOR AERONAUTICS (RTCA)

AERODROMES & INFRASTRUCTURE OPERATORS

Drones
- AIRBUS*
- BLUENEST*
- FERROVIAL*
- SKYPORTS*
- URBANV*
- URBAN-AIR PORT*

Manned Aviation
- AIRPORTS COUNCIL INTERNATIONAL (ACI)
- INTERNATIONAL AIRPORTS
- REGIONAL AIRPORTS ASSOCIATIONS

European[2] GNSS industry in the global arena

European and North American organisations dominated the manufacturing of aviation GNSS receivers in 2021 with North American receiver suppliers accounting for more than three quarters of the market and European suppliers around a fifth of the market.

The picture is more mixed regarding drones, with market share depending on the sophistication of the drone platform. Overall, Asia-Pacific companies retain the largest share.

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.

Please refer to page 23 for a comprehensive description of the GNSS value chain and how to interpret them at segment level.

Aviation and Drones EO Value Chain[1]

EARTH OBSERVATION

DATA PROVIDERS

- AIRBUS*
- AIS TECH*
- BLACKSKY
- CAPELLA SPACE
- ICEYE*
- LEONARDO (E-GEOS)*
- MAXAR
- PLANET
- SCEYE
- SPIRE GLOBAL

- COPERNICUS SENTINELS*
- EOS-4 (ISRO)
- LANDSAT (USGS/NASA)
- NOAA AND GOES (NOAA)
- RELEVANT IN-SITU NETWORKS
- RELEVANT EUROPEAN NATIONAL MISSIONS

INFRASTRUCTURE PROVIDERS

- AWS
- CLOUDFERRO*
- GOOGLE CLOUD
- GOOGLE EARTH
- IBM CLOUD
- MICROSOFT AZURE
- T-SYSTEMS*

- FEDERATED INFRASTRUCTURE (E.G. GAIA-X)*
- SENTINEL COLLABORATIVE GROUND SEGMENT*

PLATFORM PROVIDERS

- CLOUDEO*
- CREODIAS*
- EARTH-I*
- GEOSS (GLOBAL EARTH
- GOOGLE EARTH ENGINE
- OBSERVATION SYSTEM OF SYSTEMS)
- SATELLITE EARTHSTAR GEOGRAPHICS
- SENTINEL-HUB* (SINERGISE)

- CODE-DE*
- COPERNICUS DATASPACE ECOSYSTEM*
- OPENEO*
- WEKEO*

EO PRODUCTS AND SERVICES PROVIDERS

- BOHANNAN HUSTON
- CREOTECH INSTRUMENTS*
- DARES TECHNOLOGY*
- DRONE RADAR*
- E-GEOS*
- EISAT IMAGENS DE SATELITE*
- LUFTHANSA SYSTEMS*
- RHEA SYSTEM*
- SATAVIA
- SATELLITE IMAGING
- SNC-LAVALIN
- UNISPHERE*
- VANTAGE*

- COPERNICUS ATMOSPHERE MONITORING SERVICE (CAMS)*
- COPERNICUS CLIMATE CHANGE SERVICE (C3S)*
- COPERNICUS EMERGENCY MANAGEMENT SERVICE (CEMS)*
- COPERNICUS LAND MONITORING SERVICE (CLMS)*
- COPERNICUS MARINE SERVICE (CMEMS)*
- COPERNICUS SECURITY SERVICE (CSS)*

INFORMATION PROVIDERS

- ASCENDXYZ
- BOHANNAN HUSTON
- DARES TECHNOLOGY*
- EISAT IMAGENS DE SATELITE*
- FLYCOM HOLDINGS*
- LUFTHANSA SYSTEMS*
- METEOBLUE*
- SATELLITE IMAGING
- SKYMAP GLOBAL
- SNC-LAVALIN

END USERS

- AIR NAVIGATION SERVICE PROVIDERS
- AIRLINES-AIR OPERATORS
- AIRPORT PLANNERS
- AIRPORTS
- CIVIL AVIATION AUTHORITIES
- DRONE OPERATORS
- FLIGHT PLANNERS
- INSTRUMENT FLIGHT PROCEDURE DESIGNERS

LEGEND

- Commercial offering
- Public offering / entities
- User segments

European[2] EO industry in the global arena

The value of EO for Aviation and Drones is growing with more than 70 companies globally now active within the segment. Europe maintains the highest market share of commercial offerings in the Aviation and Drones sector with more than 75% in 2021. Top European players in this segment include Leonardo (E-GEOS) and RHEA System, both of which combine to around a half of the global market share.

NOTES

[1] The value chain considers the key global and European companies involved in the EO downstream activities. Please note that enterprises listed in the data providers step of the value chain often provide platforms as a service. For the sake of simplicity the data providers are not repeated in other stages of the value chain in which they are active.

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

Please refer to page 13 or a comprehensive description of the EO value chain and how to interpret them at segment level.

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

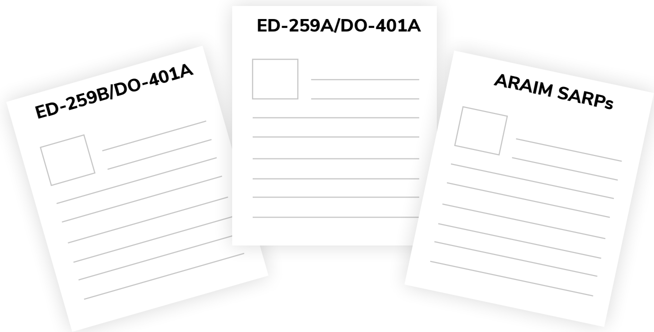
GNSS assurance and integrity critical for aviation growth

Standardising Galileo for aviation applications

DFMC GNSS standardisation efforts are continuing within international working groups including the work on **ARAIM standardisation**. In June 2022, the EU/US Working Group C provided a **ARAIM CONOPS** to support the validation of **H-ARAIM Standards and Recommended Practices (SARPs)**. In January 2023, the ICAO Navigation System Panel (NSP) validated the **ARAIM SARPs,** which were endorsed by the ICAO Air Navigation Commission in October 2023 when it endorsed and formally proposed the standards for inclusion in the next amendment of ICAO Annex 10: Aeronautical communication, Volume I (publication expected in 2025). The ICAO NSP has also developed the ARAIM CONOPS based on past work performed by the EU/US Working Group C.

Galileo will support ARAIM applications by broadcasting a Galileo Integrity Support Message (ISM), which will be added into the current INAV messages to provide all Galileo Integrity Support Data (ISD) needed by the ARAIM algorithm.

In September 2023, the **GPS/Galileo SBAS DFMC MOPS (ED-259A/DO-401)** was published. EUROCAE WG-62 intends to focus next on the updated **ED-259B/DO-401A** for Q1 2025. Although the final scope is still to be agreed, this update is expected to be the first DFMC GNSS receiver standard defining the requirements and test procedures for aviation equipment certified against a TSO and/or an ETSO. The ICAO NSP is simultaneously working on a new **DFMC GBAS** concept and corresponding standards with the intent to complete Baseline Development Standards by Q4 2024: a high-level concept agreed in ICAO and RTCA/EUROCAE, a detailed concept paper, a draft of airborne and ground RTCA/EUROCAE MOPS and a baseline development SARPs.



EGNOS becoming ubiquitous

Aircraft operators are progressively equipping with SBAS avionics in anticipation of **Commission Implementing Regulation (EU) 2018/1048**, requiring LPV (localiser performance with vertical guidance) implementation at all instrument runways from January 2024 and PBN as a standard means of navigation by 2030. ILS (instrument landing system) will remain but only as a back-up infrastructure. As of November 2023, 935 **EGNOS-based procedures** are available **at 497 airports and helipads** (AIRAC Cycle 2312).

For example, Air France is already **updating its fleet**, acquiring new aircraft that are SBAS capable from the factory, while waiting for a **Supplemental Type Certificate** (STC) or a **Service Bulletin** (SB) to upgrade their existing fleet. Pilots do not require special operational approval to fly LPV procedures as it is included in their standard instrument rating training.

Helicopter operations are also benefiting from **EGNOS**, especially for helicopter emergency medical services (HEMS). **PinS approaches** and departures continue to be designed and implemented, along with Low-Level Routes, allowing helicopters to increase their operations safely (see page European Projects for Aviation and Drones).

EGNOS V3, the next generation of EGNOS, will provide **signal augmentation** for dual-frequency bands L1/L5 (GPS constellation) and E1/E5 (Galileo constellation), protected for aviation use. As of June 2023, EGNOS payload is ready to transmit the first EGNOS V3 test signals. With the new payload, the **EGNOS Space segment** will be fully ready for EGNOS V3 delivering improved user experience and reaffirming the Union's investment in advanced space technologies. Together with the EGNOS GEO-5 and the deployment of the next generation Galileo satellites, Europe further increases its autonomous access to space.

Map of operational EGNOS procedures

Electronic Conspicuity as the key U-space enabler

Electronic Conspicuity (EC) enabling airspace integration

Electronic Conspicuity or E-conspicuity is key to **increasing safety** by reducing the likelihood of Mid-Air Collisions (MAC), especially in Class G airspace. Increasing awareness of any aircraft operating in the same airspace benefits both manned and unmanned aircraft that can transmit their position information. This is recognised in the community and a variety of **certified and uncertified EC** technologies have developed, but these are not always interoperable with each other. A lack of harmonised technical standards addressing the interoperability of EC systems is a major impediment to their widespread use in Europe and unlocking potential benefits to new entrants (e.g. drones, UAM, AAM).

Regulatory bodies are working on addressing the interoperability between airspace users and **requirements for Electronic Conspicuity of manned aircraft for U-space operations** (SERA 6005 (c)) entered into force in 2023. Additionally, ED 2022/024/R introduces four means to be conspicuous, one being **ADS-L 4 SRD860**. In January 2023, EASA published technical specification of ADS-L transmissions using the SRD860 frequency band for aircraft to become electronically conspicuous to U-space Service Providers (USSPs), intended to support manufacturers developing ADS-L compliant EC devices/systems.

For EC device position information to be relied on, the PVT transmitted needs to be of sufficient quality and integrity to support application service requirements. SBAS can deliver a cost-effective solution to ADS-L transmissions since it **improves the quality of GNSS information** by correcting signal measurement errors and **providing information about the accuracy, integrity, continuity and availability of its signals**. The signal corrections are then broadcast over the covered area using geostationary satellites providing an augmentation, or overlay, to the original GNSS signal. **Integrating SBAS capable receivers into ADS-L compliant systems would deliver a significant capability improvement** that could enhance position integrity. This has been implemented in the US where SBAS already supports TABS (Traffic Awareness Beacon System).

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U-space integration and new market entrants

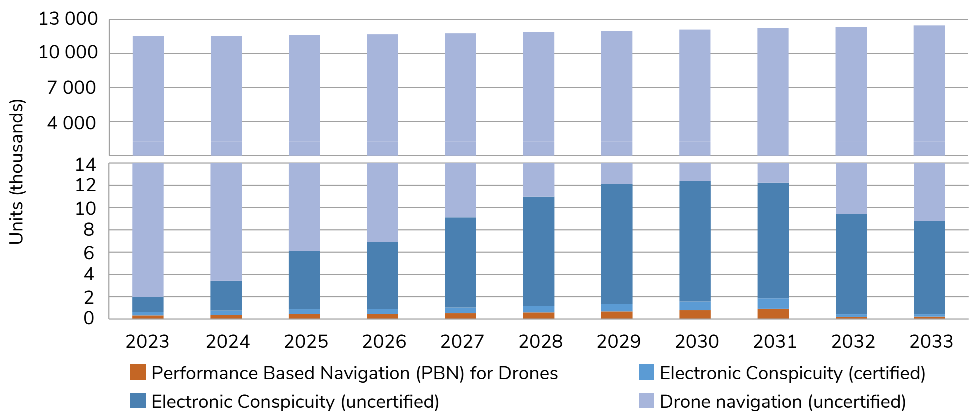
UAS operations are in a phase of considerable growth presenting both opportunities and challenges to the aviation community. Safe **integration** of these new airspace users into Europe's busy skies depends on **interoperability** between manned and unmanned aviation. With this objective, EASA published its first set of **Acceptable Means of Compliance** (AMC) and **Guidance Material** (GM) in 2022 to support the harmonised, safe and efficient **implementation of U-space** across the European Union.

The first **regulatory framework** for U-space (Commission Implementing Regulation (EU) 2021/664, 2021/665 and 2021/666) sets out much needed provisions for three new stakeholders in the aviation industry entering this market – Unmanned Aircraft Systems **(UAS)** operators, U-space Service Providers **(USSP)** and Common Information Services Providers **(CISP)**.

The U-space framework relies heavily on state-of-the-art technology with GNSS a cornerstone supporting mandatory services such as **network identification, UAS flight authorisation, geo-awareness** or **traffic information**. Precise positioning and navigation accuracy and integrity are enabled through GNSS – especially for Beyond Visual Line Of Sight (BVLOS) operations. The UCP 2022 identified several priority focus areas to support the growth of services within U-space, namely: system redundancy, authentication of GNSS signals and monitoring systems to confirm platform status, a common altitude reference system. Therefore, EGNSS solutions are key to supporting U-space services and flight planning by operators supported by EO for the ground risk assessment – for example with population density information.

Unlocking the drones' potential

Shipments of GNSS devices by application (Drones only)



Drone shipments have grown significantly over the past years, with the shipments of GNSS devices supporting navigation now dominating sales within the aviation and drones sector. The majority of the **growth** has been **driven by uncertified solutions**, which have been easier to introduce quickly within the heavily regulated aviation and drones sector. **Manned aviation** has been **growing at a much slower rate** in comparison, with negligible shipments; however, the contribution to overall revenues is higher due to certification requirements (please see page 53).

In the coming years, further growth **depends** heavily on **regulatory enablers** which have not advanced as quickly as the technology enablers. Therefore, the forecasts illustrated remain conservative.

As the **regulatory environment** for drones **matures**, the demand for services might lead to **increased shipments**. An example is the case of the introduction of the U-space regulations in 2023 placing the requirements for **electronic conspicuity, enabling integration** between manned and unmanned traffic. As a result of the regulations, all drones operating under the **EASA specific category** must be equipped with a **remote identification** device. In addition, whilst most operations are contained within SAIL I, II, higher demand for operations under SAIL III, IV is expected.

Innovative Air Mobility: Initial operations of passenger transportation on the horizon

Innovative Air Mobility (IAM) is expected to start operations in the next few years in China and USA (Elroy Air, EHang, Archer or Autoflight), with **autonomous concepts** being pioneered in the market. The **restrictive regulatory environment** in Europe is expected to result in commercial operations starting later. The German manufacturer Volocopter currently has the highest ARI (AAM Reality Index) of 8.6/10 which describes the likelihood of an OEM certifying their aircraft, entering service and producing it in thousand of units per year*. Although their VoloCity and VoloRegion aircraft are designed to be autonomous, the initial operations will be piloted. Vehicles of other European manufacturers such as Vertical Aerospace and Pipistrel will also enter service in the following years.

One of the key elements in the IAM value chain is the **physical infrastructure**. New **vertiports** are being built across Europe and the UK (e.g. Zaragoza, Coventry and Paris). The leading vertiport developers (e.g. Skyports, UrbanV, Urban-Air Port, Bluenest or Ferrovial) are partnering with various vehicle manufacturers to develop a technology-agnostic design allowing them to maximise market potential with operations beginning in the next two to three years.

* https://aamrealityindex.com/aam-reality-index

The Drone Strategy 2.0 creating a framework to enable growth

The **Drone Strategy 2.0**, launched in 2022, aims to set out a clear vision for the development of the drone sector and of a thriving and viable drone eco-system in the European Union. Growth to date has been more limited than previously predicted due to regulatory hurdles. Proposals within the Drone Strategy 2.0 establish **a framework with a number of actions** that, if implemented, are expected **to enable this multi-billion market** and create an estimated 145 thousand jobs within the EU. These actions once completed will provide the certainty needed for private investment to target those sectors seen as offering the highest potential within the sector.

Today, **drones are already used** across areas such as transport and delivery, telecommunications and weather and pollution monitoring, agriculture, construction, surveillance, film-making, healthcare, medical emergency, energy, environment, and public safety and security. The implementation of all the actions from the **Drone Strategy** will be an essential **enabler** for the **uptake for drones in transport and delivery**.

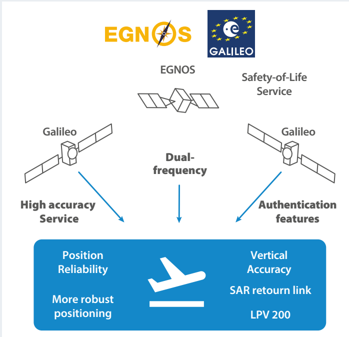
EGNOS and Galileo (including HAS and OSNMA) will play a key role in improving the performance and integrity of GNSS essential for **safety and liability critical applications** underpinning the goals of the Drone Strategy. However, to enable drone delivery applications in densely populated areas, **additional technical solutions** will be **needed** to address multipath and degradation of the GNSS signal **between buildings and urban canyons**. The release of the **3GPP Release 18 standard** enables additional GNSS assistance data, including localised signal blockage information, to be transmitted over a mobile network. This along with other industry initiatives are addressing these challenges to improve the predictability of GNSS performance in these environments.

EGNSS and Copernicus current usage

Current usage of EGNSS

EGNSS for manned aviation

EGNOS is used to improve the accuracy and reliability of GNSS positioning in all phases of flight and enables LPV-200 procedures at hundreds of European airports. The next step in improving EGNOS is to make use of other signals as well. Amendment 93 to Annex 10, Vol. I was adopted by the ICAO Council and is applicable from November 2023 and supports the introduction of DFMC GNSS by adding provisions for additional frequencies of operation for GPS, GLONASS and SBAS. It also introduces provisions for the new BeiDou Navigation Satellite System and Galileo system.



Galileo SAR for manned aviation

The Galileo SAR Return Link Service was declared operational on January 21, 2020, for the initial services, i.e. Acknowledgement Type 1. A service enabled by the Galileo SAR RLS, the Beacon Command Service for Remote Beacon Activation, has recently had manufacturer guidelines published based on the document ED-277 "MASPS for Aircraft ELT Remote Command via Return Link Service". This service allows remote beacon activation/de-activation, while also capable to trigger self-test on its own.

EGNSS for drones

In January 2023, the Galileo **High Accuracy Service (HAS)** became operational and the latest Performance Reports are now available. HAS provides free-of-charge high-accuracy **Precise Point Positioning (PPP**) corrections up to decimetre level through the Galileo signal (E6-B) and by terrestrial means (Internet). High-performance positioning systems for drones are being developed in the framework of current European projects, within the U-space framework focusing on VLL (Very Low Level) and UAS (Unmanned Aircraft System) operations.

To address any issues with **spoofing** and ensure the trustworthiness of information received from Galileo satellites, Galileo has developed **OSNMA**, a freely accessible **data authentication function** for Galileo Open Service users worldwide. This provides a level of security that protects against spoofing and ensures that the positioning data is reliable and based on known source data. OSNMA, in combination with other technologies, can pave the way to a new class of **U-space services** and eVTOL operations enabled by EGNSS for legal protection and customer accreditation. OSNMA has many potential applications, for instance: a) authenticated PVT of geotagged image/data collected from a camera/sensor onboard the drone; b) authentication of the path for **BVLOS operations**, or c) last mile authentication of position as proof of delivery.

Drone Authentication Guidelines

A Drone Authentication Guidelines document is currently under development. The main scope of the document is to provide guidelines to the manufacturers for the correct **implementation of OSNMA** in the GNSS receivers for drones' applications, in the form of tests and recommendations.

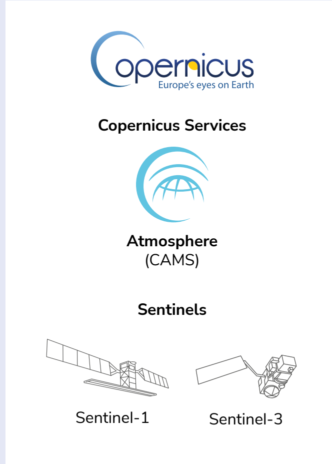
Current usage of Copernicus

Copernicus for manned aviation

Copernicus provides observation data and forecasts of atmosphere composition (e.g. trace gases, particulate matter).

Copernicus Atmosphere Monitoring Service (CAMS) supports manned aviation monitor and forecast volcanic ash and dust clouds which have potential to generate long-term damage (volcanic ash has immediate and even catastrophic damage potential) to civil aviation. CAMS data is also available in weather forecast applications. Pilots can use it in flight planning tools to monitor nitrogen dioxide, fine particle matter, aerosol optical depth and ozone layers.

AsSiSt – Aircraft Support & Maintenance Services, launched in March 2019, is a project utilising atmospheric datasets obtained via CAMS to help airlines and aircraft manufacturers optimise their plans for Maintenance, Repair and Overhaul. The datasets contain everything needed to compute three key indicators of atmospheric conditions: abrasion, clogging and corrosion.



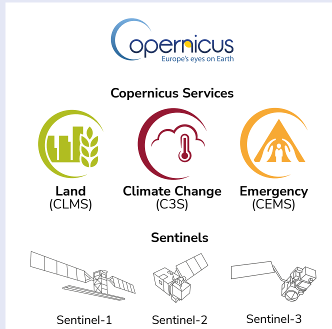
Copernicus for drones

Various drone operators in Europe have successfully integrated GHSL data from Copernicus into their drone software and used it together with Digital Elevation Model (DEM) for management and mission planning. The EO data can also be used by the authorities reviewing and approving flight permits.

Up-to-date satellite imagery from the Copernicus Emergency Management Service is also used by drone operators carrying out **disaster recovery** missions.

The weather data from the Copernicus Climate Change Service (C3S) is useful for strategic flight planning while land use/cover from the Land Monitoring Service (CLMS) can support drone operators in **assessing the ground risk** of their operations. In cooperation with a drone operator, FlyingBasket, EUSPA has explored to what extent land use/cover data can support the **intrinsic Ground Risk Class (iGRC) determination** by looking at how CLMS (land use) can support operators and regulators to understand the number of people exposed to a drone flight. The key advantage of Copernicus datasets are the widespread availability of detailed data, the open specification documentation and the consistent resolution available at a **pan-European** level, which enables **trusted** and **harmonised assessments** across Europe.

Copernicus Digital Elevation Model (DEM) can be used for **mission planning**. Having a terrain and obstacle database for low altitude flights enables operators to visualise the flight mission elevation profile and maintain safe separation from terrain.



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

Research and innovation projects in aviation and drones segment

HORIZON 2020

Demonstration Of Runway Enhanced Approaches Made with Satellite Navigation (DREAMS)

The VLD1-W2-DREAMS project researched the reduction of noise impact around the airports using **GBAS/SBAS precision approaches** via live trials in Frankfurt, Rome-Ciampino and Twente airports:

- **Increased Second Glide Slope (ISGS)** is an approach procedure consisting of approaches and landings on a steeper glide slope than the common worldwide 3° but limited to no more than 4.49°.
- **Second Runway Aiming Point (SRAP)** is an approach procedure, consisting in approaches and landings to a published second runway threshold and aiming point located further on a runway.
- **Increased Glide Slope to Second Runway Aiming Point (IGS-to-SRAP)** operation is considered as a variant type of SRAP operation, combining an increased glideslope to the second runway aiming point.

Approaching with a higher glideslope and/or at a higher altitude than the usual one reduces the **noise footprint during the final approach**. Theoretical research was also carried out on the Adaptive Increased Glide Slope (A-IGS) precision approach which introduces a significant change compared to ISGS operations as the final glide slope value is replaced with an optimised value calculated by the aircraft.

More information available at: https://www.sesarju.eu/projects/DREAMSVLD

MUlti-mode Global positioning system and Galileo (MUGG)

The MUGG project – **MUlti-mode Global positioning system (GPS) and Galileo** project – aims to develop an aviation SBAS dual-frequency multi-constellation (DFMC) receiver. The MUGG project actively supports future civil aviation **GNSS receiver standardisation and certification**. Support is implemented through a prototype of the latest EUROCAE ED-259 – MOPS for Galileo/GPS/SBAS airborne equipment – and in-flight demonstration of the enhanced capabilities.

GNSS evolution, with an increased number of satellites and new signals, available due to DFMC, enables the **GNSS navigation computation to have improved accuracy**, integrity and availability. These efficiencies increase the detection and mitigation capability of GNSS with regards to radio frequency, ionospheric interference and multipath. As a result, GNSS improves navigation capabilities worldwide.

EUSPA and Collins Aerospace are collaborating to integrate and demonstrate the **DFMC SBAS** functions into the GLU-2100 multi-mode receiver. The DFMC SBAS receiver development project started in November 2019. It will be concluded with a flight test campaign on various commercial fixed-wing and rotorcraft platforms. The GLU-2100 contributed to the validation of the ED-259A MOPS, published in September 2023 within the joint EUROCAE WG-62/RTCA SC-159 working group.

More information available at: www.collinsaerospace.com

Horizon Europe, a programme of the European Union

certiflight

Certified E-GNSS remote tracking of drone and aircraft flights (CERTIFLIGHT)

The project explores new U-space services addressing legal **certification of flight tracks** (for both manned and unmanned traffic), through the introduction of a disruptive EGNSS-IoT digital system. The system features a software platform to generate certified reports of flight tracks and the flight logs of drones and GA aircraft, especially for safety related and commercially **valuable applications**. The service will support new **U-space** business services (e.g. activation of Smart Contracts when specific conditions are met, such as flying specific routes for drone package delivery).

The recorded tracks may be useful to assess **airspace infringements** as well as for possible **accident** or **incident investigations**. The system is based on a digital **EGNSS/IoT** device installed on the aircraft, equipped with an **OSNMA Galileo/EGNOS** enabled receiver, capable to guarantee the authenticity of their position information at the origin, without the possibility of counterfeiting or spoofing.

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

HORIZON 2020

DELOREAN

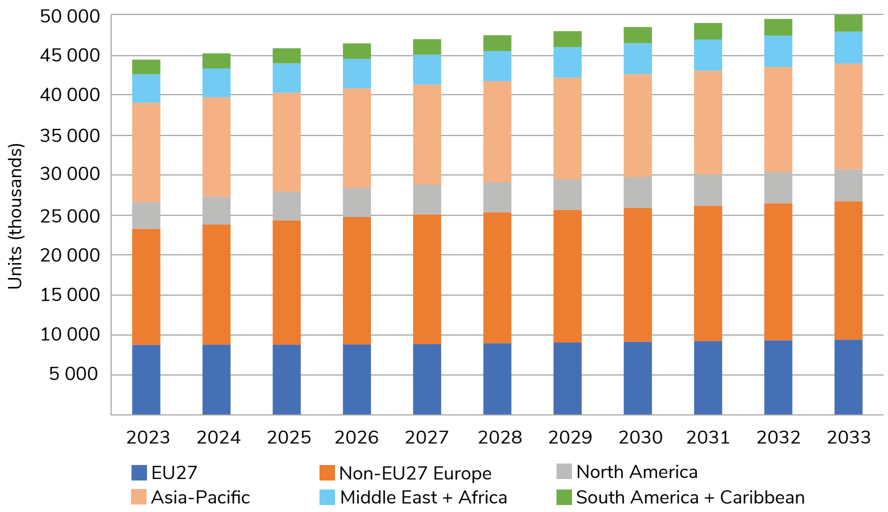
Drones and Egnss for LOw aiRspacE urbAN mobility (DELOREAN)

The DELOREAN project (drones and EGNSS for low airspace urban mobility) explores urban air mobility in the lower urban airspace. The main goal of the project is to develop **navigation** and **positioning requirements** for **UAM** applications, and to demonstrate how **EGNSS** can contribute to UAM. As part of this project, several drone test flights were carried out and EGNSS application specific requirements for UAM and package delivery were explored. The Spanish city of Benidorm hosted the **urban lab** where the testing was performed.

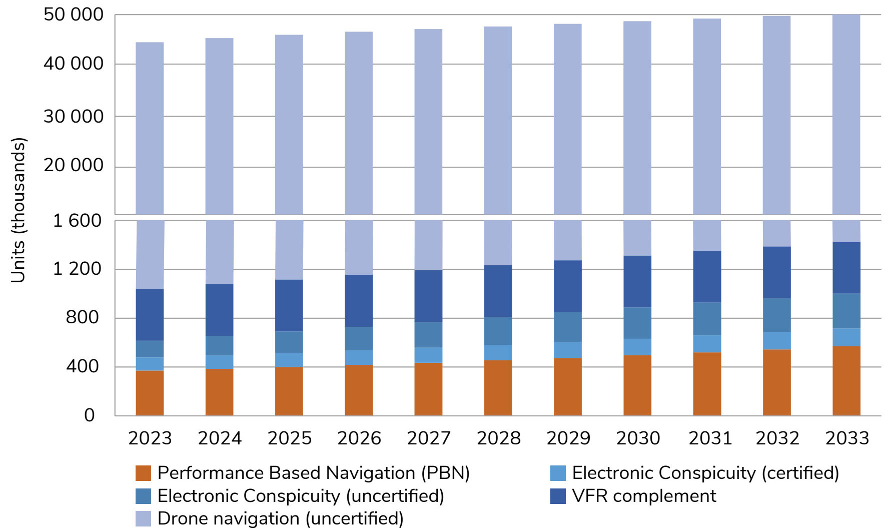
DELOREAN also aims to contribute to definition of EGNSS requirements and standards which could feed into **acceptable means of compliance (AMC)** framework in the new European drone regulation, especially for the EASA specific category (including specific operations risk assessment method - **SORA**).

More information available at: https://www.euspa.europa.eu/drones-and-egnss-low-airspace-urban-mobility

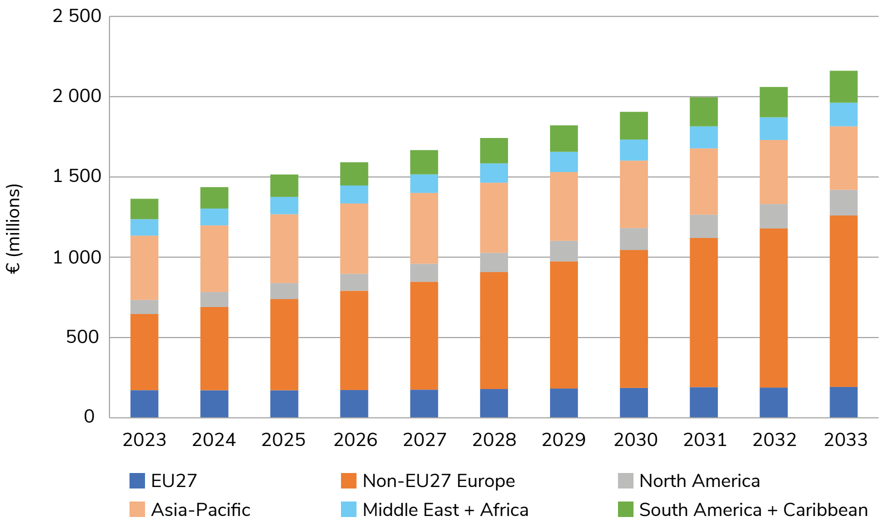
Installed base of GNSS devices by region



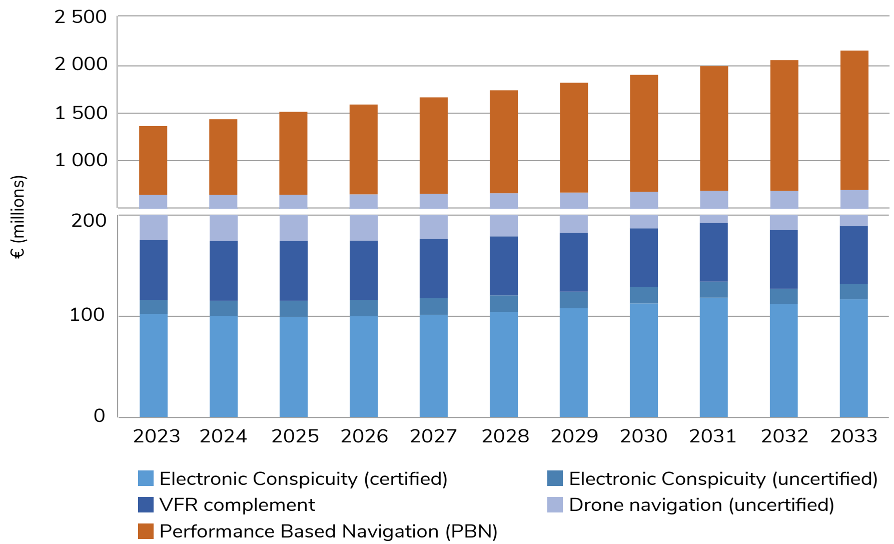
Installed base of GNSS devices by application



Revenue from GNSS device sales by region

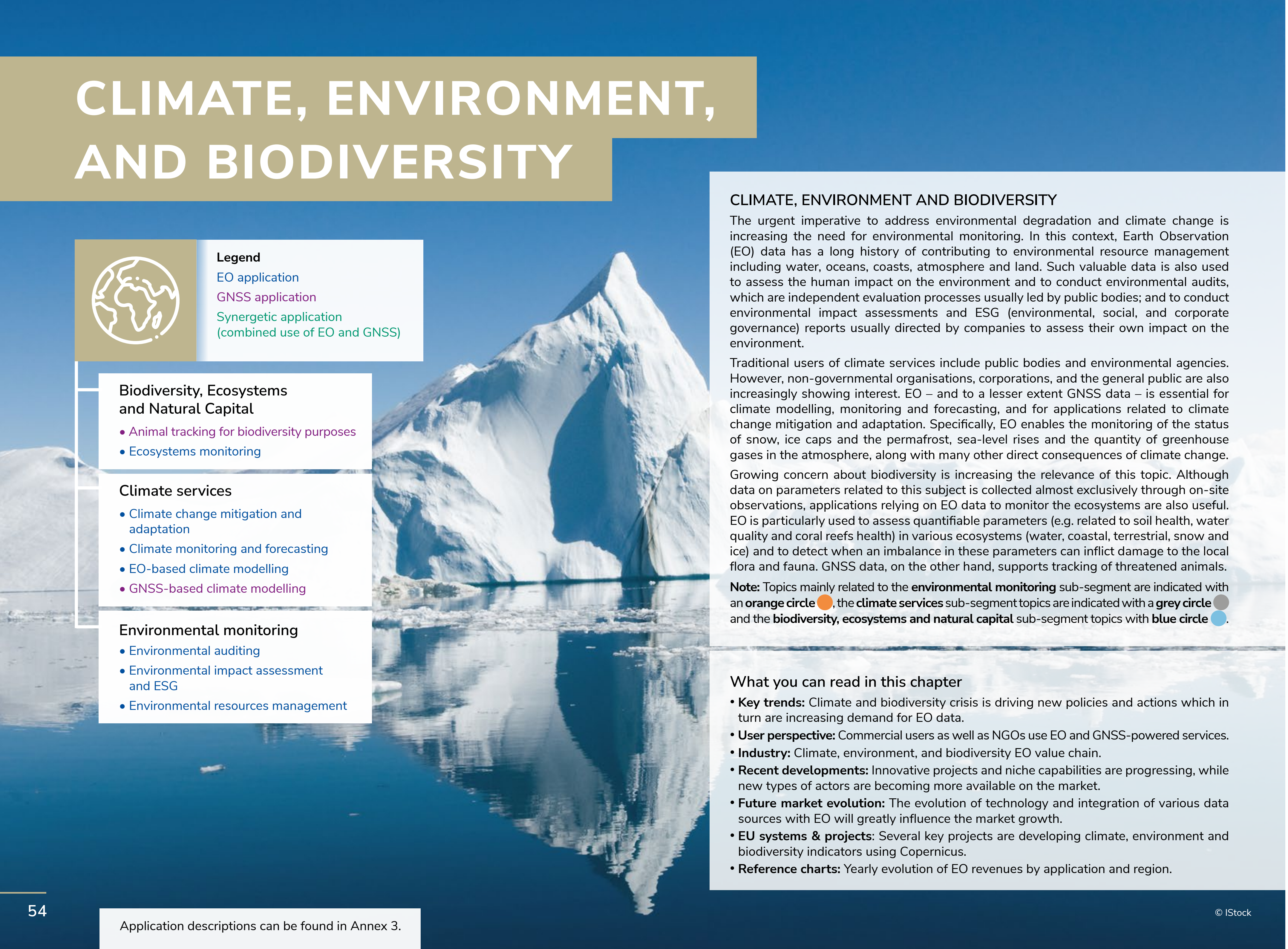


Revenue from GNSS device sales by application



NOTES
1. Certified Electronic Conspicuity devices relying on the aircraft's integrated GNSS receiver are included within the PBN application.
2. GADSS Aircraft Tracking will either use the GNSS receiver quantified under Performance Based Navigation, or Electronic Conspicuity (certified).
3. The model does not include any Innovative Air Mobility (IAM) applications (e.g. drone package delivery or Urban Air Mobility).

CLIMATE, ENVIRONMENT, AND BIODIVERSITY



Legend

EO application

GNSS application

Synergetic application (combined use of EO and GNSS)

Biodiversity, Ecosystems and Natural Capital

- Animal tracking for biodiversity purposes
- Ecosystems monitoring

Climate services

- Climate change mitigation and adaptation
- Climate monitoring and forecasting
- EO-based climate modelling
- GNSS-based climate modelling

Environmental monitoring

- Environmental auditing
- Environmental impact assessment and ESG
- Environmental resources management

CLIMATE, ENVIRONMENT AND BIODIVERSITY

The urgent imperative to address environmental degradation and climate change is increasing the need for environmental monitoring. In this context, Earth Observation (EO) data has a long history of contributing to environmental resource management including water, oceans, coasts, atmosphere and land. Such valuable data is also used to assess the human impact on the environment and to conduct environmental audits, which are independent evaluation processes usually led by public bodies; and to conduct environmental impact assessments and ESG (environmental, social, and corporate governance) reports usually directed by companies to assess their own impact on the environment.

Traditional users of climate services include public bodies and environmental agencies. However, non-governmental organisations, corporations, and the general public are also increasingly showing interest. EO – and to a lesser extent GNSS data – is essential for climate modelling, monitoring and forecasting, and for applications related to climate change mitigation and adaptation. Specifically, EO enables the monitoring of the status of snow, ice caps and the permafrost, sea-level rises and the quantity of greenhouse gases in the atmosphere, along with many other direct consequences of climate change.

Growing concern about biodiversity is increasing the relevance of this topic. Although data on parameters related to this subject is collected almost exclusively through on-site observations, applications relying on EO data to monitor the ecosystems are also useful. EO is particularly used to assess quantifiable parameters (e.g. related to soil health, water quality and coral reefs health) in various ecosystems (water, coastal, terrestrial, snow and ice) and to detect when an imbalance in these parameters can inflict damage to the local flora and fauna. GNSS data, on the other hand, supports tracking of threatened animals.

Note: Topics mainly related to the **environmental monitoring** sub-segment are indicated with an **orange circle**, the **climate services** sub-segment topics are indicated with a **grey circle** and the **biodiversity, ecosystems and natural capital** sub-segment topics with **blue circle**.

What you can read in this chapter

- **Key trends:** Climate and biodiversity crisis is driving new policies and actions which in turn are increasing demand for EO data.
- **User perspective:** Commercial users as well as NGOs use EO and GNSS-powered services.
- **Industry:** Climate, environment, and biodiversity EO value chain.
- **Recent developments:** Innovative projects and niche capabilities are progressing, while new types of actors are becoming more available on the market.
- **Future market evolution:** The evolution of technology and integration of various data sources with EO will greatly influence the market growth.
- **EU systems & projects**: Several key projects are developing climate, environment and biodiversity indicators using Copernicus.
- **Reference charts:** Yearly evolution of EO revenues by application and region.

Application descriptions can be found in Annex 3.

The escalating environmental urgency drives the emergence of new policies and markets, pushing further the need for data

Key market trends for environmental monitoring

- The urgent imperative to address environmental degradation and climate change leads to new important regulations and practices shaping the future of environmental monitoring
- EO data is increasingly being a key element to address environmental standards, which powers the emergence of integrated value chains
- EO data allows accurate monitoring of carbon sequestration efforts which will allow carbon removal markets to develop

Key new and upcoming regulations drive the need for data and services

The global environmental crisis is certainly (one of) the most pressing challenges our society faces today as we are all now facing the devastating consequences of a warming climate and environmental degradation. Actions to combat this changing environment is high on political, social, environmental and economic agendas worldwide.

The main **EU recent development** in this context is the European Green Deal, launched in 2019. It is a comprehensive package of policies and initiatives aimed at making the EU climate-neutral by 2050. Under the Green Deal, there are several new and upcoming regulations linked to environmental monitoring. Firstly, the new rule on Corporate Sustainability Reporting Directive (CSRD) which complements the EU's legacy ESG reporting program - the Non-Financial Reporting Directive (NFRD) -, requires a large set of companies to disclose information on the risks and opportunities arising from environmental issues and to report on the impact of their activities on the environment beyond just carbon, including pollution, water, waste, and biodiversity. Secondly the new regulation to fight deforestation, which recently entered into force (2023) obliges companies to ensure products sold in the EU have not led to deforestation and forest degradation. In the same vein, the EU Critical Raw Materials Act (2023) ensures secure and sustainable supply chains for raw materials. Finally, there is the new legislation for Carbon Removal Certification on which the EU is currently working. It aims to develop the necessary rules to monitor, report and verify the authenticity of these removals. At **global level**, the United Nations Sustainable Development Goals (SDGs) are also increasingly addressing environmental challenges.

In this policy context, understanding our impact on the environment and obtaining unequivocal evidence of the changes taking place are key, with EO being one the major tools used for the monitoring of various environments including **water, oceans, coasts, atmosphere and land**.

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While reporting standards are being further defined, EO data powers the emergence of integrated value chains

Verifying the impacts of activities on the environment requires rigorous data and analyses. In this context, establishing **standards** and methods is crucial for **consistency, comparability and quality assurance**. Various associations and initiatives are now providing guidance and standards to report such impacts and several of them place EO as a central part of the process. This is the case of the European Financial Reporting Advisory Group (EFRAG) which is currently working on upcoming guidance for companies to report in the context of the European Sustainability Reporting Standards (ESRS). Another interesting initiative, directly involving EO, is the recent EUSPA powered "EU Space for Green Transition" report, which helps companies to monitor their sustainability targets.

These new standards and guidance, together with the rise in demand for data, the growing availability of EO data and technology progresses, create an ideal environment for the emergence of new integrated value chains. In this context, various **startups** have seized the opportunity to bring EO into the portfolios of environmental information providers for applications such as **impact assessments, risk assessments, legal audits, damage evidence, law enforcement and environmental resources management.** Further down in the value chain, **governments** are using EO for compliance monitoring and assessing their own environmental impact.

An emerging role for EO data in carbon removal markets

To reach the EU objective of climate neutrality by 2050, there is a strong need to reduce carbon emissions but also improve carbon removals – activities and technologies that remove carbon dioxide from the atmosphere. The **carbon removal market** is boosted by the upcoming Carbon Removal Certification (cited earlier) and various financial incentives for activities, such as **afforestation, reforestation, carbon farming and direct air capture**.

A primary obstacle faced by carbon removal markets is the ability to accurately measure and quantify carbon removals. **The availability of data supporting these measurements is essential for the establishment and functionality of such markets.** In this regard, EO plays a key role in the identification of areas for afforestation/reforestation/restoration, in monitoring seasonal productivity and ongoing carbon sequestration actions, and in estimating ground biomass.

Currently, EO data is being used on a modest but increasing number of specific carbon capture projects, such as green urban spaces and planting trees on specific farmlands. We expect the number of projects using EO to greatly increase soon, especially in the context of the Carbon Removal Certification.

Improved models and services are being developed to address climate change efficiently

Key market trends for climate services

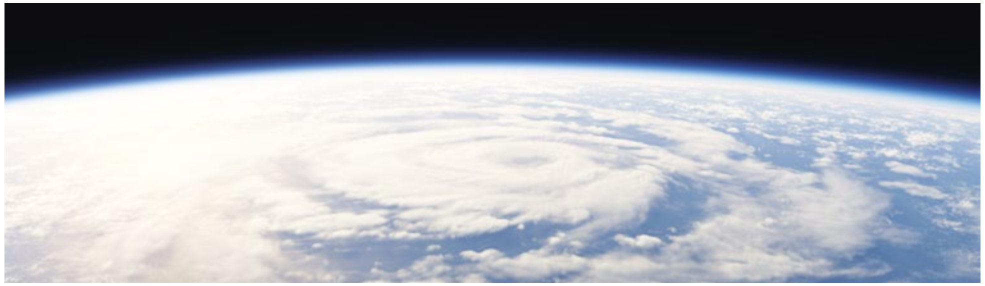
- Recent climate-related policies and investments increase the quantity of projects related to climate mitigation and adaptation
- The topic of climate resilience is rapidly gaining prominence as a major focus area
- The use of EO is essential to improve climate models and projections

Numerous climate-related policies, initiatives and decisions at EU and global level are driving the need for data

In recent years, a significant shift in countries' approach to climate change has occurred due to investment trends and forward-thinking decisions. At the **global level**, important international cooperations and projects, such as the **Paris Agreement**, the **Global Environment Facility (GEF)** and the **SDGs**, are increasingly pushing decision-makers to address climate change. More recently, the **United States' return to the Paris Agreement** (2021) is also an important event worth noting in favour of climate change mitigation worldwide. Another notable development on the global stage has been the integration of recommendations on **climate-related risks into the regulatory frameworks of several jurisdictions**. According to a Deloitte study (2023), countries such as Singapore, Canada, Japan and South Africa, have taken proactive steps recently to ensure that businesses and industries operating within their borders account for environmental risks in their strategies and operations, with many more countries soon to follow.

At EU level, the momentum for change involves pioneering decisions. A recent significant milestone is the allocation of one third of the massive €1.8 trillion of investments budgeted in the NextGenerationEU Recovery Plan to fund the European Green Deal. This colossal investment, pushing green innovation as a priority, shows the EU's commitment to be a global leader in environmental stewardship and economic recovery. Also embedded within the green deal, the EU's climate strategy encompasses policies and measures to significantly reduce greenhouse gas emissions, accelerate the transition to renewable energy sources and foster green innovation across various sectors.

In tandem, the EU Climate Adaptation Strategy, also a pivotal component of the Green Deal, underwent a crucial update in 2021. This strategy is designed to enhance the EU's resilience to the inevitable impacts of climate change, ensuring that communities, infrastructure and ecosystems are better prepared to withstand and recover from climate-related challenges, such as extreme weather events and rising sea levels.



Climate resilience is not just a keyword but a common goal driving the transformation of value chains

Climate resilience is about preparing for the inevitable consequences of climate change. This includes fortifying infrastructure, enhancing natural ecosystems, improving disaster preparedness, and fostering social and economic systems that can endure and bounce back from the challenges posed by a warming planet.

EO specific applications in climate resilience are various. For example, EO data helps monitor the **health of ecosystems and natural resources**, such as forests, wetlands, and oceans affected by climate change or to provide **timely warnings and accurate forecasts on extreme weather events** that enable communities to prepare and respond effectively, reducing the impact of these events. EO data also helps **manage water resources** by monitoring precipitation, snow cover, and river levels affected by climate change. This information supports efficient water allocation, drought mitigation and flood control measures.

With the recent and upcoming regulations pushing businesses and industries from various countries to account for environmental risks in their strategies and operations or to disclose such information, **a whole value chain is emerging with regards to climate risks**. Information providers make use of EO data to pioneer innovative services while standardisation bodies, such as the Task Force on Climate-related Financial Disclosures (TCFD), are gaining international recognition, facilitating the integration of climate resilience metrics into financial and business frameworks.

EO helps to improve climate models

Climate models provide crucial information for policymakers, government agencies, and international organisations in formulating **climate policies and strategies**. They take into account various factors, such as atmospheric conditions, ocean currents and greenhouse gas emissions, to understand interactions between the different components and make projection.

Climate modelling is in a state of continuous evolution as researchers refine existing models and create new ones, incorporating the latest scientific discoveries, data and computing capabilities. In this context, EO is a central tool in improving climate models. According to the OECD (2017), satellite data provides significant contributions to more than half of the 50 essential climate variables that are currently in use. A perfect illustration of such contribution is the EU Destination Earth project which combines EO data and AI-based climate modelling to develop a comprehensive digital model of the planet, enabling a deeper understanding of climate change impacts and informing effective mitigation strategies.

The urgent need to protect biodiversity is triggering the use of EO

Key market trends for biodiversity, ecosystems and natural capital

- The recent growing concern about biodiversity brings this topic to the centre of many new policies, funds and events
- A new market focused on supplying data to facilitate nature/ecosystems monitoring is emerging
- Ecosystem conservation and restoration projects are increasingly relying on EO

Protection and monitoring of biodiversity is becoming a major driver for EU and global policies, funds and events

Biodiversity is increasingly becoming the number-one priority in the development of new policies and initiatives, both within the EU and on a global scale.

At the global level, key milestones like UN Biodiversity Conference (COP 15) in 2022 underline the international community's dedication to safeguarding the Earth's biodiversity. Additionally, a significant step was taken in August 2023 when the Global Biodiversity Framework Fund (GBFF) was launched in Vancouver. This innovative fund aims to mobilise investments for the conservation and sustainability of wild species and ecosystems. With representatives from 185 countries in the agreement, the GBFF is set to attract funding from governments, philanthropic organisations, and the private sector.

Within the EU, the Green Deal encompasses the recent EU 2030 Biodiversity Strategy, which lays out comprehensive goals to halt biodiversity loss and restore Europe's natural environments by the end of the decade. Furthermore, the EU's dedication to biodiversity protection is marked with initiatives like Natura 2000 sites, which aim to safeguard critical habitats, while the pioneering proposals to restore Europe's nature by 2050 and halve pesticide use by 2030 underscores the EU's long-term commitment to this cause. Initiatives, previously mentioned, such as the Corporate Sustainability Reporting Directive (CSRD), also place a particular focus on biodiversity within the corporate sphere, encouraging responsible practices.

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A new market centred around the provision of data in support of nature/ecosystem monitoring is emerging

In the evolving landscape of biodiversity conservation, we observe the rise of an **emerging market centred around the provision of data**. This trend extends to the **financial sector**, which is increasingly engaging with biodiversity-related initiatives and driving the development of new service providers and standardisation bodies, such as the Taskforce on Nature-related Financial Disclosures (TNFD). Recognising the potential in this sector, **investors** are also pouring significant capital into these emerging data markets, allowing them to flourish.

Although the role of EO in this market is not as evident and key as it is for climate services (see previous page), **EO applications are developing in this field.** In this context, **startups, established corporations, and major non-governmental organisations (NGOs)** are gradually incorporating EO data into their operational workflows to enhance their understanding of biodiversity, ecosystems and natural capital.

Ecosystem conservation and restoration projects are increasingly relying on EO data

Ecosystems conservation and restoration efforts are underway on a vast scale worldwide, and the increasing significance of EO data in these initiatives is becoming more apparent.

This includes **coral reef ecosystem monitoring** for which EO data offers information about global ocean acidification, 3D models of the entire Great Barrier Reef and detection of change for coral reef health. For example, Sentinel-2 has been used for a number of years to monitor the bleaching of Australia's Great Barrier Reef. Other rich ecosystems are **wetlands** for which EO data offers precious information about their classification, habitat or biodiversity, biomass estimation, plant leaf chemistry, water quality, mangrove forest and sea level rise. A third type of ecosystem is **grassland** for which EO offers data on changes in biomass, overgrazing, grass maturity and density, informing for example grazing strategies.

An illustration of the role of EO is its integration into policies such as the monitoring of Natura 2000 sites – covering over 18% of terrestrial and 8% of marine EU territory. This initiative has seen the development of specialised Copernicus products like the Copernicus Land Monitoring Service (CLMS) Natura 2000 Land Cover product. Another recent highlight of the CLMS is the High-Resolution Vegetation Phenology and Productivity **(HR-VPP) service** released in 2021, which improved the **monitoring of vegetation dynamics** and allowed climatic and anthropogenic impacts on ecosystems to be assessed. Furthermore, the International Union for Conservation of Nature (IUCN), a global organisation comprising government and civil society organisations, has created a global typology for Earth's Ecosystems, acknowledging the critical role of remote sensing within it.

Users across the entire Climate, Environment, and Biodiversity value chain use EO and GNSS-powered services

Companies and institutions monitor their impact on the environment

Companies and institutions are under rising pressure from stakeholders, including customers, investors and regulatory bodies, to take proactive steps towards environmental responsibility. While companies and other institutions are increasingly required to monitor their environmental impact, they face challenges in finding the right data and metrics. This drives the emerging market of data/service providers to innovate and progressively integrate EO in its offer to help companies monitor their impact on the environment.

There are many instances of how companies can monitor their impact on the environment with EO data; they can monitor **land degradation** by estimating vegetation cover loss, vegetation health, erosion patterns, and changes in soil properties. Specifically, **soil degradation** can be monitored through EO by mapping different soil physiochemical properties such as soil organic carbon, salinity and nitrogen. Companies can also monitor **pollution/degradation of the marine ecosystem** by, for example, monitoring water turbidity (e.g. when performing harbour extension or dredging activities) or monitoring the development of algal bloom (which can be a sign of polluted waters) measured by the level of chlorophyll, a green pigment found in algae and plants.

Environmental centres use EO to monitor various ecosystems

Environmental centres, such as Conservation International and Eurac Research, need to tailor their missions to align with the unique characteristics of their region and the specific issues they are addressing. To support their undertakings, the availability and quality of EO services for monitoring ecosystems are improving. Some environmental centres even develop their own services to adapt to the specificities of their regions. Upcoming services, such as the ones triggered by the Cassini Maritime Prize led by EUSPA, will also be useful for environmental centres to **monitor and remove plastic in oceans and waterways**.

In **coastal areas**, environmental centres can use EO for coral reef monitoring, coastal erosion or coastal habitats monitoring. Applications are also applicable for **terrestrial areas**, such as land cover and vegetation monitoring. Finally, **snow and ice ecosystems** are intensively monitored by environmental centres, especially since they are strongly impacted by climate change.

Ecologists use GNSS for animal tracking

Ecologists need to track animals for conservation and scientific research as it provides data on animal behaviour, migration, and habitat use, contributing to biodiversity preservation and ecosystem health.

In this mission, **ecologists use specialised collars, tags or implants equipped with GNSS receivers**. It has revolutionised animal tracking, enabling researchers to study wildlife behaviour on a fine scale and gain a deeper understanding of their needs. The data obtained from GNSS on animal tracking helps ecologists, together with policymakers, to make informed decisions for wildlife conservation and management. It also helps identify critical habitats, migration corridors and areas where animals may be at risk due to human activities or environmental changes.

Sharing such data also significantly helps ecologists in their research or decisions. An example of project in this regard is Movebank, **a free platform on** which thousands of researchers manage and share data. The platform hosts more than 7 500 animal tracking studies, many of which have made their data available for anyone to view and download.

Sources of key EO and GNSS user requirements

The key EO and GNSS user requirements for the different application groups within the **climate, environment and biodiversity** segment are collected using a harmonised procedure at EU level.

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 Climate, Environment and Biodiversity user needs and requirements (starting with the 2023 UCP session on Environment). User requirements for Earth Observation (EO) services and products – as well as their evolution – are now also collected through the UCP. The process covers the EO user needs and requirements of commercial users based on inputs from industry experts and user groups, mirroring the existing process implemented for GNSS.

Moreover, the collection of specific requirements for Copernicus services and products is supported by 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; and (iii) regular and structured exchanges among representatives of the Copernicus governance structure and Member States through the Copernicus User Forum.

Climate, Environment, and Biodiversity EO Value Chain[1]

EARTH OBSERVATION	DATA PROVIDERS	INFRASTRUCTURE PROVIDERS	PLATFORM PROVIDERS	EO PRODUCTS AND SERVICES PROVIDERS	INFORMATION PROVIDERS	END USERS
Commercial offering	• AIRBUS* • BLACKSKY • CAPELLA SPACE • E-GEOS* • EARTH-I* • GEOSAT* • GHGSAT • ICEYE* • MAXAR • NEC • PLANET • SATELLOGIC* • UMBRA	• AWS • CLOUDFERRO* • GOOGLE CLOUD PLATFORM • IBM CLOUD • MICROSOFT AZURE • SERCO • T-SYSTEMS*	• CLOUDEO* • CREODIAS* • EARTH-I • EDS CEODE • EURODATACUBE* • GOOGLE EARTH ENGINE • NORTH.IO* • OPEN DATA CUBE • PLANET EXPLORER • SENTINEL-HUB* (SINERGISE) • UP42*	• 4 EARTH INTELLIGENCE* • BERRING DATA COLLECTIVE* • CLIMATESCALE* • CONSTELLR* • CYBELE* • ECOMETRICA* • E-GEOS* • EOLAB* • EOMAP* • GEOVILLE* • LOBELIA* • MEEO* • OHB* • OVERSTORY* • PLANETEK* • SATELLIGENCE* • STRATOLLOON* • WATER INSIGHT*	• AIRQAST* • CLIMATE ANALYTICS • DELTARES* • DYNAMHEX • EARTHSENSE* • FORA FOREST INTELLIGENCE* • JUPITER INTELLIGENCE • KAYRROS* • PACHAMA • SINGLE.EARTH* • WORLD FROM SPACE*	
Public offering / entities	• COPERNICUS SENTINELS* • LANDSAT (USGS) • METEOSAT (EUMETSAT)* • RADARSAT (CSA) • RELEVANT IN-SITU NETWORKS • RELEVANT EUROPEAN NATIONAL MISSIONS*	• FEDERATED INFRASTRUCTURE (E.G. GAIA-X)* • SENTINEL COLLABORATIVE GROUND SEGMENT*	• CLIMATE ADAPT* • COASTAL TEP* • CODE-DE* • COPERNICUS DATASPACE ECOSYSTEM* • FORESTRY TEP* • WEKEO*	• COPERNICUS ATMOSPHERE MONITORING SERVICE (CAMS)* • COPERNICUS CLIMATE CHANGE SERVICE (C3S)* • COPERNICUS MARINE SERVICE (CMEMS)* • COPERNICUS LAND MONITORING SERVICE (CLMS)* • GLOBAL FOREST WATCH	• CLIMATE TRACE	
User segments						• CORPORATES • DUTY HOLDERS • ENVIRONMENTAL AGENCIES • ESG AUDITING AND CERTIFICATION PROVIDERS • FINANCIAL INSTITUTIONS • GENERAL PUBLIC • INSURANCE PROVIDERS • INTERNATIONAL AGENCIES (E.G. UN) • JUDICIARY • LEGAL PRACTITIONERS • NGOS • POLICY MAKERS

LEGEND

- Commercial offering
- Public offering / entities
- User segments

European[2] EO industry in the global arena

In 2021, there were more than 100 active European EO companies in the climate, environment and biodiversity segment. Europe had a share of nearly half of the global market. Top European companies in this segment include Airbus, Leonardo (e-GEOS), and Serco.

NOTES

[1] The value chain considers the key global and European companies involved in EO downstream activities. Please note that enterprises listed in the data providers step of the value chain often provide platforms as a service. For the sake of simplicity the data providers are not repeated in other stages of the value chain in which they are active.

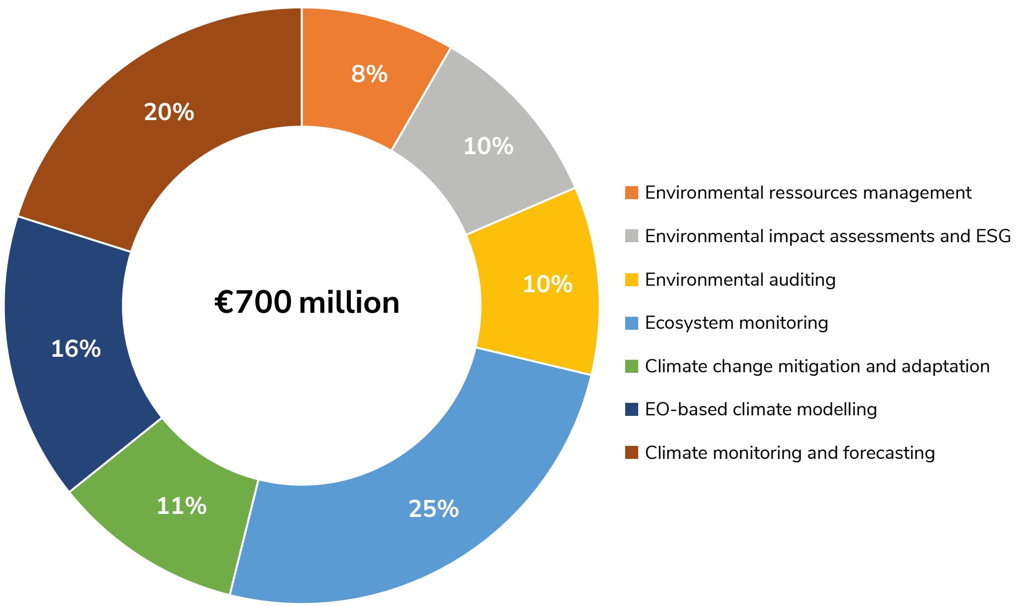
[2] In the market share analysis, Europe is defined as EU27 plus Norway, Switzerland and the UK.

Please refer to page 13 for a comprehensive description of the EO value chain and how to interpret them at segment level.

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

EO is a key tool for major international organizations

Revenue from EO data & services sales by application 2022



Climate, Environment, and Biodiversity EO data and services sales amounted to around €700 million in 2022. Recent (extreme weather) events around the world are **driving the demand for climate (physical risk) monitoring and forecasting** for a large variety of customers and assets. Specialised risk analyses are in high demand by asset managers, to build resilience against climate change. As **many climate models incorporate EO data and services,** this demand is considered a strong growth driver in the segment, and explains how climate services account for approximately half of the forecasted revenue share in this segment.

Biodiversity and environment applications each account for a quarter of the sales revenues. A major growth driver for these applications are new **environmental regulations**, such as **legally binding EU nature restoration targets** that are subject to impact assessments, many of which can benefit from EO data and services. Furthermore, increased demand for such services is foreseen in the commercial sector due to share- and stakeholders **demanding comprehensive environmental impact mitigation efforts**.

EO supports latest UN climate report

The latest UN climate report released in 2023 emphasises the urgent need for climate action to secure a sustainable future, highlighting multiple feasible options to reduce greenhouse gas emissions and adapt to climate change. EO is inherent to this report, serving as an integral component of the evidence-based evaluation of climate change effects on terrestrial, aquatic, coastal, atmospheric, mountainous and polar environments. This is especially crucial in regions where direct on-site measurements are not feasible. The largest contribution is done particularly through **ESA Climate Change Initiative (CCI)**, a long-term satellite observation datasets.

According to the European Space Agency (2023), this report features a more substantial contribution of EO data than previous iterations, while such data serves as irrefutable physical evidence of the shifts occurring in our planet's climate system. From the alarming rise in sea levels to the surge in greenhouse-gas emissions and the melting of sea ice, EO data stands as a crucial pillar in validating these critical findings, emphasising the urgency of collective global action to combat climate change.

NGOs are increasingly integrating EO

Biodiversity and environmental NGOs are starting to recognise the advantages of integrating EO into their fundamental operations. This **shift towards EO technology** has been instrumental in enhancing the effectiveness of conservation efforts worldwide. An exemplary illustration of this transformation is the GLOBIL initiative, an online ArcGIS toolkit developed by the **World Wide Fund for Nature (WWF)**. This innovative toolkit serves as a valuable resource for supporting ecosystem conservation initiatives across the globe. It consolidates geospatial data and readily available resources, empowering both WWF staff and partner organisations to make informed decisions and take targeted actions to safeguard our planet's biodiversity. In addition to these large organisations, smaller NGOs are also increasingly using EO data to validate and monitor the successful implementation of their biodiversity-focused projects, further illustrating the growing importance of EO for biodiversity, ecosystems and natural capital conservation.

JRC latest development from a market point of view

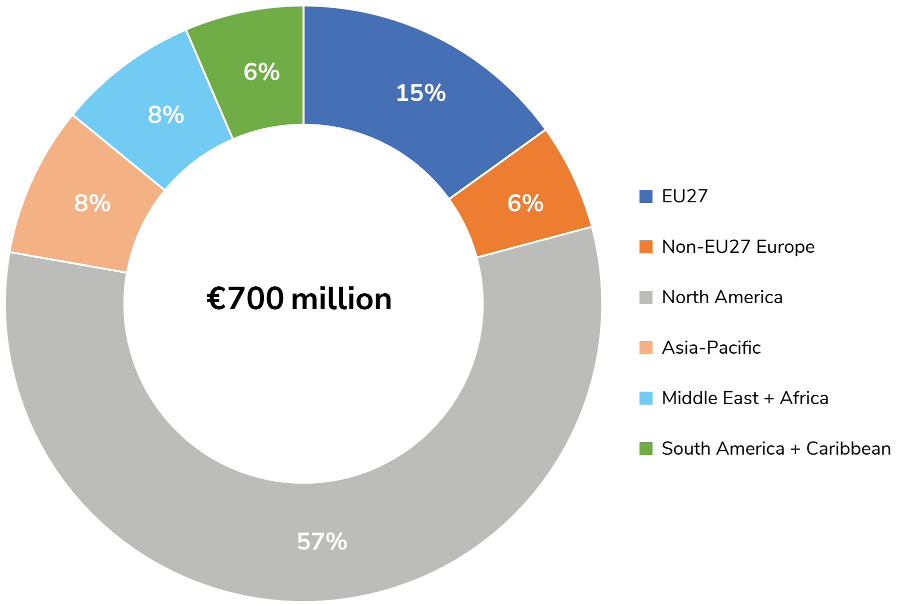
The establishment of the Knowledge Centre on Earth Observation in 2021 by the EU Joint research Centre (JRC) marks a significant development with substantial market implications. This initiative aims to provide essential support for effectively realising the European Commission's key political priorities, notably the **European Green Deal** and the Digital Agenda. The JRC's dedicated efforts have far-reaching consequences for various market sectors, with a particular focus on applications related to wetlands, biodiversity investments, agricultural landscapes and marine protected areas.

The central role of EO for climate change adaptation and for environmental compliance assurance

The breakdown in terms of region shows that **North America has the greatest share** of the market (around 60%) in terms of EO data and services sales in 2022. This may be explained due to a history of frequent extreme weather events in this region, such as hurricanes and floodings, as well as the **capacity of its technological private sector to address the needs of customers in this specific segment**.

The remaining revenues are split evenly between Europe and the rest of the world, each accounting for approximately one-fifth, or around €150 million, in sales. When comparing these numbers to North America, it shows clear potential for growth in these geographical areas, driven by existing and upcoming climate and environmental monitoring regulations as well as commercial demand.

Revenue from EO data & services sales by application 2022



The increasing role of EO in environmental compliance assurance

Environmental compliance assurance refers to a range of measures and regulations put in place to protect the environment. It includes **rules, permits, monitoring and enforcement actions** designed to ensure that individuals, businesses and organisations comply with environmental laws and regulations. The goal is to prevent and mitigate environmental harm, such as pollution, habitat destruction and overexploitation of natural resources.

The role of **EO spans the entire policy cycle**, beginning with the preparation and design of new environmental policies for which EO data provides insights into the current environmental landscape and relevant technical parameters. During the implementation phase, EO data continues to be indispensable, facilitating monitoring and compliance checks, thereby ensuring that environmental regulations are adhered to effectively. Finally, in the evaluation phase, such data enables comprehensive before-and-after comparisons of environmental conditions, offering concrete evidence of significant changes.

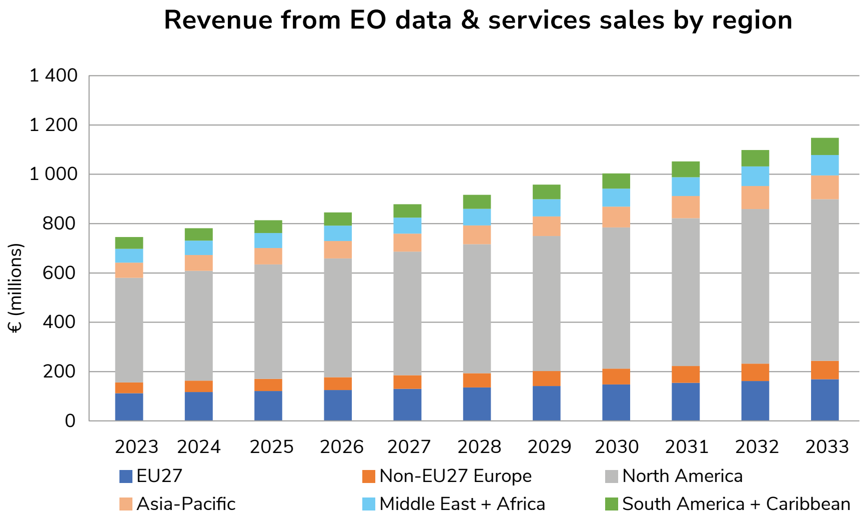
As illustrative examples, **Sentinel data** is being used in some regions to monitor illegal use of ground water thanks to the monitoring of land subsidence due to aquifer exploitation with Sentinel-1 (SAR Interferometry) together with the monitoring of greenness of crop and vegetation in dry regions with Sentinel-2 (high-resolution optical images) and also Sentinel-1 which reveals information about the plant's structure and how much water is in the plant. Additionally, according to a study from EARSC on Water Quality in Finland (2022), Sentinel data had been used to assess turbidity levels resulting from local dredging activities that were harming biodiversity.

EO in support of a resilient society

EO data plays an essential role in climate change adaptation, particularly in **assessing risks associated with water scarcity, sea-level rise, flooding, irregular water streams, deforestation and extreme heat**, offering a comprehensive understanding of changing climate conditions. Such data allows precise information on factors like changing precipitation patterns, forest cover, temperature anomalies, and water body conditions to be collected. It then **supports informed decision-making in developing strategies and policies** to mitigate climate-related risks, enhance resilience, and plan for sustainable resource management and infrastructure development.

In September 2023, a workshop on Copernicus and Climate Adaptation reviewed challenges and opportunities for climate adaptation across Copernicus, Earth Observation and the policy landscape. It highlighted the recent developments such as **improvements in seasonal and short-term predictions** allowing, for example, risks linked to **urban hazards** to be better assessed and improving adaptation strategies. Its applications range from better **winter street maintenance** to **reducing exposure of vulnerable populations to heat waves**.

EO utilisation for ESG practices and court proceedings is expected to grow



EO data and services sales in the Climate, Environment and Biodiversity segment are expected to exceed €1 billion by 2031. **The average predicted yearly growth exceeds 4%** and is similar across all regions and all years. **North America is expected to remain the largest geographical actor in the forecast**, building on its well established market share.

The growth in this sector is driven by initiatives such as the Paris Agreement, the Global Environment Facility (GEF), and the SDGs, **which drive demand for environment and climate related applications in institutions and companies across the world**. Regions with the fastest forecasted growth include Asia-Pacific and Non-EU27 Europe, in part driven by **increased capabilities of local service providers** to address climate, environment and biodiversity related needs and applications.

Increasing utilisation of EO data as evidence in legal and court proceedings

EO data serve as persuasive evidence in several **environment-related legal cases**. For instance, EO data can offer high-resolution satellite imagery illustrating changes in **land use and deforestation**, aiding in cases involving illegal land clearing or environmental violations. Moreover, EO data can capture indicators of **climate change impacts**, such as rising sea levels or altered vegetation cover, helping establish causal links between human activities and environmental consequences. It can also detect and monitor **pollution sources**, supporting lawsuits against polluters and quantifying environmental damage. EO data help the assessment of biodiversity changes, habitat loss and the presence of endangered species, underlining ecological value and challenging threats to protected areas. Finally, EO data provide insights into **urban planning**, aiding assessments of construction project compliance with environmental regulations.

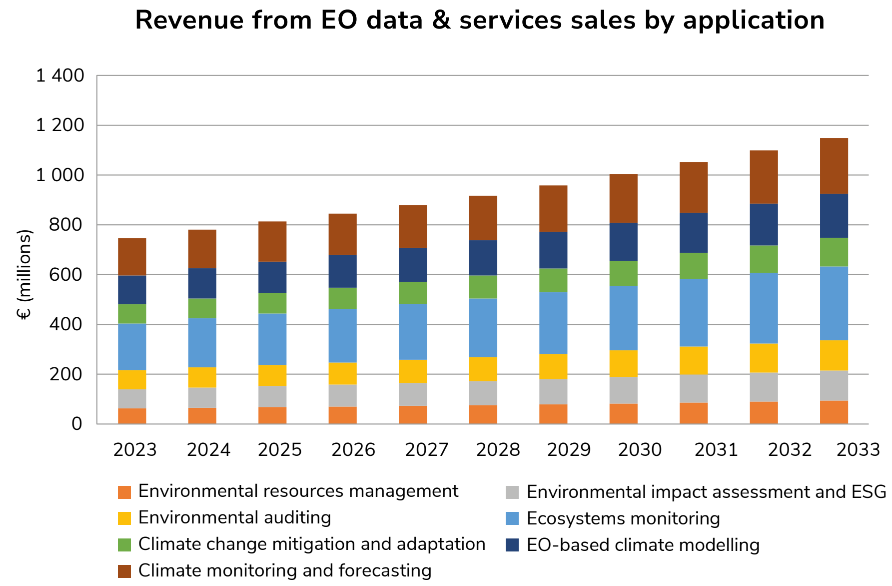
While the use of EO data in legal proceedings is currently limited to isolated instances, we anticipate a ripple effect as its usage in court becomes more widespread. This is particularly promising knowing that such images **facilitate common understanding**, making it easier for everyone involved in the court decision to understand the situation as it provides a clear and common basis for discussion and analysis.

An increasing number of organisations will adopt EO data for environmental monitoring

The increase in environmental reporting is partly driven by the new EU Corporate Sustainability Reporting Directive (CSRD) – which requires a large set of companies to disclose information on the risks and opportunities arising from environmental issues, and on the impact of their activities on the environment beyond just carbon, including pollution, water, waste and biodiversity. Such an increase in environmental reporting is also influenced by the growing pressure from customer and investor expectations, the need for effective risk management, brand reputation considerations, talent attraction, employee retention and alignment with core values.

However, accurately assessing and mitigating companies' environmental impacts is not an easy task. In this context, **various large companies are starting to rely on EO data to fulfil their environmental commitments, while it enables consistent and comparative analyses at a continental scale**. For example, it can provide information on land cover to show the absence of deforestation or reforestation efforts, which is useful to certify deforestation-free production of commodities (e.g. palm oil and cocoa) in line with the recent regulation that obliges companies to ensure products sold in the EU have not led to deforestation and forest degradation. EO is also useful for providing data on atmospheric gas emission and evidence on the absence of pollution, such as oil spills in drilling sites.

Developments in technology will improve the significance of EO in the field of climate modelling and forecasting



Predicted growth is similar across the applications with an average of over 4% per year. Climate related applications, due to the **increased demand for specialised risk modelling and climate resilience building**, are forecasted to retain the majority of market share. Service providers that are able to use and interpret climate projections, and turn these into actionable insights, will continue to be high demand in the coming decade.

Slightly higher growth of around 5% per year is forecasted for environmental and ecosystem monitoring applications as uptake opportunities are increasing worldwide, **driven by regulations and commercial market demands**, which for example require monitoring of habitat degradation and impact on natural resources. Space-based data and services provide an economical alternative to in-situ data collection, further driving the need for such services in this segment.

DestinE will use unprecedented EO and AI capabilities to address climate change

The European Commission's flagship initiative, Destination Earth (DestinE), aims to create an exceptionally **precise digital representation of Earth** by the end of this decade. This model's purpose is to observe and simulate both natural processes and human behaviours, facilitating the testing of scenarios for more sustainable development and the support of European environmental policies. DestinE aligns with the European Commission's Green Deal and Digital Strategy, contributing to the twin transitions (both green and digital) by monitoring and predicting the interplay between nature and human activities on a global scale. This initiative will allow users to explore the consequences of different strategies to tackle climate change by testing a range of scenarios and mitigation strategies.

DestinE will enhance our readiness to address significant natural calamities, adjust to climate change and forecast the socioeconomic consequences. Additionally, this endeavour plays a crucial role in the European Data Strategy by centralising access to valuable data resources throughout Europe.

The already powerful climate modelling and forecasting tools will be further strengthened/renovated

According to the European Centre for Medium-Range Weather Forecasts (ECMWF) factsheet on reanalysis (2023), it is an important process that will improve climate modelling and forecasting tools. It compiles comprehensive historical weather and climate data by blending past observations with previous short-term weather forecasts to rerun modern forecasting models. These datasets, often called 'maps without gaps', offer a globally complete and time-consistent view of Earth's past conditions filling gaps in the observational record in a consistent time frame, minimising erroneous signals of change.

Reanalysis is crucial for **understanding climate change and extreme weather events since historical observations**. Users can access ECMWF (European Centre for Medium-Range Weather Forecasts) reanalysis data through the EU-funded Copernicus Climate Change Service, notably ERA5, which covers data from 1940 onward and provides information on various Earth variables. Reanalysis data find application in climate monitoring, research, education, policymaking and industry sectors like renewable energy and agriculture. Future developments include detailed datasets based on ERA5 and the planning of ERA6, a coupled reanalysis incorporating both atmospheric and ocean observations for a more balanced Earth system climate reconstruction.

Improvements in the use and integration of data will drive the EO market while coastal ecosystems will increasingly be monitored

Coastal areas will be increasingly monitored, with EO playing a crucial role in the process

Coastal ecosystems serve key roles as reservoirs of biodiversity and provide ecosystems services for millions of people such as coastal protection against wave action, and recreational activities. However, many factors are affecting these fragile ecosystems such as sea-level rise, sea temperature rise, pollution and contamination, recreational activities, unsustainable fishing practices and urbanisation. These factor make it a particularly sensitive area and its evolution can be dramatic, which is why focus is increasingly being directed towards these ecosystems.

In parallel, the role of EO data in monitoring the above factors is also important. Such data complement field measurements and provide useful information to map the **hydromorphological** (freshwater discharge, currents, shoreline evolution), **physico-chemical** (water transparency, temperature, salinity, oxygen, nutrients, and pollutants), and **biological** (habitats, phytoplankton blooms) properties of the coastal zones.

The evolution of technology and integration of various data sources with EO will push the boundaries of ecosystem monitoring applications

In the coming years, the biodiversity and ecosystems monitoring markets will experiment significant growth, involving a growing demand for data, including EO data. However, the exact role of EO data in this expanding market is difficult to predict as it depends on the evolution of various factors.

A key factor is the integration of EO data with **citizen science** initiatives and **crowdsourcing** platforms, which facilitates large-scale data collection and engages the public in biodiversity monitoring. This collaborative approach is already manifesting in projects including water resources, forest and land use monitoring. Additionally, the field is witnessing a significant evolution of **in-situ technologies** which are increasingly being merged with EO technologies to enhance ecosystem monitoring across various applications. One of latest interesting developments in this field is the monitoring of environmental DNA (eDNA) which are the traces of DNA that organisms leave as they move through their environment. Furthermore, the **consolidation of diverse data sources into single platforms**, as demonstrated by initiatives such as the EuropaBON project, which integrates data streams to support policy, promise to significantly elevate data quality. Lastly, as technology improves, with the **evolution of Sentinel missions and the anticipated launch of private satellite constellations**, EO data quality will also improve, which is a critical element in the success of ecosystems monitoring.

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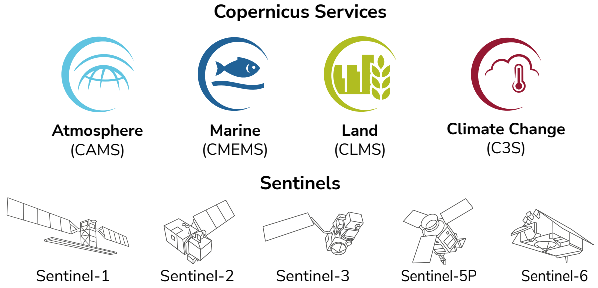
Current usage of Galileo and Copernicus in the Climate, Environment and Biodiversity segment



Current usage of Copernicus for environmental monitoring

Extensive usage of Copernicus data and services is made 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 and atmospheric emissions). This range of possibilities offered by space technologies to face environmental and climate challenges is detailed in the UN report on EU Space supporting a world of 8 billion people.

Data can also be provided to support Member States and bodies in reporting under directives. This is the case, for example, of the **European Marine Observation and Data Network** (EMODnet) catalogue released in June 2021 by the **Copernicus Marine Service (CMEMS)**. The catalogue aims to support Member States in the implementation of the Marine Safety Framework Directive which itself also includes environmental protection.

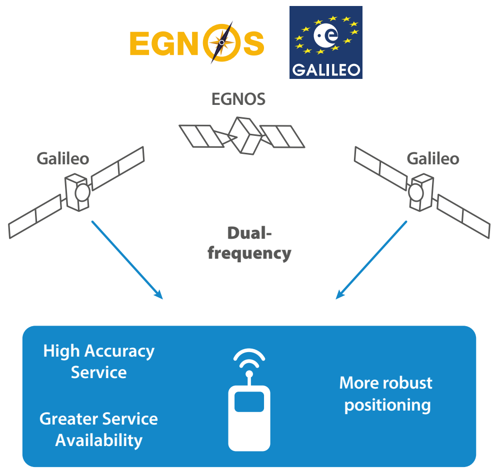
Current usage of Copernicus for climate services

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 to support 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 Copernicus for biodiversity monitoring

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.

Additionally, the CLMS released the **High Resolution Vegetation Phenology and Productivity (HR-VPP) service in 2021**, which improves the monitoring of vegetation dynamics and allows the assessment of climatic as well as anthropogenic impacts on ecosystems.



Current usage of EGNSS for climate services

Although there is limited use of GNSS and thus EGNSS within the climate domain, several techniques such as GNSS radio occultation sounding and GNSS Reflectometry support climate modelling. Both techniques can benefit from improved performances offered by Galileo and its services. More specifically, Galileo provides enhanced signal availability and accuracy at high latitudes compared with other GNSS systems. This is particularly important for **climate modelling**, as accurate positioning data in these regions helps scientists monitor and predict climate changes happening in polar regions. Additionally, Galileo offers faster and more **frequent updates of positioning information**, enabling more rapid updates of meteorological measurements. This is crucial for real-time monitoring, forecasting and early warning systems.

Current usage of EGNSS for biodiversity monitoring

Biologists, scientific researchers, or conservation agencies are interested to remotely monitor the relatively fine-scale migratory patterns of free-range animals. **EGNSS** represents an ideal technology to track their location. By attaching an EGNSS-enabled tracker to a collar, harness, or directly to the animal, data on its location can be continuously collected and analysed. This helps us better understand what (potentially endangered) animals need to be healthy and thrive in their environment.

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

Several European-funded projects utilise EO to propose solutions in support of environment and biodiversity

MyEUSPACE Competition: Our green planet

MyEUSPACE is a competition organised by EUSPA in 2023 addressing environmental challenges and sustainable life. The solutions aim to contribute to the implementation of the European Green Deal and play a central role in the green transformation of corporations.

The competition supports the development of innovative commercial solutions – such as mobile apps or hardware-based solutions – that leverage EU Space data from Galileo and/or Copernicus. Applicants could participate in the contest with an idea, a prototype or a product, depending on the maturity of the solution at the time of the submission.

An interesting outcome of this competition is the product **Waterjade**, which aims to forecast water inflow from the upstream catchment to an industrial plant in order to optimise water abstraction and storage. Another project, currently at prototype stage, is **Overview**. This is a software platform that allows users to access, compute and visualise environmental data over any time scale and location for which data is available. The objective is to make it simple for users to work with Copernicus and other environmental data in a fast and intuitive way.

More information available at: https://www.euspa.europa.eu/cassinichallenges

CASSINI Maritime Prize

Space-based remote sensing technologies and data can play a significant role in detecting, tracking and mapping concentrations of plastics, identifying hotspots and sources of the litter, detecting proxies of potential plastic pollution and can contribute to the effective deployment of clean-up solutions.

The Cassini Maritime prize aimed to stimulate the **development of innovative solutions** – using EU Space Programme data – **to solve problems related to the detection, monitoring and the removal of microplastics, plastic litter as well as of larger items in rivers, shores and coastal zones**.

In November 2023, the three winners EOMAP, GEOMATYS, and SCIDRONES were each awarded €950 000, which will be used to further develop, scale up and, ultimately, accelerate the commercialisation and promotion of their applications. Solutions included differentiating between plastic pollution and natural debris using Copernicus multi-spectral data, mapping and monitoring plastic pollution in real-time using Copernicus and other data sources, as well as detecting debris at sea and forecasting its drift by coupling ocean current and wind models with satellite observations.

More information available at: https://www.euspa.europa.eu/newsroom/news/eu-space-applications-fish-plastics-out-our-oceans-and-rivers

Horizon Europe, a programme of the European Union

Birdwatch: Habitat sustainability of farmland birds

Birdwatch is a **Copernicus-based service** aiming to improve the habitat of farmland birds via satellite-enabled monitoring, evaluation and optimisation of the Common Agricultural Policy (CAP) greening measures.

Birdwatch has a comprehensive mission to enhance biodiversity, improve farmland ecosystems, and encourage sustainable farming. The product combines both **rigorous species distribution modelling together with EO data-based** geospatial features of the individual farmland parcels to provide stakeholders with maps of bird habitat suitability in agricultural areas. It then helps to identify appropriate greening measures by considering the associated economic consequences. It also assists in evidence-based policymaking and fosters communication between scientists, farmers and authorities.

More information available at: https://birdwatch-europe.org/

Horizon Europe, a programme of the European Union

Marco-Bolo: Observing a new way to explore marine biodiversity

MARCO-BOLO (Marine Coastal Biodiversity Long-term Observations) aims to **structure and strengthen European coastal and marine biodiversity observation capabilities**, linking them to global efforts to understand and restore ocean health, hence ensuring that outputs respond to explicit stakeholder needs from policy, planning and industry. It will connect existing initiatives, optimise and improve methods, and further innovate technologies (remote sensing, eDNA, robotics, and optical and acoustic observations) to understand and restore ocean health.

MARCO BOLO results will be designed to build upon existing capabilities and infrastructures, and to be relevant to existing frameworks so that outputs can be easily integrated into national, regional (EU and adjacent sea basins), and global observation systems, with no delay, ensuring the reusability of the investments Europe is already making in data generation.

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

Several European funded projects utilise EO to propose solutions in support of climate and biodiversity

Horizon Europe, a programme of the European Union

100K TREEs

The ambition of the HORIZON Europe project 100KTREEs is to make cities a better and healthier place to live by encouraging municipalities to plant more trees and to optimise the impact of tree planting.

100KTREEs will develop mapping and modelling tools to optimise the planting of trees and to monitor their health, based on satellite data from the Copernicus EU space programme and in-situ data. By assigning monetary value to the key attributes of a tree, e.g. pollution absorption, cooling effect, noise abatement, flood risk reduction and increased biodiversity, a number of business cases will be developed for two partner cities.

Sofia (Bulgaria) and Copenhagen (Denmark) are the two metropolitan use cases where technical and socio-economic approach of 100KTREES will be tested and demonstrated. The team will support cities by mapping the existing trees and by showing a business case for planting new trees, as well as attracting third party sponsorships to make it happen.

More information available at: https://www.100ktrees.eu/

E-shape, strengthens the benefits for Europe of GEO

E-shape is a unique initiative that brought together decades of public investment in EO and in cloud capabilities into services for decision-makers, citizens, industry and researchers.

Within the project, 37 pilot applications under seven thematic areas addressed societal challenges, fostered entrepreneurship and supported sustainable development.

Climate was one of e-shape's thematic areas. Interesting pilots such as one on **urban resilience to extreme weather** aimed to increase the preparedness of city authorities and decrease the vulnerability of urban population to hazardous weather events and risks caused by climate variability and climate change. Another interesting pilot involved the **super resolution air quality monitoring service** which aims to provide a competitive service that fills the gap between the local in-situ sensors data, and the lower resolution, global satellite data.

More information available at: https://e-shape.eu/

EuropaBON: integrating data streams to support policy

Biodiversity loss has severe impacts on ecosystem services and humans. Several EU policies and initiatives are oriented towards an objective, integrated and permanently updated biodiversity and ecosystem service data. However, biodiversity observation is restricted by a sequence of gaps. The EU-funded EuropaBON (Europa Biodiversity Observation Network) project will **design a new structure for monitoring biodiversity and ecosystem services, including remote sensing**.

It will model essential variables to **integrate different reporting streams, data sources and monitoring strategies**. Project partners will deliver solid knowledge about the dimensions of biodiversity change across space and time to **support decision-making**. Based on stakeholders' engagement and knowledge exchange, EuropaBON will assess existing monitoring efforts, identify user and policy needs, and investigate the feasibility of a European coordination centre of monitoring operations.

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

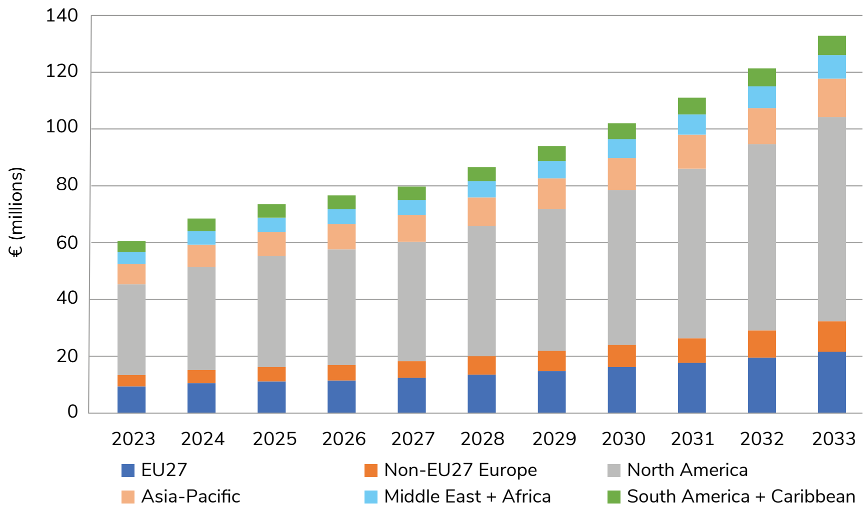
Hermosa project for ecosystems restoration

The project initially started in 2018 with an ESA Business Applications kick-start activity, "EO-li - Earth Observation based location identifier".

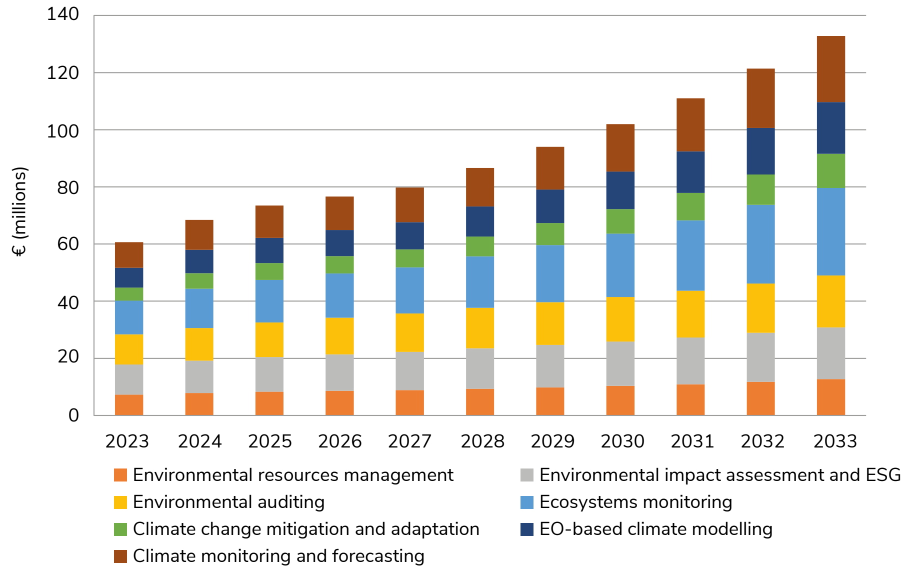
It is now **an open-source service platform that supports ecosystem restoration and biodiversity conservation locally and globally**. The concept appeals to several customer groups, such as investors and financial institutions that want to invest in reforestation activities, local farmers who offer their land, planting companies that carry out the various projects on-site and governments that are committed to national and international initiatives in the context of mitigating or adapting to climate change and sustainable development, among numerous other stakeholders.

More information available at: https://hermosa.mundialis.de

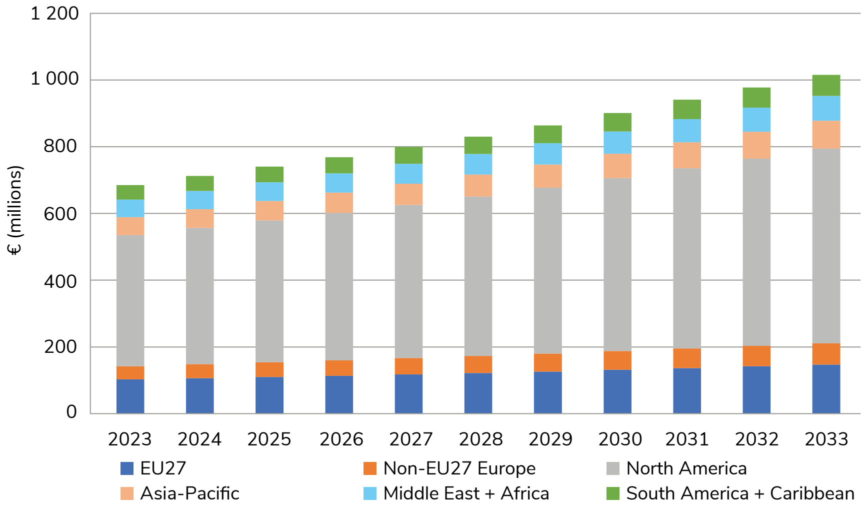
Revenue from EO data sales by region



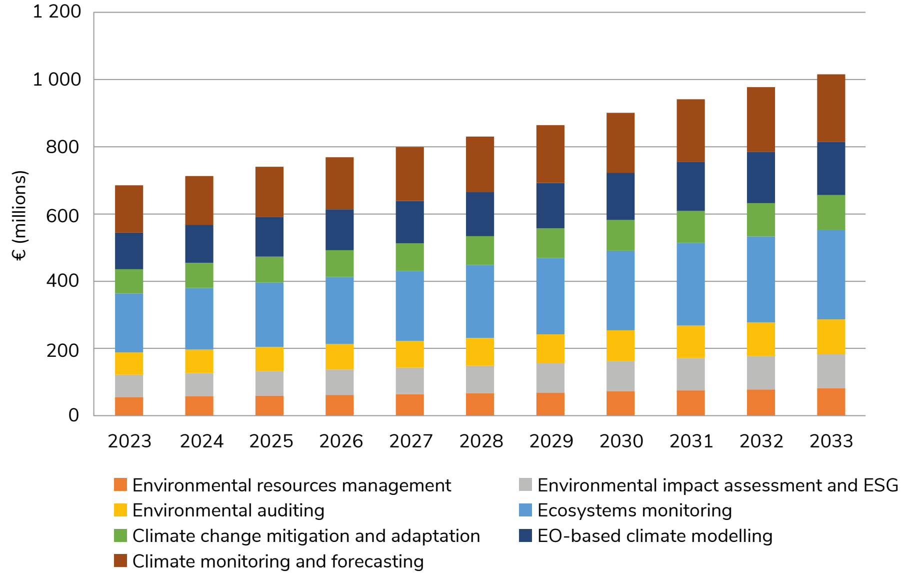
Revenue from EO data sales by application



Revenue from EO services sales by region



Revenue from EO services sales by application



CONSUMER SOLUTIONS, TOURISM AND HEALTH

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

Corporate
- Location-based billing
- Geo-advertising
- Mapping and GIS
- Workforce management

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

Navigation & Tracking
- Navigation for smartphone users
- Personal & asset tracking
- Visually impaired support

Robotics
- Consumer robotics
- Enhanced human

Application descriptions can be found in Annex 3

CONSUMER SOLUTIONS DEVICES AND APPLICATIONS

EO- and GNSS-enabled consumer solutions encompass a wide range of applications catering to diverse user needs and preferences (e.g., navigation and tracking, health and lifestyle, tourism, etc.). These applications are supported by various types of connected devices, primarily smartphones and wearables, as well as other specialised equipment like tablets, personal tracking devices, digital cameras and portable computers.

Advancements in Internet of Things (IoT) allow virtually any physical device to become connected to one another. This is best exemplified by the advent of consumer robotics. Other emerging trends include Artificial Intelligence (AI) and Machine Learning (ML), which open up new layers of possibilities in offering greater connectivity and capabilities to these devices and functionalities, thus, further enhancing well-being and lifestyle.

Driven by technological advancements and cost reduction, the increasing accessibility of satellite imagery to the general public in recent years has facilitated the commercialisation of Earth Observation data and has pushed boundaries on how such data can be used in users' day-to-day lives in various domains.

What you can read in this chapter

- **Key trends:** Space data gains momentum in consumers' daily lives.
- **User perspective:** Unlocking opportunities: satellite data for mobile apps, geo-location revenues, and sustainable tourism.
- **Industry:** Consumer solutions, health and tourism value chains.
- **Recent developments:** Smartphone shipments continue to dominate despite experiencing a slowdown; growing digitalisation sustains the market growth, while EO is playing a growing role in collaborative decision-making.
- **Future market evolution:** Edge and quantum computing integration with space technologies is transforming the future of data processing and mobile devices while EO revenues continue growing and space technologies drive inclusivity, diversity and equality in the society.
- **European systems:** Current usage of Galileo and Copernicus in consumer solutions, tourism and health.
- **European Projects:** EUSPA continues to support to SMEs and start-ups to develop GNSS and EO applications for consumer solutions, tourism and health.
- **Reference charts:** Yearly evolution of installed base of GNSS devices and revenues as well as EO revenues by application and region.

Space data gains momentum in consumers' daily lives

Key market trends

- Apps are becoming more and more integrated, enabling the use of a single app for multiple services
- Generative AI is revolutionising mobile apps development through advanced Machine Learning
- The use of EO and GNSS in healthcare provides an environmental dimension to patient care
- The rise of digital twins in the gaming world has pushed developers to use satellite imagery for the development of better visualisation graphics and 3D models

The rise of Super Apps – one app for all

Super apps as a concept are growing in popularity in Europe. These apps provide users with a **seamlessly integrated experience via a one-stop solution** that solves different needs and purposes simultaneously.

The rise of **super apps** will change the way people interact with their phones, since **many different applications can be integrated into one**, such as social and communication platforms, e-commerce, transport and ride-hailing services, financial services, food delivery, bill and utility management and healthcare services.

Large companies such as Meta and Amazon **have started integrating such features**, by going a step further from the initial purpose of their platform. More recently, Twitter announced that it is planning to build its super app, X, which will provide a range of services from social networks to purchase apps while offering personalised entertainment according to the user's location and preferences.

In this regard, the role of **geolocation, cybersecurity and privacy** is extremely **important** since user's personal data is aggregated in a single platform, which will enable the seamless operation of such super apps.

Uncovering the link between climate change, air quality and asthma: the key role of Copernicus

Climate change may affect and worsen air quality through increasing temperature, air pollution and increasing risk of wildfires, all of which may exacerbate asthma attacks, a condition already affecting 30 million Europeans. In this context, **Copernicus Atmosphere Monitoring Service (CAMS)** represents a key source of information to monitor and address climate change and health issues that it might cause. As the healthcare sector embraces Copernicus data, a new era of understanding and tackling health-related challenges is set to unfold.

The global pharmaceutical company Teva, is investigating the link between **wildfire air pollution and asthma triggers** with the help of the **Copernicus Atmosphere Monitoring Service (CAMS)**.

CAMS, which offers comprehensive atmospheric data, **aids Teva's research by providing insights** into **global wildfires and air pollution**. This collaboration represents a major step forward in addressing respiratory diseases amid climate change.

To date, the **integration of innovative technologies**, such as 5G connectivity, robotics, augmented reality (AR), and 3D printing, **is poised to revolutionise healthcare and disease monitoring**. This transformation is bolstered by the harnessing of big data platforms and advanced analytics, facilitating more robust and proactive public health efforts. Notably, apps like GIDEON's interactive disease outbreak and distribution map are already in use and continually updated with fresh data. Similarly, Lymeapp, a mobile and web-based app, provides users with risk maps for their specific locations, exemplifying the synergy between technology and public health for enhanced monitoring and response.

Generative AI and its potential to increase the commercialisation of EO in mobile apps

In recent years, there has been a greater demand for personalised consumer experiences. Through the use of **Generative AI,** a type of AI system that uses advanced Machine Learning (ML) algorithms, prominent applications such as chatGPT, DALL-E, BART and Stability Diffusion, have been on the rise, enabling the generation of text, images or other media on immediate demand.

AI and ML have indeed emerged as prominent trends in mobile app development, **enabling optimised search processes, integrating audio or video recognition and learning user behaviour patterns in order to provide better services and create intelligent digital assistants**. Moreover, these apps are accessible to specific geolocation and user groups, enabling them to answer diverse questions and assist with day-to-day tasks for creators, consultants, researchers, and more. This integration not only enhances productivity, but also provides tailored content to meet specific user needs.

As the demand for exceptional mobile experience rises, leveraging this technology can support developers in creating seamless, personalised and highly engaging apps that cater to the evolving needs of users. With the integration of high-resolution satellite imagery to recreate real-world locations or generate fictional landscapes, app creators can enhance the authenticity, leading to a more captivating user experience.

The rise of EO and digital twins in the gaming and tourism world

The use of **digital twins** has seen a **significant expansion thanks** to the **ability to recreate the real world with remarkable visualisations and great attention to detail**. In the gaming world, game developers and the creators of metaverse environments have begun to utilise EO in order to produce photorealistic digital 3D replicas of real localities, including video game textures and terrain models.

The same technology is also **currently used in the tourism sector** to provide visitors with a more personalised experience specifically tailored to each individual. Moreover, it can bring about positive effects on the protection, conservation, informational and awareness aspects of tourism activities.

Additionally, **high-resolution imagery can be used** to recreate real-world locations or generate fictional landscapes based on actual geographical features. With the support of AI, it is possible to enhance VR in digital twins, creating a more immersive experience, with more scalable and accurate virtual worlds, including the interaction with 3D digital objects and 3D virtual avatars. Importing space data into a metaverse project may accelerate the development and recreation of natural ecosystems, seasons, weather and climate conditions.

Unlocking Opportunities: Satellite Data for Mobile Apps, Geo-Location Revenues, and Sustainable Tourism

Sustainable tourism must integrate EO data, says UN World Tourism Organisation

The Baseline Report on the Integration of Sustainable Consumption and Production Patterns into Tourism Policies by the UNWTO **mandates the incorporation of geospatial data** to measure and visualise the impacts of tourism on the environment for the tourism industry in order to ensure sustainable practices within the sector.

The World Tourism Organisation has been exploring the possibilities of using satellite data and its potential to improve tourism planning, including in helping tour operators minimise their environmental impact. For example, through the partnership with Google Earth, the WTO has been able to map out tourist attractions and conservation areas, providing a comprehensive overview of the environment.

In this sense, EO has been revolutionising sustainable tourism by enabling multi-level environmental monitoring and analysis. These insights will **enable tourism industry stakeholders to make well-informed decisions about the future of tourism** by utilising the collected data on its impacts on natural resources, biodiversity and the environment at large.

Space technology: a key solution for sustainable development in a growing world

The global population is expected to reach 9 billion by 2037, raising concerns about its impact on the environment and sustainability. The "Contribution to the Space2030 Agenda" report by EUSPA, in collaboration with the United Nations Office for Outer Space Affairs (UNOOSA), highlights that **space technology holds the key to addressing these challenges** while ensuring sustainable development.

In alignment with global agendas such as the 2030 SDGs or the Paris Agreement, the UN Committee on the Peaceful Uses of Outer Space (COPUOS) has ratified the **"Space2030" Agenda**, in which space data from programmes such as Copernicus, Galileo, EGNOS, and GOVSATCOM can tackle issues such as food security, water management, climate change, and environmental sustainability in a world of growing population.

The report highlights how consumer devices, supported by GNSS and EO, can contribute to the fulfilment of the sustainable urbanisation challenge, sustain a better environmental monitoring and enhance more effective healthcare systems.

Further information on this report is available on page 24.

Mobile apps support sustainable tourism practices

From planning to protecting, several apps have been developed already integrating EO and GNSS to support achieving sustainable development goals (SDGs) in the tourism sector and, thus, **playing an important role in the management of tourism sites and the impact of tourism on natural habitats**.

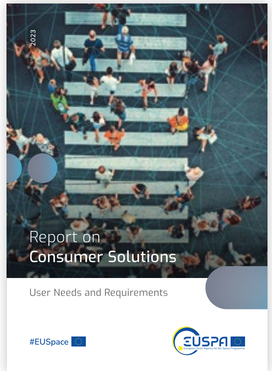
These **mobile apps can give end users information on of their environmental footprint** and can revolutionise the travel market, by transforming the way travellers plan, book and navigate their trips.

For instance, thanks to the significant investments that both private and public enterprises have made in **bike-sharing apps** such as Vélib' in France or nextbike in several European cities, users can enjoy a stress-free and green way to get around when on holiday.

Additionally, **sustainable destination information apps** can be used to aid the environmental education of tourists and residents, while interactive guide maps or activity routes apps can show the location of the attractions, plan routes and provide easy-to-access information on accommodation, transportation and local culinary specialities, among others.

All these apps will help the surge of green tourism and bring value to the sector. It is denoted that 66% of consumers globally want to have a positive impact on the environment in their daily lives and, thus, are more inclined to engage in services and products that are participating in sustainability efforts, including in tourism.

Sources of key EO and GNSS user requirements



The key EO and GNSS user requirements for the different application groups within the **consumer solutions, tourism and health** segment are, at EU level, collected using a harmonised procedure. 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 Consumer Solutions user needs and requirements.

User requirements for Earth Observation (EO) services and products – as well as their evolution – are now also collected through the UCP. The process covers the EO user needs and requirements of commercial users based on inputs from industry experts and user groups, mirroring the existing process implemented for GNSS.

Moreover, the collection of specific requirements for Copernicus services and products is supported by 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; and (iii) regular and structured exchanges among representatives of the Copernicus governance structure and Member States through the Copernicus User Forum.

Consumer Solutions, Tourism and Health GNSS Value Chain[1]

GNSS

COMPONENT AND RECEIVER MANUFACTURERS

- BEIJING BDSTAR NAVIGATION
- BROADCOM
- INFINEON*
- INTEL
- LEADTEK RESEARCH
- MEDIATEK
- NIHON DEMPA KOGYO
- NXP SEMICONDUCTORS*
- QUALCOMM
- QUECTEL WIRELESS
- SAMSUNG
- SEIKO EPSON
- SIERRA WIRELESS
- SITRONIX TECHNOLOGY
- SONY
- SPREADTRUM COMMUNICATIONS
- STMICROELECTRONICS*
- U-BLOX*
- UNISTRONG GNSS
- YAGEO

OPERATING SYSTEM DEVELOPERS

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

DEVICE INTEGRATORS AND VENDORS

SMARTPHONE/ TABLETS:

- ALPHABET
- APPLE
- HUAWEI
- LENOVO
- LG
- NOKIA
- OPPO
- SAMSUNG
- SONY
- VIVO
- XIAOMI
- ZTE

WEARABLES:

- ALPHABET
- APPLE
- AMER SPORTS*
- GARMIN
- LG
- POLAR*
- SAMSUNG
- SUUNTO*
- 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
- KDDI
- ORANGE*
- SOFTBANK
- TELEFÓNICA*
- VERIZON WIRELESS
- VODAFONE*

APP DEVELOPERS/ RETAILERS

GENERAL APP DEVELOPERS:

- ALIBABA
- APPLE
- GOOGLE
- META
- MICROSOFT
- SAMSUNG
- SUPERCELL*
- TENCENT
- TRIPADVISOR
- XIAOMI
- Many small app developers

mCOMMERCE:

- ALIBABA
- AMAZON
- EBAY
- PAYPAL
- RAKUTEN
- ZALANDO*

mHEALTH:

- CALM
- FITBIT
- FLO HEALTH*
- HEADSPACE
- MYFITNESSPAL

RETAILERS:

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

APP STORES

- AMAZON APPSTORE
- APPLE APP STORE
- GOOGLE PLAY
- HUAWEI APPGALLERY
- MICROSOFT STORE
- TENCENT APPSTORE

USERS

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

LEGEND

- Commercial offering
- Public offering / entities
- User segments

European[2] GNSS industry in the global arena

European companies STMicroelectronics, Infineon Technologies and U-Blox were among the top 10 largest businesses in the GNSS component and receiver sector in 2021. However, Europe's market share stood at around 5%, behind North America (50%) and Asia (45%). Meanwhile, European GNSS system integrators (e.g. smartphone and wearable manufacturers) maintained around 5% of the segment turnover in 2021 behind Asia (60%) and North America (35%).

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.

Please refer to page 23 for a comprehensive description of the GNSS value chain and how to interpret them at segment level.
* European-based companies. The region is defined with respect to the headquarters of the company, though the actual area of activity might be wider

Consumer Solutions, Tourism and Health EO Value Chain[1]

EARTH OBSERVATION

DATA PROVIDERS

- AIRBUS*
- BLACKSKY
- CAPELLA SPACE
- CGSTL
- GEOSAT*
- E-GEOS*
- ICEYE*
- MAXAR
- PLANET
- UMBRA

MAP PROVIDERS:
APPLE, GOOGLE, HERE*, MAPQUEST, MICROSOFT, OPENSTREETMAP*, TOMTOM*

- COPERNICUS SENTINELS*
- COSMO-SKYMED (ASI)*
- LANDSAT (USGS)
- METEOSAT (EUMETSAT)*
- RADARSAT (CSA)
- RELEVANT IN-SITU NETWORKS
- OTHER RELEVANT EUROPEAN NATIONAL MISSIONS

INFRASTRUCTURE PROVIDERS

- AWS
- CLOUDFERRO*
- GOOGLE CLOUD PLATFORM
- IBM CLOUD
- MICROSOFT AZURE
- T-SYSTEMS*

- FEDERATED INFRASTRUCTURE (E.G. GAIA-X)*
- SENTINEL COLLABORATIVE GROUND SEGMENT*

PLATFORM PROVIDERS

- ADAM*
- PIESAT
- CLEOS*
- CLOUDEO*
- CREODIAS*
- MAXAR
- NOR*
- PLANET EXPLORER
- SENTINEL HUB* (SINERGISE)
- TERRADUE*
- UP42*
- VITO*

- WEKEO*

EO PRODUCTS AND SERVICES PROVIDERS

- AIRBUS*
- BIKEMAPPS*
- CGI
- DEEPTRACE TECHNOLOGIES*
- DATEL*
- MAXAR

- COPERNICUS ATMOSPHERE MONITORING SERVICE (CAMS)*
- COPERNICUS CLIMATE CHANGE SERVICE (C3S)*

INFORMATION PROVIDERS

- ACCUWEATHER
- AIRBUS*
- CGI
- DRAXIS*
- SM GEODIS*

END USERS

- SMARTPHONE DEVELOPERS
- APP DEVELOPERS
- CITIZENS
- ELDERLY AND VULNERABLE GROUPS
- TOURISTS
- SPORT ENTHUSIASTS
- WORKFORCE

LEGEND

- Commercial offering
- Public offering / entities
- User segments

European[2] EO industry in the global arena

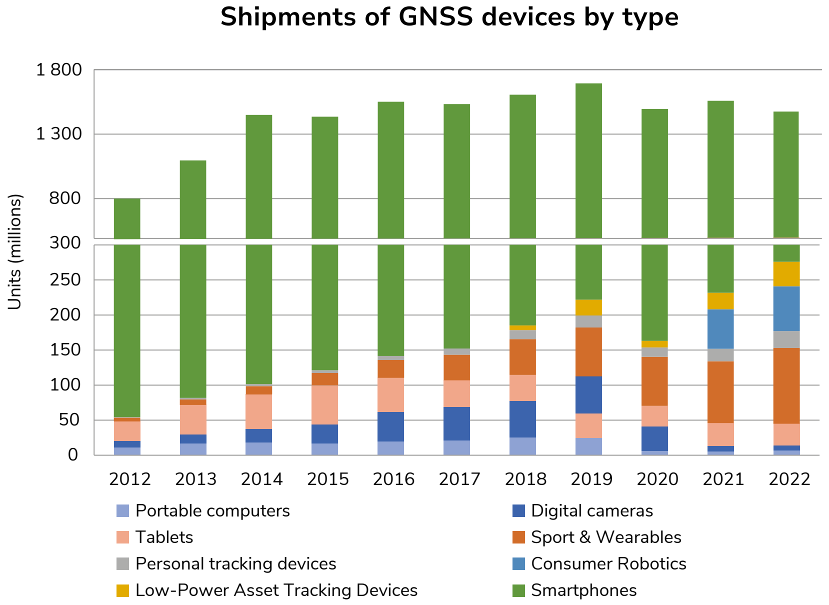
In 2021, European EO companies accounted almost a third of the global market share. Top European companies in this segment include Airbus, Hispasat, and ICEYE. Meanwhile, North American companies are still dominating the market, enjoying around 60% of the global share.

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.

Please refer to page 13 for a comprehensive description of the EO value chain and how to interpret them at segment level.
* 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 while experiencing a slowdown, the growing digitalisation sustain the market growth



Smartphones continued to dominate the market accounting for around 80% of around 1.5 billion unit shipments in 2022, significantly exceeding other consumer devices. Nevertheless, their dominance **decreased** from 2019 to 2021 due to the increasingly saturated market, the COVID-19 pandemic and increasing attention on the sustainability of devices (i.e. a focus on **longer lifetime**). The disruption of the **supply chain** is also contributing to the setback, especially concerning semiconductors, and the suppressing growth in the consumer sector caused by the ongoing international crises, which are expected to reduce the shipments of smartphones. This is only partially counterbalanced by the growing uptake of smartphones in less developed regions of the world.

Other GNSS-enabled consumer devices combined amount to over 250 million units in 2022, out of which around 100 million unit shipments in 2022 are attributed to **sports and wearable devices, growing** with a CAGR of 35% between 2012 and 2022. **Personal tracking devices** continued to grow with a CAGR of 40% in 2012-2022 boosted by increasing consumer awareness and affordability. **Personal tracking devices and low-power asset trackers**, which experienced a slump in 2020 due to COVID-19, rebounded to their pre-pandemic numbers in 2022 and even surpassed them for low-power asset trackers. **Consumer robotics**, which was added as a separate application in 2021, **observed strong growth** from 2021 to 2022.

The remaining devices experienced negative growth for the time period observed. Shipments for portable computers, tablets and digital cameras have been shrinking since 2020, mainly due to the slowdown in the global economy due to the pandemic, together with the growing maturity of these markets and, hence, declining consumer demand, particularly for portable computers and digital cameras.

Overall, the market is forecast to continue to grow, thanks to the increasing use of wearables and digitalisation, particularly in healthcare and tourism. The expected overall effects of these forces can be visualised in the reference charts at the end of this chapter.

The hospitality sector relies on robots to improve operation, costs-effectiveness and guest experience

The market size for the service of autonomous robots in the hospitality sector is projected to grow significantly. Today, robots are being used in a variety of hotel departments, including housekeeping, food and beverage and even security. For instance, autonomous robots, such as Pepper or Nao, can provide smart catering and retail services boosting operational efficiency, enhancing competitiveness as well as reducing costs.

COVID-19 has further accelerated the adoption of autonomous robots, as they can provide safe and contactless services, in addition to helping to improve **operational efficiency** by automating tasks that are typically done manually. In indoor operations, such robots can use functionalities such as inertial sensors, Lidar or simultaneous localisation and mapping (SLAM) to navigate.

© unsplash.com

AI is changing the way businesses operate in the field of robotics and hospitality by **improving customer experience, brand awareness and customer loyalty**. Western cultures are starting to adopt more autonomous robots in hospitality, although at a slower pace than Asia. Factors such as cost, technological capabilities and customer acceptance play a role in determining the extent to which autonomous robots are integrated into hospitality operations.

Digitalisation is at the forefront of healthcare innovation

The rise of AR and VR in health applications, in parallel with the integration of space technologies, will provide a better patient experience, increase compliance with treatment and improve patient outcomes, including the training and performance of medical treatments by healthcare professionals.

Software for virtual and augmented reality surgery has been developed, enabling doctors and other healthcare providers to be better prepared, while medical students can receive greater amounts of surgical training than normally possible with actual patients. **Geospatial mapping and digital twins capabilities** enabled by GNSS and EO can enhance training and preparation experiences by modelling organs, the immune system, and many other physical characteristics of a patient or the surrounding locations.

The growth in healthcare data has enabled the rise and use of healthcare databases, which are paving the way for the implementation of AI in the healthcare industry. **The integration of AI can lead to better care outcomes and improve the productivity and efficiency of care delivery**. In synergies with satellite data, AI can enhance pre-operative planning and patient monitoring, as well as enabling telemedicine and remote surgeries. This **digitalisation of healthcare will** ultimately **require the integration of satellite-enabled solutions** such as IoT, cloud computing and access to large databases for physicians.

Earth Observation growing presence in collaborative decision making

How gaming and EO can support solving world problems

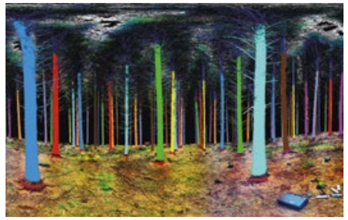
Human mappers, especially gamers, offer crowdsourced data that, combined with machine learning systems, allows mapping to be based on direct visual recognition of elements, as well as the surrounding region. BlackShore is an example of how **game-based crowdsourcing**, can deliver accurate, **up-to-date and low-cost map products and data labels** based on the crowd-sourced interpretation of satellite data and aerial imagery to monitor different kinds of needs. Their practical **applications range from mapping forests to detecting illegal fishing, supporting farmers and disaster mapping**.

In the past few years, the combination of crowdsourcing and gaming in order to support the reduction of uncertainties in mapping land cover has seen substantial growth. For instance, IIASA has already been using games and social networking to build a citizen scientists network (e.g., Cropland Capture, Picture Pile, FotoQuest Go and LandSense).

© BlackShore

Another success story is represented by eBird, a crowd-sourced **bird-watching** mobile and desktop application, developed by Cornell's ornithology lab, serves as an online repository of bird observations. The app offers scientists, researchers, and amateur naturalists immediate access to real-time data regarding bird distribution and abundance. Another app that aims to support the **scientific community** is iNaturalist.

The growing role of LiDAR in real life applications



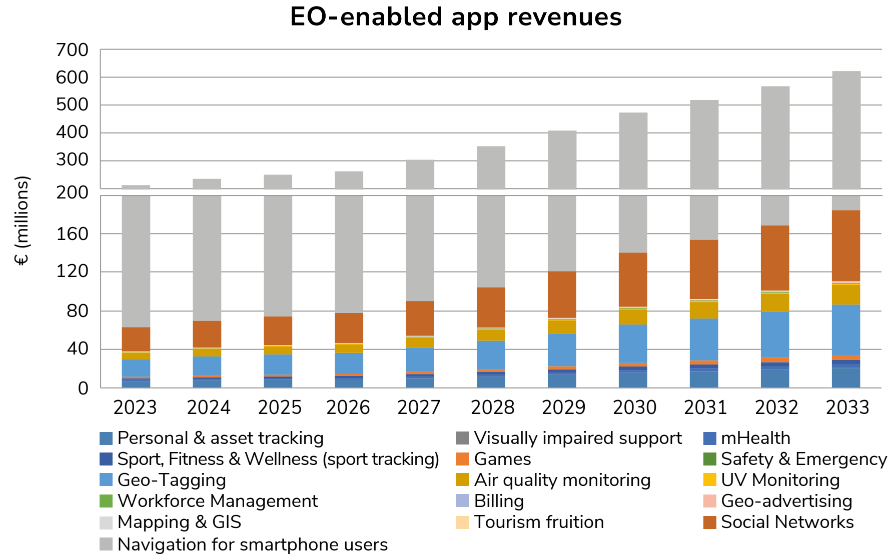
© Treemetrics

The use of **LiDAR in smartphones has been growing** significantly. It provides **better visualisation and interaction with the user** by scanning and measuring more accurately the distances of surrounding objects compared to regular laser scan. Particularly in dark conditions, LiDAR makes it possible to capture superior-quality photos in low light.

Additionally, **LiDAR can be complemented with photogrammetry (the art and science of extracting 3D information from photographs) and/or a neural radiance field (NeRF)**, which enables the creation of 3D objects from two-dimensional photos. The technology has brought AR to the forefront since it enables virtual taping and measuring of objects, creating a replica of an object, a scene or a character and showing, for example, how furniture can look around our homes by scanning and recreating 3D models, as well as enhancing our online shopping experience.

Mobile **devices equipped with LiDAR have also been applying EO in the forestry** sector for inventory-related tasks such as individual tree stem measurements, for which LiDAR enables more efficient and precise data collection, while requiring less time and resources than manual data collection.

Discontinuities in geological structures can be identified through the use of LiDAR in the field using smartphones. These applications can therefore be very useful for the analysis of geologic natural hazards and resource management.



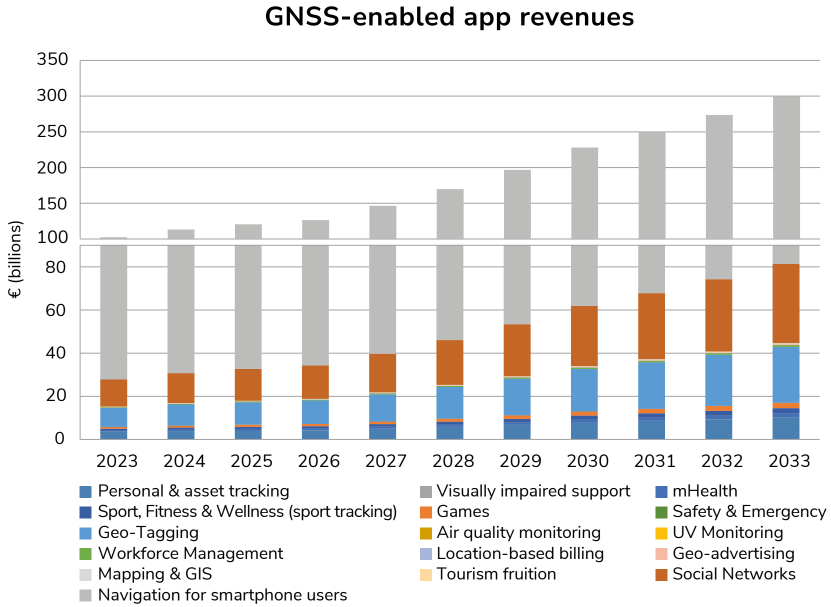
EO-enabled app revenues

As a new analysis included for this edition of the Market Report, **the global revenue from EO-enabled apps is predicted to grow to around €600 million by 2033** from around €200 million in 2023 with a **CAGR of 11%**. Within consumer solutions, **navigation for smartphone users** is the largest application, with revenue projected to increase from €150 million in 2023 to almost €450 million by 2033 with a CAGR of 11%. Meanwhile, **Social networks** is the second-ranked category with cumulative revenue of €55 million over the decade, followed closely by **geo-tagging** which is expected to grow from almost €20 million in 2023 to just over €50 million in 2033.

Meanwhile, the rest of the applications combined represent less than 10% of the market, led by **personal and asset tracking** and **air quality monitoring**, which are both expected to almost triple by 2033.

These EO-enabled apps revenues are generated based on a quantitative analysis of EO-enabled mobile apps, taking into account the **downloads** of each app delineated by each sub-application, as well as data on global mobile apps revenues. For each app, the relevance of EO for the functionalities of the app is considered, which corresponds to the EO-enabled app revenues as illustrated in the graph. Therefore, the quantified revenues are the share of sales generated by the apps (through in-app purchase, pay-per-download or advertising) that can be attributed to EO data or services, The reader should note that, being a new piece of analysis, EO-enabled app revenues are **not included in the reference charts** featured on page 81.

Edge and quantum computing integration with space technologies transforming the future of data processing and mobile devices



In comparison with the relatively mature GNSS devices market (see page 74), **revenues generated from GNSS-enabled apps are expected to significantly rise from around €100 billion in 2023 to around €300 bn by 2033, exhibiting a CAGR of 10%.**

The most relevant category of apps remains **navigation and tracking apps**, with revenue of almost €80 billion in 2023. This figure is expected to grow to around €230 billion by 2023 (CAGR of 11%), accounting just over 75% of the market.

Social networks apps were valued at more than €12 billion in 2023, and they are expected to triple in the upcoming decade, being the second most important category of apps, followed by geo-tagging and personal and asset tracking.

The other apps in the health, lifestyle, tourism and corporate categories remain niche segments, with revenues of just 3% of the total.

These GNSS-enabled apps revenues are generated based on a quantitative analysis of GNSS-enabled mobile apps, taking into account the **downloads** of each app delineated by each sub-application, as well as data on global mobile apps revenues. For each app, the relevance of GNSS for the functionalities of the app is considered, to determine the GNSS-enabled app revenues illustrated in the graph. Therefore, the quantified revenues represent the share of sales generated by the apps (through in-app purchase, pay-per-download or advertising) enabled by GNSS technology, The reader should note that associated revenues are included in the reference charts featured on page 80.

The future of EO and GNSS with Edge and Quantum computing

Edge computing plays a crucial role in **optimising data processing by bringing computations closer to the source, which reduces the strain on bandwidth and significantly decreases latency**. Importantly, it also improves data security, as it lowers the risk of attack during data exchange between sender and receiver. In relation to EO and GNSS technologies, edge computing offers several advantages such as on-device EO data processing, enhanced GNSS accuracy and reliability and real-time GNSS data processing.

The potential integration of **quantum technology** into smartphones is vital, and in fact the industry is already moving towards this direction. For instance, Samsung launched the Quantum 2 smartphone in 2021 featuring built-in quantum cryptography technology – a quantum random number generator (QRNG) chipset – showing how the technology can deliver safer and more secure services for the user. This advancement aligns with the importance of data integrity and privacy in today's technological landscape. Quantum computing promises to revolutionise **smartphone batteries** by accelerating the development of advanced battery chemistry models. Lighter batteries with higher energy capacities would prolong battery life and thus provide a better user experience. In the short to mid-term, electronic devices equipped with quantum sensors (i.e. implementing quantum sensing) are well on their way to replacing our current personal electronics.

As edge computing and quantum technology applications mature, it becomes evident that **future computing devices will be able to operate with optimised resources while prioritising data integrity, privacy and security.**

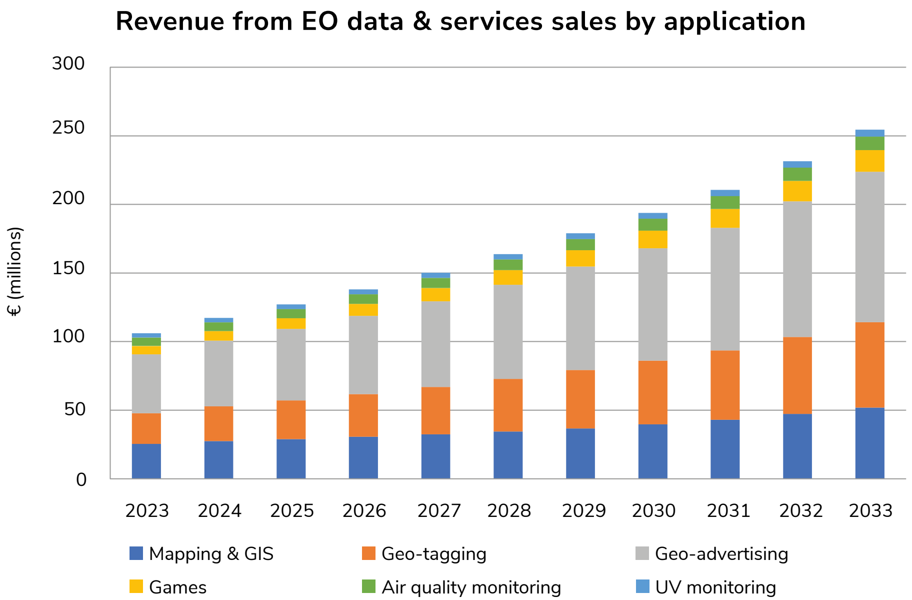
The growing importance of GNSS and EO for marketing strategy development

Recent years have seen the convergence of significant attention on improving marketing strategies via the use of GNSS and EO data, including **retail location planning, geo-marketing, geo-coding and geo-analysis for risk management.** Space data can be applied to many levels of **planning, implementation and control** of activities aimed at achieving market goals and satisfying customer needs.

For instance, Pitney Bowes Business Insight and MB-Research examined how the application of consumer data, combined with their location, can benefit the retail sector. These services offer big data related to customers' purchasing behaviour to optimise retail strategy based on location insights in order to increase revenue. The increasing availability of location-based insights has allowed more access to companies to target existing and emerging markets with tailored advertising campaigns.

Nonetheless, these advancements are not without their challenges. Tracking the effectiveness of these marketing campaigns would not be easy as it would entail various different aspects to be measured. Meanwhile, the high cost of satellite launches remains a barrier to entry, especially for smaller players.

EO growing revenues and the role of space technologies in driving inclusivity, diversity and equality in the society



The global revenue from EO data and services sales is predicted to grow to over €250 million by 2033 from around €100 m in 2023 with a CAGR of 10%.

Within consumer solutions, **geo-advertising** retains its top spot, with a projected revenue increase from €40 million in 2023 to €110 million by 2033 with a CAGR of 10%. Meanwhile, **mapping and GIS** remains the second-ranked application with revenue of around €25 million in 2023. This total is expected to grow to just over €50 million by 2033 (CAGR of 5%). Revenue from **geo-tagging** is expected to grow from just over €20 million in 2023 to around €60 million in 2033, eclipsing mapping and GIS (CAGR of 10%). **UV monitoring** and **air quality monitoring** will remain the two smallest applications, with revenues only growing slightly from 2023 to 2033. The two applications will retain a CAGR of around 5%, projecting the slowest growth within the segment for the next decade. However, this is due to the applications playing more of an informative role for end-users instead of a commercial one similar to other applications.

Finally, EO **Games** revenue is expected to almost triple from around €5 million in 2023 to around €15 million in 2033 (10% CAGR). Nonetheless, EO games in themselves remain niche relative to in-game content purchases.

Typically, EO offers a layer of geospatial information contributing to better audience targeting, supporting map features, or providing specific information on the surrounding area or atmosphere.

How EO and GNSS can make society more inclusive, diverse and equal

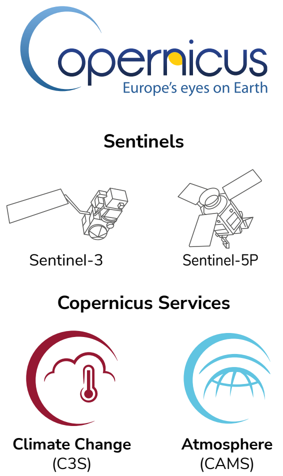
According to the World Health Organisation, an estimated 1.3 billion people experience significant disability. This represents 16% of the world's population or one in six of us. In recent years, new technological solutions have been developed in order to address better accessibility and inclusion in society. It has started to become the norm by incorporating, for example, automatic doors, audiobooks, hand-gesture options and loud text reading, among others. According to the UN, **COVID-19 has accelerated the pace of digital transformation, and with it come opportunities for more digital inclusion and social protection**. EO and GNSS are playing an ever important role in enabling inclusion, diversity and equality.

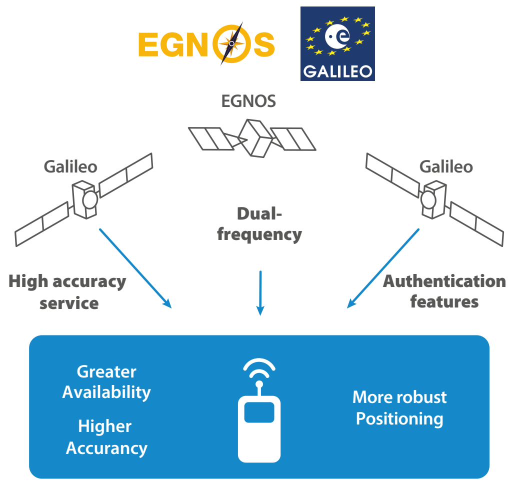
Whilst inclusivity, diversity and equality are difficult topics to quantify due to their broad definition and massive scope, EO and GNSS have the potential to produce meaningful societal impact in that direction. For example, an initiative from the UN Office for Outer Space Affairs (UNOOSA), "Space for Persons with Disabilities", aims at removing barriers for people with disabilities and build an inclusive and equitable development in the space sector. UNOOSA's activities entail two focus areas, namely innovative tools and technologies enabling accessibility and inclusive practices to remove barriers and enhance the **employment processes of persons with disabilities in the space sector**. This includes exploring the role of space technologies in improving accessibility, healthcare and quality of life for persons with disabilities and converting space data to a format that is more accessible for persons with disabilities through sonification.

Additionally, easy **access to smartphones and other mobile devices** and the rapid development of **mobile apps** that facilitate different users' needs have given rise to a **plenitude of offerings**, including those that can foster the inclusion of people with different disabilities, impairments or mobility issues. Various space programmes and initiatives may hold an important role in inclusion, diversity and equality, and competition such as Copernicus and Galileo Masters and myEUspace can foster the development of new apps by supporting entrepreneurs' ideas and giving platforms to app developers to fill in such gaps in the mobile app market.

For example, apps such as iAccess Life or Wheelmap can support people with disabilities and mobility issues by locating wheelchair-accessible places close to shops, restaurants and cafes. Meanwhile, some science-based apps have been developed to provide safety and support for people with Alzheimer's or dementia, including Iridis and Luminosity. Other apps, relying on GNSS functionalities, have been developed to help people with vision impairment to safely and autonomously navigate the streets, such as BlindSquare and Lazarillo Accessible GPS. Lastly, some apps have been created to enable people, unfamiliar with their surroundings, to gain a better understanding of friendly LGBTQ+ spaces, including to enhance safety and comfort while travelling.

Current usage of Galileo and Copernicus in Consumer Solutions, Tourism and Health





Current usage of Copernicus

The **Copernicus Atmosphere Monitoring Service** (CAMS) **maps atmospheric and climate information** for air quality and weather analyses and forecasts in Europe and other regions of the world. **CAMS' products have** now **made their way to everyday users**, by providing real-time information on weather conditions and atmospheric parameters that can be accessed via personal devices and wearables, which enables users to make informative decisions, also concerning their influence on public health matters.

The **Copernicus Climate Change Service** (C3S) supports the society by providing authoritative- and consistent **information about the past, present and future climate** in Europe and the rest of the world. Over time, its use has been expanding, as new ways are found to support people take informative decisions. **Platforms** such as BioSuccess, a new web-based and mobile tool that uses C3S to help users make informed decisions regarding biopesticide application, are meant to ease the access to Copernicus services.

Current usage of EGNSS

With the rise of 5G, the **use of GNSS is becoming increasingly important** since it can support the growing commercialisation of PNT applications. The use of GNSS will enhance mobile broadband, user capacity, awareness and the use of multiple GNSS rates. Specific to consumer solutions, 5G will enhance the positioning and navigation functionalities of smartphones.

Galileo-enabled devices will enjoy access to more constellations, becoming more accurate and reliable. According to useGalileo.eu, over 1,600 smartphone models from around 60 brands are already Galileo-enabled, including over 360 models from around 25 brands supporting dual-frequency capabilities.

Galileo differentiators, such as the **Galileo High Accuracy Service** (HAS) and the **Galileo Authentication feature** (OSNMA) are meant to enable the development of such innovative solutions and/or functions. HAS provides accuracy below a few decimetres, which directly impacts the performance of a wide range of consumer application categories, such as gaming, healthcare, robotics, AR and geo-marketing. The use of HAS is more prevalent in professional and specialised devices, as opposed to regular consumer devices, for the time being.

Focusing on **OSNMA**, although the specifics of how smartphones will utilise its data authentication function are still evolving, **will add security** to **mobile payments** and **enterprise workforce management and tracking** solutions.

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

EUSPA continues to support to SMEs and start-ups to develop GNSS and EO applications for consumer solutions, tourism and health

UV-BODYGUARD

Focused on skin cancer prevention, **Ajuma employs satellite data for UV monitoring**, empowering individuals to safeguard their health. Ajuma's UV-BODYGUARD device measures incident UV radiation and the device can be easily worn akin to a wristband or attached to, for example, a backpack or bike handle. From the associated app that is available for Android or iOS, **users can obtain information on current UV intensity, individual UV exposure and user's personal UV dosage in real-time**, as well as the remaining time they can stay in the sun without being harmed. To determine the atmospheric influence, Ajuma uses the data from the Atmosphere Monitoring Service of the European space programme Copernicus. This unique technology allows the UV-BODYGUARD to calculate the actual UV radiation very reliably and to the exact second.

Ajuma was one of the winners of the **myEUspace competition** in 2023.

More information available at: https://ajuma.eu/en

Murmuration

Murmuration **aims to monitor the environmental impact of tourism by utilising satellite data**, paving the way for sustainable practices in the industry. It prioritises the environmental dimension in every decision by utilising satellite EO data on a global scale. This data is then merged with other sources, such as statistical data, in-situ measurements and geolocated databases to offer precise and transparent information on the environmental state and tourism pressure at any location on the planet. The service comes equipped with a catalogue of around 20 environmental indicators covering five crucial environmental themes, namely air, water, biodiversity, soil and climate.

Murmuration creates **environmental monitoring dashboards** for decision-makers and local authorities to aid in their decision-making process and improve their consideration of their territories' environmental conditions.

Murmuration was one of the winners of the **myEUspace competition** in 2023.

More information available at: https://murmuration-sas.com/en/homepage

EUSPA supports EU objectives through open-source applications

EUSPA supported the **development of open-source mobile apps** to ease and enhance the use of EGNSS differentiators and Copernicus sentinel data and services, to serve multiple domains.

Three open-source Android and iOS applications have been created:

- **EGNSS4CAP:** deploys EGNSS in the digitalisation procedures for EU farmers to satisfy their reporting requirements, implementing some features of Galileo
- **EGNSS4ALL:** goes beyond the CAP (e.g., logistics, urban planning, emergency services, insurance, etc.), offering robust and authenticated geotagging and mapping
- **SEN4ALL:** incorporates Copernicus Sentinels 1, 2 and 5 and CORINE land cover service offering easily accessible information on land, water and air monitoring.

More information available at: http://egnss4cap.eu

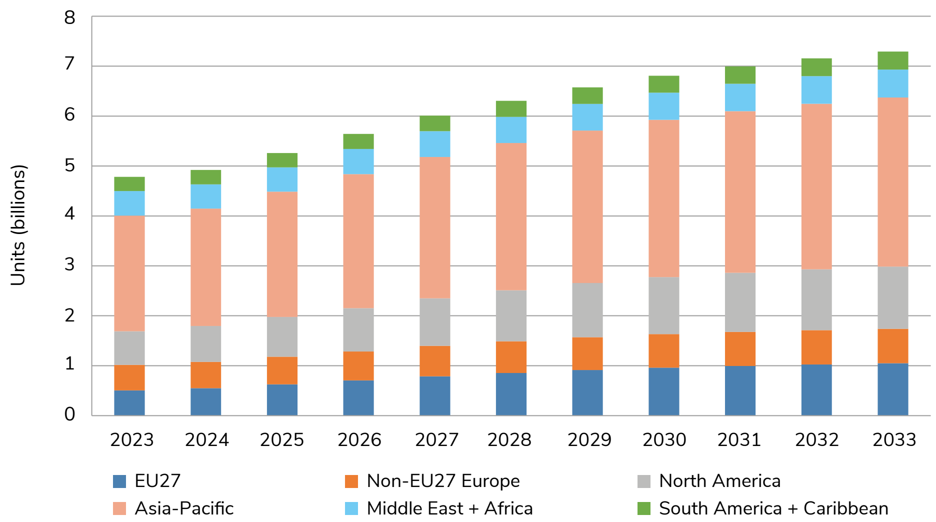
WeCENT - Weather, Climate and Environmental information for Tourism

The WeCENT (Weather, Climate and ENvironmental information for Tourism) project was funded by the EU under the Horizon 2020 grant framework. The project **aims to bring some of the latest scientific information on climate and environment closer to the general public** to be used for day-to-day activities, by tailoring this information for direct and easy use for tourists, adapted for four different touristic destinations types (i.e. beach, mountain, rural, urban areas) and seasons.

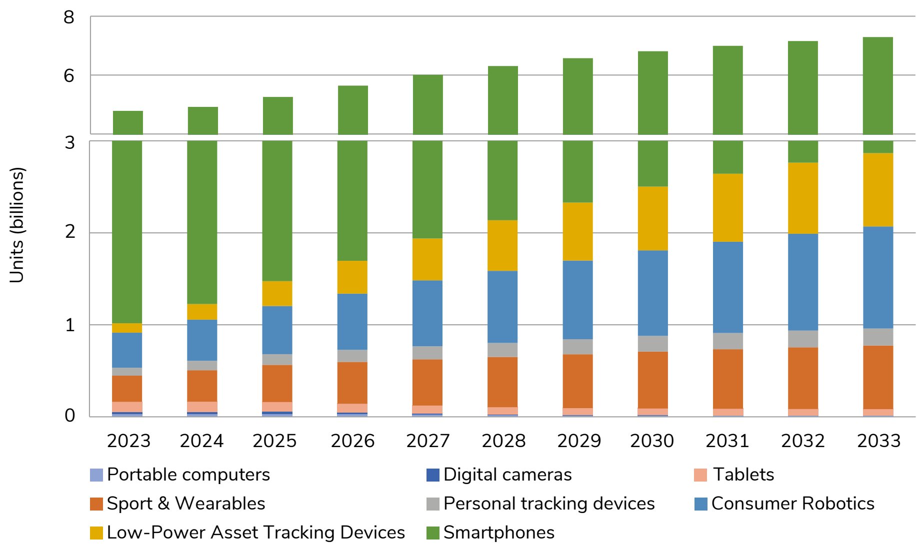
The platform, which **makes use of a variety of tourism-customised information**, adapted for urban, rural, mountain and beach destinations in Italy and Romania, is based on climate reanalysis, satellite-based products, analysis and forecast products. The project will measure user interest in environmental particularities, and will select and determine relevant climate and environmental information based on site, season and leisure activities, as well as **translate EO data into user-friendly information** delivered to the user in a compact and timely form. The results of the project will provide innovative information to tourism actors and open new spaces for innovative applications based on satellite data.

More information available at: https://cordis.europa.eu/project/id/887544

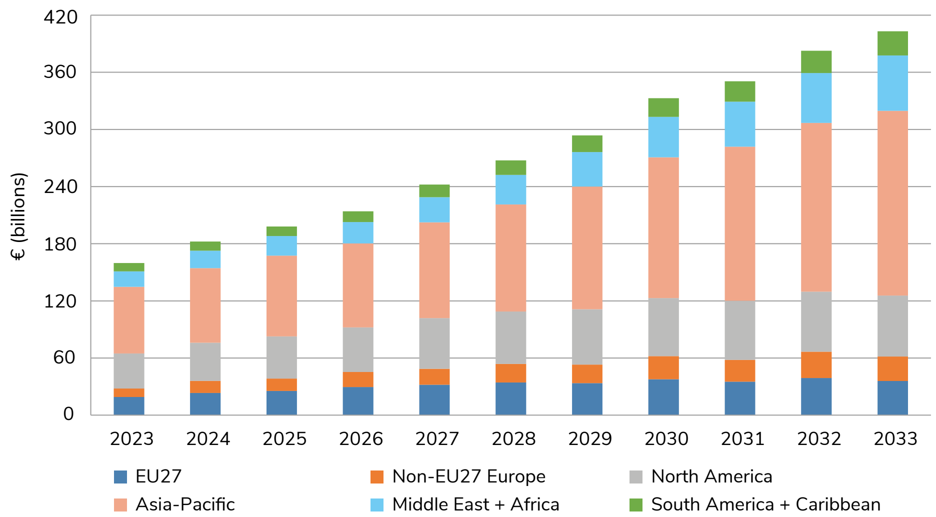
Installed base of GNSS devices by region



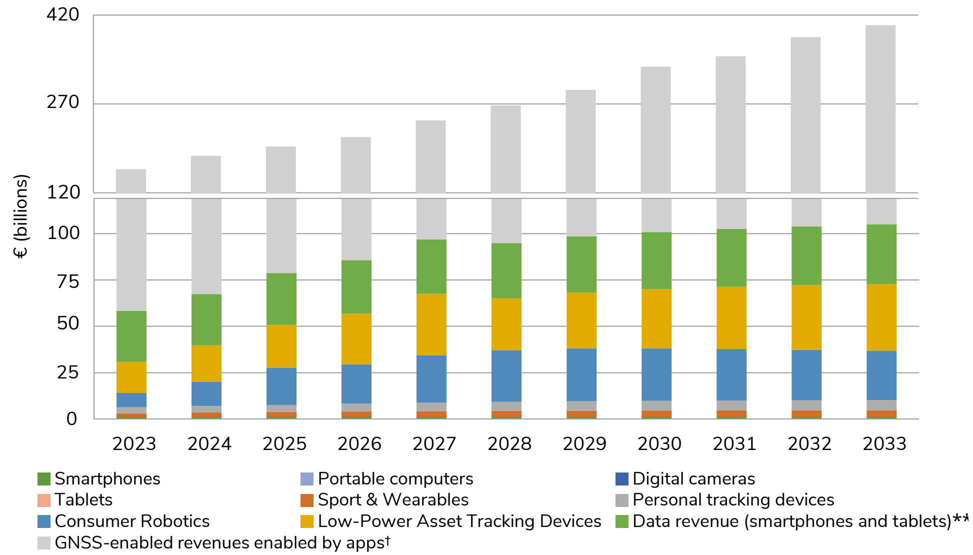
Installed base of GNSS devices by type



Revenue from GNSS device sales and services by region

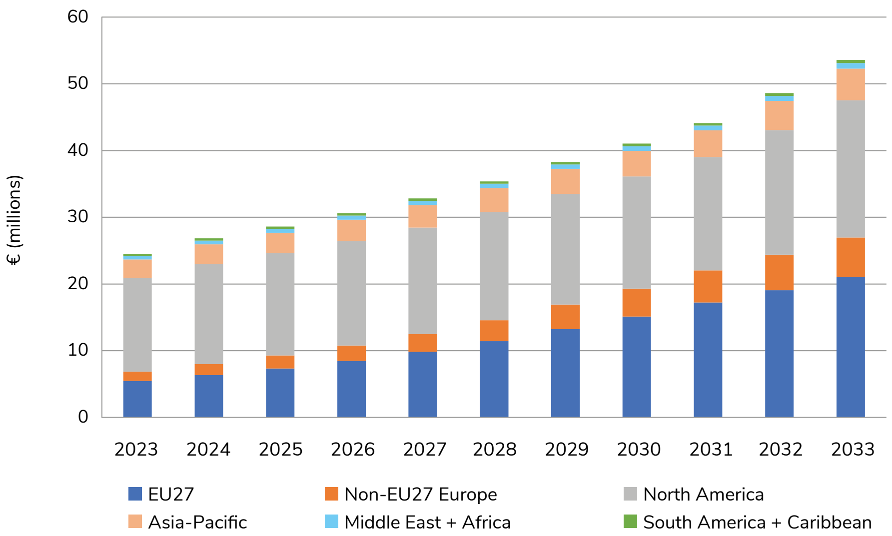


Revenue from GNSS device sales and services by type

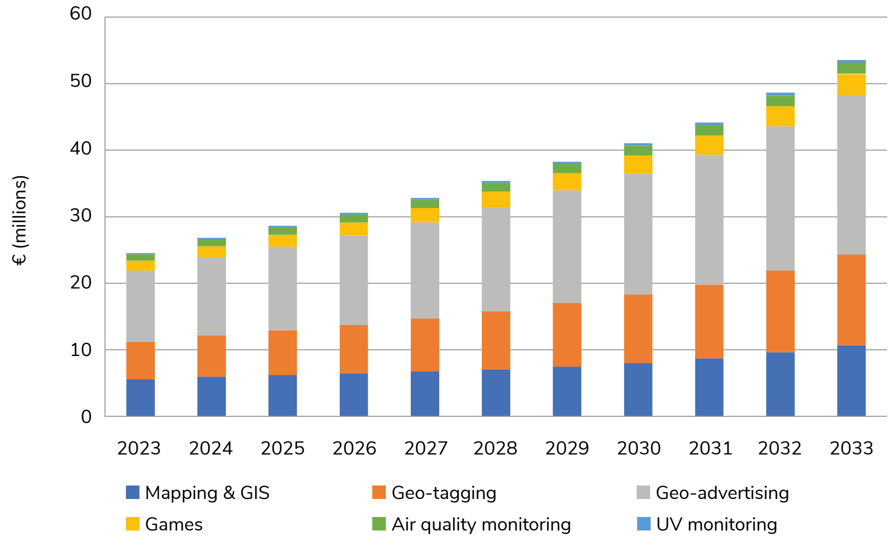


**: Only data revenue arising from the use of GNSS-based services considered;
†: Pay-to-download, In-app-purchases and ad revenue from health & lifestyle, navigation & trackings, tourism, and corporate apps

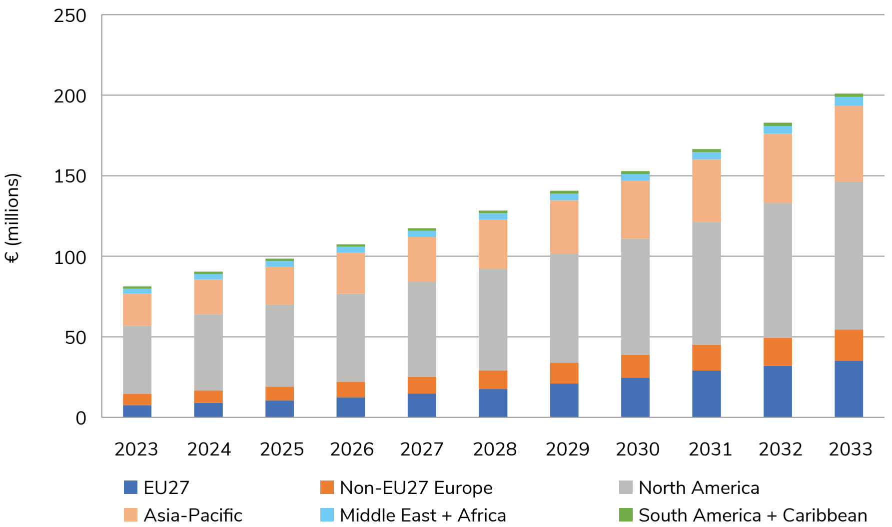
Revenue from EO data sales by region



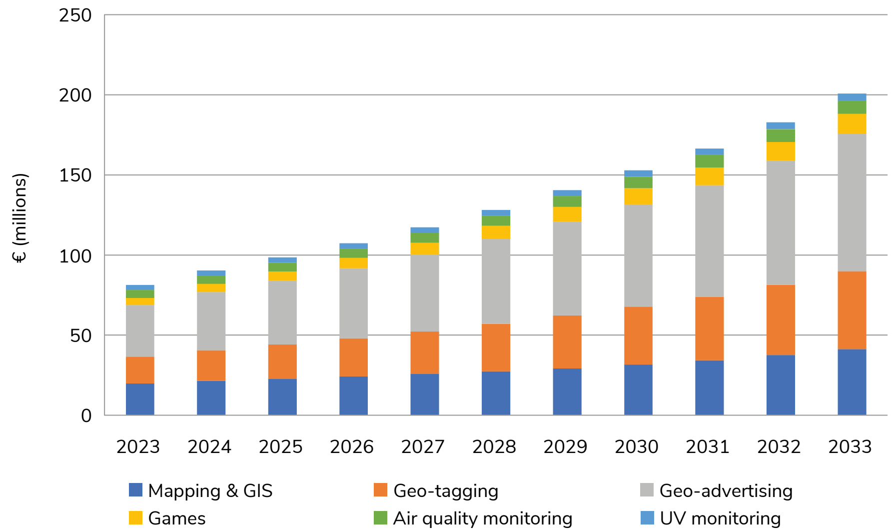
Revenue from EO data sales by application



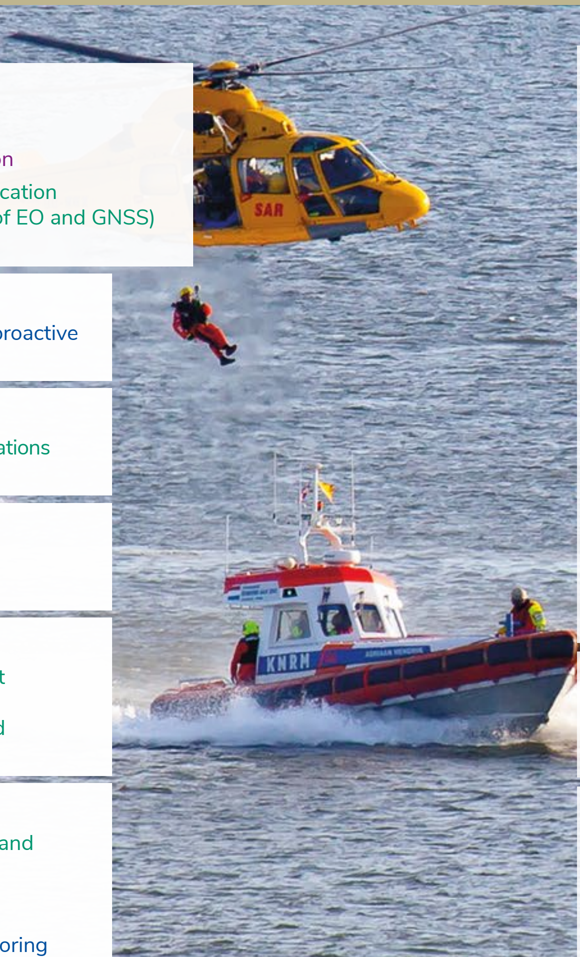
Revenue from EO services sales by region



Revenue from EO services sales by application



EMERGENCY MANAGEMENT AND HUMANITARIAN AID



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

Prevention and mitigation
- Impact exposure analysis and proactive mitigation measures

Preparedness
- Early warning emergency applications
- Hazards monitoring

Response
- Crisis area assessment
- Operational wildfires modelling

Post-event recovery
- Post-crisis damage assessment and building inspection
- Restoration of supply chain and infrastructure services

Humanitarian aid
- Health and medicine response and coordination (incl. Anticipatory humanitarian action)
- Management of refugee camps
- Population displacement monitoring
- NGO's asset management[4]
- Welcome applications to people in need of humanitarian aid

Search and Rescue
- SAR operations: at sea[1]
- SAR operations: aviation[2]
- SAR operations: land[3]
- Situational awareness supporting SAR

[1] 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)
[2] Incl. Emergency locator transmitter (ELT), Emergency locator transmitter Distress Tracking (ELT-DT) and Personal Locator Beacons (PLBs)
[3] Incl. PLBs
[4] Incl. Telematics for vehicles and assets

Application descriptions can be found in Annex 3.

EMERGENCY MANAGEMENT AND HUMANITARIAN AID

The synergetic EMAid segment, which sees a balanced use of both EO and GNSS technologies, is composed of two sub-segments: emergency management, which encompasses the organisation, planning and application of emergency management measures to prepare for, respond to and recover from disasters; and humanitarian aid, which consists of delivering life-saving assistance to those in need, without any adverse distinction.

The domain of EMAid, 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 support actors both on the field and behind their desk at coordination centres across the world. Actors within this segment include national governments, international organisations, NGOs, dedicated agencies and private companies.

EO plays an important role, providing key information for emergency management in each of the four stages of EMAid: prevention/mitigation, preparedness, response and recovery. EO also provides data for SAR operations, as part of an emergency response phase, and post-event recovery analysis via the comparison of recent and archival damage assessment from EO data. EO provides comprehensive information over vast, remote and volatile areas, offering reliable and frequently updated documentation, assessments, and real-time monitoring of humanitarian situations.

GNSS provides humanitarian aid operators with precise geolocation information, enabling efficient logistics planning, asset management, and navigation in remote or disaster-stricken areas, thereby enhancing the effectiveness of emergency response efforts. GNSS-enabled geolocation is fundamental when responding to emergency situations caused by droughts, earthquakes, floods, and other natural disasters.

Cross-reference: *GNSS-enabled search and rescue beacons are presented and quantified in this market segment. However, these beacons are used by different users across maritime and inland waterways, fisheries and aquaculture, manned aviation as well as on land (e.g. consumer solutions).*

What you can read in this chapter
- **Key trends:** EO and GNSS are supporting increasing demand for humanitarian and emergency response efforts.
- **User perspective:** User-centred design brings tangible benefits to those in need of assistance.
- **Industry:** Emergency management and humanitarian aid value chains.
- **Recent developments:** Multifaceted satellite data improves response to disasters and humanitarian assistance – Preparedness, prevention and mitigation lead the EO data and service market.
- **Future market evolution:** The role of EO in crisis management and assistance mobilisation is absolute.
- **European systems and projects:** EGNSS and Copernicus are adaptable and ever-evolving.
- **Reference charts:** Yearly evolution of installed base of GNSS devices and revenues as well as EO revenues by application and region in the EMAid sector.

EO and GNSS are supporting increasing demand for humanitarian and emergency response efforts

Key market trends

- The holistic use of EO and GNSS data to the **four stages** of emergency management (prevention and mitigation, preparedness, response, and post-event recovery) has been observed, driven by the expanding use of satellite-derived EO and GNSS geospatial information, which support continual planning and action cycles when needed
- Data is helping actors active in humanitarian aid make better informed decisions and logistic planning, customising the most effective way to allocate resources to the specificities of the emergency, location and priorities
- The Galileo SAR beacon market is expected to grow significantly in the coming years, with the installed base of GNSS-enabled SAR beacons expected to double by 2029 (see page 88)

Prevention and mitigation is an integral part of the emergency management cycle

The risk mitigation and prevention phase is focused on **minimising the effects of disasters by identifying and evaluating potential risks** (differently in urban/rural areas). The EU Disaster Risk Management policy developments focus on the prevention and reduction of disaster risks, tackling them through preventive, preparedness, response and recovery actions.

The Disaster Risk Reduction Working Group established under the coordination of Group on Earth Observations (GEO) is developing and implementing a clear and crosscutting approach to advance the use of EO in Disaster Risk Reduction efforts, both at the national and local level. GNSS can support monitoring and early warning systems for natural disasters such as landslides, earthquakes and tsunamis, providing critical information for preparedness and mitigation. GNSS is essential in a variety of applications related to disaster management, enabling precise emergency response, recovery activities, and logistics operations.

The **European Commission Disaster Risk Management Knowledge Centre** (EC DRMKC) integrates existing scientific multi-disciplinary knowledge and co-develops innovative solutions for existing needs. Activities of the EC DRMKC support the translation of complex scientific data and analyses into usable information and provides science-based advice for DRM policies.

Satellite technology offer crucial support to cope with the challenging geopolitical context

The UN recognises **the important role that Earth Observation and geolocation (provided by GNSS) plays in supporting sustainable development**, including humanitarian aid operations. EO can provide information over large, remote and unstable areas, providing reliable and frequently updatable documentation, assessments and monitoring in near real-time of the evolution of humanitarian situations. GNSS positioning is used during emergencies and disasters to optimise efficient and effective responses to emergency situations, as well as to support logistics operations.

Given the growing risks in the EU's vicinity, **humanitarian aid and diplomatic efforts to resolve conflicts are more crucial than ever**. The 2023 humanitarian budget is around €1.8 billion, with a focus on Ukraine and regions in the Middle East and Africa. Thematic Copernicus Emergency Management Service-based workshops help aid workers harness Copernicus tools effectively. Space data tailored to the needs of the humanitarian community aids logistics, asset management, and refugee camp planning and monitoring.

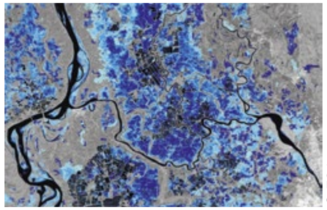
In this context, EUSpace4Ukraine is an initiative through which EUSPA is connecting the EU space innovation community with NGOs offering humanitarian aid to provide technological solutions enhancing humanitarian support for the Ukrainian people. You can read more about this programme on page 87.

An integrated approach is crucial to save lives, dispense emergency assistance and provide disaster relief

In recognition that disaster preparedness plays an important role in building the resilience of communities, the EU is aiming to mainstream preparedness and risk reduction measures across all its humanitarian programming. The approach to disaster preparedness and risk-informed humanitarian response promotes **multi-hazard preparedness and anticipatory action** as a means for a quicker and more effective response. To support this work, the EU's Civil Protection and Humanitarian Aid Operations department published a new Disaster Preparedness Guidance Note in 2021, which explains its approach to disaster preparedness.

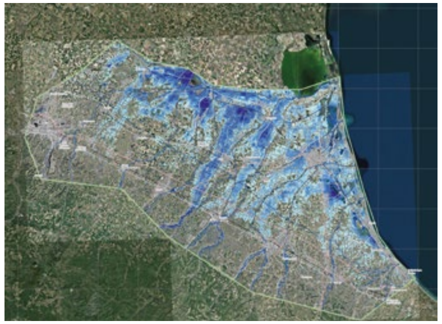
Disaster management is an area where the use of satellite data can make a difference and even save lives, and the **Copernicus Emergency Management Service** (CEMS) is a major tool supporting disaster preparedness and management. It is free of charge and available for emergency actors anywhere in the world. The service supports crisis managers, civil protection authorities and humanitarian aid actors dealing with natural disasters, manmade emergency situations, and humanitarian crises, as well as those involved in disaster risk reduction and recovery activities. CEMS consists of five main components: risk & recovery mapping; rapid mapping; early warning & monitoring systems for forest fires (European and global); early warning & monitoring systems for floods (European and global); and the European Drought Observatory (EDO). CEMS provides all actors involved in the management of natural disasters, manmade emergency situations, and humanitarian crises with timely and accurate geospatial information derived from satellite remote sensing and completed by available in situ or open data sources. It has become the main space-enabled support services for a variety of emergencies, A total of 86 activations of the rapid mapping service were carried out in 2022 alone.

In this context, the **Emergency Response Coordination Centre** (ERCC) is the heart of EU Civil protection mechanism, acting as a deployment hub for all EU Member States, participating states, the affected country and civil protection and humanitarian experts. The centre coordinates the delivery of assistance to disaster-stricken countries and fulfils a pivotal role in coordination emergencies inside and outside the EU, enhancing integrated and coordinated actions.



User-centred design brings tangible benefits to those in need of assistance

Delineation monitoring of a fire in Tenerife, Spain. Copernicus Emergency Management Service (© 2023 European Union), EMSR685



Delineation monitoring of flooding in Emilia-Romagna, Italy. Copernicus EMS mapping service (© 2023 European Union), EMSN154

Detail of landslide risk assessment for Olympia archaeological site. Copernicus Emergency Management Service (© 2022 European Union), EMSN128

Data for humanitarian needs is widely available but more awareness, training and know-how are needed

A key trend in the humanitarian aid sector is the **adoption of new technologies and services**. The integration of these new technologies into pre-existing systems can be complex, but their advancement and implementation **can help improve decision-making processes**. NGOs are already using GNSS in addition to EO for asset management. The leveraging of EO data into solutions can offer significant solutions to users, such as:

- Detecting changes during armed conflict, including the destruction of urban/suburban environments, population displacement and camp monitoring;
- Leveraging a full-time series of satellite data for long-term analysis. The Copernicus programme delivers analogous datasets and time series, ensuring that trends and changes are monitored over time.

However, broadly speaking, **users of EO data** in the humanitarian aid sector **still encounter several challenges** and difficulties when using these data.

First and foremost, it is often the case that NGOs and humanitarian actors are working with **limited and/or strict budgets**. This affects the ability to acquire EO data and services which can be expensive, especially considering the many data factors needed for applications in this sector. A way to overcome these constraints could be for EO service providers to offer tailor-made, budget-friendly services or to price these services at discounted rates for enterprises in the sector.

Furthermore, **EO data and products can be technologically too complex** for users not accustomed to data processing or such data formats. The biggest challenge is the lack of technical expertise, namely the difficulty in accessing and processing the raw data into usable information, and then communicating that information effectively to diverse stakeholders. What the sector needs is easy-to-use data and systems, delivered quickly at a low cost. This was confirmed during the 2022 User Consultation Platform (see below), where users identified the need for easily manipulable datasets with robust and frequently updated (at least daily) data.

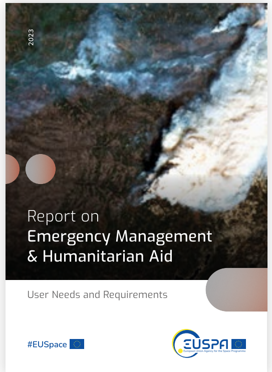
Apart from tailor-made solutions by service providers, humanitarian aid organisations may need technical **training** in **remote sensing techniques and data processing, management and analysis** to effectively use Copernicus EO data, in addition to training for specific applications involving EO data, such as disaster response or food security monitoring. This can assist humanitarian aid workers to better understand how to use Copernicus EO data to support their work. Thematic Copernicus EMS-based workshops can also help in this matter.

Sources of key EO and GNSS user requirements

The key EO and GNSS user requirements for the different application groups within the **emergency management and humanitarian aid** segment are collected using a harmonised procedure at EU level.

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 Emergency Management and Humanitarian Aid user needs and requirements. User requirements for Earth Observation (EO) services and products – as well as their evolution – are now also collected through the UCP. The process covers the EO user needs and requirements of commercial users based on inputs from industry experts and user groups, mirroring the existing process implemented for GNSS.

Moreover, the collection of specific requirements for Copernicus services and products is supported by 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; and (iii) regular and structured exchanges among representatives of the Copernicus governance structure and Member States through the Copernicus User Forum.



Emergency Management and Humanitarian Aid Value Chains[1]

EARTH OBSERVATION

DATA PROVIDERS

- AIRBUS*
- BLACKSKY
- CAPELLA SPACE
- GEOSAT*
- E-GEOS*
- ICEYE*
- MAXAR
- PLANET
- UMBRA

- COPERNICUS SENTINELS*
- COSMO-SKYMED (ASI)*
- DMC*
- LANDSAT (USGS)
- METEOSAT (EUMETSAT)*
- RADARSAT (CSA)
- RELEVANT IN-SITU NETWORKS
- RELEVANT NATIONAL MISSIONS

INFRASTRUCTURE PROVIDERS

- AWS
- CLOUDFERRO*
- GOOGLE CLOUD PLATFORM
- IBM CLOUD
- MICROSOFT AZURE
- T-SYSTEMS*

- FEDERATED INFRASTRUCTURE (E.G. GAIA-X)*
- SENTINEL COLLABORATIVE GROUND SEGMENT*

PLATFORM PROVIDERS

- CLOUDEO*
- CREODIAS*
- EARTH-I
- EDS CEODE
- EURODATACUBE*
- GOOGLE EARTH ENGINE
- NORTH.IO*
- OPEN DATA CUBE
- OPENEO*
- PLANET EXPLORER
- SENTINEL-HUB* (SINERGISE)
- SPATIAL SERVICES*
- UP42*

- GEOHAZARDS HYDROLOGY TEP*
- COPERNICUS DATASPACE ECOSYSTEM*
- NOAA ONESTOP (NOAA)
- CODE-DE*
- WEKEO*

EO PRODUCTS AND SERVICE PROVIDERS

- 4EARTHINTELLIGENCE*
- CONSTELLR*
- DEIMOS*
- DEWBERRY
- DHI GRAS*
- GAF*
- GEOVILLE*
- HR WALLINGFORD*
- INDRA SISTEMAS*
- KSAT*
- ORORATECH*
- PIESAT*
- SERCO*
- SKYGEO
- TRE ALTAMIRA (CLS GROUP)*
- VERISK ANALYTICS

- COPERNICUS CLIMATE CHANGE SERVICE (C3S)*
- COPERNICUS EMERGENCY MANAGEMENT SERVICE (CEMS)*
- COPERNICUS SECURITY SERVICE (CSS)*

INFORMATION PROVIDERS

EMAid CROSS CUTTING:
- E-GEOS*
- EO4GEO*

EMERGENCY MANAGEMENT SERVICES:
- ORBITAL INSIGHTS*

HUMANITARIAN AID SERVICES:
- GEOHUM*

END USERS

- CIVIL PROTECTIONS, SMALL PUBLIC SPACE AGENCIES
- NATIONAL GOVERNMENTS
- NGOS (UNHCR, RED CROSS, MEDICINS SANS FRONTIERES (MSF))
- REGIONAL AUTHORITIES

GNSS

COMPONENT AND RECEIVER MANUFACTURERS

- ACK TECHNOLOGIES
- ACR ELECTRONICS
- AEROMARINE SRT
- ASTRONICS CORPORATION
- BABCOCK MISSION CRITICAL*
- BLUE SKY NETWORK
- COMNAV TECHNOLOGY*
- CORE CORPORATION
- CYBERNETICA*
- GME
- HEICO
- HR SMITH*
- INTELLIAN TECHNOLOGIES
- NEW SUNRISE CO.
- OHB*
- SAFRAN*
- SYRLINKS*
- SEPTENTRIO*
- TECHTEST LIMITED*
- U-BLOX*

SAR BEACON MANUFACTURERS

EPIRB & PLB
ACR ELECTRONICS, COBHAM*, FURUNO ELECTRIC, H R SMITH*,JAPAN RADIO CO, JOTRON AS*, OCEAN SIGNAL*, SAFRAN*, SYRLINKS*, TECHTEST*, WÄRTSILÄ*

AIS-SART & AIS-MOB
ACR ELECTRONICS, COBHAM*, FURUNO ELECTRIC, JOTRON AS*, KONGSBERG MARITIME*, OCEAN SIGNAL*, SAFRAN*, WÄRTSILÄ*

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

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

LEGEND
- Commercial offering
- Public offering / entities
- User segments

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

Europe held several top positions among GNSS Component and Receiver manufacturers for the Emergency management and humanitarian aid sector in 2021. U-blox held second place after ACR Electronics. Overall, European companies and North American manufacturers hold 90% of the market.

In EO, the market is mainly divided between North America and Asia, which have a combined share of 65%. In comparison, European companies retain almost 35% of the market, led by companies such as e-GEOS (Leonardo), Deimos, and Indra Sistemas.

NOTES

[1] The value chain considers the key global and European companies involved in GNSS and EO downstream activities. Please note that enterprises listed in the data providers step of the value chain often provide platforms as a service. For the sake of simplicity the data providers are not repeated in other stages of the value chain in which they are active.

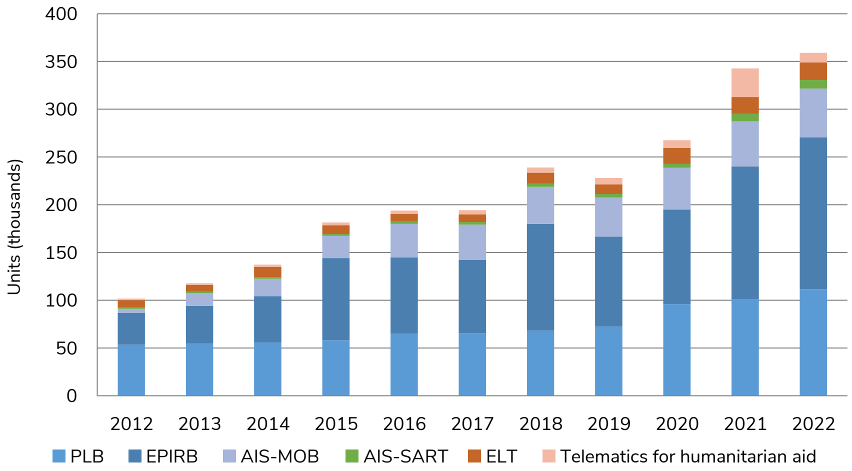
[2] In the market share analysis, Europe is defined as EU27 plus Norway, Switzerland and the UK.

Please refer to page 13 and 23 for a comprehensive description of value chains and how to interpret them at segment level.

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

Multifaceted satellite data improves response to disasters and humanitarian assistance

Shipments of GNSS devices by type



With over 150 000 units in 2022, **Emergency Position Indicating Radio Beacons (EPIRBs)** are by far **the largest group** of GNSS-enabled search and rescue beacons being sold each year. **Personal Locator Beacons are** the **second**-largest category, reaching over 110 000 units, ahead of **AIS-MOB (Man Over Board)**, which grew the fastest, registering a CAGR of 28% over the period 2012-2022.

Emergency Locator Transmitter (ELT), although only forming a small portion of the market, is still **growing steadily** over the years. The same goes for **Telematics for humanitarian aid**, for which a significant rise was observed in 2021, before returning to its previous growth rate in 2022.

The pronounced rise in 2018 and fall in 2019 reflect the overestimation by manufacturers of the size of the market and subsequent adjustments to the supply chain. Another significant shipment rise in 2021 is attributed to the rebound after the COVID-19 pandemic and the increasing functionalities of GNSS in handling crisis situations.

The expected future growth in the shipments GNSS devices for emergency management and humanitarian aid is reflected also in the evolution of the installed base (see reference charts on page 90).

Galileo Emergency Warning Satellite Service providing free and accessible early warning systems

According to Regulation 2021/696, in the near future, Galileo, the European GNSS, is set to contribute to early warning systems through a new service named the **'Galileo Emergency Warning Satellite Service' (EWSS)**. Offered at no cost to users, this satellite service will communicate warning messages to populations facing the threat of natural disasters or other emergencies in affected regions. The service can be **accessed on any Galileo-enabled devices that can receive, decipher and display these messages**.

The EWSS will span **global coverage** and will be complementary to the public **warning system**. This public warning system has been implemented across mobile networks since June 2022, in line with the Directive (EU) 2018/1972 which established the European Electronic Communications Code.

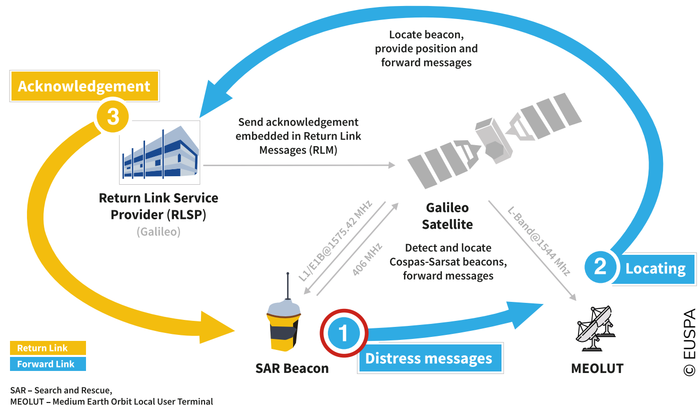
The service is **free of charge for users** and will broadcast warnings on natural disasters and other emergencies in close cooperation with Member States' national civil protection authorities. Galileo's messaging function transmits an **alert to Galileo-enabled devices with instructions to follow depending on the area** in which the user is located.

Galileo's Return Link Services paving the way for greater EGNSS adoption as well as the introduction of Remote Beacon Activation to support the search and rescue of aircraft and vessels suspected of being in distress

Galileo **supports SAR Rescue operations** with the introduction of its unique feature: **the Return Link Service (RLS)**, which has been operational since 2021. This feature complements Galileo Forward Link Service which has been in operation since 2016. Whereas **the Forward Link Service relays distress** signals from emergency beacons to the ground segment or the response centre, **the RLS acknowledges and confirms the receipt of the signals to the emergency beacon users**. The return and forward link is graphically represented on the illustration below.

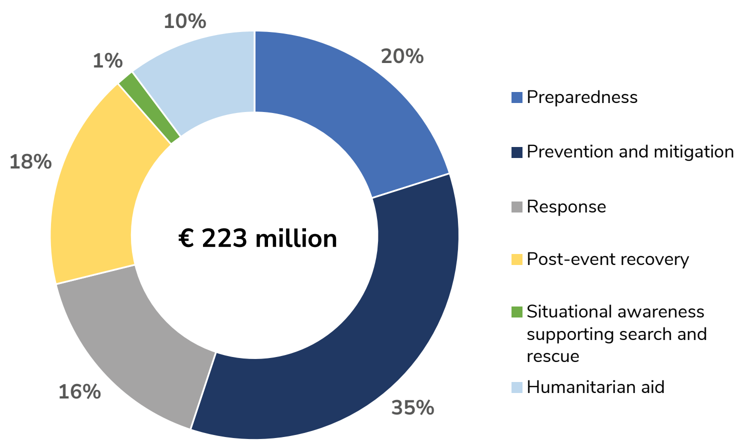
Currently, **Galileo RLS-enabled emergency beacons** for personal use, maritime and aviation (PLBs, EPIRBs and ELTs) **are already available on the market**.

Moreover, RLS will enable the additional service of Galileo Remote SAR Beacon Activation (RBA), for which the beacons would constantly read the return link signals. Consequently, the Galileo ground segment would be able to remotely activate a specific beacon in the event the vessel or aircraft is suspected to be in an emergency (e.g. no communication received, concerns raised by owner/operator, etc.). This activation would thereby aid the rescue operators or allow for the subsequent de-activation in case it is confirmed that there is no real emergency.



Preparedness, prevention and mitigation lead the EO data and service market

Revenue from EO data & services sales by application in 2022



The **EO market for data and services concerning emergency management** and humanitarian aid was valued at nearly **a quarter of a billion euros in 2022**. The **market has grown** by an expected CAGR of 7% since 2020.

Prevention and mitigation are the largest category with 35% of the market share; the segment has grown the most since 2020. **Preparedness is second** with 20%, followed closely by post-event recovery and response. This growth reflects the increased attention that citizens and public organisations devote to emergency prevention and preparedness, which is not surprising considering the growing frequency of natural and man-made emergencies.

Humanitarian aid constitutes 10% of the market, while the smallest market share is attributed to the application of situational awareness supporting search and rescue, which has been re-segmented in this year's iteration of the report. The market for this application is expected to double by 2032 as the service is already well-developed and it will continue to grow over the coming years.

The Copernicus Emergency Management Service (CEMS) 10-year anniversary

CEMS celebrated a decade of operation in June 2022 as a world leader in emergency mapping, early warning, and monitoring. CEMS has provided a truly global service as **the world's only fully operational emergency mapping service at no cost to users and with open access data** for the past 10 years, with most components of CEMS operating 24/7/365. CEMS is constantly evolving and integrating the latest developments in science and technology to improve its services. CEMS components include:

- **On-demand mapping**, offering on-demand detailed information for selected emergency situations that arise from natural or man-made disasters anywhere in the world. This include Rapid Mapping, able to provide geospatial information within hours or days, and Risk and Recovery Mapping, which supports disaster management activities.
- **Exposure mapping** providing highly accurate and continuously updated information on the presence of human settlements and population with the Global Human Settlement Layer (GHSL). This component include Population grids, able to quantify the amount of population exposed to hazard, and Built-up surface grids providing information on human settlements.
- **Early Warning & Monitoring** offers critical geospatial information at European and global level through continuous observations and forecasts for floods, droughts and forest fires.

For more information, please visit the CEMS website

Mobilising the EU Space innovation community to enhance humanitarian support in Ukraine

The **EUSpace4Ukraine initiative**, initiated by the EU Agency for the Space Programme (EUSPA), **focuses on satellite data applications to support civilian/humanitarian efforts in Ukraine**. Through this initiative, EUSPA connects EO and navigation app developers with NGOs, volunteers and personnel in Ukraine, allowing them to utilise satellite data for humanitarian purposes.
The **EUSpace4Ukraine demonstration** was held in Poland with a focus on the **Copernicus enhanced map application and Galileo-enabled drones** for search and rescue operations. The mapping application provides up-to-date, accurate Copernicus imagery which is used to support humanitarian aid workers in navigating a challenging terrain faster and supports mission planning more efficiently considering the impacts on the terrain. The drones, on the other hand, are equipped with thermal cameras and optical zoom which support the assessment of the structural integrity of damaged buildings and facilitate the search for people in remote locations.
Both applications were then used and tested by the Ukrainian Red Cross in a simulated emergency environment near Lublin and will undergo further testing in actual fieldwork in the weeks and months following the demonstrator.

More information available at:
https://www.euspa.europa.eu/euspace4Ukraine

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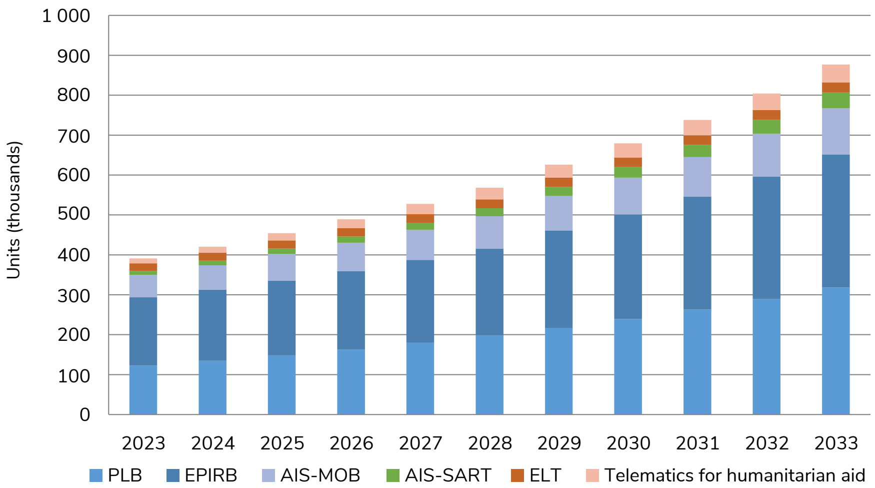
The role of GNSS and EO in crisis management and assistance mobilisation is absolute

Shipments of GNSS devices by type



The chart shows that from 2023 to 2033, **shipments of emergency management and humanitarian aid GNSS devices** will grow consistently, indicating an increasing emphasis on safety measures.

The **largest share of the market is taken by EPIRB units**, growing from around 170 000 units in 2023 to just over 300 000 by 2033. This is **followed by PLB and AIS-MOB**, growing to more than 300 000 and 100 000 units respectively by 2033 – more than double the current shipments number for PLB over a period of 10 years. The ELT category will also grow, although with a lower CAGR.

Both PLBs and EPIRBs contributed to around 40% of the global installed base in 2023 (see reference charts on page 90), and EPIRBs are projected to lead the market from 2023 onwards, taking over from PLBs' market dominance in the past decade. The installed base of AIS-MOBs, which are quite popular among recreational boaters and crews of smaller vessels, has reached around 10% of the market.

Understanding emergency and risk as an all-encompassing system with multiple synergies

Earth Observation data and geolocation provided by GNSS play a crucial role in achieving the **United Nations' 2030 Agenda for sustainable development** (see page 24). The United Nations' Office for Outer Space and EUSPA wrote a collaborative report highlighting the positive impact EGNSS and Copernicus applications have on fulfilling sustainable development goals. There are 17 **main sustainable** development goals, 13 of which **benefit significantly from EGNSS and Copernicus**. The study also emphasises the potential of EGNSS-EO convergence to stimulate innovation and increase the use of space technology.

GNSS ensures accurate positioning globally at any time, while **Earth Observation (EO) supplies data on the Earth's surface, atmosphere and marine systems**. This research distinctly illustrates that the collaborative utilisation of both systems unlocks numerous synergies with a significant influence on sustainable development.

Illustrating the integration of GNSS and EO, the EUSPA H2020 project "**GEO VISION**" delivered global visual situational awareness, facilitating "observation to action" within a minute. It is specifically designed for applications such as humanitarian crisis management. Notably, **products and applications from the project are actively employed by the United Nations**, such as mapping earthquake impacts in Nepal to enhance Search and Rescue (SAR) operation efficiency.

Revolutionising wildfire detection with thermal imagery technology

Wildfires occur at greater frequencies than they have in past decades. **Fire prevention and swift detection** immediately after a fire ignites **are vital elements** in firefighting efforts. Presently, in densely populated regions, human observations, often through smoke or aerial surveys, are the primary means of detecting fires. **In remote areas, satellites**, including weather satellites like GOES or moderate-resolution imagery like NPP-VIIRS, as well as Sentinel-2 SWIR bands **can be utilised for fire detection**.

Munich-based **OroraTech**, a major player in the global earth observation industry, will launch a break-through on-orbit fire processing technology that is able, in merely 3 minutes, to detect and send fire notification alarms to customers via the multi-satellite link once the satellite has passed the affected area. The new on-orbit detection with the unique satellite constellation will be launched in 2024.

© Copernicus Climate Change Service European State of the Climate | 2022

Constellr is another company that provides wildfire solutions with land surface temperature monitoring, using a combination of publicly available data and Constellr proprietary data.

These are just two examples of enterprises that utilise space data to provide solutions for natural disasters.

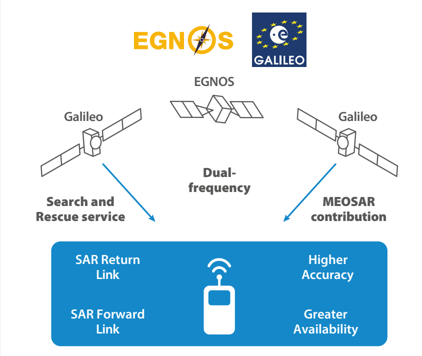
EGNSS and Copernicus are adaptable and ever-evolving

Current usage of EGNSS

The Galileo Return Link Service (RLS) is a worldwide service provided at no cost to COSPAS-SARSAT RLS compatible beacons.

Exclusive to Galileo, this innovative feature establishes a communication link that transmits Return Link Messages (RLM) back to the beacon's source, notifying the user that the alert has been identified and localised.

The introduction of RLS underscores Europe's leadership in cutting-edge technological solutions for emergency management operations.



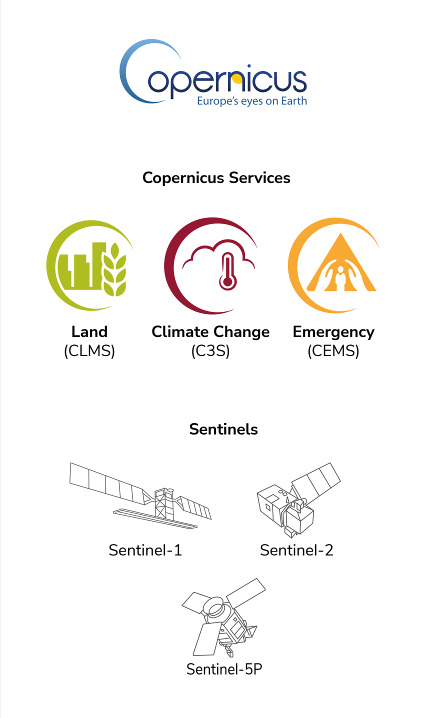
Copernicus Usage for Emergency Management and Humanitarian Aid

Copernicus plays an important role in emergency management, providing key information at each of the four stages: **prevention, preparedness, response and recovery** activities for different natural and man-made disasters and other humanitarian crises.

The **Copernicus Emergency Management Service (CEMS)** provides data about the effects of impact exposure such as assets and population density. Concerning **prevention and preparedness**, CEMS is used, including through the risk and recovery mapping, to support monitoring activities and risk assessments, as well as preparedness studies for resilience of specific areas, e.g. to rain events.

Supported also by other Copernicus services (e.g. C3S provides continuous observations and forecasts relevant for many types of disasters), many **CEMS components** are used to prevent or cope with emergencies, including **the rapid mapping component**, in search and rescue activities, as part of an **emergency response** phase, supporting situational awareness. Finally, during the post-event **recovery** analysis stage, the comparison of recent and archival **EO data supports damage assessment**.

Humanitarian aid actions are transversal and tend to cover the whole cycle; in this regard, **Copernicus can help monitor displacement of refugees** and internally displaced persons, among other uses such as population counting.



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

Horizon Europe, a programme of the European Union

Overwatch

OVERWATCH – Integrated holographic map for disaster events

EO data is a key element for **hazard impact evaluation and recovery planning** in case of large-scale disaster events. Combined with low-height drones, it allows to obtain for high-accuracy terrain mapping.

OVERWATCH designs and develops a **holographic management map for emergency management for wildfires and floods.** The developed platform **covers the lifecycle of data management** starting with data ingestion, and followed by harmonisation, standardisation, and data processing. The data is then transformed into exploitable information supporting emergency/crisis management for floods and wildfires.

The project is also developing a new set of machine-learning algorithms to map floods, fires, and damaged area, using Copernicus Sentinel and drone data. In particular, for Sentinel-2, super-resolution techniques will be trained on the 10m visible and NIR bands and the 20m red edge, SWIR bands to enhance the spatial resolution of the source data by up to 4 times (5m). The AR/VR-enabled holographic map provides the user (person in charge of crisis management and response) with an intuitive and visually appealing interface.

More information available at: https://overwatchproject.eu/en/

Horizon Europe, a programme of the European Union

AWARE: enAabling EWS/GAlileo maRket uptake in widEspread PWS Solutions

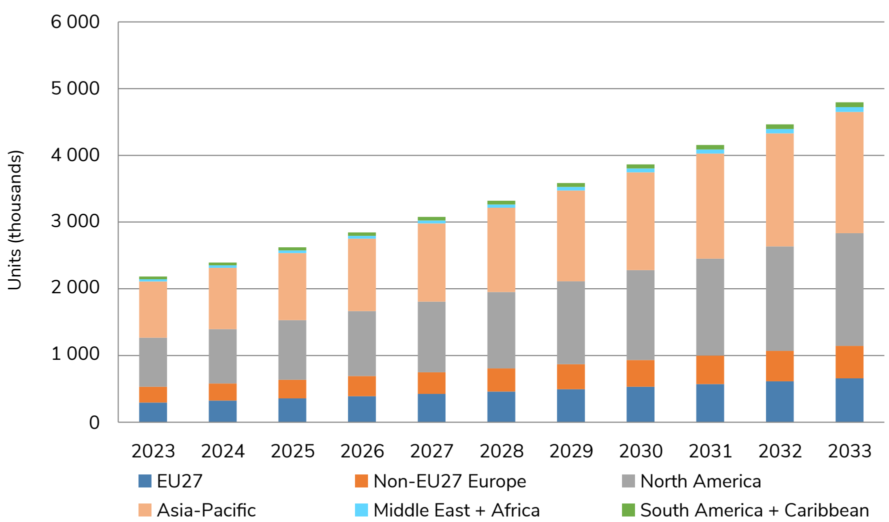
The European Commission is expected to launch the Galileo Emergency Warning satellite service (EWSS) in the near future. **EWSS is a worldwide service to broadcast emergency warnings linked to natural or manmade disasters**, with the major advantage of remaining operational when all terrestrial communication networks are down, and in places where they do not exist at all.

Final recipients of EWSS messages are primarily citizens equipped with Galileo-enabled smartphones, although another category of end-users exists: the **Public Warning Systems (PWS) stakeholders**. For these, specific GNSS equipment is needed to receive and process the EWSS messages. The equipment must be integrated into **fixed devices which alert citizens** via audio, video and text alert messages (such as Long-Range Acoustic Devices or Digital Panels) or adequate digital messages flows within IT systems.

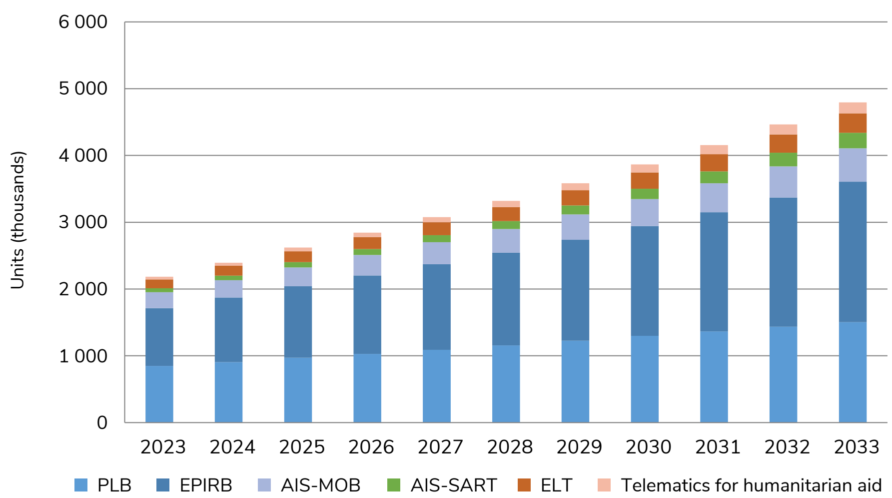
The **purpose of the AWARE project is to develop this specific GNSS equipment**, also benefitting from the OSNMA feature. AWARE will also enhance the adoption of EWSS by European civil **protection** authorities by performing activities to support the EUSPA and the EC for the service.

More information is available at: https://www.euspa.europa.eu/enabling-ewsgalileo-market-uptake-widespread-pws-solutions#tab-details

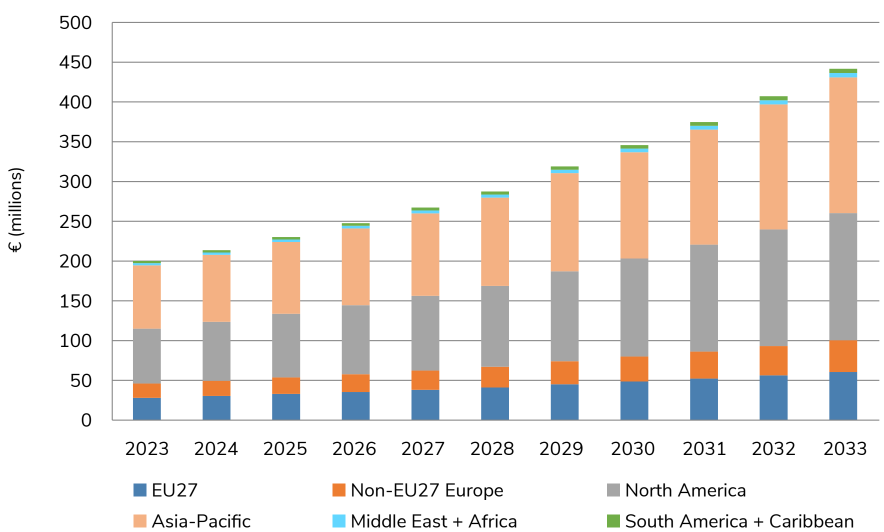
Installed base of GNSS devices by region



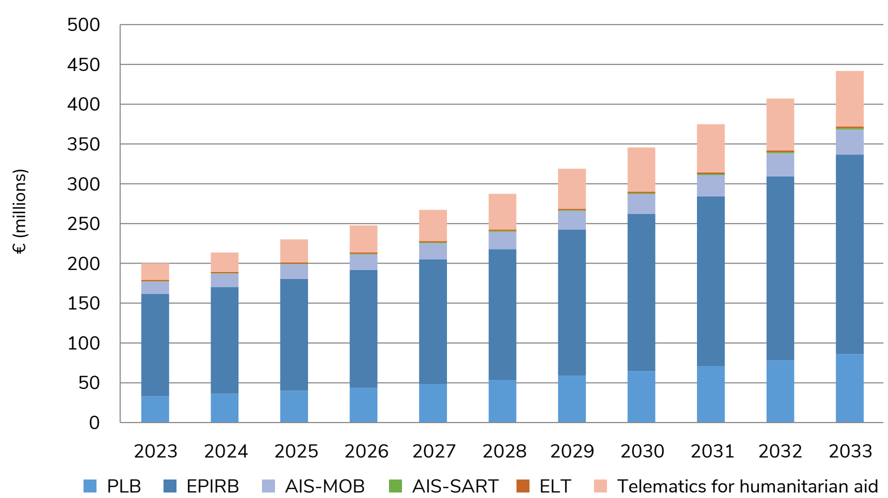
Installed base of GNSS devices by type



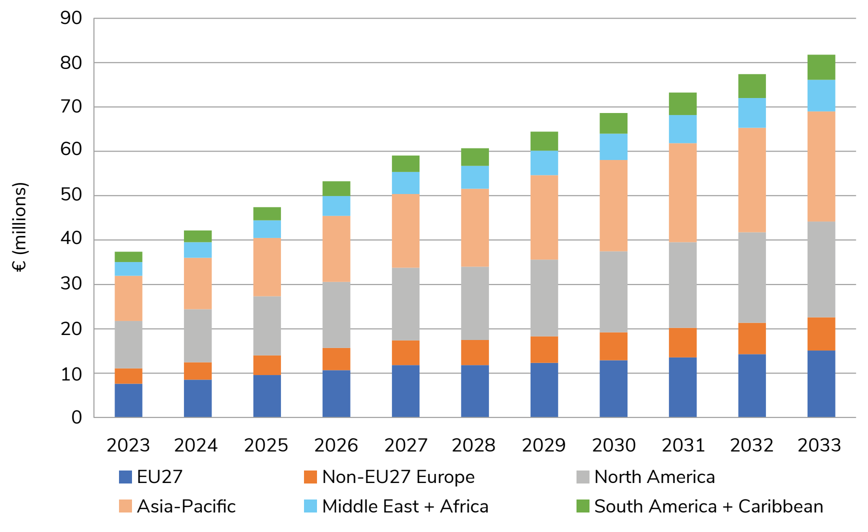
Revenue from GNSS device sales by region



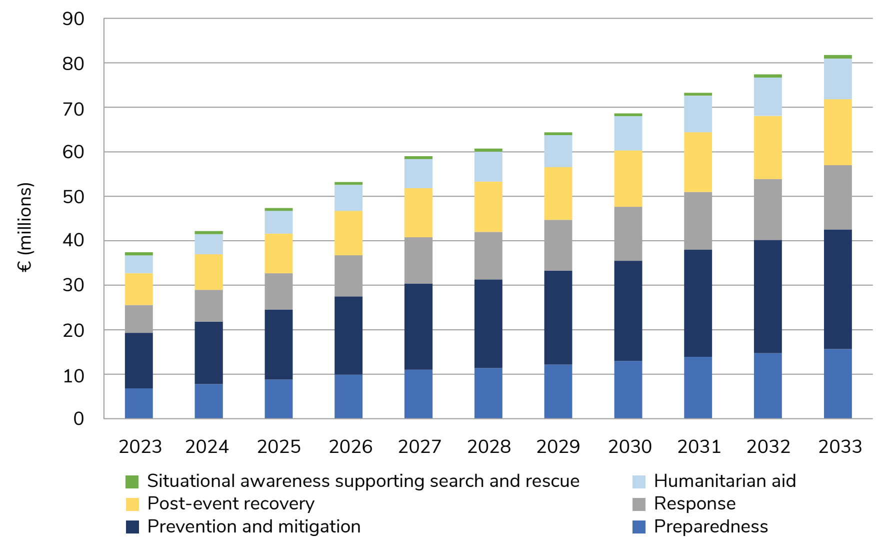
Revenue from GNSS device sales by application



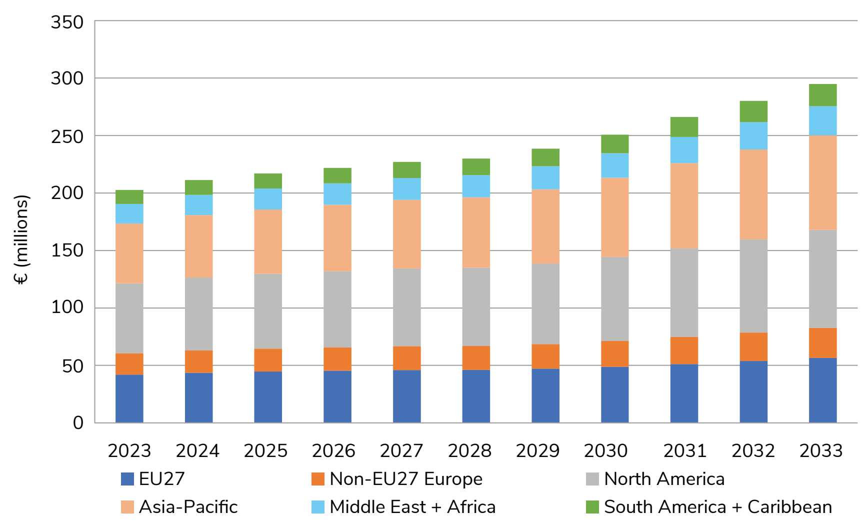
Revenue from EO data sales by region



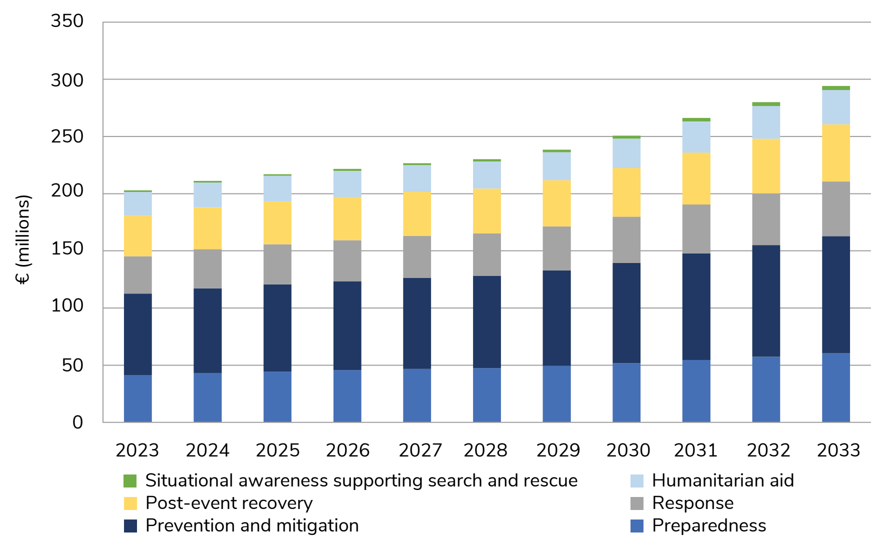
Revenue from EO data sales by application



Revenue from EO services sales by region



Revenue from EO services sales by application



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)

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

Environmental Impact Monitoring
- Environmental impact assessment for energy and raw materials

Market Intelligence
- Supply chain insights

Raw Materials
- Illegal mining monitoring
- Mineral exploration, site planning/monitoring
- Mining vehicle management and control

Application descriptions can be found in Annex 3.

ENERGY AND RAW MATERIALS

Stakeholders in the energy sector include energy project developers, utility companies, energy asset manufacturers, financiers, as well as government institutions, energy traders and supply chain managers. These actors leverage the potential of space data to plan and monitor assets, audit environmental policies and regulation, and gain an overall information edge. A multitude of applications in the energy domain derive substantial benefits from EO data. Among these, a key function is the facilitation of site selection, planning and monitoring. Satellite data proves instrumental in forecasting the potential for renewable energy generation, in the context of solar, wind and hydropower energy sites. Furthermore, it contributes to the enhancement of energy grid stability, and helps anticipate near-term energy prices, by assessing real-time renewable energy production. Energy transmission networks are similarly monitored from space, to ensure their integrity. Moreover, GNSS technology is a key enabling technology for the synchronisation of energy network smart grids through Phasor Measurement Units. Space data and services will prove essential to this sector as the world accelerates the green energy transition.

Stakeholders in the raw materials sector, such as mining companies and associations, financiers, government institutions, commodity traders, and supply chain managers, operationalise EO and GNSS-powered services and products in various ways. For example, space-based data enable efficiency improvements, the tracking of assets, and monitoring of environmental impact. A key application within the raw materials sector is that of exploration: satellite imagery helps identify areas with the highest mineral resources potential. From an operations point of view, satellite imagery can help increase safety, for example, by continuously monitoring mine pit and tailings slope stability. Such data is furthermore leveraged to detect illegal mining activities, or to monitor the post-operational phase of mines, particularly for site clean-up, rehabilitation and waste management.

Note: Topics mainly related to the **Energy** sub-segment are indicated with an **orange circle** while the **Raw Materials** sub-segment topics are indicated with a **blue circle**.

What you can read in this chapter

- **Key trends:** Space data plays an important role in the energy sector, spanning from permitting processes to grid balancing. Enhancing mineral exploration, sourcing, and operational safety with space data for the raw materials sector.
- **User perspective:** Users across the entire energy and raw materials value chain use EO and GNSS-powered services.
- **Industry:** Energy and raw materials value chains.
- **Recent developments:** Mining industry moves to fully automise a wide range of mining operations and increase efficiency and site safety supported by space data. Offshore wind farms deployments and smart grids leverage space data.
- **Future market evolution:** Digital twins will play a key role in optimising mining operations and increasing safety, hyperspectral data provides cost-effective exploration applications. EO can help us understand how climate change will impact renewable energy and help assess environmental impact of renewable energy sites.
- **European Systems:** Current usage of Galileo and Copernicus in the energy and raw materials sector.
- **European projects:** Several European-funded projects combine space data to propose solutions in support of the Energy and Raw Materials sector.
- **Reference charts:** Yearly evolution of installed base of GNSS devices and revenues as well as EO revenues by application and region.

Space data plays an important role in the energy sector, spanning from permitting processes to grid balancing

Key market trends for Energy

- The increasingly complex geopolitical context, climate change and rising energy demand drive governments to further accelerate the green energy transition
- Grid balancing is becoming a major issue as intermittent renewable technologies (wind, solar) increase variability and limited predictability of the energy supply
- Permitting procedures, which include Environmental Impact Assessments, are considered a key bottleneck to rapid deployment of renewable energies
- As climate change increases the frequency of extreme weather events, energy infrastructure is increasingly exposed to extreme ambient temperatures, floods, and high winds

The green energy transition is experiencing major acceleration

Energy markets face extreme volatility, driven by geopolitical developments such as the war in Ukraine, increasing energy demand and a **major shift in the energy mix** as governments and businesses strive to achieve decarbonisation targets. A key factor in reaching the energy transition goals is to **increase the share of electricity** in the power mix and **increase the share of renewables in the generation of electricity**, as electrification is one of the first decarbonisation levers. It is the least expensive and the easiest to implement in most sectors. According to McKinsey, the demand for electricity in Europe is projected to triple by 2050, at which time the overall energy mix is projected to consist of 50% electricity and hydrogen.

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Space data and services support this major shift in the energy mix in various ways, through renewable energy resource assessments (e.g. for wind, solar, hydro and tidal energy sources), environmental impact analysis, and electricity grid synchronisation and balancing. The responsible and effective deployment of renewable energy technologies furthermore leverages space assets, accelerating global efforts to decarbonise and mitigate climate change.

The intermittent nature of renewable energy introduces complexity to grid balancing

Grid balancing has emerged as a significant challenge due to the intermittent nature of renewable energy sources. Unlike traditional fossil fuels, renewables such as solar and wind are **subject to weather variations, leading to fluctuations in energy production**, which strains grid stability and requires careful management as sudden drops in production causes voltage instability and potential blackouts, where overproduction may create surges and overload the grid.

The process of balancing the grid greatly benefits from space data as derived insights **provide real-time information** that enhance the integration of renewable energy sources and optimise energy distribution. Specifically, **space data and services can track weather patterns, cloud cover, solar irradiance and wind speed**, offering accurate near-term forecasts for renewable energy production. This helps operators determine when to charge or discharge energy storage systems (or use excess energy to produce storable clean fuels like hydrogen), and when to ramp up or slow down fossil fuel energy production, crucial for maintaining a reliable and resilient electricity system. Additionally, satellite imagery helps **plan for grid infrastructure extensions** (currently lacking readiness) to connect new renewable energy projects.

Long permitting procedures are holding back rapid deployments of renewable energy projects

The permitting procedure for renewable energy projects involves a **series of regulatory steps** aimed at ensuring **compliance with environmental, safety and land use requirements**. The procedure includes conducting environmental impact assessments (EIAs), to evaluate potential ecological, social and economic effects. **Complexity, variety and excessive duration** of the permitting process constitute a major barrier to the swift necessary deployment of renewable energy. In some extremes, the permitting procedure can take over eight years. To accelerate this, the Renewable Energy Directive requires Member States to permit new renewable energy projects within two years and repowered projects (replacing old infrastructure) within one year. The performance of EIAs can greatly benefit from satellite imagery as **historical, current and projected environmental or human settlement-related information** can be derived, contributing where knowledge and data gaps may otherwise occur. Furthermore, as part of the REPowerEU plan, the European Commission has obligated EU Member States to identify 'acceleration areas'. These are locations with minimal foreseen environmental impact resulting from the construction of renewable energy sites. **EO information can support the identification and classification of these acceleration areas**, specifically aiding the **evaluation of ecological risks** such as potential impact on biodiversity.

Energy infrastructure more frequently exposed to extreme weather and climate hazards

Energy infrastructure is increasingly **vulnerable to extreme weather and climate hazards**, such as extreme ambient temperatures, high winds and flooding, driven by climate change. As most electricity infrastructure is **built for past or current climate conditions**, these events can disrupt energy generation, transmission and distribution, leading to grid instability and power outages. The process of assessing and mitigating the risks of such events strongly relies on space data.

For example, early warning systems powered by space data can provide **real-time and predictive information** about weather patterns, such as hurricanes, storms and heatwaves, allowing operators to **prepare and respond more effectively**. Vulnerability mapping, by **identifying areas prone to flooding, landslides, or coastal erosion**, is furthermore supported by satellite imagery. Additionally, climate modeling powered by EO data can help assess the likely **frequency or intensity of future extreme weather events**.

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Enhancing mineral exploration, sourcing, and operational safety with space data for the raw materials sector

Key market trends for raw materials

- Drastically increasing demand for (critical) raw materials is forcing Europe to diversify its imports, improve circularity and sustainability, and heavily invest in innovation
- Ensuring secure, resilient and sustainable battery supply chains will be a key factor in accelerating global uptake of electric vehicles
- Environmental concerns drive the need to strictly monitor mining environmental impact, with an increased focus on their greenhouse gas emissions
- Mining sector looking to decarbonise their operations to reduce business risk and minimise impact on climate

Europe redefines its approach to critical raw materials

EU's Critical Raw Materials Act (CRMA) underscores the **resilience, diversification, collaboration, innovation and sustainability** of the critical raw material supply chain. Key focal points of this initiatives are to increase domestic capacities of raw materials extraction, processing and recycling with high social and environmental standards. The Commission aims to strengthen the uptake and deployment of breakthrough technologies, such as **space data**, that plays an important role throughout a mine's life cycle, from reconnaissance to post-closure. Space data can also help accelerate the objectives set out by the EU. Highlighting **environmental sustainability** as a central theme in the CRMA, space data enables the continuous monitoring of a mine's ecological impact, in addition to increasing mine operations safety and overall efficiency. Space data integration into a mine's operational management, both in Europe and beyond, will support **better informed and environmentally conscious decisions** in pursuit of Europe's critical raw material objectives.

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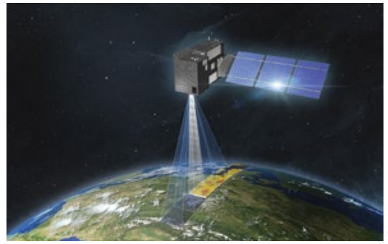
Environmental concerns drive need to strictly monitor mining environmental impact

Total carbon emissions from steel, aluminium, copper, nickel and cobalt output is estimated at 4.5Gt of carbon dioxide equivalent, or 13.5% of global carbon dioxide emissions. Given the climate impact of these emissions, there is a pressing need to **monitor, make transparent and mitigate this impact. Recently deployed satellite technologies**, such as the Sentinel-5P, as well as foreseen future satellites such as the Copernicus Anthropogenic Carbon Dioxide Monitoring (CO2M) mission, **provide an important solution to increase this transparency**, as mines across the world can **be objectively monitored**. This presents **a unique and independent source of information** to assess the effectiveness of policy measures, and to **track national emission reduction targets** and their **impact towards decarbonisation**.



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Reliable battery supply chains are key to electric vehicle uptake

Batteries typically account for **30% to 40% of the value of electric vehicles** (EVs). The race to net zero will be **heavily dependent on the supply of critical minerals and metals** required to manufacture such batteries. The creation of efficient and sustainable supply chains is supported by space infrastructure, as demonstrated by its ability to aid in the exploration of crucial battery minerals like lithium. The demand for this key component of modern batteries has skyrocketed as electric vehicles gain popularity.

EO satellites equipped with multispectral and hyperspectral sensors **can detect the unique spectral signatures of lithium-rich areas**, supporting feature discrimination, mineral identification and abundance mapping. This data-driven approach streamlines the exploration process, making it more cost-effective and environmentally friendly.

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Decarbonisation of mining operations

Faced with the pressing need to **mitigate climate change and reduce climate-related business risks, environmental regulations, and shifting market dynamics**, mining companies are increasingly embracing decarbonisation strategies. This transformation is not only a response to environmental concerns but also a proactive business strategy aimed at ensuring long-term sustainability and resilience.

Mining companies are using a **combination of solutions** such as renewables, corporate power purchase agreements (PPAs), electrification, carbon offsetting, data management and ensuring data integrity in environmental, social and governance (ESG) reporting. The integration of space data adds an extra layer of efficacy to these decarbonisation efforts, specifically for **reporting purposes and overall environmental monitoring**.

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Users across the entire energy and raw materials value chain use EO and GNSS-powered services

Estimating lifespans of wind turbines

Wind turbine manufacturers need to **assess wind turbine suitability for specific site conditions** according to IEC 61400 standards. They do this by **evaluating the wind characteristics of specific locations** and estimating the lifespan of various turbine types. For these assessments, in-situ measurements (meteorological masts indicating speed, direction, pressure, temperature, etc., as well as their location through GNSS) are used and **complemented by satellite imagery to reduce uncertainties of long-term projections**.

Snow water equivalent assessments for hydropower

Hydropower companies aim to **optimise water inflows** and subsequent energy production. **Insights into snow distribution and snow water** on a regional to global scale is in part enabled by satellite observations. Service providers issue **short- and long-term forecasts**, based on advanced weather models and physical snowpack models, enabling hydropower companies to anticipate future water supply and adapt their energy production levels accordingly (avoiding under- or over-production).

Synchronisation needs are increasing with smart grid deployments

It is expected that **existing and foreseen smart grid services will become more and more data driven** due to the ongoing adoption of 5G networks, the introduction of AI and the wide-scale deployment of IoT systems. This evolution goes hand in hand with the **widescale adoption of smart meters and sustainability objectives** which **further increase the amount and resolution of data** collected through the smart grid network. While these technologies are expected to allow the implementation of microgrids using renewable energy, batteries for energy storage and generators to produce power as a complement to the national grids, it will lead **to growing needs for synchronisation** of the entire energy grid. These increasing requirements for robust and resilient timing and synchronisation can **be provided through GNSS-enabled timing receivers** that are deployed across the energy grid.

EO plays important role in slope stability monitoring

Mineral extraction activities create **inherently unstable structures**, such as mining pit slopes, tailings dams, or waste rock piles (storing by-products of mining operations). These structures **require constant monitoring** so that (slope) failures can be detected ahead of time, and appropriate measures can be taken to minimise risk and impact. **Multitemporal satellite radar data**, such as those provided by Sentinel-1, is **one of the key technologies used in the monitoring of such structures**, complemented by in-situ radar/monitoring systems.

Hyperspectral data used to identify mineral-rich areas

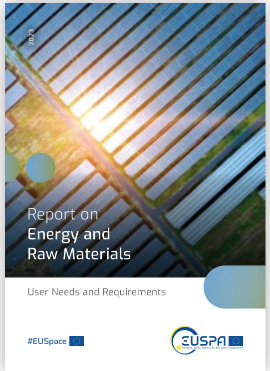
As easy access mineral sources are depleting, **mining exploration projects are forced to explore the most remote parts of the globe**, making manual surveys expensive and time consuming. **The identification and quantification of mineral deposits** leverage cost-effective solutions enabled by satellite imagery, where new in-orbit hyperspectral sensors are particularly useful.

Sources of key EO and GNSS user requirements

The key EO and GNSS user requirements for the different application groups within the **energy and raw materials** segment are, at EU level, collected using a harmonised procedure.

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 Energy and Raw Materials user needs and requirements. User requirements for Earth Observation (EO) services and products – as well as their evolution – are now also collected through the UCP. The process covers the EO user needs and requirements of commercial users based on inputs from industry experts and user groups, mirroring the existing process implemented for GNSS.

Moreover, the collection of specific requirements for Copernicus services and products is supported by 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.



Energy EO & GNSS Value Chain[1]

EARTH OBSERVATION

DATA PROVIDERS

- AIRBUS*
- BLACKSKY
- CAPELLA SPACE
- E-GEOS*
- GEOSAT*
- GHGSAT
- ICEYE*
- MAXAR
- PLANET
- SATELLOGIC*
- UMBRA

- COPERNICUS SENTINELS*
- ENMAP*
- PRISMA*
- LANDSAT (USGS)
- METEOSAT (EUMETSAT)*
- RADARSAT (CSA)
- OTHER RELEVANT EUROPEAN NATIONAL MISSIONS
- RELEVANT IN-SITU NETWORKS

INFRASTRUCTURE PROVIDERS

- AWS
- CLOUDFERRO*
- CLOUD PLGOOGLEATFORM
- IBM CLOUD
- MICROSOFT AZURE
- T-SYSTEMS*

- FEDERATED INFRASTRUCTURE (E.G. GAIA-X)*
- SENTINEL COLLABORATIVE GROUND SEGMENT*

PLATFORM PROVIDERS

- CLOUDEO*
- CREODIAS*
- EARTH-I
- EDS CEODE
- EURODATACUBE*
- GOOGLE EARTH ENGINE
- NORTH.IO*
- OPEN DATA CUBE
- PLANET EXPLORER
- SENTINEL-HUB* (SINERGISE)
- UP42*

- CODE-DE*
- COPERNICUS DATASPACE ECOSYSTEM*
- OPENEO*
- WEKEO*

EO PRODUCTS AND SERVICE PROVIDERS

- CLIMATESCALE*
- CLS GROUP*
- DHI GROUP*
- EXOLABS*
- NEO*
- KSAT*
- LIVEEO*
- METEODYN*
- OHB*
- ORBITAL EYE*
- PIESAT
- REBASE.ENERGY*
- REUNIWATT*
- SATELLOGIC*
- SOLARGIS*
- SOLCAST
- SOLEA*
- TRANSVALOR*
- VORTEX*
- WEGAW*

- COPERNICUS ATMOSPHERE MONITORING SERVICE (CAMS)*
- COPERNICUS CLIMATE CHANGE SERVICE (C3S)*
- COPERNICUS MARINE SERVICE (CMEMS)*
- COPERNICUS LAND MONITORING SERVICE (CLMS)*

INFORMATION PROVIDERS

- CYIENT
- GEODATA*
- ICIS*
- OILX*
- NOVELTIS*
- S&P GLOBAL
- THE SNIFFERS*

END USERS

- ENERGY COMPANIES
- ENERGY TRADERS
- ENVIRONMENTAL AGENCIES
- GOVERNMENTAL AUTHORITIES
- GRID OPERATORS
- PROJECT DEVELOPERS
- SUPPLY CHAIN MANAGERS
- UTILITY COMPANIES

European[2] GNSS industry in the global arena

In the combined Energy and Raw Materials segment, European companies capture approximately one-third of the global market share for component and receiver manufacturing, with major players such as Hexagon and Topcon, and over 40% of the system integration market, prominently led by Ericsson. GNSS receivers in Energy are used for timing and synchronisation purposes. European T&S System Integrators such as Nokia and Ericsson own a combined two fifths of the global Energy value chain.

GNSS

AUGMENTATION SERVICE PROVIDERS

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

- NATIONAL AND REGIONAL RTK NETWORK PROVIDERS

COMPONENT AND RECEIVER MANUFACTURERS

- ANALOG DEVICES
- CAMPBELL SCIENTIFIC
- HEXAGON*
- MEINBERG*
- SCHNEIDER ELECTRIC*
- SEPTENTRIO*
- TRIMBLE NAVIGATION
- VICTRON ENERGY*

DEVICE MANUFACTURERS

- ARBITER
- BRANDYWINE
- CHRONOS TECHNOLOGY*
- ELPROMA*
- ENDRUN
- GORGY TIMING*
- HEXAGON*
- HOPF ELEKTRONIK*
- MASTERCLOCK
- MICROSEMI
- OMICRON*
- OROLIA*
- OSCILLOQUARTZ*
- SEIKO
- SEL
- SYNERGY SYSTEMS
- TIMELINK*

SYSTEM INTEGRATORS DESIGN CONSULTANCIES TESTING & MAINTENANCE

- ABB*
- ERICSSON*
- HUAWEI
- NOKIA*

END USERS

- TRANSMISSION AND DISTRIBUTION SYSTEM OPERATORS

LEGEND

- Commercial offering
- Public offering / entities
- User segments

NOTES

[1] The value chain considers the key global and European companies involved in GNSS and EO downstream activities. Please note that enterprises listed in the data providers step of the value chain often provide platforms as a service. For the sake of simplicity the data providers are not repeated in other stages of the value chain in which they are active.

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

Please refer to page 13 and 23 for a comprehensive description of value chains and how to interpret them at segment level.

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

Raw Materials EO & GNSS Value Chain[1]

EARTH OBSERVATION

DATA PROVIDERS

- AIRBUS*
- BLACKSKY
- CAPELLA SPACE
- E-GEOS*
- GEOSAT*
- GHGSAT
- ICEYE*
- MAXAR
- OHB
- PLANET
- SATELLOGIC*
- UMBRA

- COPERNICUS SENTINELS*
- ENMAP*
- PRISMA*
- LANDSAT (USGS)
- METEOSAT (EUMETSAT)*
- OTHER RELEVANT EUROPEAN NATIONAL MISSIONS
- RADARSAT (CSA)

INFRASTRUCTURE PROVIDERS

- AWS
- CLOUDFERRO*
- GOOGLE CLOUD PLATFORM
- IBM CLOUD
- MICROSOFT AZURE
- T-SYSTEMS*

- FEDERATED INFRASTRUCTURE (E.G. GAIA-X)*
- SENTINEL COLLABORATIVE GROUND SEGMENT*

PLATFORM PROVIDERS

- CLOUDEO*
- CREODIAS*
- EARTH-I*
- EDS CEODE
- EURODATACUBE*
- GOOGLE EARTH ENGINE
- NORTH.IO*
- OPEN DATA CUBE
- PLANET EXPLORER
- SENTINEL-HUB (SINERGISE)
- UP42*

- CODE-DE*
- COPERNICUS DATASPACE ECOSYSTEM*
- OPENEO*
- WEKEO*

EO PRODUCTS AND SERVICE PROVIDERS

- DARES TECH*
- DESCARTES LABS
- EFTAS*
- GAF*
- GEOVILLE*
- OHB*
- ORBITAL INSIGHT
- ROSA EARTH*
- SATELLOGIC*
- S[&]T*
- SKYGEO*
- TERRAEYE*
- THEIAX*
- TRE ALTAMIRA*
- VITO*

- COPERNICUS EUROPEAN GROUND MONITORING SERVICE (EGMS)*
- COPERNICUS LAND MONITORING SERVICE (CLMS)*

INFORMATION PROVIDERS

- AGP MINING
- CGG*
- FLSMIDTH*
- FUGRO*
- KAYRROS*
- SLR CONSULTING*
- STANTEC
- SRK*

END USERS

- MINING COMPANIES
- SUPPLY CHAIN MANAGERS
- ENERGY TRADERS
- GOVERNMENTAL AUTHORITIES

European[2] EO industry in the global arena

In 2021, European EO companies in the Energy and Raw Materials segment held an estimated half of the global market share. Top European companies in the full segment include Airbus, CLS, and Leonardo (e-GEOS).

GNSS

AUGMENTATION SERVICE PROVIDERS

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

- NATIONAL AND REGIONAL RTK NETWORK PROVIDERS

COMPONENT AND RECEIVER MANUFACTURERS

- ANALOG DEVICES
- CADDEN*
- CAMPBELL SCIENTIFIC
- CHCNAV
- HEXAGON*
- HEMISPHERE
- NOVATEL
- NUVOTON
- OXFORD TECHNICAL SOLUTIONS*
- SEPTENTRIO*
- TOPCON
- TRIMBLE NAVIGATION
- YAGEO

DEVICE MANUFACTURERS

- CHCNAV
- HEXAGON*
- OUSTER
- RIEGL LASER MEASUREMENT SYSTEMS*
- SEPTENTRIO*
- TRIMBLE NAVIGATION

SYSTEM INTEGRATORS DESIGN CONSULTANCIES TESTING & MAINTENANCE

- AB VOLVO*
- CATERPILLAR
- EATON*
- ERICSSON*
- HEXAGON*
- KOMATSU

COMPONENT AND RECEIVER MANUFACTURERS

- MINING COMPANIES
- REGULATORY AUTHORITIES
- ENVIRONMENTAL AGENCIES

LEGEND

- Commercial offering
- Public offering / entities
- User segments

NOTES

[1] The value chain considers the key global and European companies involved in GNSS and EO downstream activities. Please note that enterprises listed in the data providers step of the value chain often provide platforms as a service. For the sake of simplicity the data providers are not repeated in other stages of the value chain in which they are active.

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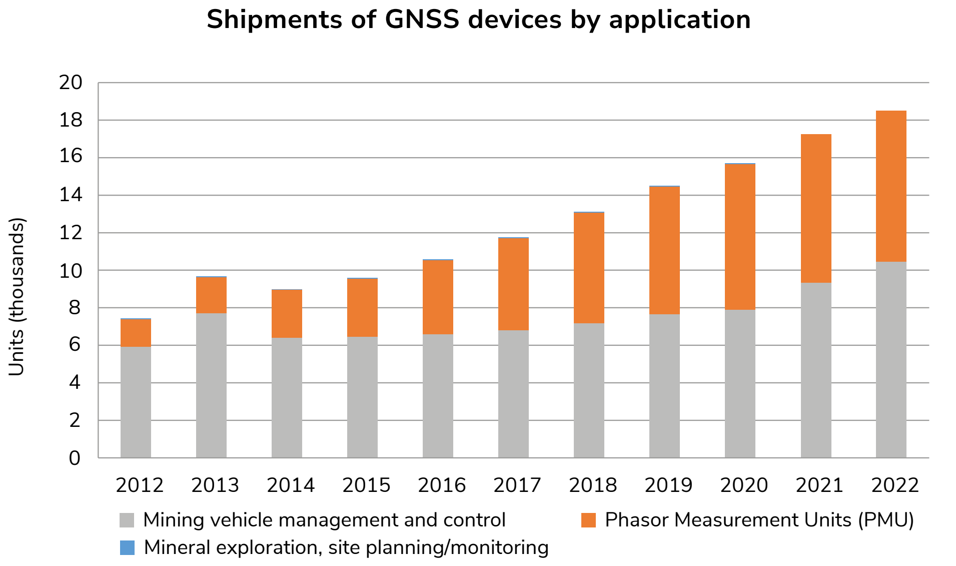
* European-based companies. The region is defined with respect to the headquarters of the company, though the actual area of activity might be wider.

Mining industry moves to fully automise a wide range of mining operations and increase efficiency and site safety supported by space data



As mining companies attempt to **increase efficiency and safety** through a variety of means, the shipments of GNSS devices in this sector has seen steady growth in the past decade. **Specifically in large open pit mines**, GNSS devices are utilised widely and are particularly suitable for fleet automation, including **autonomous hauling operations as well as automated blasting and drilling activities**. More recently, the **use of digital twins** in the mining industry as a means to increase operational awareness is considered a strong driver for mine site data collection, including location information derived from GNSS.

Shipments of phasor measurement units have seen steady growth in the past decade, with just under 1 500 shipments in 2012, rising to over 8 000 shipments in 2022, illustrating their increasing importance in the management of energy infrastructure. As smart grids (dependent on PMUs) are becoming more common, the trend of the past decade is likely to continue.

GNSS key technology in move to automate of wide range of mining operations

GNSS is becoming a crucial technology in **automating various mining operations**, as active mines across the globe have already implemented some level of autonomous and or automated mining equipment. **GNSS is a core enabling technology** in these efforts. Rio Tinto's Autonomous Haulage System, which was introduced in 2022, handles over 130 autonomous haul trucks as part of the company's iron ore operations, and heavily relies on GNSS. It significantly reduces operator risks and lowers costs by 15%. Furthermore, GNSS enables the **automation of drilling and blasting operations** by accurately determining the position and orientation of drilling equipment.

This not only enhances precision but also ensures safer working conditions by reducing human involvement in potentially hazardous activities. **By automating surveying and mapping** tasks, enabled by GNSS receivers, surveyors can quickly and accurately **map mining areas**, measure **stockpile volumes**, and monitor **ground deformation**. McKinsey estimates that by 2035 smart mining achieved through autonomous mining using data analysis and digital technologies including Artificial Intelligence will save between **$290 billion** and **$390 billion** annually for mineral raw materials producers.

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SAR data plays increasingly important role in mining site safety monitoring

In mining operations, ensuring the safety and stability of critical assets is paramount. This is particularly true for assets like tailings dams, waste stockpiles and open pit slopes, which **demand continuous monitoring to detect and prevent potential failures**. To meet this challenge, an array of advanced monitoring tools and technologies is employed. In-situ instrumentation, such as radars developed by IDS Georadar, robotic total stations by Leica, and laser scanners, form the foundation of ground-based monitoring systems. **These tools are significantly enhanced by the integration of satellite-based Synthetic Aperture Radar (InSAR) data**, with Sentinel 1 being a prominent example.

InSAR provides invaluable insights by **detecting ground movement with millimetre-level accuracy**, even over vast mining areas. Satellites often detect initial ground movements, flagging an area as unstable. Afterwards, ground-based radar systems are strategically aimed at the area of concern to provide real-time monitoring. This **integrated approach to stability monitoring** not only enhances safety but also minimises the potential for costly disruptions and environmental damage.

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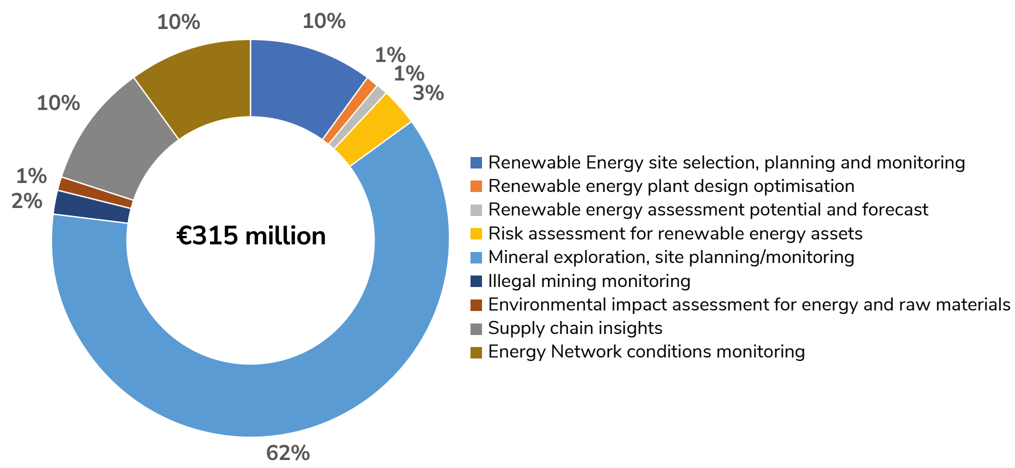
Offshore wind farms deployments and smart grids leverage space data

Energy & Raw Materials revenues from EO data & services sales by application 2022



Various applications in the energy and raw materials segment have been able to **leverage enhanced space-based sensing capabilities**, such as improved revisit time and increased spatial and spectral resolution. For the application of network (pipelines, powerlines) conditions monitoring, currently accounting for 10% of the revenues, improved upstream capabilities enable EO service providers to continuously improve their ability to monitor energy assets, further reducing the need for air and ground patrols.

Furthermore, as illustrated by a two-third revenue share of approximately €200 million attributed to the application of mineral exploration and site planning/monitoring, satellite imagery continues to provide a **safe and economically interesting alternative to in-situ data collection** when exploring remote areas with low data availability. This is considered a strong value driver in the sector, particularly for exploration as 'easy access' deposits are increasingly depleted.

Moreover, as the green energy transition accelerates further, space-based data and services may **alleviate some of the of permitting bottlenecks related to environmental impact assessments**, generating additional growth in the sector.

SAR data helps assess atmospheric wakes of offshore wind farms

Offshore wind farm deployments are accelerated to satisfy the demand for renewable energy, particularly in Northern Europe. These massive structures cause areas of **increased turbulence and reduced wind speeds downwind, known as atmospheric wakes,** which can spread over tens of kilometres, affecting the yields of potential new sites. The correct quantification of the resulting wind velocity decrease is critical to accurately assess energy yields of sites placed in the wakes of existing ones.

Satellite SAR data is particularly useful for measuring wind speeds on the surface of the ocean. Wind farm project developers can leverage these data as a **cost-effective way of assessing large areas for potential wakes of existing wind farms**. These insights can in turn be used to assist the localisation of subsequent in-situ measurement campaigns, utilising equipment such as ocean buoys, meteorological masts and wind lidars.

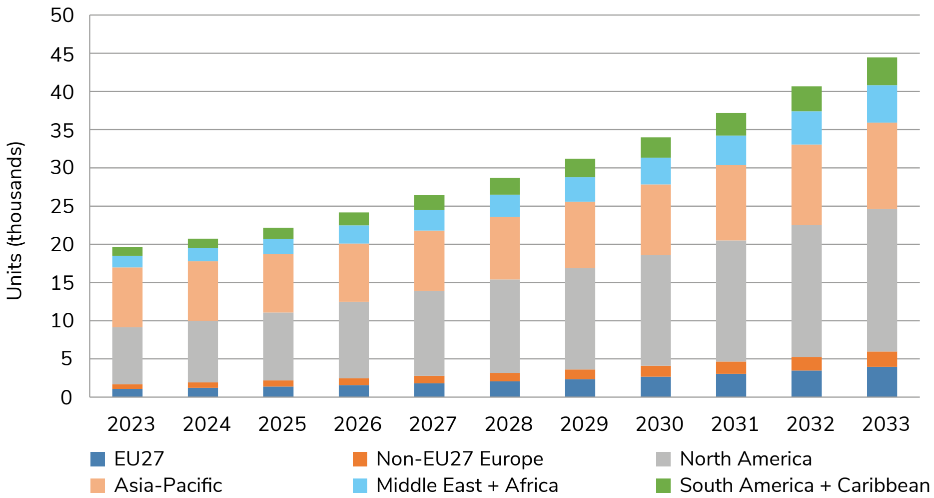
Synchronisation quality at the core of smart grid protection and control applications

The growing adoption of smart grids and PMUs is facilitated by substation digitisation, which has reduced the amount of equipment per substation, while also leading to **improved protection and control applications such as real-time modelling, fault analysis, fault localisation and wide-area monitoring (WAM). Improved data synchronisation quality** is key to the **protection of digital substations** as well as for the **control applications**. The accuracy of this data is measured in microseconds, as they require accurate timestamping and a timely delivery.

State-of-the-art GNSS receivers, providing timing and synchronisation information, can fulfil these requirements and provide the necessary level of quality, with the latest receivers contributing to an overall **higher level of resilience** for the smart grid. As a back-up time source, **Precision Time Protocol (PTP) concepts** are being explored, with some of these also relying on the use of GNSS receivers.

Digital twins will play a key role in optimising mining operations and increasing safety, hyperspectral data provides cost-effective exploration applications

Shipments of GNSS devices by region



Open-pit mines are particularly suitable for GNSS-supported applications such as blasthole drilling or fleet tracking and automation. The modelling methodology in the report has been updated to reflect the increasing number of devices in use per mine. The distribution of open pit mines worldwide drives the GNSS market, with the Americas, Asia-Pacific and Middle East and Africa generating the largest demand. Conversely, this makes Europe's demand for GNSS devices in the raw materials segment **relatively small on a global scale**, as it merely hosts 10% of all open-pit mines. Furthermore, surface mines in Europe often deploy very large bucket wheel excavators (such as those operating in German lignite mines or Polish coal mines) rather than numerous blasthole drills and smaller excavators with individual GNSS devices.

Modernisation of old energy infrastructure accelerates PMU deployments across the world. In the past decade, **the Asia Pacific and North America regions have been on the forefront** of modernisation, boasting the largest numbers of PMU devices shipped. **Europe, the Middle East and Africa are starting to catch up** and are forecast to account for 40% of global PMU device shipments by 2033, up from 30% in 2023. The GNSS device installed base per application can be found in the reference charts at the end of this chapter.

Use of Digital Twins in the mining sector

Effectively managing engineering and asset information throughout a mining asset's lifecycle has long posed a significant challenge for operators in the industry. To address this issue, a transformative solution is emerging in the form of digital twins. These **digital replicas** offer a comprehensive representation of physical assets, processes and systems, capturing both their core elements and the dynamic interactions. Digital twins leverage cutting-edge technologies such as AI alongside advanced software analytics, **supported by (near-)real-time inputs like space data**.

This enables the creation of dynamic, **continually updated digital simulation models that mirror the changes occurring in their physical counterparts**, often referred to as their 'twins'. For instance, Anglo American, a prominent UK-based mining company engaged in extracting commodities like nickel, coal, and precious metals, has recently adopted digital twin technology at the Quellaveco copper mine in Peru. Here, digital twins are being deployed to **optimise the mining fleet, enhance operational efficiency and boost safety standards**.

Impact of new hyperspectral imaging satellites will further increase applicability of space-based data for the raw materials sector

New **hyperspectral satellite systems**, such as PRISMA launched in 2019, EnMAP in 2022, and CHIME due for launch by the end of this decade, as well as various commercial satellite constellations, will produce hyperspectral data with a regional to global scale. This data is expected to **further transform the use of EO data in the raw materials industry**. The public missions offer **free access to hyperspectral data**, a game-changing alternative to expensive airborne acquisitions.

One of the most promising hyperspectral applications for the mining industry **is cost-effective exploration activities** by delivering mineral maps of large areas, or mineral detection products (alteration zone maps, mineral vector maps) for **targeted exploration**. Additionally, the **increased spectral range** of this type of data (compared with those offered by more dated in-orbit sensors) will enable **more elaborate and precise monitoring of environmental indicators**.

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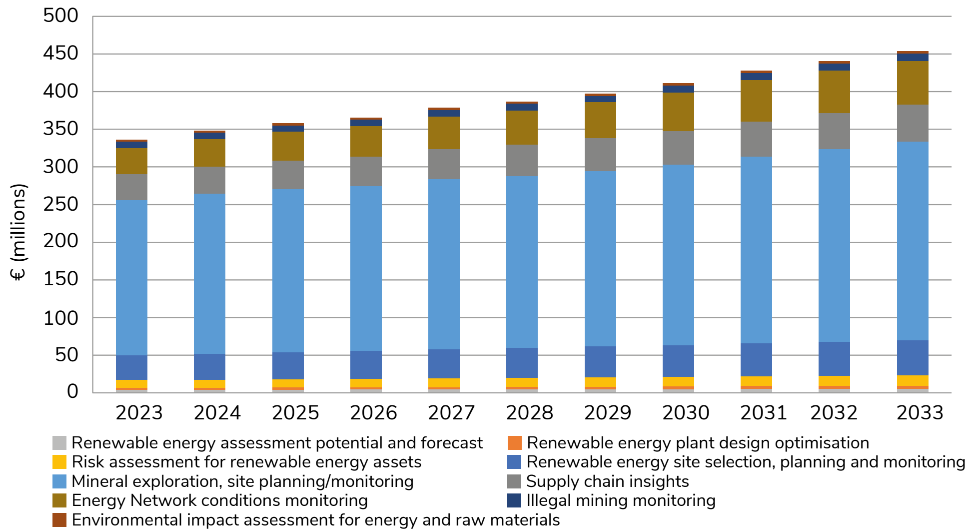
EO can help us understand how climate change will impact renewable energy and help assess environmental impact of renewable energy sites

Revenue from EO data & services sales by application



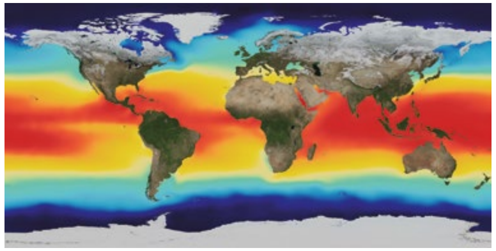
EO data and services sales in the energy and raw materials segment are forecast to increase at a compounded annual growth rate of 3% **from an estimated €330 million in 2023 to over €450 million in 2033**.

Energy network conditions monitoring is the application with the **largest foreseen relative growth** in the next decade, with around 70% higher revenues forecast for 2033 as compared to 2023. This growth is driven by the desire for more environmentally conscious infrastructure monitoring (minimising use of helicopters or ground patrols), as well as maturing downstream capabilities which enable wide-scale and autonomous monitoring. More performant upstream solutions are considered an important growth driver in this segment as well, such as the deployment of hyperspectral imaging sensors, which produce data particularly useful for the exploration activities of mining companies.

This translates into **significant opportunities for the application of mineral exploration, site planning and monitoring**, which will see yearly revenues increase by almost €60 million over the next decade.

Climate change is impacting potential of renewable energy sources and EO data can help understand these changes

Longer-term climate change may significantly affect the energy potential of renewable energy systems, particularly wind power. Over the next few decades, **substantial shifts in wind characteristics** are anticipated due to the ongoing rise in average global temperatures. As temperatures increase, air density decreases, which **directly impacts wind power potential**. This poses a considerable challenge for the renewable energy sector. To address this issue, research initiatives like the KliWiSt project, aim to analyse **historical climate data and near-future projections** (with a focus on the next 50 years). These efforts aim to comprehensively understand how climatic changes will impact wind patterns and, consequently, wind farm yields. Crucially, EO data is heavily utilised for this research, as it **provides invaluable insights into climate variability**, helping us gain a deeper understanding of these changes.



© NASA

Satellite imagery enables independent environmental assessments for renewable energy deployments

A critical hurdle in the widespread adoption of renewable energy is not just its cost, but also the **careful management of land use**. The challenge lies in **deploying extensive wind and solar parks** to meet challenging renewable energy goals, while **minimising adverse effects on stakeholders like nature and biodiversity**. As environmental considerations become increasingly stringent, EO data emerges as an important tool in evaluating the suitability of specific regions for the establishment of renewable energy installations.

By harnessing the insights gained from space data, stakeholders can make **informed decisions about where to place renewable energy infrastructure**, identifying areas that have **minimal ecological sensitivity and lower risks to biodiversity**.

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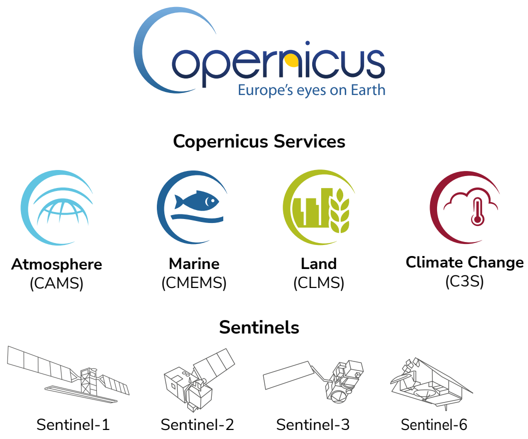
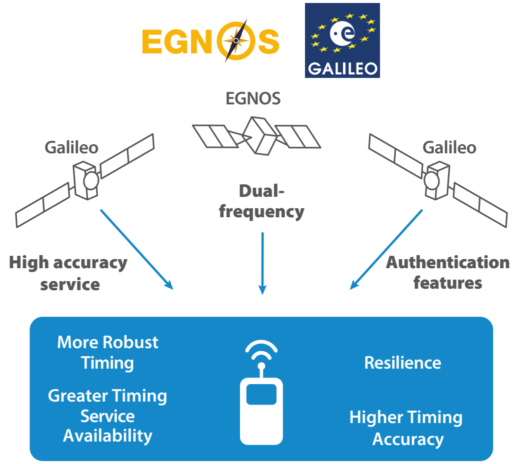
Current usage of Galileo and Copernicus





Current usage of Copernicus for Energy

The Energy Operational Service of **C3S** delivers key information for climate-related indicators relevant to the European energy sector, such as electricity demand and renewables production. **CAMS** provides solar irradiance data, which is critically important for planning and operating solar installations. **C3S** and **CAMS** are also well suited for long-term projections and optimisation of energy systems, to forecast the future energy mix as well as its reliability. The services furthermore help to understand the reliance of renewables on the (changing) climate system underpinning them. **CMEMS**, which is partly powered by **Sentinel-3 and 6**, provides data related to surface temperature, water conditions and water level useful for onshore, offshore and tidal energy installations. For specific wind farm analysis, service providers rely on the climate re-analysis dataset **ERA5** under **C3S** as well as **CLMS** for land cover and elevation assessments. The data are dynamically downscaled and provide information at windfarm scale, which are used in the investor due diligence process.

Current usage of EGNSS for Energy

The integration of Galileo capabilities within Phasor Measurement Units (PMUs) is **increasing steadily**. PMUs are devices used in electric power systems to measure and monitor the real-time electrical conditions, such as voltage, current, power and frequency. They are primarily used for monitoring and controlling the stability and reliability of power grids. PMUs typically rely on GPS or other GNSS for accurate time synchronisation of the measurements. GPS is the most widely used GNSS in PMUs due to its availability, accuracy and well-established infrastructure. While Galileo aims to provide independent, reliable, and accurate positioning, navigation, and timing services, its adoption in PMUs is still relatively limited. This is primarily because GPS has become the de facto standard for PMUs, and most existing installations and infrastructure are designed around GPS. However, as the Galileo constellation **continues to expand** and more satellites become operational, there may be **wider adoption of Galileo in the future**. It could provide an **alternative** or backup to GPS for PMUs, **enhancing the overall redundancy** and reliability of the positioning and timing data used in power grid monitoring and control applications.

Current usage of Copernicus for Raw Materials

The **European Ground Monitoring System**, powered in part by **Sentinel-1** InSAR data, enables services for ground motion monitoring. Such services, often working in conjunction with GNSS, are essential for mining (safety) operations. **Sentinel-1** data also enables water regime monitoring to map acid mine drainage characteristics and predict its impact on surrounding ground water levels. **Sentinel-2** data (e.g. Red-Edge, NDVI, etc.) is used to provide a baseline vegetation study prior to the start of mining activities and continuously monitor the stress on vegetation over time. **CLMS** provides a wide range of biophysical parameters (e.g. land cover) which further support site selection and monitoring in the mining sector.

Current usage of EGNSS for Raw Materials

The highly accurate positioning capabilities of Galileo are crucial for the extraction, mining and transportation of raw material production. Supported by RTK networks, centimetre-level accuracy enables **precise surveying/monitoring** and **machine guidance** that support resource exploration, optimised excavation and efficient logistics planning. Galileo provides integrity monitoring and authentication capabilities, ensuring the wholeness of the positioning information and protecting against spoofing or jamming attempts. These security measures can enhance safety in mining operations that rely on machine guidance.

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

Several European-funded projects combine space data to propose solutions in support of the Energy and Raw Materials sector

HORIZON 2020 CLARA

Climate forecast enabled knowledge services – CLARA

The aim of the CLARA innovation action was to **develop a set of leading-edge climate services** building upon the newly developed Copernicus Climate Change Services near-term forecasts and sectorial information systems (SIS) and sustain their marketability and value. It aimed to **facilitate the development of new climate services and enhanced existing ones** by drawing on the recent seasonal to decadal projections and projections developed under the Copernicus Climate Change Services (C3S). Moreover, the project set out to **analyse and demonstrate the economic and social value** of climate forecast enabled climate services and corroborate the ensuing direct and indirect benefits various end users and customers obtain from them including **reduced risk, more efficient resource management and improved resilience to climate variability and change**. The activities included engaging service developers, purveyors and end-users in mutually beneficial collaboration and partnerships for service co-design, co-development, co-assessment and co-delivery. Lastly, it strived to contribute to advancing European innovation, competitiveness and market performance for climate services, by designing and implementing innovative exploitation, business and market-oriented activities.

More information available at: https://www.clara-project.eu/

Horizon Europe, a programme of the European Union

Renewable energy sources power forecasting and synchronization for smart grid networks management – RESPONDENT

As the EU seeks to **transition from a system of legacy energy and an over-reliance on fossil fuels to a new era of clean, sustainable energy**, the bloc has been seeking dynamic and effective ways to turn this vision into a reality. Although the EU has made significant strides in increasing its use of renewable energy sources (RES), more needs to be done if the most calamitous effects of climate change are to be mitigated or reversed. Furthermore, the desire of the EU to shift away from fossil fuels, the majority of which are imported, would also leave it **less exposed to external geopolitical factors** that threaten the energy security of the bloc. The RESPONDENT project, through the utilisation and leveraging of both Galileo and Copernicus systems and services, aims to **develop and promote the integration of RES into Europe's existing power grids**, as well as to **demonstrate their viability and reliability** compared to traditional sources of energy that are wreaking havoc on global temperatures and accelerating the most destructive impacts of our rapidly changing climate.

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

Horizon Europe, a programme of the European Union

MultiMiner Earth Observation for Smart Mining

Multi-source and multi-scale earth observation and novel machine learning methods for mineral exploration and mine site monitoring – MULTIMINER

Earth Observation data can aid mineral exploration and mining activities. The EU-funded MultiMiner project will develop **innovative data processing algorithms** based on machine learning for **cost-effective utilisation of EO technologies for mineral exploration and mine site monitoring**. In this way, it will unlock the potential of EO data, including Copernicus, commercial satellites, upcoming missions, airborne and low altitude, and in situ data. The project will focus on **novel EO-based exploration technologies** for critical raw materials to increase the probability of finding new sources within the EU, thus **reinforcing its autonomy in the raw materials sector**. MultiMiner will create generic but highly innovative machine learning solutions with extremely low environmental impact to support the entire mining life cycle.

More information available at: https://www.multiminer.eu/

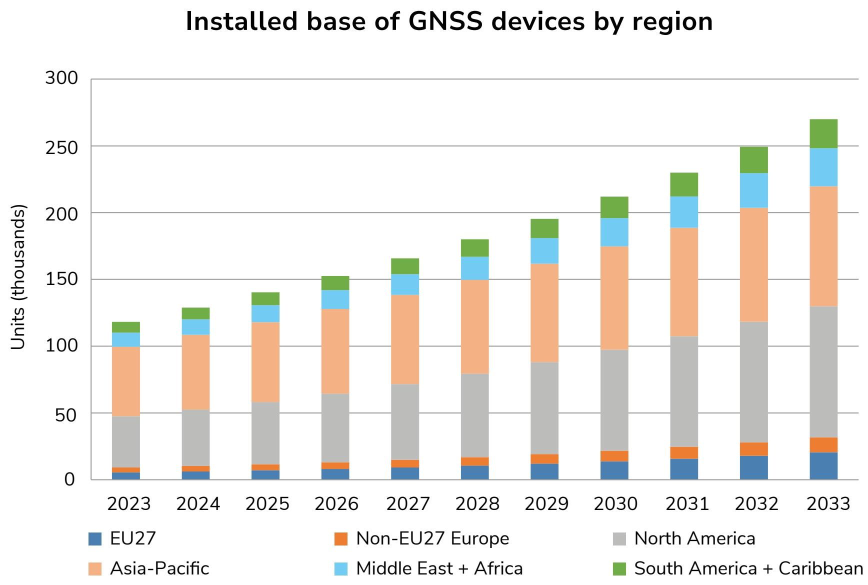
Horizon Europe, a programme of the European Union

MOSMIN

Multiscale observation services for mining-related deposits - MOSMIN

The MOSMIN project aims to develop **holistic, full-site services for the geotechnical and environmental monitoring** as well as **valorisation** of mining-related deposits. For this, the team aims to combine EO and geophysical data. **Copernicus data specifically is used for large-scale monitoring** of ground deformation and surface composition. Change detection algorithms will highlight displacements and **identify environmental hazards**. Satellite data will be integrated with real-time, high resolution data obtained from unoccupied aerial vehicles and sensors installed at the site, leveraging the power of machine learning for fusion and resolution enhancement of multi-scale, multi-source data. Novel, non-invasive geophysical techniques such as distributed fibre-optic sensing will provide **subsurface information to identify resource potential, and risks such as internal deformation and seepage**. The MOSMIN team collaborates with international mining companies, using pilot sites in the EU, South America, and Africa to develop and trial comprehensive monitoring services.

More information available at: https://www.euspa.europa.eu/mosmin-multiscale-observation-services-mining-related-deposits


Installed base of GNSS devices by region
Units (thousands)
0
50
100
150
200
250
300
2023
2024
2025
2026
2027
2028
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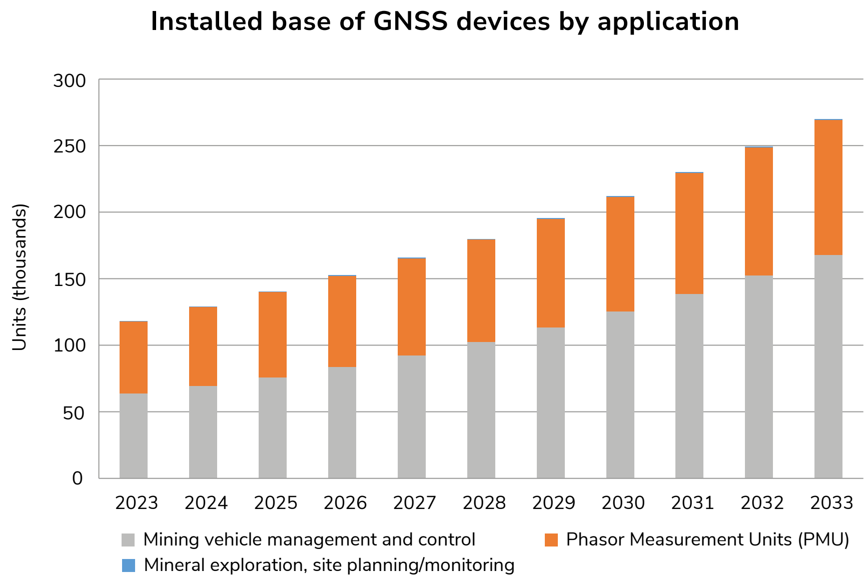
EU27
Non-EU27 Europe
North America
Asia-Pacific
Middle East + Africa
South America + Caribbean


Installed base of GNSS devices by application
Units (thousands)
0
50
100
150
200
250
300
2023
2024
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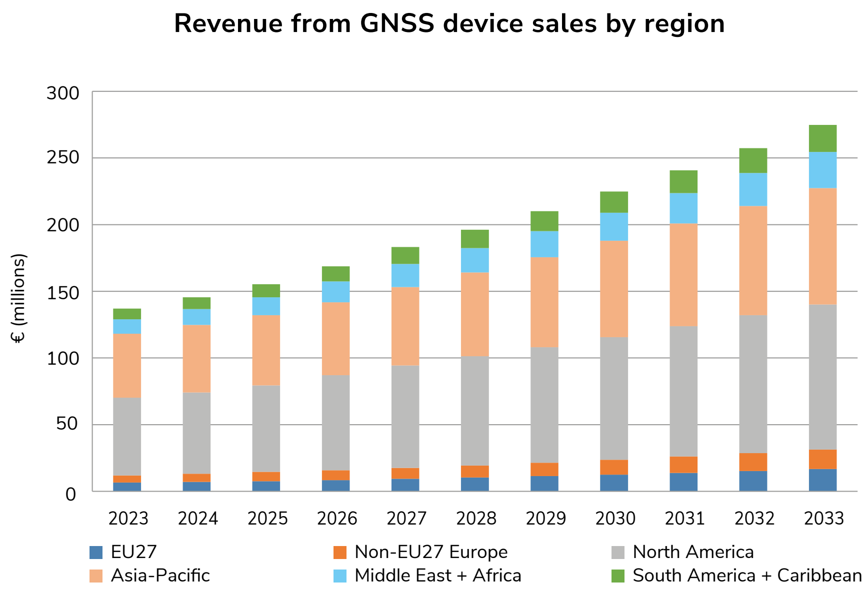
Mining vehicle management and control
Phasor Measurement Units (PMU)
Mineral exploration, site planning/monitoring


Revenue from GNSS device sales by region
€ (millions)
0
50
100
150
200
250
300
2023
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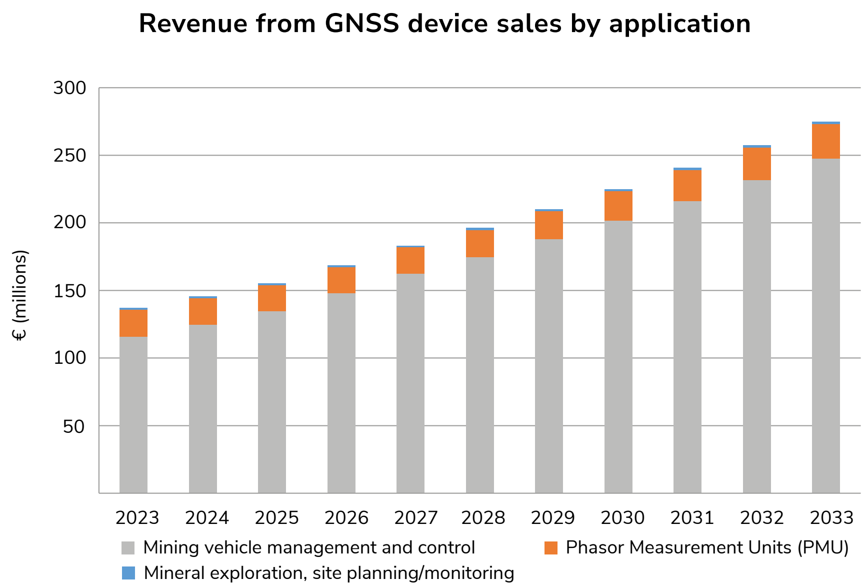
Non-EU27 Europe
North America
Asia-Pacific
Middle East + Africa
South America + Caribbean


Revenue from GNSS device sales by application
€ (millions)
50
100
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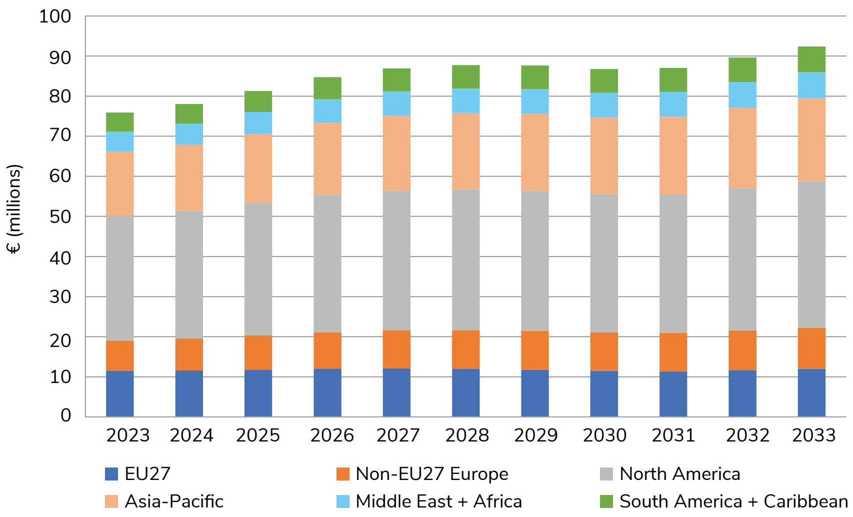
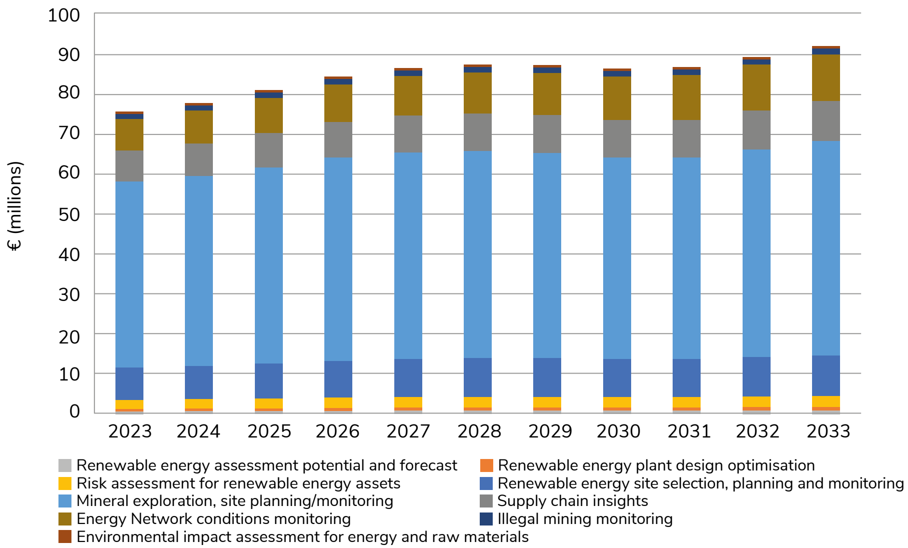
Mining vehicle management and control
Phasor Measurement Units (PMU)
Mineral exploration, site planning/monitoring

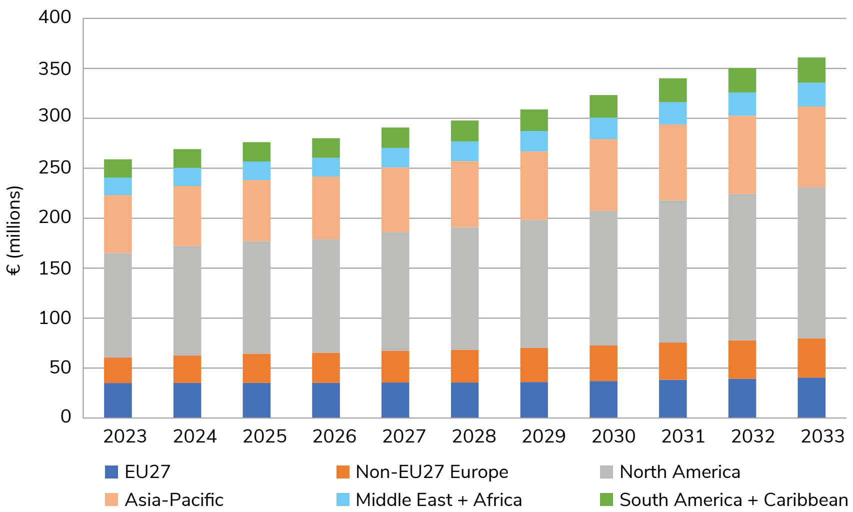
Revenue from EO data sales by region



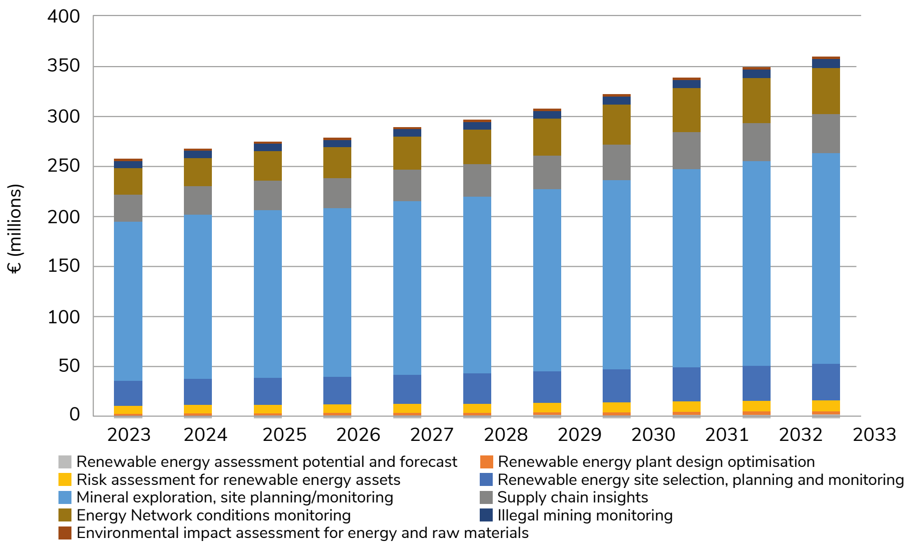
Revenue from EO data sales by application

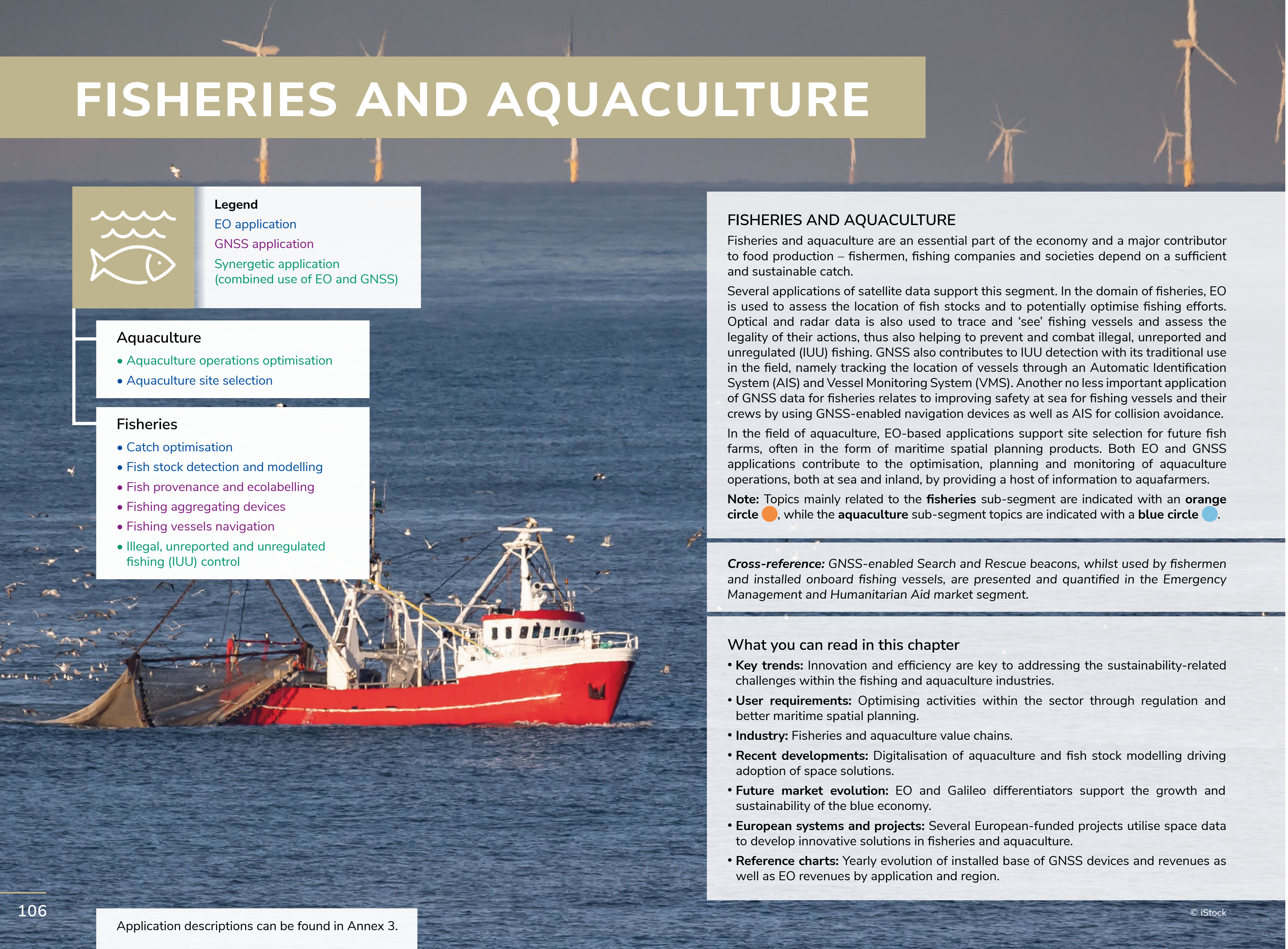


Revenue from EO services sales by region



Revenue from EO services sales by application





FISHERIES AND AQUACULTURE

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

Aquaculture

- Aquaculture operations optimisation
- Aquaculture site selection

Fisheries

- Catch optimisation
- Fish stock detection and modelling
- Fish provenance and ecolabelling
- Fishing aggregating devices
- Fishing vessels navigation
- Illegal, unreported and unregulated fishing (IUU) control

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 depend on a 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 an 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 support site selection for future fish farms, often in the form of maritime spatial planning products. Both EO and GNSS applications contribute to the optimisation, planning and monitoring of aquaculture operations, both at sea and inland, by providing a host of information to aquafarmers.

Note: Topics mainly related to the **fisheries** sub-segment are indicated with an **orange circle**, while the **aquaculture** sub-segment topics are indicated with a **blue circle**.

Cross-reference: *GNSS-enabled Search and Rescue beacons, whilst used by fishermen and installed onboard fishing vessels, are presented and quantified in the Emergency Management and Humanitarian Aid market segment.*

What you can read in this chapter

- **Key trends:** Innovation and efficiency are key to addressing the sustainability-related challenges within the fishing and aquaculture industries.
- **User requirements:** Optimising activities within the sector through regulation and better maritime spatial planning.
- **Industry:** Fisheries and aquaculture value chains.
- **Recent developments:** Digitalisation of aquaculture and fish stock modelling driving adoption of space solutions.
- **Future market evolution:** EO and Galileo differentiators support the growth and sustainability of the blue economy.
- **European systems and projects:** Several European-funded projects utilise space data to develop innovative solutions in 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.

Innovation and efficiency are key to addressing the sustainability-related challenges within the fishing and aquaculture industries

Key market trends

- Various environmental, economic and regulatory dynamics are driving several sustainability-related efforts in the sector
- Efficiency and sustainable use of resources is now a major focus in fisheries & aquaculture, with new technologies helping us to reach these goals
- Applying cutting-edge technologies such as Big Data Analytics and AI to EO and GNSS data is driving innovation in the sector

Various environmental, economic and regulatory dynamics are resulting in an increased focus on the sustainability and resilience of our oceans

In addition to climate concerns, the fisheries and aquaculture sector operates within a multifaceted global context, which encompasses several key dynamics. **Firstly, the blue economy is gaining prominence, marked by activities such as maritime spatial planning (e.g. wind energy installations, blue carbon sequestration efforts) and advancements in marine biotechnology**. Secondly, efforts are being directed towards the sustainable management of oceans and seas, guided by an ecosystem-based approach. Initiatives like the European Green Deal and the development of comprehensive knowledge bases, such as the Digital Twin of the Ocean, play crucial roles in this endeavour.

Other major initiatives include the United Nations' Decade of Ocean Science for Sustainable Development, the European Union's mission to restore oceans by 2030, the forthcoming Treaty on the High Seas, as well as the EU's aquaculture guidelines, which identify 13 areas where further work is needed to promote the sustainability, competitiveness and resilience of EU aquaculture. A global perspective on fisheries and aquaculture is also needed by the growing demand for food. **Addressing global food inequalities involves diversifying aquaculture practices and designing resilient aquafarms capable of withstanding the impacts of climate change, thereby producing food and other derived products in as efficient a manner as possible.**

Digitisation continuing to improve the sector with automation on the rise

Digital solutions are key to unlocking efficiency gains in the fisheries and aquaculture sector. **Automation plays a transformative role in various crucial aspects of operations and the value chain.** This includes automating fish processing, the use of fish aggregating devices (FADs), deploying Autonomous Underwater Vehicles (AUVs) and Remotely Operated Vehicles (ROVs) for underwater exploration, mapping fish habitats, inspecting aquaculture farms, optimising feed usage, managing waste, and maintaining water quality in and around fish farms. Moreover, traceability of fishery operations is a topic that has become more and more pertinent in recent years. By using EO and GNSS in conjunction with other sources of data (i.e., Cooperative Surveillance Systems (CSS), AIS and VMS), digital solutions can now better address issues like **Illegal, Unreported, and Unregulated fishing (IUU) and securely log findings via blockchain technology, reducing the need for on-the-spot checks.** Similar approaches can also be applied to monitor catch origins and certify against given regulatory criteria.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Applying cutting-edge technologies to EO and GNSS data is driving innovation in the sector

The integration of diverse datasets from sources such as fishing vessels, satellites, in-situ measurements and weather stations is driving the emergence of cutting-edge technologies such as **Big Data Analytics and AI-powered predictive services in the fisheries sector**. These services could play a pivotal role in species forecasting, detecting, identifying, and sizing of catches, thereby enhancing fishing decisions and facilitating quota tracking.

The fusion and analysis of multiple data streams can involve EO and GNSS data in conjunction with various vessel and in-situ sources to offer never-before-seen predictive insights. Additionally, the deployment of 5G, long-range radio (LoRa), and radiofrequency techniques for vessel detection (notable companies in this domain include Unseenlabs and Hawkeye 360), along with cost-effective satellite connectivity and broadband access from Starlink and OneWeb are reshaping the diversity and availability of valuable data sources within the industry.

Optimising activities within the sector through regulation and better maritime spatial planning

EO and GNSS contribute to sustainability of fisheries by supporting regulation and control

In order for fisheries to remain sustainable, regulation is needed across the sector. Fisheries can now benefit from the adoption of EO and GNSS to help them keep their operations in line with what is required from a policy point of view. In 2022, EUSPA and the European Fisheries Control Agency (EFCA), the EU entity responsible for coordinating national fisheries operational activities and assisting Member States in implementing the Common Fisheries Policy (CFP), formalised their collaboration through a Memorandum of Understanding (MoU). This agreement underscores the shared dedication of both agencies to fostering sustainable fisheries and aquaculture, **which are integral components of the EU's "new approach for a sustainable blue economy", an initiative which aims to ensure the blue economy plays its part in achieving the goals of European Union's Green Deal**. Through this MoU, EUSPA will support EFCA in optimising the utilisation of the EU Space Programme, particularly the Galileo and Copernicus programmes.

Complementing EFCA's efforts, various public, private and non-governmental initiatives have emerged with the objective of bolstering sustainable fishing practices by enhancing traceability from catch to plate. Organisations including the Marine Stewardship Council (MSC) are establishing standards to address critical social and environmental impacts, placing a strong emphasis on traceability. **EO and GNSS technologies play pivotal roles in enabling traceability features. For instance, the AIS can be combined with EO to seamlessly monitor certified fishing fleets, thereby facilitating sustainable seafood production**. Furthermore, in 2023, the United Nations' 193 Member States ratified a groundbreaking legally binding marine biodiversity agreement after nearly two decades of intense negotiations. This treaty, known as BBNJ (biodiversity beyond national jurisdiction), establishes a mechanism for the creation of extensive marine protected areas in the high seas. It also sets out provisions for equitable sharing of benefits derived from marine genetic resources, along with provisions for capacity building and the transfer of marine technology among the participating parties.

Maritime Spatial Planning – optimising site selection

Planning the development of any type of infrastructure in a marine environment brings with it unique challenges; this is where EO-aided Maritime Spatial Planning (MSP) can help the aquaculture sector. MSP represents a holistic approach aimed at balancing the growing demand for maritime areas by both traditional and emerging sectors while safeguarding the integrity of marine ecosystems. **The European Maritime Spatial Planning Platform serves as an invaluable information and communication hub, offering comprehensive assistance to all EU Member States in their MSP implementation endeavours.** It operates with financial support from the EU Directorate General for Maritime Affairs and Fisheries (DG MARE) and acts as the central forum for sharing the wealth of knowledge generated through past, ongoing, and upcoming MSP initiatives and projects.

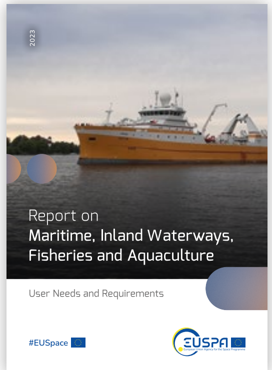
This serves as a foundation for government officials, planners and other stakeholders interested in MSP, enabling them to leverage existing resources, prevent redundancy, facilitate capacity development and promote the evolution of innovative practices. Within the aquaculture sector, EO-based applications primarily support the identification of suitable sites for future fish farms. These applications incorporate environmental factors, forecasts and predictions, often in the context of maritime spatial planning products. Regulatory authorities delineate specific zones designated for aquaculture as part of a strategic coastal spatial planning process, which may occur at the local, regional or national level. In this process, environmental data is amalgamated with administrative and socio-economic criteria to determine the appropriateness of an area for aquaculture development. **In addition, projects such as MSP-GREEN and PLASMAR+ have taken further steps to promote the advancement of several aspects relating to MSP, including the development of new tools based and the identification of technological gaps in MSP applications.**

Sources of key EO and GNSS user requirements

The key EO and GNSS user requirements for the different application groups within the **fisheries and aquaculture** segment are collected using a harmonised procedure at EU level.

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, Inland Waterways, Fisheries and Aquaculture user needs and requirements. User requirements for Earth Observation (EO) services and products – as well as their evolution – are now also collected through the UCP. The process covers the EO user needs and requirements of commercial users based on inputs from industry experts and user groups, mirroring the existing process implemented for GNSS.

Moreover, the collection of specific requirements for Copernicus services and products is supported by 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.



Fisheries and Aquaculture Value Chains[1]

EARTH OBSERVATION

DATA PROVIDERS

- AIRBUS*
- BLACKSKY
- CAPELLA SPACE
- GEOSAT*
- ICEYE*
- E-GEOS*
- MAXAR
- PLANET
- SATELLOGIC*
- UMBRA

- COPERNICUS SENTINELS*
- LANDSAT (USGS)
- METEOSAT (EUMETSAT)*
- RADARSAT (CSA)
- RELEVANT IN-SITU NETWORKS
- RELEVANT EUROPEAN NATIONAL MISSIONS
- METEOROLOGICAL AGENCIES
- OCEANOGRAPHIC AGENCIES

INFRASTRUCTURE PROVIDERS

- AWS
- CLOUDFERRO*
- GOOGLE CLOUD PLATFORM
- IBM CLOUD
- MICROSOFT AZURE
- T-SYSTEMS*

- FEDERATED INFRASTRUCTURE (E.G. GAIA-X)*
- SENTINEL COLLABORATIVE GROUND SEGMENT*

PLATFORM PROVIDERS

- CLOUDEO*
- CREODIAS*
- EARTH-I*
- EDS CEODE
- EURODATACUBE*
- GOOGLE EARTH ENGINE
- NORTH.IO*
- OPEN DATA CUBE
- PLANET EXPLORER
- SENTINEL-HUB* (SINERGISE)
- TERRADUE*
- UP42*

- COPERNICUS DATASPACE ECOSYSTEM*
- OPENEO*
- COASTAL TEP*
- WEKEO*

EO PRODUCTS AND SERVICE PROVIDERS

- ACRI*
- BERRING DATA COLLECTIVE*
- BIOCEANOR*
- CLS*
- DEIMOS*
- EOMAP*
- KSAT*
- OCEANMIND*
- PLANETEK*
- PML*
- SKYTRUTH
- VAKE*
- VITO*
- WATER INSIGHT*

- COPERNICUS MARINE SERVICE (CMEMS)*

INFORMATION PROVIDERS

- BREVISCO*
- DELTARES*
- DNV*
- GLOBAL MARITIME*
- INNOVASEA
- SEASCAPE*

- BGS*
- ILVO*

END USERS

- FISHERIES
- AQUAFARMERS
- ENVIRONMENTAL AGENCIES
- CONSERVATION GROUPS
- NGOS
- MARINE RESEARCH INSTITUTES
- MARINE PROTECTION AGENCIES
- SUPERMARKETS

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

European companies dominate the Fisheries and Aquaculture segment for EO with over two thirds of the global market share. Top European companies leading the segment include Airbus, CLS, Leonardo (e-GEOS), and KSAT.

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 almost half of the total market for component and receiver manufacturing combined.

GNSS

MARITIME ORGANISATIONS

- **CIRM** – AN INTERNATIONAL ASSOCIATION FOR MARINE ELECTRONICS COMPANIES

- **EFCA** – EUROPEAN FISHERIES CONTROL AGENCY
- **EMSA** – EUROPEAN MARITIME SAFETY AGENCY

COMPONENT AND RECEIVER MANUFACTURERS

- ADVANTECH
- ALPHATRON MARINE* (PART OF JAPAN RADIO CO)
- BEIJER ELECTRONICS*
- CADDEN
- CHCNAV
- COBHAM*
- COBRA ELECTRONICS
- FURUNO ELECTRIC
- GARMIN
- GENERAL ELECTRIC
- GMT CO.
- HEXAGON*
- INTELLIAN TECHNOLOGIES
- KONGSBERG MARITIME*
- NAVICO*
- NUVOTON
- ORBCOMM
- SEPTENTRIO*
- WARTSILA*
- U-BLOX*
- UNISTRONG GNSS

SYSTEM INTEGRATORS DESIGN CONSULTANCIES TESTING & MAINTENANCE

- AB VOLVO*
- BEIBU GULF PORT GROUP
- COBHAM*
- FURUNO ELECTRIC
- GME
- HYUNDAI
- INMARSAT*
- JAPAN RADIO CO
- JOHNSON OUTDOORS
- KONGSBERG MARITIME*
- MITSUBISHI
- PARTNER PLAST*
- PRONAV
- SAAB*
- SAMYUNG ENC
- WARTSILA*
- UNISTRONG GNSS*
- VIASAT
- XIAMEN YAXON NETWORK
- XINUO

USERS

- FISHING BOAT OPERATORS
- RECREATIONAL BOATERS

USERS OF POSITIONING INFORMATION

- FISHING COMPANIES
- PORT AUTHORITIES
- SURVEILLANCE AUTHORITIES
- DATA-ANALYTICS COMPANIES:
- MARINETRAFFIC, MYSHIPTRACKING, VESSELTRACKER

LEGEND

- Commercial offering
- Public offering / entities
- User segments

NOTES

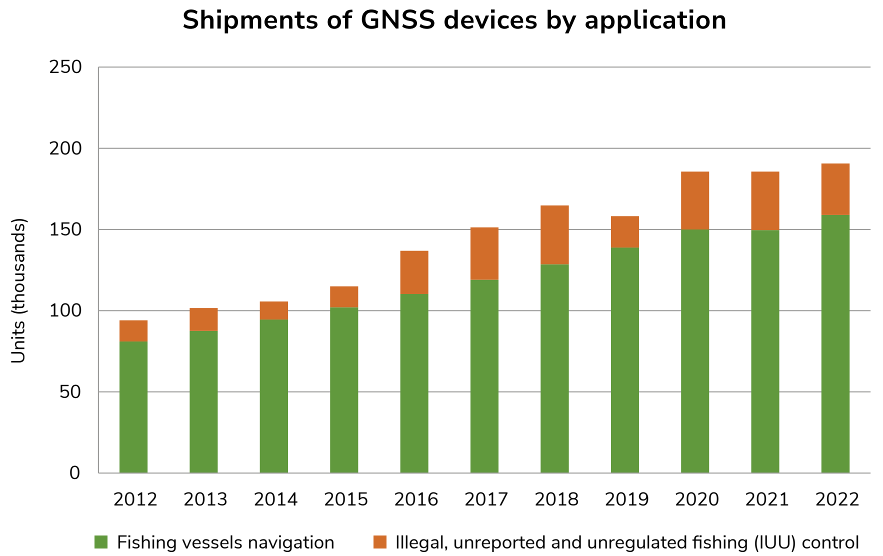
[1] The value chain considers the key global and European companies involved in GNSS and EO downstream activities. Please note that enterprises listed in the data providers step of the value chain often provide platforms as a service. For the sake of simplicity, the data providers are not repeated in other stages of the value chain in which they are active.

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

Please refer to page 13 and 23 for a comprehensive description of value chains and how to interpret them at segment level.

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

Digitalisation of aquaculture and fish stock modelling driving adoption of space solutions



The annual sales of navigational devices greatly increased over the past decade, almost doubling from **just over 80 000 units in 2012 to nearly 160 000 units in 2022**. This growth could be attributed to navigational safety being substantially enhanced by the adoption of dedicated navigation devices, particularly when paired with an AIS that supports collision avoidance. The overall shipment figures grew from **just under 100 000 units in 2012 to just shy of 200 000 units in 2022**.

In the realm of combating Illegal, unreported, and unregulated (IUU) fishing, **VMS and AIS devices had shipped nearly 32 000 units by 2022**. VMS, mandatory for vessels of more than 12m long, is a satellite-based monitoring system that furnishes fisheries authorities with critical data on vessel location, trajectory and activity.

Conversely, AIS serves as a safety radio system enabling the exchange of navigation and other pertinent data between ships and with shore-based facilities, and it is mandated for vessels measuring 15 metres or more. Both of these systems play a pivotal role in aiding authorities in monitoring vessel movements, rendering valuable assistance in the fight against IUU activities. Therefore, they are collectively addressed within the context of IUU control applications

Fish stock modelling and Artificial Intelligence

EO services and products can play a pivotal role in monitoring and modeling fish stock or shoal locations, as well as optimising fishing operations. **These applications harness physical and bio-geochemical analyses, along with forecasting techniques, to gain insights into the vulnerability or resilience of these stocks.** Moreover, EO can offer valuable data regarding the fish habitat, encompassing a range of parameters that help predict the presence or movement of fish at sea.

Key inputs for numerical modeling of fish stocks include global and regional data on sea temperature, salinity, topography, ocean colour and ocean currents.

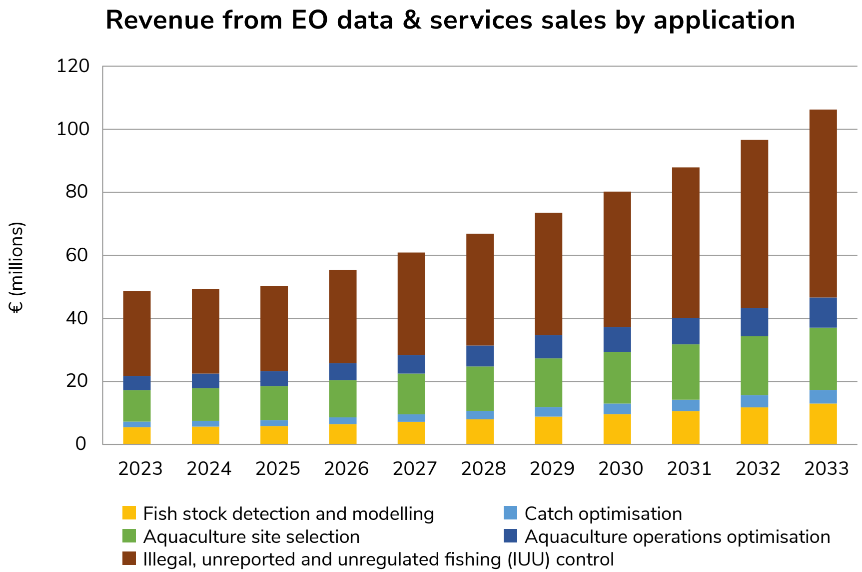
The integration of Artificial Intelligence algorithms with satellite imagery and other data sources enhances the precision of estimates related to fish stock sizes and their precise locations. This fusion of technologies contributes to the overall efficiency of fisheries, benefiting areas, such as navigation and human resource management.

Digitalisation and modernisation of aquaculture farms and their control

Remote monitoring in the management of aquaculture facilities offers a range of advantages to various stakeholders. **Firstly, the technology provides investors, regulatory agencies and retailers with the ability to closely track the growth of fish stocks.** It also promotes transparency within the aquaculture industry, addressing environmental concerns and fostering trust among stakeholders. Aquaculture operations can also be optimised through the integration of EO and GNSS. This includes monitoring water quality and issuing alerts, as well as addressing challenges such as algae blooms, for which solutions like Hidromod (as presented at the 2022 UCP) are available.

EO can help monitor the performance of Recirculating Aquaculture Systems. These systems involve the continuous purification and reuse of culture water, creating nearly closed-loop circuits. Examples of such systems include Big Akwa and BioFishency EXL. **Additionally, the Horizon Europe project SmartAqua4FuturE (SAFE) contributes to advancements in this field.** Finally, EO and GNSS technologies are also adaptable to various aquaculture farm types, including those situated nearshore, offshore, and on land, enabling efficient management and sustainability of aquaculture in diverse settings.

EO and Galileo differentiators support the growth and sustainability of the blue economy



The annual revenue generated from the sale of both EO data and services to the fisheries sector is projected to increase from almost €50 million in 2023 to almost €110 million by 2033.

Throughout the forecasted period, revenues for combating Illegal, unreported, and unregulated (IUU) fishing are expected to dominate the market, **achieving a 56% market share by the end of the decade**.

Another foreseen significant market share is for aquaculture site selection. In 2023, this application accounts for almost €10 million in revenue and is expected to grow to almost double that value in the next 10 years. This could be a result of the **increasing importance of aquaculture in recent key policies and the overall projected increase in global food demand**.

Galileo differentiators expected to play an increasing role in EU waters

An AIS serves as a vessel tracking system, transmitting vital information about a vessel's location, behaviour and identity. However, vessel operators can manipulate their AIS, either by falsifying their location or identity, an act commonly known as "spoofing", or by deactivating their AIS entirely. While legitimate reasons might exist for disabling an AIS device, it can also be exploited to conceal illicit activities. To counteract this issue, Galileo has developed the **Open Service Navigation Message Authentication (OSNMA)**, an anti-spoofing service. OSNMA enables secure end-to-end data transmission from Galileo satellites to GNSS receivers equipped with OSNMA capabilities.

By providing data authentication, the freely accessible Galileo OSNMA offers users assurance that the Galileo navigation message they receive originates from the authentic system itself, free from any alterations caused by a spoofing attempt (see Blue Porbeagle project on the next page). Furthermore, the European Geostationary Navigation Overlay Service (EGNOS) plays a pivotal role in monitoring maritime operations and traffic, particularly when AIS equipment utilises SBAS corrections. Moreover, EGNOS can prove instrumental in the concluding phase of search and rescue operations by furnishing highly accurate location information, especially in cases where the beacon incorporates AIS capabilities.

Blue Carbon – EO aiding in the cultivation of carbon absorbing seaweed

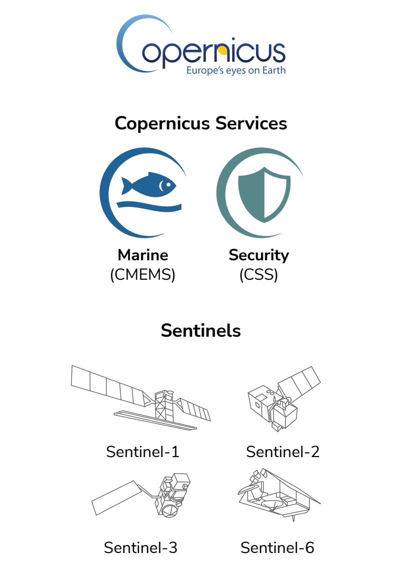
Several varieties of seaweed, including kelp, have the remarkable capacity to absorb and store carbon dioxide through sequestration. When kelp reaches the end of its life cycle, a significant portion of the carbon dioxide it has captured becomes encapsulated within its tissues and subsequently sinks to the ocean floor. Kelp's rapid growth compared to terrestrial forests provides it with a distinct advantage, enabling it to sequester carbon at an accelerated pace. **Various indices derived from EO data can be used to map and monitor the growth of seaweed in conjunction with other monitoring activities that involve field sampling and surveys**. Additionally, EU4Algae, is a European led platform which serves as a distinctive arena for cooperation among various stakeholders in the European algae sector. It encompasses algae farmers, producers, distributors, consumers, technology innovators, business support entities, investors, public authorities, academic institutions, researchers and non-governmental organisations (NGOs).

A promising overall trend is the significant growth of the commercial seaweed farming sector in recent years. This surge is propelled by mounting pressures on food and feed resources, the demand for sustainable alternatives, and an enhanced comprehension of the distinctive attributes of seaweed. These factors have sparked innovations, creating a wave of enthusiasm about the global potential of seaweed, including from blue technology investors and accelerators such as Hatch Blue.

Several European-funded projects utilise space data to develop innovative solutions in fisheries and aquaculture

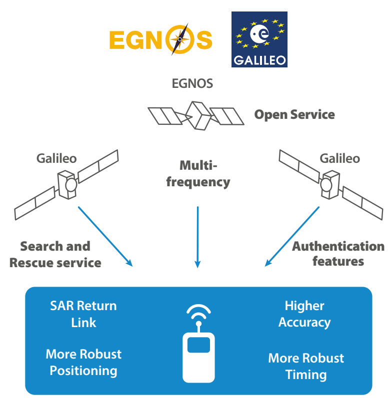
Current usage of Copernicus

The **Copernicus Marine Environment Monitoring Service (CMEMS)** plays a crucial role in supporting a wide range of applications relevant to the fisheries and aquaculture segment, including **fisheries management, marine safety, climate monitoring and environmental protection.** The service integrates data from various sources, including satellite observations, in situ measurements, and models, to provide comprehensive and up-to-date information on the condition of the world's oceans. A related and important product is **MyOcean Viewer**. This tool gives users access to maps, charts and local time series based on information generated by CMEMS. 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. Moreover, Under the **Copernicus Security Service (CSS)**, there is a service called the Copernicus Maritime Surveillance Service (CMS) which is used by EFCA for fisheries control.



Current usage of EGNSS

Galileo enables essential positioning and navigation capabilities to fishing vessels. **AIS and VMS play central roles** when it comes to monitoring fishing vessels and their activities. The new **Very High Frequency Data Exchange System (VDES)**, expected to be operational in 2024, is a radio communication system that operates between ships, shore stations and satellites. The VDES is seen as an effective and efficient use of radio spectrum, **building on the capabilities of AIS** and addressing the increasing requirements for data through the system. This, in conjunction with the upcoming **Open Service Navigation Message Authentication (OSNMA)**, which is designed to provide receivers with the assurance that the received Galileo navigation message is coming from the system itself, will bolster the efficiency and effectiveness of vessel monitoring activities.



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

HORIZON 2020 — NEXT OCEAN

Next Generation of Fishing and Aquaculture Services - NextOcean

The NextOcean project is testing whether Copernicus and GEOSS data can be used by fishing **authorities to improve control over marine resources** and by fishing companies to certify their sustainability **compliance by ecolabeling fish provenance**. The data will also assist aquaculture regulators in assessing the impact of fish farms. The project involved workshops and training sessions to inform the broader community about the use of Earth Observation commercial services.

More information available at: https://www.nextocean.eu/

HORIZON 2020 — FORCOAST

Fishery, Bivalves Mariculture and Oyster Ground Restoration - FORCOAST

The FORCOAST project developed, tested and demonstrated, in operational mode, novel **Copernicus-based downstream information services** in the sectors of wild fisheries, oyster grounds restoration and bivalve mariculture. The services integrated Copernicus EO Products with local models and other **diverse data sources** (local, regional or global) **with ICT** (enhancing new frontiers opened by web, and use of cloud). FORCOAST provided consistent coastal data products, based on a standardised data processing scheme.

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

HORIZON 2020 — GAMBAS

Breakthrough Applications for Safety and Security - GAMBAS

The GAMBAS project showcased how **Galileo's specific characteristics are essential for fisheries.** The project addressed three major aspects of safety and security, namely piracy, illegal fishing and maritime emergencies. GAMBAS developed applications and **supported demonstrations at sea in Europe and beyond**.

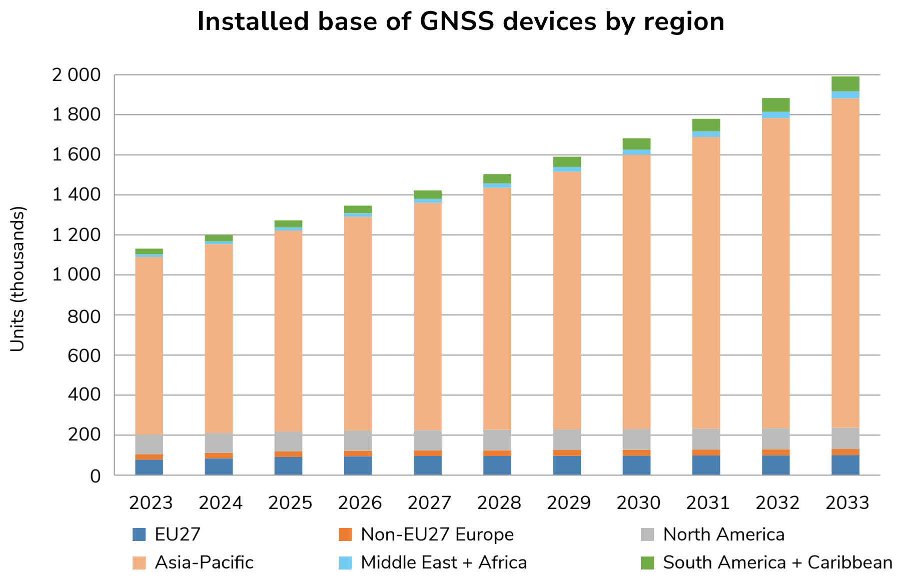
More information available at:
https://gambasgsaproject.com/

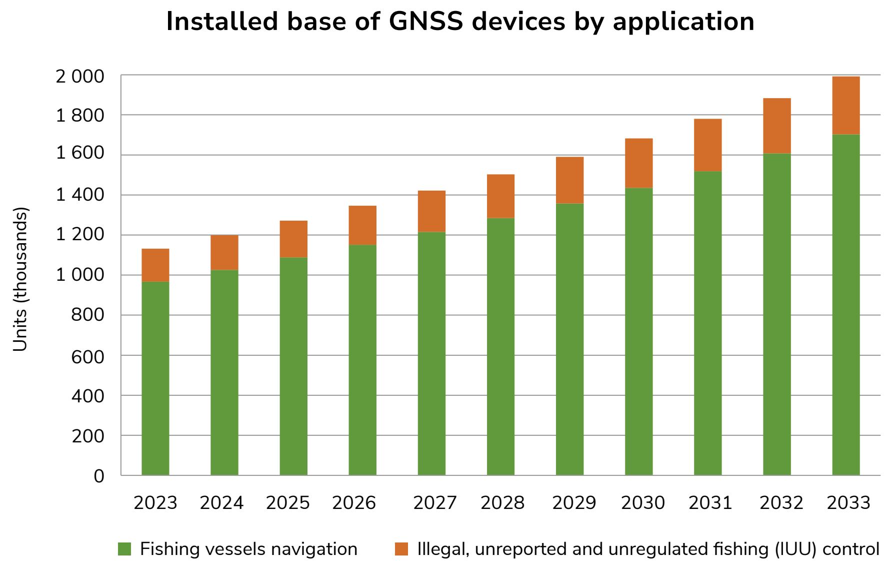
Fundamental Elements — BLUE PORBEAGLE

Developing shipborne integrated equipment - Blue Porbeagle

The goal of the project was to **develop an integrated on-board device**, which, through the pioneering use of dual-frequency technology and an **authentication-based spoofing detection system using Galileo OSNMA**, enabled more precise and authenticated positioning across Galileo-enabled receivers. The project was a success and will give new utility to the European Galileo satellites.

More information available at:
https://www.linkedin.com/showcase/blue-box-porbeagle-vms


Installed base of GNSS devices by region
Units (thousands)
2 000
1 800
1 600
1 400
1 200
1 000
800
600
400
200
0
2023
2024
2025
2026
2027
2028
2029
2030
2031
2032
2033
EU27
Non-EU27 Europe
North America
Asia-Pacific
Middle East + Africa
South America + Caribbean


Installed base of GNSS devices by application
Units (thousands)
2 000
1 800
1 600
1 400
1 200
1 000
800
600
400
200
0
2023
2024
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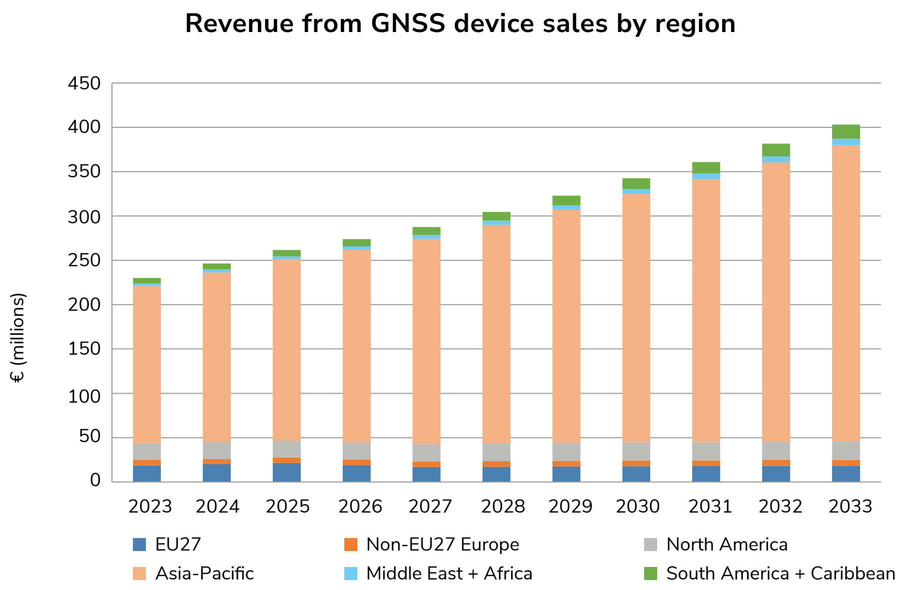
2031
2032
2033
Fishing vessels navigation
Illegal, unreported and unregulated fishing (IUU) control


Revenue from GNSS device sales by region
€ (millions)
450
400
350
300
250
200
150
100
50
0
2023
2024
2025
2026
2027
2028
2029
2030
2031
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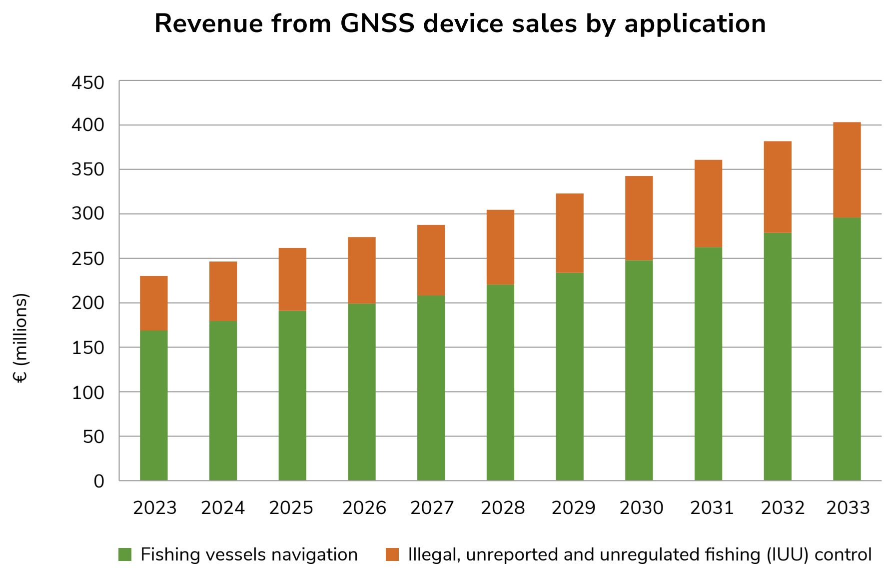
EU27
Non-EU27 Europe
North America
Asia-Pacific
Middle East + Africa
South America + Caribbean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450
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2025
2026
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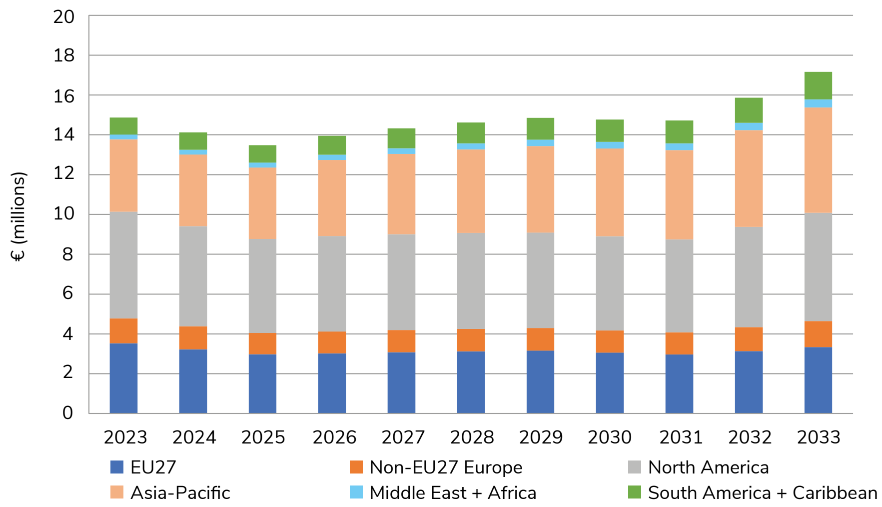
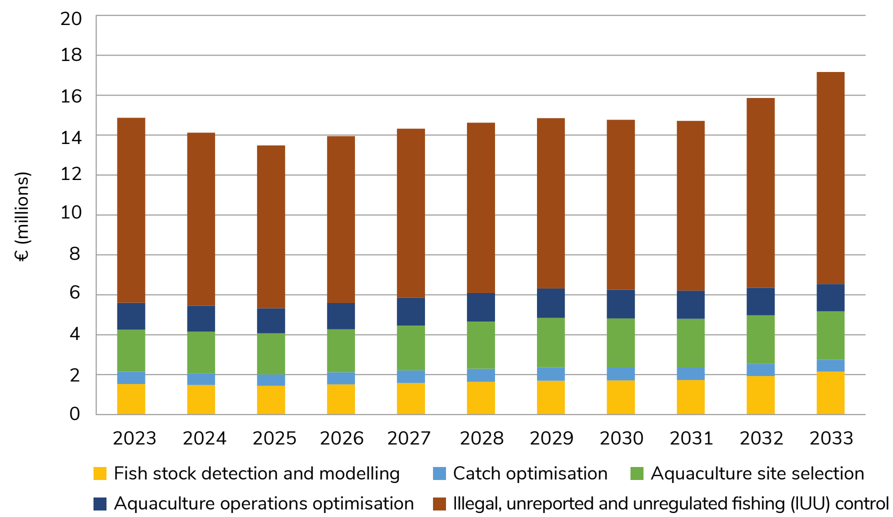
2031
2032
2033
Fishing vessels navigation
Illegal, unreported and unregulated fishing (IUU) control

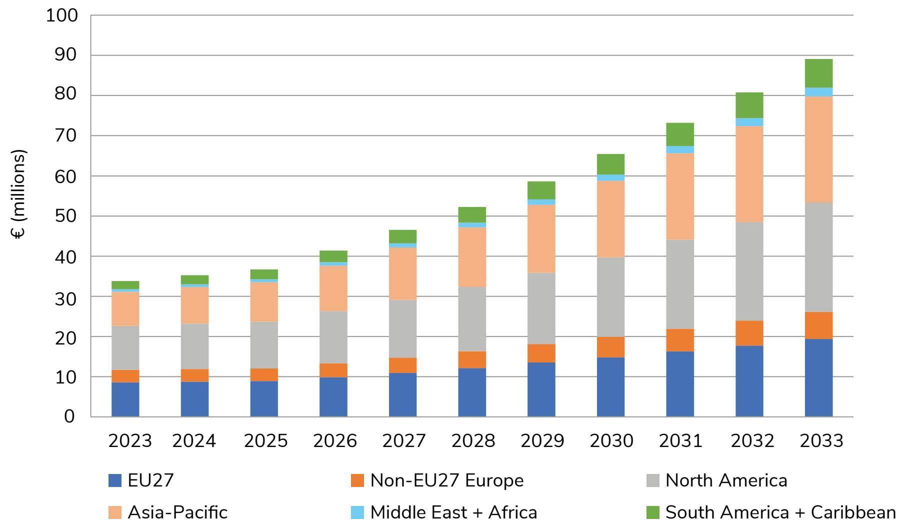
Revenue from EO data sales by region



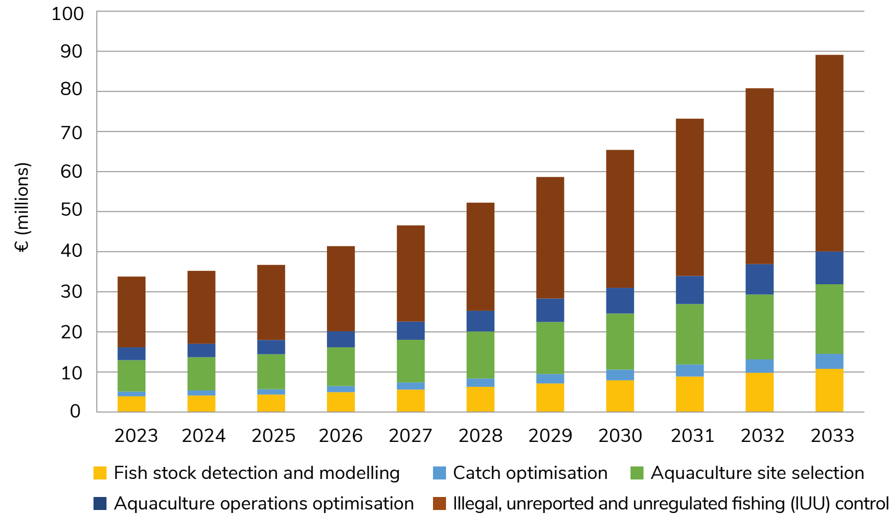
Revenue from EO data sales by application



Revenue from EO services sales by region



Revenue from EO services sales by application



FORESTRY

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

Environmental Monitoring
- Biomass monitoring
- Deforestation and degradation monitoring

Forest Resources Monitoring
- Forest Inventory monitoring[1]
- Forest vegetation health monitoring
- Illegal logging monitoring

Operations Management
- Automatic steering
- Forest asset management[1]
- Forest certification
- Forest machinery guidance[1]

[1] For Forest Inventory Monitoring and Forest Machinery Guidance, shipments and installed base of GNSS devices are quantified. In addition to these quantified units, revenues (not units) from Forest Asset Management services are quantified.

Application descriptions can be found in Annex 3.

FORESTRY

This chapter looks into various activities surrounding the cultivation, maintenance, and development of forests, including recent developments, future trends and key stakeholders across the sector. 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, the positioning and guidance of drones for the likes of hyperspectral/lidar imaging or in precisely locating "on-tree" health sensors.

What you can read in this chapter

- **Key trends:** The new EU Forest Strategy for 2030, emerging online collaboration and commerce platforms and the Forest Information System for Europe.
- **Industry:** Forestry value chains.
- **Recent developments:** Blockchain is supporting traceability applications and the future of forest health monitoring utilises GNSS and EO.
- **Future market evolution:** Forestry operations optimised through better trafficability and new forest regeneration efforts.
- **European systems and projects:** The European Space Programme supports R&D activities in forestry.
- **Reference charts:** Yearly evolution of installed base of GNSS devices and revenues as well as EO revenues by application and region.

The new EU Forest Strategy for 2030, emerging online collaboration and commerce platforms and the Forest Information System for Europe

Key market trends

- The new EU Forest Strategy for 2030 and Deforestation-Free Products Regulation will guide how we monitor and manage forestry for years to come
- New digital platforms utilising GNSS and EO to increase collaboration across the forestry value chain
- The Forest Information System for Europe is our most comprehensive source of data on European forests

New EU Forestry Strategy for 2030 and Deforestation-Free Products Regulation driving how the sector will reach the goals of the Green Deal

The new **EU Forestry Strategy for 2030** outlines a comprehensive vision to enhance both the quantity and quality of European forests while reinforcing their protection, restoration and resilience. Its primary objective is to adapt these forests to the changing environmental conditions, including extreme weather events and heightened uncertainty due to climate change. **The integration of EO data, coupled with Artificial Intelligence and advanced big data analytics, leveraging the capabilities of cloud computing, introduces objectivity and transparency to the evaluation of the strategy's effectiveness.**

Additionally, in 2023, the European Parliament passed a ground-breaking law aimed at combatting global deforestation, known as the **Deforestation-Free Products Regulation (EUDR)**. This regulation establishes mandatory due diligence requirements for all operators and traders involved in the import, distribution or export of various commodities within the EU market, including soy, beef, palm oil, cocoa, coffee, rubber and timber, along with derived products, such as furniture and printed paper. To enforce this law, EU authorities will now use company-provided information such as GNSS-enabled coordinates of land plots where commodities are produced, EO-based deforestation analysis or complementary data (e.g. geotagged photographs). They will also conduct thorough inspections utilising satellite monitoring tools and DNA analysis, ensuring that the commodities in question do not originate from deforested areas.

E-commerce platforms connecting forestry value chain actors like never before

A burgeoning category of digital business solutions within the forestry industry comprises specialised IT platforms designed to facilitate e-commerce. These platforms enable seamless collaboration among various stakeholders within the forestry supply chain, including forest managers, harvesting contractors, transportation companies, timber traders and forest-based industries. **By harnessing technologies such as GNSS data to record wood pile locations and track their movement for logistical purposes, as well as EO data for monitoring and optimising forestry operations, logistics platforms empower actors to enhance their planning horizons and optimise supply chain operations across different companies.**

Some of these systems provide comprehensive solutions that cover the full spectrum of forestry-related activities and can seamlessly integrate with commonly used IT systems. **In recent years, e-business platforms have witnessed widespread adoption in the forestry sector.** Numerous instances of online marketplaces for timber and forestry services have emerged, fostering business partnerships and facilitating transactions, particularly in rural areas.

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The Forest Information System for Europe (FISE) – our most comprehensive source for forest monitoring

The Forest Information System for Europe (FISE) stands as the pioneering centralised database for forest-related information across Europe. **Through its web portal, FISE offers customised data and insights to a diverse audience, including national, EU and international policymakers, forest industry experts, forest owners and conservationists, as well as scientists and researchers.** FISE also extensively leverages data and information sourced from the Copernicus programme. Beyond enhancing forest monitoring capabilities, FISE is poised to foster data-driven decision-making in forestry. Its implementation is anticipated to bolster public trust in forest management, curb illicit logging activities, promote and incentivise sustainable forest management practices, and provide support for forests' adaptation to the challenges posed by climate change. Furthermore, **FISE contributes to shaping a digitally advanced Europe by empowering individuals, businesses and administrations with access to standardised forest-related data and by harnessing digital technologies to their fullest potential.** Finally, a legislative proposal has been drawn up under the new Forest Strategy for 2030 to create a framework for ensuring coordinated EU forest observation, reporting and data collection, within which FISE could play a central role. The monitoring framework will enable the collection and sharing of timely and comparable forest data **obtained through a combination of EO and ground measurements.** It will also ensure cooperation among Member States by encouraging them to set up long-term forest plans.

Forestry Value Chains[1]

EARTH OBSERVATION

DATA PROVIDERS

- AIRBUS*
- BLACKSKY
- CAPELLA SPACE
- CONSTELLR*
- GEOSAT*
- ICEYE*
- E-GEOS*
- MAXAR
- PLANET
- SATELLOGIC*
- UMBRA

- COPERNICUS SENTINELS*
- LANDSAT (USGS)
- METEOSAT (EUMETSAT)*
- RADARSAT (CSA)
- RELEVANT EUROPEAN NATIONAL MISSIONS
- RELEVANT IN-SITU NETWORKS

INFRASTRUCTURE PROVIDERS

- AWS
- CLOUDFERRO*
- GOOGLE CLOUD PLATFORM
- IBM CLOUD
- MICROSOFT AZURE
- T-SYSTEMS*

- FEDERATED INFRASTRUCTURE (E.G. GAIA-X)*
- SENTINEL COLLABORATIVE GROUND SEGMENT*

PLATFORM PROVIDERS

- CLOUDEO*
- CREODIAS*
- EARTH-I*
- PIESAT
- PLANET EXPLORER
- SENTINEL HUB* (SINERGISE)
- SPACESENSE*
- TERRADUE*
- UP42*
- VITO*

- COPERNICUS DATA SPACE ECOSYSTEM*
- FORESTRY TEP*
- GLOBAL FOREST WATCH
- WEKEO*

EO PRODUCTS AND SERVICE PROVIDERS

- ARBONAUT*
- BEETLEFORTECH*
- CGI INC
- CONSTELLR*
- DAVEY TREE EXPERT COMPANY
- EARTH DAILY
- EOS DATA ANALYTICS
- ECOMETRICA*
- GAF*
- GEOVILLE*
- GMV*
- KAYRROS*
- KERMAP*
- KSAT*
- LIVEEO*
- METRIA*
- ORBIFY*
- ROSA.IO*
- SATELLIGENCE*
- SINERGISE
- SITOWISE*
- SPACEBEL*
- TERRAEYE*
- VITO*
- XYLENE*

- COPERNICUS CLIMATE CHANGE SERVICE (C3S)*
- COPERNICUS EMERGENCY MANAGEMENT SERVICE (CEMS)*
- COPERNICUS LAND MONITORING SERVICE (CLMS)*

INFORMATION PROVIDERS

- COLLECTIVE CRUNCH*
- F&W
- FORESTRADAR*
- FORLIANCE*
- FORSTIFY*
- KANOP*
- KUVA SPACE*
- NIRAS ALECTIA FONDEN*
- OIKON*
- SYMBIA SOLUTIONS*
- TREEMETRICS*
- WUUDIS*

- EU OBSERVATORY ON DEFORESTATION AND FOREST DEGRADATION*

END USERS

- ENVIRONMENTAL AGENCIES
- FORESTRY CONSULTANTS
- FORESTRY MANAGERS
- FORESTRY-INSURERS
- INTERNATIONAL AGENCIES (E.G. FAO, WFP...)
- MACHINE MANUFACTURERS
- PAYING AGENCIES
- FOREST CERTIFICATION BODIES
- FOOD/INDUSTRIAL MANUFACTURING COMPANIES CONCERNED WITH DEFORESTATION-FREE PRODUCTS

GNSS

AUGMENTATION SERVICE PROVIDERS

- CNH INDUSTRIAL*
- DEERE
- HEMISPHERE (ATLAS)
- HEXAGON*
- SAPCORDA*
- SWIFT
- TERIA*
- TOPCON
- TRIMBLE

- NATIONAL AND REGIONAL RTK NETWORK PROVIDERS

COMPONENT AND RECEIVER MANUFACTURERS

- AG LEADER TECHNOLOGY
- AGJUNCTION
- ANALOG DEVICES
- ANTCOM
- ARAG*
- AVMAP*
- BEIJING BDSTAR NAVIGATION
- CAMPBELL SCIENTIFIC
- CHCNAV
- CNH INDUSTRIAL*
- COMNAV TECHNOLOGY
- DEERE
- HARXON
- HEXAGON*
- MEINBERG*
- RAVEN INDUSTRIES
- SEPTENTRIO*
- TOPCON CORPORATION
- TRIMBLE NAVIGATION
- UNISTRONG GNSS
- YAGEO

SYSTEM INTEGRATORS DESIGN CONSULTANCIES TESTING & MAINTENANCE

- AGJUNCTION
- AL-GHAZI TRACTORS
- AMAZONEN-WERKE*
- BARKO
- C-ASTRAL
- CATERPILLAR INC
- CLAAS KGAA*
- CHCNAV
- CNH INDUSTRIAL*
- DELAIR*
- DEERE
- DUSITECH
- HEXAGON*
- HITACHI
- JCB*
- KOMATSU*
- KUBOTA CORPORATION*
- LINDNER TRAKTOREN*
- MILLAT TRACTORS
- QIANXUN SI
- SDF GROUP*
- TEEJET TECHNOLOGIES*
- VOLVO*
- YANMAR

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 Airbus, Leonardo (e-GEOS), and KSAT leading the segment for Europe, European companies constitute almost half of the global EO data processing, analysis, insights and decision support market.

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 are among the top 10 global companies when it comes to components and receivers manufacturing, holding almost one sixth of the market share combined.

LEGEND

- Commercial offering
- Public offering / entities
- User segments

NOTES

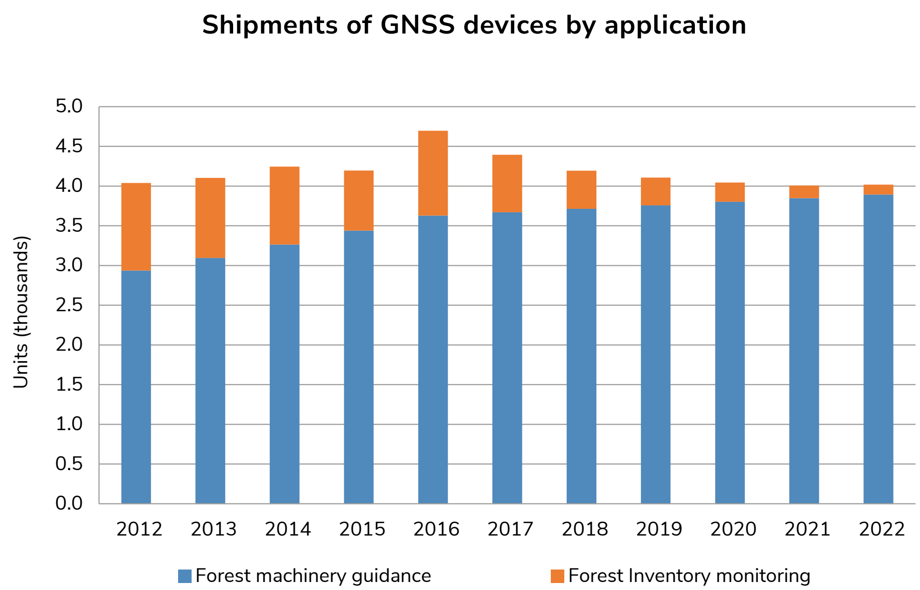
[1] The value chain considers the key global and European companies involved in GNSS and EO downstream activities. Please note that enterprises listed in the data providers step of the value chain often provide platforms as a service. For the sake of simplicity the data providers are not repeated in other stages of the value chain in which they are active.

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

Please refer to page 13 and 23 for a comprehensive description of value chains and how to interpret them at segment level.

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

Blockchain is supporting traceability applications and the future of forest health monitoring utilises GNSS and EO



The **shipments of GNSS receivers** over the past 10 years has shown **fluctuating** and overall, little growth. While there was a hopeful growth trend leading up to 2016, overall shipment numbers ultimately declined since then and now stand roughly at the same point as they did a decade ago.

Forest Machinery Guidance held the largest market share over the past decade. **Forest Inventory Monitoring** uses GNSS for accurately locating inventory plots during operations. The application used to be supported by dedicated handheld devices, but has progressively transitioned towards the use of specific software empowering tablets and smartphones.

EO is also extensively used in this application to first classify and then analyse forested areas to produce estimates on the number of trees in a defined area. Forest Inventory Monitoring lost almost all of its market share to Forest Machinery Guidance, dwindling to a small percentage at the end of the decade in question. This decline could be attributed to a number of factors, such EO being used more and more in lieu of GNSS within this application and the growing use of smartphones instead of conventional GNSS-enabled devices.

EO and blockchain increasing forestry traceability

A pressing concern within the forestry industry pertains to the infiltration of illegal logging products into the supply chain, perpetuating the existence of these detrimental practices. Consequently, the destruction of forests, jungles and habitats ensues, with far-reaching and devastating consequences for indigenous communities.

To address this issue, **one promising solution involves the utilisation of blockchain, a type of distributed ledger technology**. During the logging process, the precise location of each tree can be automatically recorded in the blockchain and an intelligent tag can be affixed to track the wood's journey throughout the entire supply network, all of which can be aided through the adoption of GNSS data. This robust system ensures the secure traceability of wood origins, effectively mitigating concerns related to the authenticity of wood and other natural resource supply chains. **Additionally, blockchain facilitates real-time tracking and auditing of timber, enhancing transparency and accountability in the industry.**

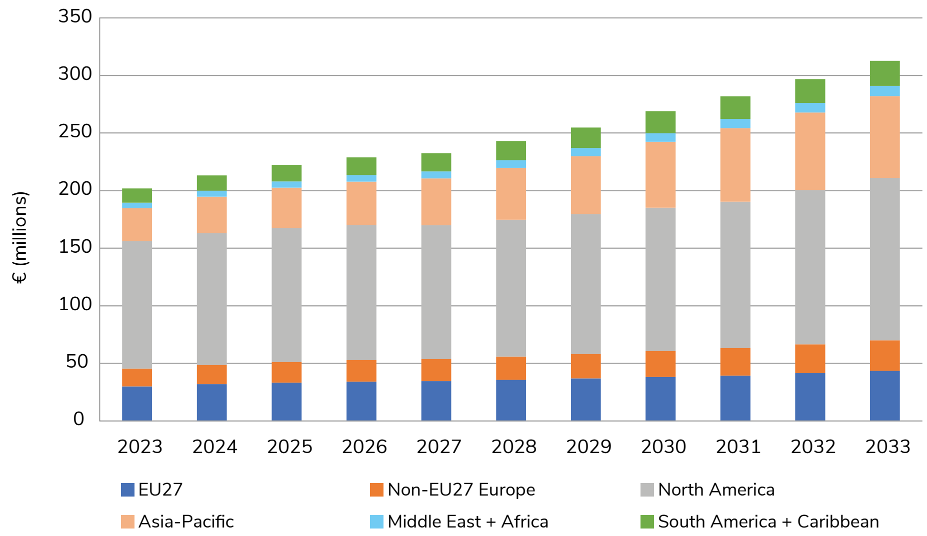
More accurate forest health monitoring

Tree monitoring systems offer a means for authorities to maintain a vigilant watch over the well-being of forests. **Foresters can affix sensors to selected trees within woodland areas, enabling the measurement of various parameters that serve as indicators of tree health.** This practice enables both foresters and community stakeholders to take decisions based on reliable data, whether the goal is to preserve existing tree cover or expand into urban and forested areas. These sensors are capable of capturing eco-physiological and biological data, including such details as water transport within trees, stem water content, diameter growth, and the quality and quantity of tree foliage.

To precisely pinpoint tree locations, GNSS technology is employed, aiding foresters in obtaining a comprehensive assessment of overall forest health. Furthermore, EO data, encompassing resources like Copernicus Sentinel-1 and Sentinel-2 data, complements sensor data by providing insights into the overall canopy health through various derived indices. EO technology extends its monitoring capabilities to aspects such as soil conditions and forest cover, offering a holistic view of a forest's health status.

Forestry operations optimised through better trafficability and new forest regeneration efforts

Revenue from EO data & services sales by region



Total revenues from EO data and services sales are expected **to show strong and continuous growth over the next 10 years**, reaching over **€300 m by the end of the decade**.

North America is expected to retain a dominant **market share** from both the sales of EO data and services over the coming decade, **reaching €140 m by 2033**.

Over the next decade, the Asia Pacific region is poised to significantly increase its market presence, surpassing that of the EU27. Likewise, **Latin America will gradually but consistently expand its market share**, thanks to the continued significance of forestry-related activities in the Amazon. Its overall market share, however, will remain comparable to other parts of the world.

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Forest "trafficability" – Optimising navigation and forestry operations in all weather conditions with EO

Heavy machinery used in forest harvesting operations can result in significant soil rutting, which is detrimental to the growth of forests. The extent of rutting risks is contingent upon the soil's bearing capacity, which exhibits substantial spatial and temporal variability. **It is imperative to predict the trafficability of forested areas** when selecting suitable operation sites within specific timeframes and under varying conditions.

Additionally, on-site route optimisation during operations necessitates the use of integrated tools to minimise adverse ecological and economic impacts. To accomplish these objectives, the integration of various tools is essential for the effective planning and execution of forest operations. **EO-enabled mapping and seasonal forecasting play pivotal roles in predicting factors such as frozen soil depth, snow accumulation and moisture content.** This valuable information empowers forestry operators to identify areas with the most favorable soil conditions well in advance, facilitating more efficient planning and ensuring optimal forest trafficability conditions.

Advanced regeneration efforts aiming to encourage new forest growth

Cutting-edge solutions for forest regeneration are playing a pivotal role in advancing sustainable forest yields. A diverse array of technology-driven approaches is now at our disposal. **These solutions harness the power of GNSS and EO data, in conjunction with advanced analytics and Artificial Intelligence**, to achieve objectives including enhancing seedling dispersal, optimising nutrient allocation and predicting yield outcomes.

Precision forestry machinery guided by GNSS technology, including the use of unmanned robotic systems, showcases remarkable capabilities. It can meticulously plant hundreds of thousands of seeds in a single day. Some technologies go even further by packaging seeds into precisely balanced fertiliser mixes and dispensing them automatically – a task that easily surpasses the capacity of a human labourer within the same timeframe. **Furthermore, a plethora of indices derived from resources like Copernicus Sentinel-1, Sentinel-2, and the Copernicus Land Monitoring Service (CLMS)** provides invaluable data and services that can be employed for remote monitoring of forest growth progress and health assessment.

The European Space Programme supports R&D activities in forestry

Current usage of Copernicus

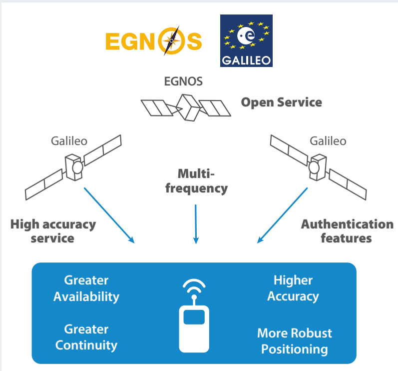
Forest monitoring applications can benefit greatly from Copernicus data and services.

The programme offers dedicated services for land monitoring (i.e. **the Copernicus Land Monitoring Service, (CLMS))**, which includes the **Tree Cover Density (TCD), Dominant Leaf Type (DLT)** and **Forest Type (FTY)** products. Additional services include the Copernicus Climate Change Service (C3S) and, specifically concerning forest fires, the Copernicus Emergency Management Service (CEMS).

The programme also supplies satellite data from the Sentinels, which are seamlessly integrated into numerous forest monitoring and management applications, such as in deforestation monitoring.

Current usage of EGNSS

Galileo provides highly accurate real-time positioning and navigation information, which allows forestry professionals to precisely locate and map forest areas, boundaries, roads and trails. The Galileo **High Accuracy Service (HAS)** went live in 2023, offering greater accuracy than 20cm horizontally and 40cm vertically, free of charge. Accurate positioning is essential for tasks such as **machinery guidance, planning tree planting, authenticating plot sizes/positions to track deforestation rates, or identifying specific areas for timber harvesting**. Moreover, the Open Service Navigation Message Authentication **(OSNMA)** provides receivers with the assurance that the received Galileo navigation message is coming from the system itself and has not been modified.



The real-time data allows forestry managers to monitor and track moving assets within the forest, such as vehicles or personnel, **which enhances safety and efficiency**. The combination of precise positioning and real-time data also enables the use of advanced technologies like remote sensing and aerial imagery to be integrated with the positioning data to create **detailed forest inventory maps**.

Horizon Europe, a programme of the European Union

Satellites for wilderness inspection and forest threat tracking - SWIFTT

SWIFTT will provide **forest managers with affordable, simple and effective remote sensing tools** backed up by Copernicus satellite imagery and powerful machine learning models to help monitor and manage forest risks.

It will **enable forest managers to adapt to climate change** with affordable, simple and effective remote sensing tools backed up by machine learning models. This solution will be tested in real conditions.

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

Horizon Europe, a programme of the European Union

Digital analytics and robotics for sustainable forestry - Digiforest

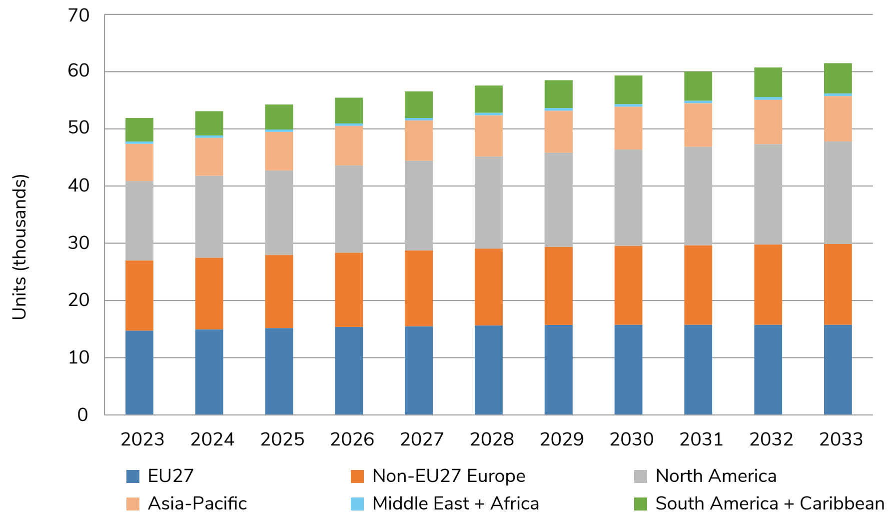
The mission of Digiforest is to develop the technology needed to **achieve sustainable digital forestry**. It brings together partners working on **GNSS-enabled aerial robots, walking robots, autonomous (lightweight) harvesters**, as well as forestry decision-makers and commercial companies.

These stakeholders aim to create a full data pipeline to **digitise the state of forests (at scale)** and to collect maps and inventories which can be used by foresters in more **precise, sustainable and modern ways**.

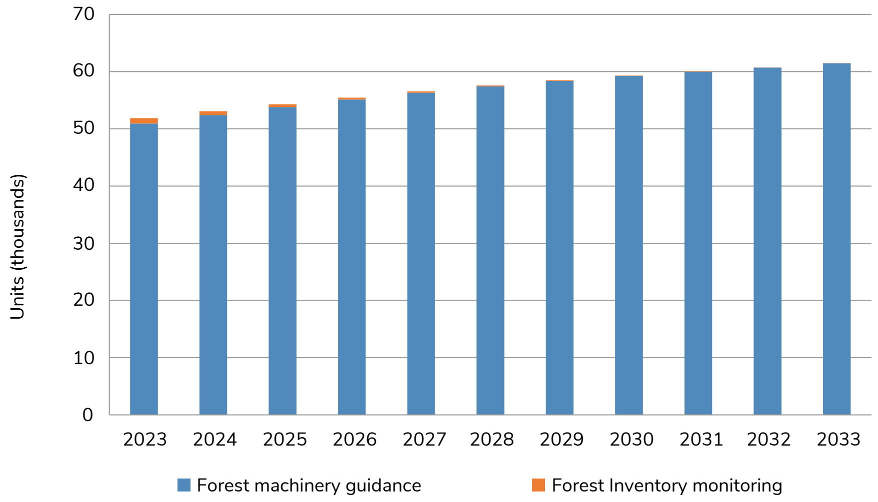
More information available at: https://digiforest.eu/

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

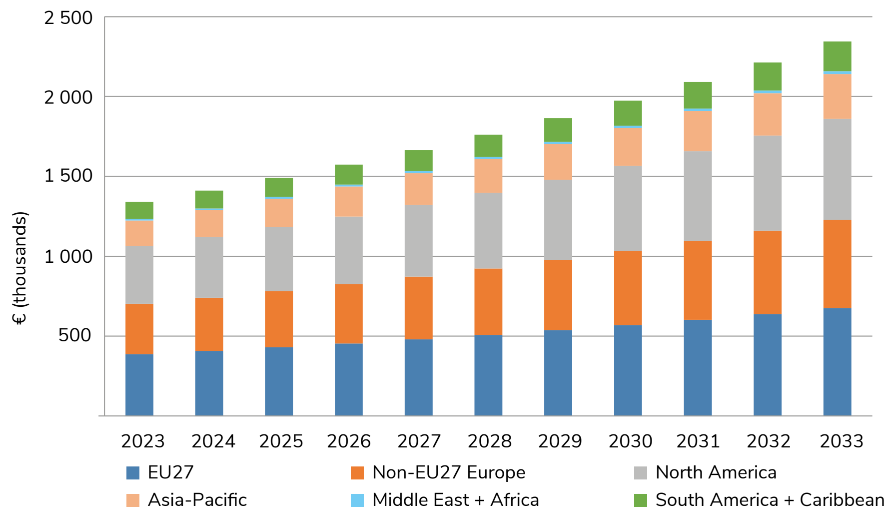
Installed base of GNSS devices by region



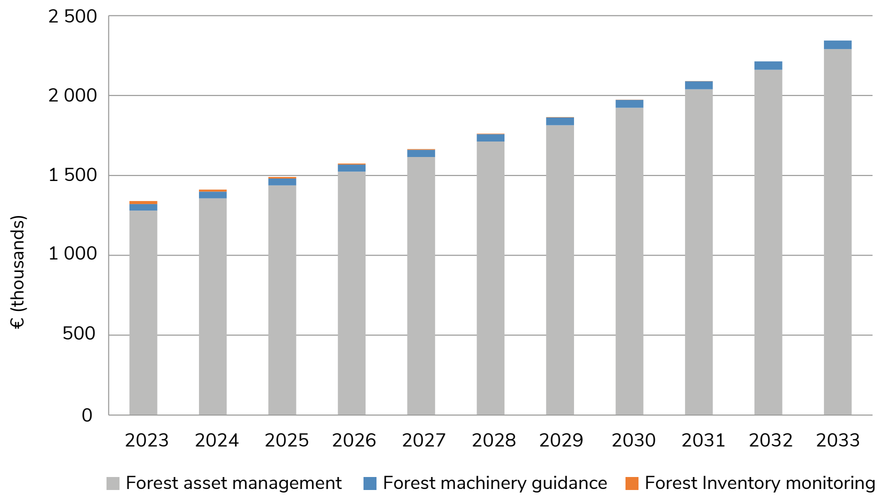
Installed base of GNSS devices by application



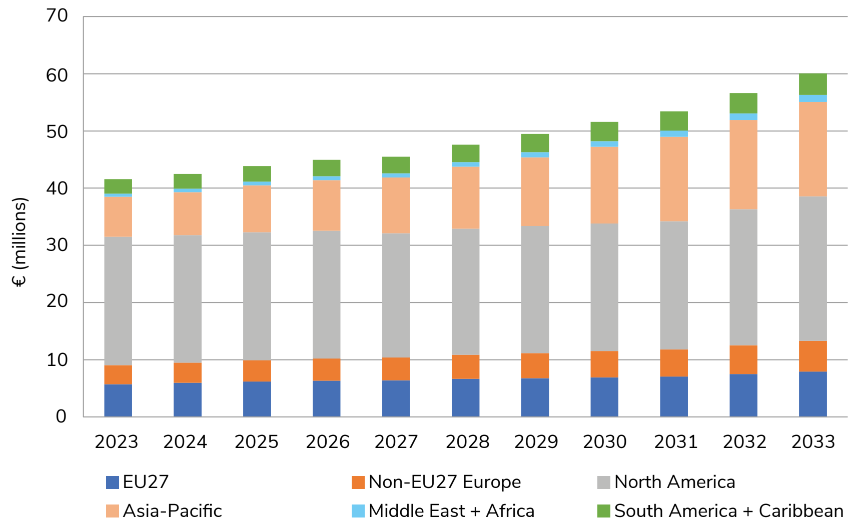
Revenue from GNSS device sales and services by region



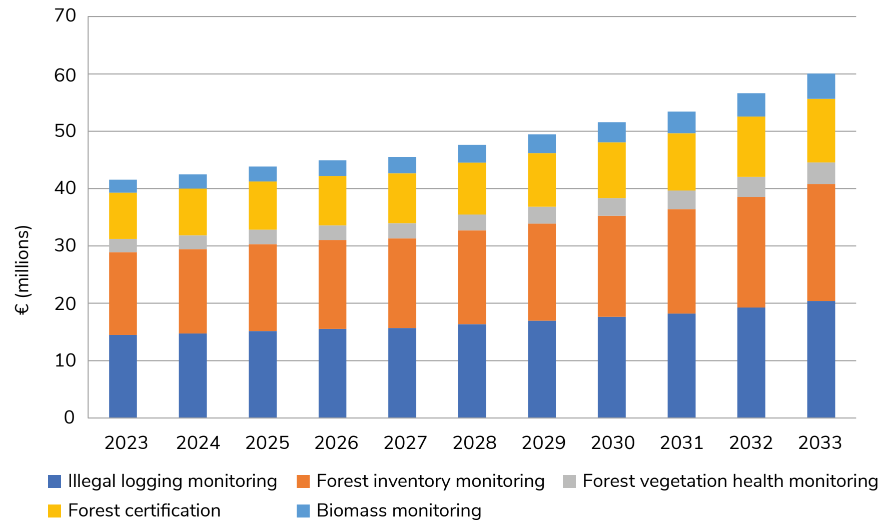
Revenue from GNSS device sales and services by application



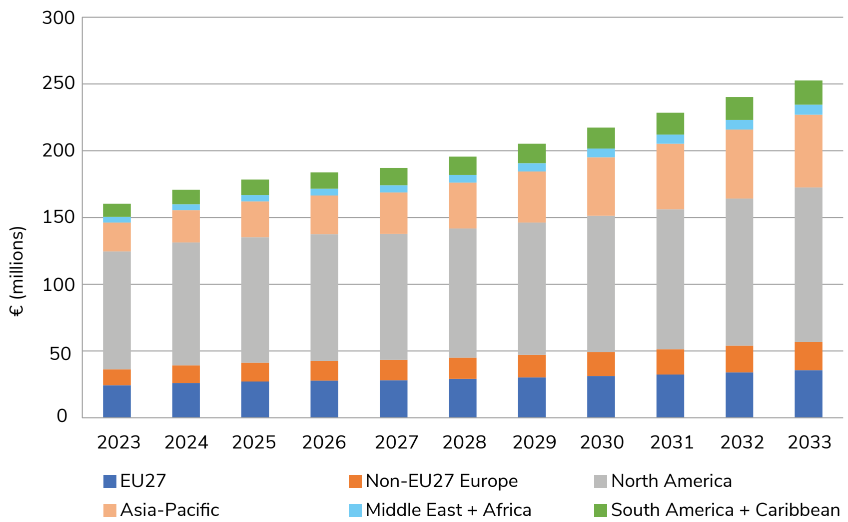
Revenue from EO data sales by region



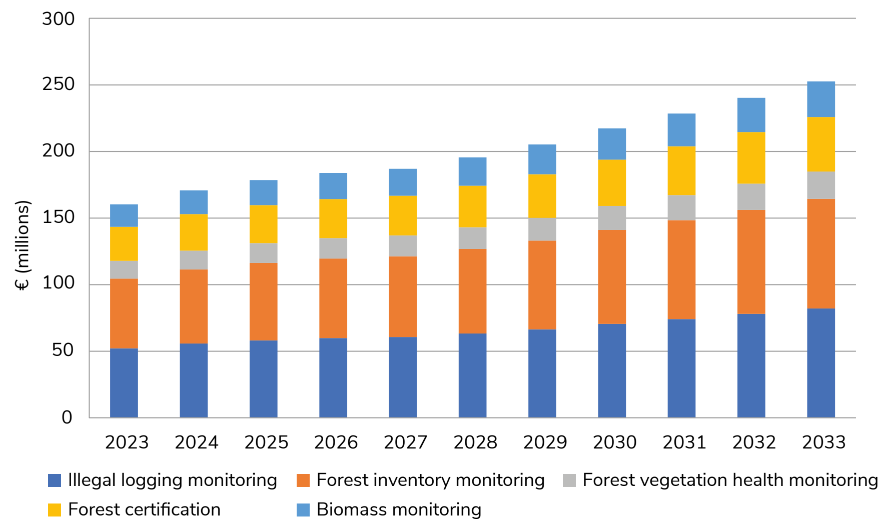
Revenue from EO data sales by application



Revenue from EO services sales by region



Revenue from EO services sales by application



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 Monitoring
- Monitoring of impact of human activities on infrastructure
- Official Development Assistance (ODA) Support Monitoring
- Pipeline Monitoring
- Post-Construction Monitoring

Infrastructure Planning

- Infrastructure Site Selection and Planning
- Permitting
- Vulnerability Analysis

Timing & Synchronisation of Telecommunication Networks

- Data Centre
- Digital Cellular Network (DCN)
- DTV Broadcast
- 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.

By integrating receivers into heavy machinery or drones, GNSS offers high-accuracy services which support the various phases of the infrastructure life cycle, including construction works and maintenance operations. In addition, GNSS-based timing and synchronisation improves the protection and resilience of telecommunication networks, data centres, cloud services and state-of-the-art industrial production systems.

Satellite-based imagery also supports the entire infrastructure life cycle, from initial site selection to the monitoring of construction and post-construction operations. It contributes to the characterisation of potential construction sites and to the monitoring of construction operations and of their impacts on the environment. Thanks to its capacity to deliver information on risk exposure and future impacts of climate change, EO also enables to design more resilient infrastructure and to optimise maintenance operations.

Whatever the type of infrastructure (e.g. buildings, bridges, roads, railway lines, pipelines, dams, factories, power plants, telecommunication networks, data centres), GNSS and EO support the actors involved in infrastructure management in their effort 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:** Space-based services increasingly support the planning, design and management of resilient infrastructure.
- **User perspective:** GNSS and EO help optimise construction operations and monitor their impact on the environment.
- **Industry:** Infrastructure Value Chains.
- **Recent developments:** GNSS positioning and timing power robust solutions in the infrastructure sector while EO-based construction progress monitoring and ground deformation monitoring are on the rise.
- **Future market evolution:** New constellations and applications contribute to the growth of the GNSS market and the penetration of EO-based solutions should benefit from state-of-the-art data computing technologies.
- **European systems:** The EU Space Programme provides invaluable benefits for infrastructure.
- **European Projects:** Several EU-funded projects investigate solutions to improve infrastructure resilience.
- **Reference charts:** Yearly evolution of the installed base of GNSS devices and revenues as well as EO revenues by application and region.

Space-based services increasingly support the planning, design and management of resilient infrastructure

Key market trends

- Climate neutrality goals, UN SDGs and climate change mitigation foster the use of EO data for informed decisions related to the design of resilient infrastructure and its maintenance
- The EU Space Programme, along with GIS and cutting-edge AI technologies, supports the automation of monitoring processes and the optimisation of construction and maintenance operations
- EGNSS is expected to play a key role in satisfying the growing needs of the industry and critical infrastructure for robust and threat-resistant timing and synchronisation solutions
- InSAR ground deformation assessment is progressively generalising for large infrastructure works while satellite-based change detection is increasingly used for construction progress monitoring

GNSS-based positioning supports inspection and preventive maintenance operations

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The **inspection** of large or remote infrastructure can be a **costly** endeavour, particularly when considering predictive or preventive maintenance efforts to avoid potential disruptions. Regular inspections are crucial for identifying and addressing issues before they escalate. In this context, **autonomous** devices, such as drones, have emerged as a cost-effective and versatile alternative for performing both inspection and maintenance tasks.

These devices come equipped with an array of sensors, cameras, and specialised tools that enable comprehensive assessments of infrastructure. Their capacity to integrate GNSS receivers is ensuring **precise positioning** and **mapping** along the length and breadth of the infrastructure under examination. Not only does it facilitate accurate navigation, but it also allows for the creation of highly detailed maps, greatly enhancing the accuracy and comprehensiveness of inspections.

Such autonomous devices can further enhance their utility through the incorporation of **authentication** features, adding an extra layer of **trust** and **reliability**, and ensuring that the devices can be safely deployed in various operational settings including sensitive or critical infrastructure environments.

GNSS T&S capacities coupled with cybersecurity tools can provide a secure environment for data centres and cloud services

The ongoing transition to **cloud-based environments, hybrid cloud networks and interconnected data centres** is posing new challenges to companies in the form of increased **cyber risks as well as GNSS-related threats** such as jamming and spoofing. Fortunately, **GNSS itself is part of the hybrid solution to mitigate these threats**.

To monitor and control their own security architectures as well as to mitigate both challenges, large enterprises deem it essential to rely on so-called **Security Operation Centres** (SOCs). These SOCs rely on a vast amount of properly timed and synchronised logs, with a single time source, to ensure continuity of operations, automation, threat detection and support analytical tools.

State-of-the-art dual-frequency receivers and protected GNSS signals such as Galileo OSNMA can form a first stage of a **resilient PNT environment** (detection). Besides the use of GNSS hardware, the huge amount of GNSS PNT data available in the cloud allows for a processing using AI techniques and machine learning algorithms to derive meaningful information to mitigate GNSS threats.

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EO helps infrastructure planners and managers to mitigate threats from climate change

Due to their long life cycle (generally several decades), most types of infrastructure are strongly exposed to the negative impacts of climate change. Whether it is local infrastructure, such as buildings, airports or bridges, or infrastructure extending over large areas, such as road networks, railway lines or pipelines, the intensification of extreme weather events (e.g. heat waves, droughts, storms, floods) is putting at risk both their **structural health** and in some cases the **continuity of operations**.

In this context, building **resilient infrastructure** is a necessity but is challenging. It requires in particular that the surrounding environmental conditions and their evolution in the long-term are known and taken into account since the early phases of infrastructure planning. In this domain, EO brings a significant added-value to infrastructure planners and managers. In particular, it provides long time series of observation data that **help model the evolution of climate conditions** (e.g. average temperatures, water level) and to quantify the **exposure to natural threats** of the various sites.

Thus, EO can help managers to optimise the planning and definition of **maintenance operations** for existing infrastructure. For new projects, EO can support **site selection** and contribute to informed decisions with regard to the **design of resilient constructions**.

InSAR-based ground deformation monitoring is becoming increasingly popular in the infrastructure sector

Among the multiple risks infrastructure is exposed to, **ground deformation** is certainly considered by infrastructure managers as a major threat since it can cause severe damage to buildings.

Several in situ means already exist to measure ground deformations but the technique known as Interferometric Synthetic Aperture Radar **(InSAR)** is becoming increasingly used in the infrastructure sector. Thanks to its capacity to detect **millimetric ground deformations** from space over large areas, to observe seasonal ground deformations and to identify deformation trends (e.g. subsidence) over time, InSAR supports the various phases of the infrastructure life cycle.

During the infrastructure **planning phase**, InSAR helps characterise potential sites through the provision of **ground deformation risk mapping**. During **construction operations**, InSAR enables large-scale monitoring of the surroundings and the detection of ground deformations that would be caused by the construction works (e.g. in case of tunnelling activities). Concerning post-construction monitoring, the global nature of InSAR makes it particularly well fitted to the **monitoring of linear infrastructure** such as rail and road networks, electric lines or pipelines. The size of these types of infrastructure generally makes their monitoring costly and challenging when done with in situ means. InSAR enables the **optimisation of maintenance operations** by identifying zones at risk that need to be monitored with additional on-site equipment.

GNSS and EO help optimise construction operations and monitor their impact on the environment

Increased integration of GNSS with other technologies enables automation, enhanced safety, and sustainability

In construction, **ensuring the safety of personnel and third parties** while **enhancing efficiency and precision** is paramount. One valuable tool for achieving these goals is **GNSS technology**, which is seamlessly integrated into construction equipment and systems, including **machine control and Building Information Modelling (BIM)**. This integration enables greater automation of construction processes, such as grading, excavation, and site preparation, resulting in improved efficiency and accuracy.

GNSS information also allows site managers and operators to **monitor equipment location, movement and performance**, facilitating the optimisation of workflows and enhancing security.

By defining designated areas, the risk of accidents can be reduced, further bolstering site safety. Moreover, optimising construction processes not only streamlines operations but also minimises fuel consumption and emissions, thereby mitigating the environmental impact associated with construction activities. In essence, the incorporation of **GNSS** in construction practices **contributes to safer, more efficient and environmentally conscious construction processes**.

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Sources of key EO and GNSS user requirements

The key EO and GNSS user requirements for the different application groups within the **infrastructure** segment are, at EU level, collected using a harmonised procedure.

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 Infrastructure. User requirements for EO services and products – as well as their evolution – are now also collected through the UCP. The process covers the EO user needs and requirements of commercial users based on inputs from industry experts and user groups, mirroring the existing process implemented for GNSS.

Moreover, the collection of specific requirements for Copernicus services and products is supported by 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; and (iii) regular and structured exchanges among representatives of the Copernicus governance structure and Member States through the Copernicus User Forum.

EO offers a cost-effective solution to monitor the impact of large construction works on their environment

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The **permanent transformation of large** cities involves **construction works taking place over large and densely populated urban areas**. The "Grand Paris Express", a public transport infrastructure project which foresees the construction of four new automated metro lines and the extension of two existing ones in the Paris suburban area, along with "Westconnex", a 33 km motorway tunnelling project in Sydney's urban area, perfectly illustrate the modernisation of urban areas and the challenges it poses.

Both for economic and political reasons, the implementation of such projects must not be detrimental to the well-being of the people living in the concerned areas. Yet, because of the dense urban environment, these projects often require **underground construction activities** which may cause damage to buildings located in their vicinity due to the **ground deformations** they may induce.

It is therefore extremely important for local authorities, infrastructure managers and construction companies to **monitor the impact on the environment** of construction activities. However, when taking place over large areas and implemented with in situ inspections and conventional means, such a **monitoring is very resource-consuming**. With InSAR-based ground deformation monitoring, **EO provides** the abovementioned stakeholders with **a large-scale and cost-effective solution** enabling them to achieve their objectives while optimising the use of conventional means.

In the longer term, public authorities and infrastructure managers need to better understand the impact of new infrastructure on their environment. Beyond the construction phase, EO can also support the identification and monitoring of the **environmental and socio-economic impacts** of large infrastructure (e.g. public transport, stadiums, large commercial areas, airports and harbours) on their environment. Indeed, when combined with other data in geographic information systems, satellite-based observations can contribute to the assessment of indicators, such as population evolution patterns, degradation of green areas, evolution of the built environment and intensity of economic activities, which can help the various actors to better understand these impacts.

Infrastructure GNSS Value Chain[1]

GNSS

AUGMENTATION SERVICE PROVIDERS

- HEMISPHERE (ATLAS)
- HEXAGON (LEICA GEOSYSTEMS, NOVATEL)*
- SAPCORDA*
- SPACEOPAL*
- SWIFT
- TERIA*
- TOPCON
- TRIMBLE

- NATIONAL AND REGIONAL RTK NETWORK PROVIDERS

COMPONENT MANUFACTURERS

Construction
- BEIJING BDSTAR NAVIGATION
- FURUNO
- HEXAGON*
- SEPTENTRIO*
- STMICROELECTRONICS*
- TAI-SAW TECHNOLOGY
- TRIMBLE NAVIGATION
- U-BLOX*
- YAGEO CORPORATION

Timing & Synchronisation
- COMNAV TECHNOLOGY
- FURUNO
- MICROCHIP TECHNOLOGY
- NIHON DENGYO KOSAKU
- QORVO
- SCHNEIDER ELECTRIC*
- SEIKO EPSON
- SEPTENTRIO*
- STMICROELECTRONICS*

RECEIVER MANUFACTURERS

Construction
- BEIJING UNISTRONG SCIENCE & TECHNOLOGY
- HEXAGON*
- KONGSBERG MARITIME*
- TOPCON CORPORATION
- TRIMBLE NAVIGATION

Timing & Synchronisation
- CAMPBELL SCIENTIFIC
- CHRONOS TECHNOLOGY*
- ELPROMA*
- GORGY TIMING*
- HEXAGON*
- HOPF ELEKTRONIK*
- MEINBERG*
- MICROCHIP
- OMICRON*
- OSCILLOQUARTZ*
- SAFRAN TRUSTED 4D*
- SEIKO
- SEPTENTRIO*
- STMICROELECTRONICS*
- TIMELINK*
- U-BLOX*

SYSTEM INTEGRATORS DESIGN CONSULTANCIES TESTING & MAINTENANCE

Construction
- AB VOLVO*
- CATERPILLAR
- CNH INDUSTRIAL*
- DEERE
- HEXAGON*
- J.C.B. SERVICE*
- KOMATSU
- KONGSBERG SATELLITE SERVICES*

Timing & Synchronisation
- ABB*
- ACCENTURE
- CHRONOS TECHNOLOGY*
- EATON*
- ERICSSON*
- HUAWEI
- JUNIPER
- KERLINK*
- NOKIA*
- SICE*
- ZTE

USERS

- CONSTRUCTION COMPANIES
- ENGINEERS
- PIPELINE OPERATORS
- REGULATING AUTHORITIES
- TELECOM OPERATORS

European[2] GNSS industry in the global arena

As evident from the value chain, the use of GNSS for infrastructure can be split in two different use cases. On the one hand, there are receivers related to **construction applications**, and on the other hand, **receivers for the timing and synchronisation** of telecommunications networks. As far as construction is concerned, some of the leading companies in Europe are Hexagon and Kongsberg Maritime.

Regarding timing and synchronisation, notable European receiver manufacturers include STMicroelectronics, Safran Trusted 4D, U-Blox, Oscilloquartz and Meinberg.

LEGEND

- Commercial offering
- Public offering / entities
- 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.

Please refer to page 23 for a comprehensive description of the GNSS value chain and how to interpret them at segment level.
* 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]

EARTH OBSERVATION	DATA PROVIDERS	INFRASTRUCTURE PROVIDERS	PLATFORM PROVIDERS	EO PRODUCTS AND SERVICE PROVIDERS	INFORMATION PROVIDERS	END USERS
Commercial offering	• 21AT • AIRBUS* • AXELSPACE • BLACKSKY • CAPELLA SPACE • CGSTL • EARTHDAILY • E-GEOS* • GEOCENTO* • GEOIMAGE • ICEYE* • MAXAR • ORBITA AEROSPACE • PLANET • SATELLOGIC • UMBRA	• AWS • CLOUDFERRO* • GOOGLE CLOUD PLATFORM • IBM CLOUD • MICROSOFT AZURE • T-SYSTEMS*	• CLOUDEO* • CREODIAS* • EARTH-I* • EURODATACUBE* • EXOLABS* • NORTH.IO* • OPEN DATA CUBE • PICTERRA* • SENTINEL HUB* (SINERGISE)	• 3DEO* • C-CORE • CLS* • DETEKTIA* • E-GEOS* • EXOLABS* • GEO4I* • GAF* • GEOFEM* • GEOVILLE* • HYDROSAT • INSAR.SK* • KSAT* • ORBITAL EYE* • PIXSTART* • PLANETEK* • SATSURE • SKYGEO • SPACESUR • SPOTLITE* • TERRASIGNA* • TRE ALTAMIRA* • VITO*	• 4 EARTH INTELLIGENCE • AVINEON* • BUILDING RADAR* • DARES TECHNOLOGY* • DEWBERRY • DHI* • FUGRO* • GEOCONCEPT* • LIVEEO* • RINA* • SENSAR* • SIXENSE* • SUPERVISION* • TESSELO* • TRIMBLE	
Public offering / entities	• ALOS-2 (JAXA) • COPERNICUS SENTINELS* • COSMO-SKYMED (ASI)* • LANDSAT (USCG) • RADARSAT (CSA) • RELEVANT IN-SITU NETWORKS • OTHER RELEVANT EUROPEAN NATIONAL MISSIONS	• FEDERATED INFRASTRUCTURE (E.G. GAIA-X)* • COPERNICUS COLLABORATIVE GROUND SEGMENT*	• COPERNICUS DATA SPACE ECOSYSTEM* • WEKEO*	• COPERNICUS ATMOSPHERE MONITORING SERVICE (CAMS)* • COPERNICUS CLIMATE CHANGE SERVICE (C3S)* • COPERNICUS EUROPEAN GROUND MONITORING SERVICE (EGMS)* • COPERNICUS LAND MONITORING SERVICE (CLMS)*		
User segments						• CONSTRUCTION COMPANIES • FINANCIAL INSTITUTIONS • INFRASTRUCTURE MANAGERS • INTERNATIONAL DEVELOPMENT ORGANISATIONS • LOCAL, REGIONAL & NATIONAL AUTHORITIES • PUBLIC WORKS COMPANIES • PIPELINE OPERATORS • OIL & GAS PRODUCERS • UTILITY COMPANIES

European[2] EO industry in the global arena

The market remains dominated by North American companies, with almost half of market shares, thanks to their strong position in the data acquisition & dissemination market and in the data processing market. Thanks to leading companies such as Airbus, Leonardo (e-GEOS) and Fugro, Europe ranks second and is almost on a par with its North American counterparts. With seven companies among the top ten, Europe even ranks first in the market for analysis, insights & decision support.

LEGEND

- Commercial offering
- Public offering / entities
- User segments

NOTES

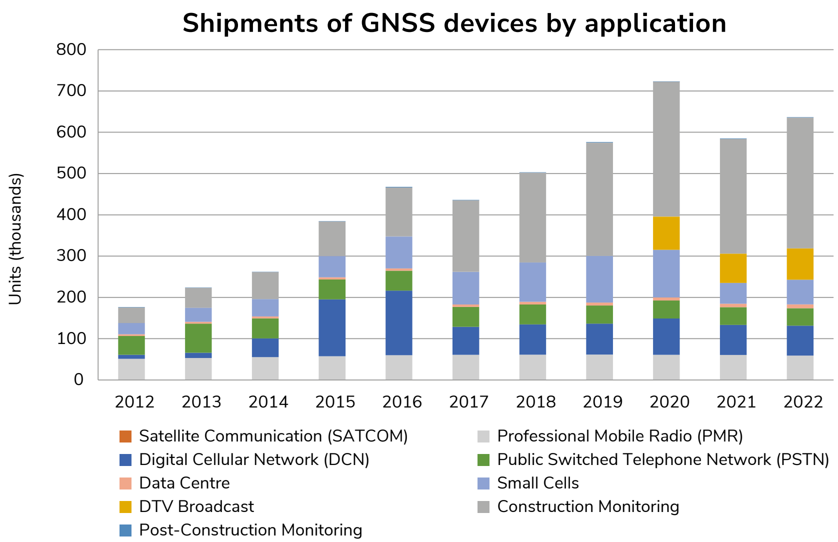
[1] The value chain considers the key global and European companies involved in EO downstream activities. Please note that enterprises listed in the data providers step of the value chain often provide platforms as a service. For the sake of simplicity the data providers are not repeated in other stages of the value chain in which they are active.

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

Please refer to page 13 for a comprehensive description of the EO value chain and how to interpret them at segment level.

* 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 positioning and timing power robust solutions in the infrastructure sector



Modern infrastructure drives the demand for high-end GNSS solutions

Over the past decade, the deployment of 4G and 5G communication networks has led to the **stable growth of T&S GNSS receivers**. Their annual shipments have mainly been pushed by the upgrades to the Digital Cellular Network as well as the deployment of small cells.

Annual shipments of around 50 000 **PMRs** confirm the **stability of the marke**t; shipments mainly serve to replace outgoing products. In 2012, Europe, North America and Asia-Pacific had a roughly equal share of 25% of the global market. The **geographical balance had shifted** by 2022 with Asia-Pacific leading the market with roughly 40%, while North America fell to nearly 20% and the EU27 tying with Africa and the Middle East (almost 15% each).

As shown in the graph, the overall drop in annual shipments in 2017 and subsequently in 2021 was due to a decline in the sales of timing receivers for the Digital Cellular Network (DCN) and Small Cells applications. The **rapid growth of DCN prior to 2017** led to a satisfactory installed base of DCN which was then followed by **years of moderate growth in anticipation of the 5G roll-out**. The 2021 drop in Small Cells shipments is a consequence of the COVID-19 pandemic that slowed down the deployment of Small Cells.

Shipments of GNSS-based solutions (e.g. integrated in heavy machinery for machine guidance) in particular for **construction monitoring** (and on a much smaller scale for post-construction monitoring) continue their **strong growth**.

GNSS enables the 3D machine guidance system

In the construction industry, the effective operation of heavy machinery relies on RTK positioning solutions to achieve pinpoint accuracy. However, maintaining precision and ensuring the availability of position data, especially in challenging terrains, requires the integration of diverse technologies and data sources.

GNSS receivers serve as the foundation for precise positioning, harnessing satellite signals to determine the exact location of machinery. **Multi-constellation** receivers further elevate accuracy, providing redundancy and enhancing performance, especially in environments where signal reception may be compromised.

For improved precision, complementing base stations serve as **reference points** for the GNSS signals. The introduction of Galileo High Accuracy Service (HAS) has the potential to further innovate the construction industry in that regard, providing high-precision positioning without the need for extensive RTK networks.

Further, **inertial measurement** systems are utilised to accurately measure and track the movements of heavy machinery. This enhances the precision of positioning and supports safe operation.

Machine control systems are harnessed to automate machine operation based on GNSS data, bolstering precision, and increasing **efficiency** of construction projects.

Additionally, **visualisation** solutions offer real-time guidance and feedback to operators, ensuring that they can navigate the machinery precisely.

The **seamless integration** of these technologies and data sources into construction processes is fundamental to achieving the precision and efficiency required for heavy machinery operations.

Modern industrial systems rely heavily on timing and synchronisation for their data

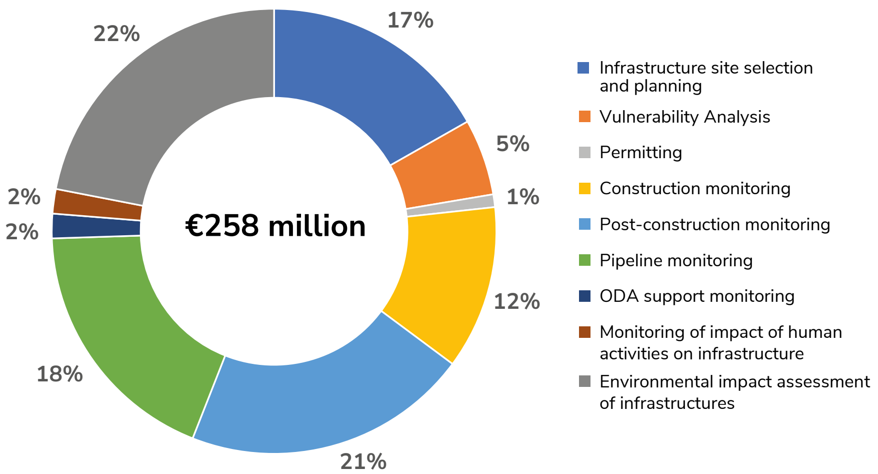
Today's production systems increasingly rely on data from machines, processes and other sources. As the amount and resolution of these various data streams continually increase, the **benefits of complex models such as Machine Learning algorithms** can be properly trained and re-applied to improve and optimise the production process.

This increasing **complexity automatically leads to higher and more stringent timing and synchronisation needs**, which can be offered by the newest generations of timing receivers. To ensure the smooth operation of different communication requirements needed for different operations such as motion control, programmable logic control or predictive maintenance, implementing and applying **IEEE Time Sensitive Network (TSN) standards** is the current trend in the industrial automation market.

On top of this, the market for **industrial Internet of Things (IoT)** devices is booming, and with it the reporting data that these devices provide. At the moment, these data often lack the proper **synchronisation with the same time source**. This gap is highlighted as one of the many IoT challenges that the market currently faces. The adjustment of the internal clock in order to align it with the clocks of other devices within a larger network, particularly for low-power IoT, can be solved by relying on the latest GNSS technology.

EO-based construction progress monitoring and ground deformation monitoring are on the rise

Revenue from EO data & services sales by application 2023



EO is increasingly used for the monitoring of large infrastructure

The use of **EO-based services** has not yet generalised in the infrastructure market but **is becoming common for the monitoring of large construction works and the management of widespread infrastructure** such as electric lines, road and railway networks or pipelines.

EO has many assets for the infrastructure sector: it **provides historical data** to assess exposure to natural risks, it makes it possible to **establish projections linked to the future impacts of climate change** and it provides frequently updated optical and radar images to **track construction progress and monitor threats** to building structures. These key assets support the progressive penetration of EO in the various infrastructure management activities, at all stages of the infrastructure life cycle.

In 2022, **the total revenue** generated by the sales of EO data and EO-based services to the infrastructure sector **represented more than €250 million**, with more than 75% of this revenue being generated by service sales.

In terms of applications, more than a half of this revenue can be attributed to the **monitoring of construction activities** and to the **monitoring of existing infrastructure for maintenance purposes**. The predominance of these application domains can largely be explained by the possibilities offered by EO-based services to monitor large areas while minimising the need for on-site equipment and inspection teams. The other main domains of application are the assessment of the environmental impact of infrastructure and the selection of construction sites (with around 20% of revenues each).

EO improves construction progress monitoring while optimising costs

Unlike construction companies, which by definition have visibility on the progress of the work they are carrying out, infrastructure owners and financing institutions cannot ensure a **physical presence** on-site during the entire construction phase. Nevertheless, to make sound decisions they need to receive regular, unbiased and error-free information about construction progress.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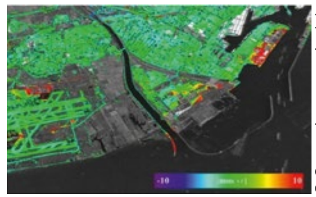
Thanks to the availability of **very high resolution** and frequently updated satellite images, EO brings new solutions in response to this need. Indeed, the comparison of **successive satellite images** of a construction site enables to remotely **track progress** through the monitoring of indicators such as the set-up or removal of cranes, the presence of construction materials, waste materials or trucks, and through the detection of new buildings. This can help **optimise onsite inspections** and **reduce inspection costs** while **improving worker safety**.

Satellite-based construction progress monitoring is most particularly relevant to large construction sites (e.g. gigafactories, airports) or construction works on multi-sites (e.g. construction of new metro lines and stations) likely to involve a large number of actors, as well as construction activities taking place in remote locations.

Copernicus EGMS supports the assessment of ground motion affecting infrastructure

Based on Sentinel-1 images, the Copernicus **European Ground Motion Service** (EGMS) is available free of charge since May 2022 and provides users with ground motion data for all the Copernicus Participating States plus the UK. The first baseline product, which covers the period 2015-2021, will be updated annually and will include a five-year rolling archive.

Infrastructure is one of the targeted market sectors for EGMS, which enables the extraction of **ground motion velocity** values and **time series of deformation** for reliable measurement points. The various products delivered by the service can be used as a starting point for the investigation of ground motion affecting built assets (e.g. buildings, dams, bridges, airports) and linear infrastructure (e.g. railways, highways, pipelines), and can serve as a basis for a **systematic large-scale monitoring**.

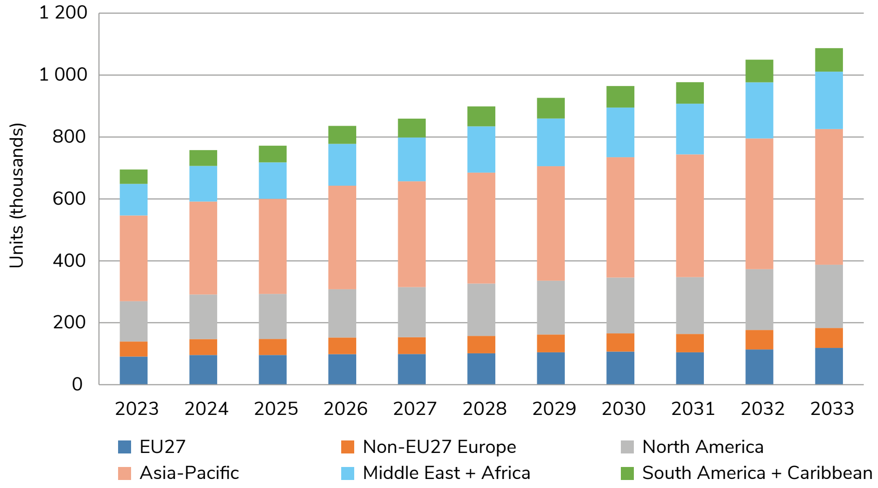

© Copernicus – sentinel data

Prior to construction activities, EGMS enables **ground stability to be assessed** (e.g. to support the identification of areas needing consolidation). During construction operations, it contributes to the analysis of the impact of construction works on their immediate environment (e.g. to detect if a ground deformation coincides with the start of tunnelling activities). Once construction is completed, the service helps identify whether ground subsidence threatens infrastructure **structural health** in the long term. Moreover, the availability of continuous time series enables to better understand trends in ground deformations, seasonal effects, and local discontinuities.

EGMS data are accessible via the EGMS Explorer at https://egms.land.copernicus.eu

Advanced data integration and applications contribute to further growth of the GNSS market

Shipments of GNSS devices by region



Asia Pacific, EU27 and North America pushing GNSS adoption

While **Asia-Pacific continues to dominate** the infrastructure GNSS market (40%), Europe and North America are expected to maintain around 10% and 20% of the market, respectively, over the next 10 years. With roughly 15% in 2022, the Africa and Middle East region is expected to see the largest growth and secure almost 20% of the market by 2033.

Focusing specifically on the **market for T&S receivers, the annual shipments are expected to see a steady annual growth** of 5%, bringing the total shipments from 260 000 units in 2023 to more than 430 000 units in 2033. These shipments will largely be dominated by small cells and DCN, in line with the ongoing deployment of 5G networks as well as the preparation for the next evolution of our communications network (see the box below on 6G). Over time, it is expected that the market for dedicated satcom will disappear, in line with the latest smartphones being connected to satellite networks (annual shipments going from 500 to 340 units). The application seeing the **largest growth** in terms of annual shipments is forecast to be **data centres**, which are expected to more than double sales figures from 9 000 in 2023 to 23 000 by 2033. This trend is further explained on the 'Key Trends' page at the beginning of this segment.

On the **geomatics side**, shipments of **devices for construction monitoring will grow annually** by 10% for the next three years before slowing down in the following years, with around 355 000 units shipped in 2023 rising to 580 000 units in 2033.

Although projections on GNSS device shipments are higher than in the previous market report, the projections for associated revenues have been slightly revised downwards due to evolutions of the average price of receivers and the extension of their lifetime.

LEO satellites are transforming GNSS precision

GNSS constellations are composed of L-Band satellites orbiting the Earth, primarily in Medium Earth Orbit (MEO) and Geosynchronous Earth Orbit (GEO). These constellations provide crucial positioning and navigation data for a wide range of applications. A significant challenge in GNSS positioning is **convergence time** when comparing Precise Point Positioning (PPP) to Real-Time Kinematic (RTK). PPP typically requires a longer convergence time to achieve high-precision positioning due to the need for precise atmospheric corrections. PPP-RTK further improves performance and reduces convergence time for PPP by using corrections from a ground reference network. However, an even more rapid convergence time is desired for some applications.

One promising development addressing this limitation is the incorporation of Low Earth Orbit (LEO) satellites into the GNSS constellations which has the potential to **eliminate the dependency on precise atmospheric corrections for PPP-RTK users**. This breakthrough could significantly expedite the time required to achieve accurate positioning. Moreover, the integration of LEO satellites into Positioning, Navigation, and Timing (PNT) solutions will open doors to rapid two-way **authentication** checks, enhancing security in various applications.

In addition, having a substantial number of LEO satellites **increases signal availability**. A larger constellation of satellites can potentially reduce Geometric Dilution of Precision (GDOP) and improve Position Dilution of Precision (PDOP), ultimately leading to more accurate and reliable positioning data.

In the context of infrastructure-related applications, high-precision positioning achieved through the integration of LEO satellite data can further enhance the efficiency and accuracy of construction operations and maintenance activities.

The deployment of future mobile telecom networks should open up new perspectives for GNSS-based Timing & Synchronisation

In 2022, **Non-Terrestrial Networks (NTN)** were listed as part of the 3GPP Release 17 (Rel-17) projects with the aim of defining the future of 6G. Following the approval of normative activities on NTN in the Rel-17, the topic attracted increasing interest from industry. Through NTN, 6G networks will contribute to greater **enhanced communication** for end users (both human and machines) and provide a **ubiquitous network coverage** across regions and areas that are currently receiving limited 5G coverage.

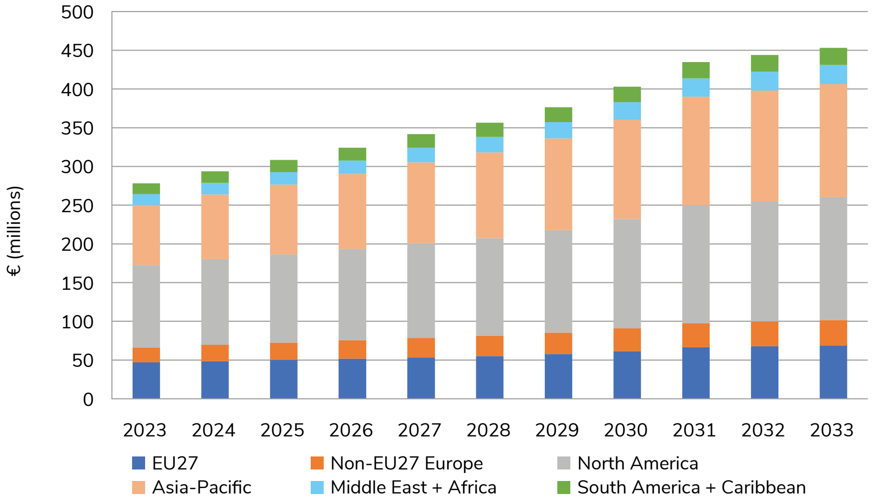
In a nutshell, NTN has become an umbrella term for any network that involves **non-terrestrial flying objects**, including satellite communication networks, high-altitude platform systems (HAPS) and air-to-ground networks. Today, a communication device will either be connected to the 3GPP terrestrial network (e.g. smartphones), or to satellites (e.g. satellite phones). With NTNs, all these communication devices will be connected to both terrestrial and satellite networks in the grander 3GPP ecosystem.

The timing and synchronisation of these networks, which can be provided by GNSS timing receivers, has already been identified to be a **crucial aspect of the roll-out of NTNs** as timing relationships, the uplink time and frequency synchronisation demand stringent performances.

More information on Rel-17 is available at:
https://www.3gpp.org/specifications-technologies/releases/release-17

Benefiting from state-of-the-art data computing technologies, EO-based solutions are expected to become increasingly popular with infrastructure stakeholders

Revenue from EO data & services sales by region



Behind a global revenue increase, regional disparities should persist

In the infrastructure sector, the **total revenues** generated by the sales of EO data and EO-based services **are expected to increase** at a regular pace in the years to come.

However, significant regional disparities exist. **North America has a dominant position**, closely **followed by** the **Asia-Pacific** region. These two regions alone account for two-thirds of global revenues. With its third position, the European Union represents a share similar to the cumulative share of all the remaining regions, namely non-EU Europe, Latin America, Africa and the Middle East.

By 2033, the ranking of the different regions should remain unchanged despite some evolutions in their respective shares. Thus, the share of the **Asia-Pacific** region is **expected to increase slightly** while that of North America and the European Union is expected to decrease slightly.

Although the capacity to develop and commercialise EO-based services 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 **dominant regions** are also the ones that happen to **have the most dynamic upstream sector**.

The role played by the European Union in the provision of EO-based data and services relevant to the infrastructure sector (e.g. Sentinel 1 data and the European Ground Motion Service delivered as part of the **Copernicus** Land Monitoring Service) is not fully reflected when looking only at revenues. Indeed, the corresponding **data and products are** made available **free-of-charge** to users by the Copernicus programme **and** are therefore **not accounted for in data and service sales**.

International and EU initiatives to monitor the pollution caused by methane transport infrastructure might boost the use of EO

Cutting **methane emissions**, which are responsible for about 30% of global warming, is part of the fastest way to slow the rise of temperature and to fight against climate change. In this perspective, the EU established its Methane Strategy in 2020 and launched, jointly with the US, the Global Methane Pledge (GMP) at the occasion of the COP26 in 2021.

Since then, the Council of the EU and the European Parliament worked on a regulation which will put **new obligations** on the actors of the energy sector.

In particular, **operators** will **have to detect** (and repair) **methane leaks** at set intervals, not only on production sites but also in the **gas transport infrastructure** (e.g. pipelines). So far, methane leaks were generally monitored through on-site inspections and hand-held sensors. The generalisation of leak detection over large (and sometimes remote) areas on a regular basis will be **very costly** and **resource-consuming** if performed by ground crews.

Due to its very specific spectral signature, methane can be detected from space and several public and private satellite missions exist (or will be launched soon) which have the capacity to monitor methane concentrations in the atmosphere. In this context, the new **EU regulation might** well **boost** the development of **operational satellite-based rapid methane leak detection services** for gas transport infrastructure.

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Artificial Intelligence and Machine Learning are expected to support the adoption of EO-based applications in the infrastructure sector

During the past few years, the improvement of spatial resolution and update frequency of satellite-based observation data and the multiplication of EO satellite missions and constellations have resulted into a **massive increase in the volume of data** available to service providers and users.

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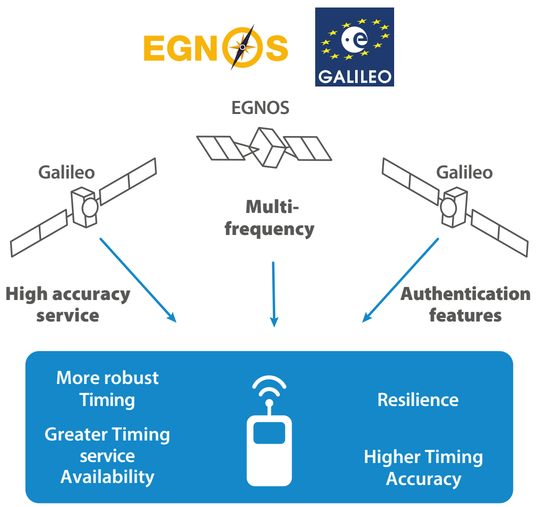
Thanks to their capacity to enable high-performance data processing and the fusion of data coming from multiple sources (e.g. various types of optical and radar data, GNSS, seismometers), **Artificial Intelligence** (AI) and **Machine Learning** (ML) are expected to become essential for the exploitation of the huge amount of available data.

In the domain of infrastructure, AI and ML enable the **automation of processes** such as change detection based on pattern recognition and object characterisation, which are key to infrastructure management and to the monitoring and understanding of phenomena threatening infrastructure (e.g. ground motion, vegetation encroachments). They should also help **improve the quality** of the information delivered to users, for instance, through smart filtering of measurement points that would not meet certain reliability thresholds.

The EU Space Programme provides invaluable benefits for infrastructure



Current usage of Galileo

Across the majority of telecom applications, the outcome of the UCP discussions and other user consultations has shown that **Galileo-enabled receivers are widely in use**. With **Galileo OSNMA**, communication networks, as well as other critical infrastructure, are enjoying the **additional layer of trust** that is provided. Network synchronisation thereby becomes more robust against certain level of spoofing attacks that otherwise have the potential to disrupt services.

Galileo contributes to selection and planning phases of infrastructure construction, in particular. Here, GNSS-RTK (Real-Time Kinematic) solutions offer high precision and are the preferred solution, providing significant cost savings through reduced field expenses. Construction phases benefit from receivers built into heavy machinery, enabling precise operations.

In **Europe, the majority of RTK providers have already upgraded or have started to upgrade to Galileo**.

EGNSS services and features to be explored

Studies and research are ongoing to identify use cases for authenticated SBAS as a complement to **Galileo OSNMA** as an **additional layer of security and trustworthiness**. As with Galileo OSNMA, this service would be of great importance for critical infrastructure such as the telecommunication networks as well as for data centres. In the specific case of EGNOS, its added value in terms of time accuracy and stability is already known within the industry. Looking at the future, the provision of an independent time source (EGNOS Network Time) and its built-in integrity make it an ideal candidate to provide a certified Time service.

With **HAS**, Galileo is the **first constellation able to provide a high-accuracy PPP service globally**, directly through the Signal-in-Space (SiS).

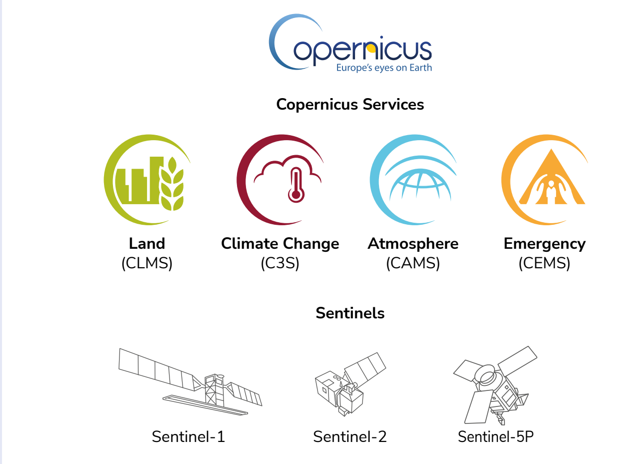
The provision of highly accurate measurements, necessary during the phases of infrastructure planning and construction, should be of interest to the sector.

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 **Sentinel imagery** offers 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. Thanks to the availability of **long time series**, it also offers possibilities of **change detection and evolution trend assessment** that can then be followed up with other High Resolution (HR) or Very High Resolution (VHR) imagery when necessary (tip-and-cue paradigm).

The diversity and amount of data and products offered by the Sentinels and the Copernicus services 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 **Copernicus Climate Change Service (C3S)** allows for the assessment of the impact of climate change on future constructions. On the longer-term, the **Copernicus Land Monitoring Service (CLMS)** and **Copernicus Atmosphere Monitoring Service (CAMS)** deliver information (e.g. land cover information, air quality information) that can **help to better identify the impacts of infrastructure** on their surroundings and on the environment. Delivered as part of CLMS, the **European Ground Motion Service (EGMS)** provides **millimetre-accuracy ground deformation maps** at European scale, updated on a yearly basis and with a five-year rolling archive, which **support the identification of the areas** where ground movements put infrastructure **at risk**. The **Early Warning & Monitoring component** of the **Copernicus Emergency Management Service (CEMS)** also **supports the protection of infrastructure** through the delivery of critical geospatial information for flood, fire and drought risk, at both European and global levels.



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

Several EU-funded projects investigate solutions to improve infrastructure resilience

Horizon Europe, a programme of the European Union

EOinTime - Satellite-based change detection and predictive monitoring of infrastructure grids based on high resolution data

EOinTime is an 18-month EU-funded project that intends to **scale up an EO monitoring service**, to help managers of large infrastructure networks to mitigate natural and anthropogenic risks and keep operations running smoothly.

EOinTime **integrates optical and radar satellite imagery with machine learning** algorithms **and** uses **AI-based change detection algorithms** that combine multiple time series data to assess data patterns and detect abnormalities.

The project's final goal is to enable timely identification of any potential threat to infrastructure networks, from rapid changes (e.g. extreme weather events) to quickly assess the location and extent of damage, to slow changes (e.g. ground deformations, vegetation encroachments) to facilitate the prediction of potential risks. Actionable insights are made available to users through mobile and web apps.

More information available at: https://cordis.europa.eu/project/id/190100375/en

Horizon Europe, a programme of the European Union

BUILDSPACE

BUILDSPACE - Enabling Innovative Space-driven Services for Energy-Efficient Buildings and Climate Resilient Cities

BUILDSPACE is a three-year EU-funded project that aims to **procure innovative services for the building and urban stakeholders** and to **support informed decision-making towards energy-efficient buildings and climate-resilient cities**.

Tested in three European cities, the project will **combine terrestrial data** (from IoT platforms and BIM solutions), **aerial imagery from drones and data from satellite services** (Copernicus, EGNSS), to enable the identification of hotspots with increased pressure on local city ecosystems and higher probability for natural disasters (e.g. flooding), with the objective of issuing alerts and recommendations for action to local governments and regions (e.g. support of policies for building renovation in vulnerable areas).

BUILDSPACE will create a set of replication guidelines and blueprints for the adoption of the proposed applications in building resilient cities at large.

More information available at: https://www.euspa.europa.eu/enabling-innovative-space-driven-services-energy-efficient-buildings-and-climate-resilient-cities

Horizon Europe, a programme of the European Union

STARLITE - Preparation Of Standards For Galileo Timing Receivers

STARLITE is a two-year project funded by the European Commission and benefiting from a technical support from the EU Agency for the Space Programme (EUSPA) and from the European Commission's Joint Research Centre (JRC). The project aims to **initiate the standardisation process for Timing Receivers**, with particular emphasis on exploiting the capabilities offered by the **Galileo Timing Service**.

The target users for the standard are all Galileo Timing users, with special focus on critical infrastructure and critical applications within Telecommunications, Finance and Energy Sectors. It is expected that the standard takes into account the specificities of the Galileo Timing and of the various service monitoring levels it supports.

More information available at: https://ted.europa.eu/udl?uri=TED:NOTICE:059407-2022:TEXT:EN:HTML

Horizon Europe, a programme of the European Union

CHRISS

CHRISS - Critical infrastructure High accuracy and Robustness increase Integrated Synchronisation Solutions

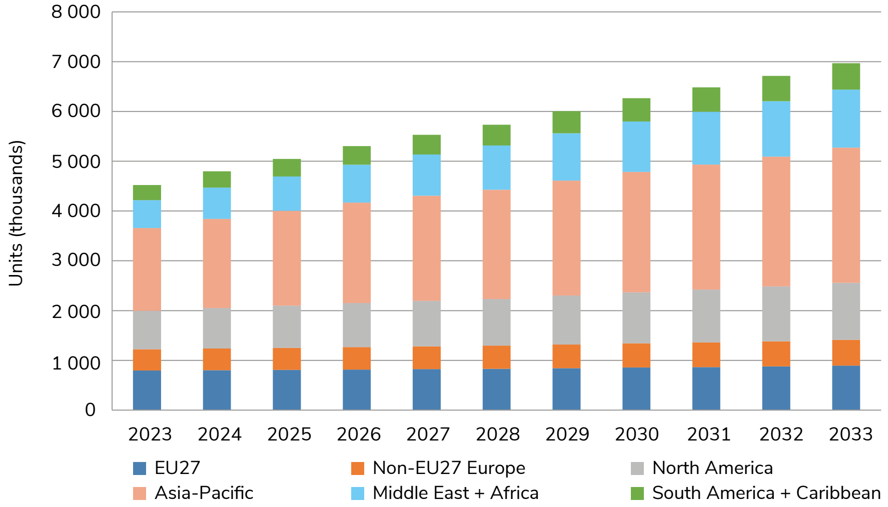
CHRISS is a three-year EU-funded project which **develops approaches for detecting and mitigating radio interferences, jamming and spoofing attacks** for the security of **telecommunication networks**.

The project combines **robust interference detection** and mitigation algorithms, with **spoofing detection** and **user notification** methods. **Galileo OSNMA will ensure the authenticity of GNSS data**, and Galileo-based timing and synchronisation, together with blockchain-based built-in security mechanism, will increase resilience to GNSS signals interference, jamming, spoofing and cyberattacks on the fibre-optics distribution layer.

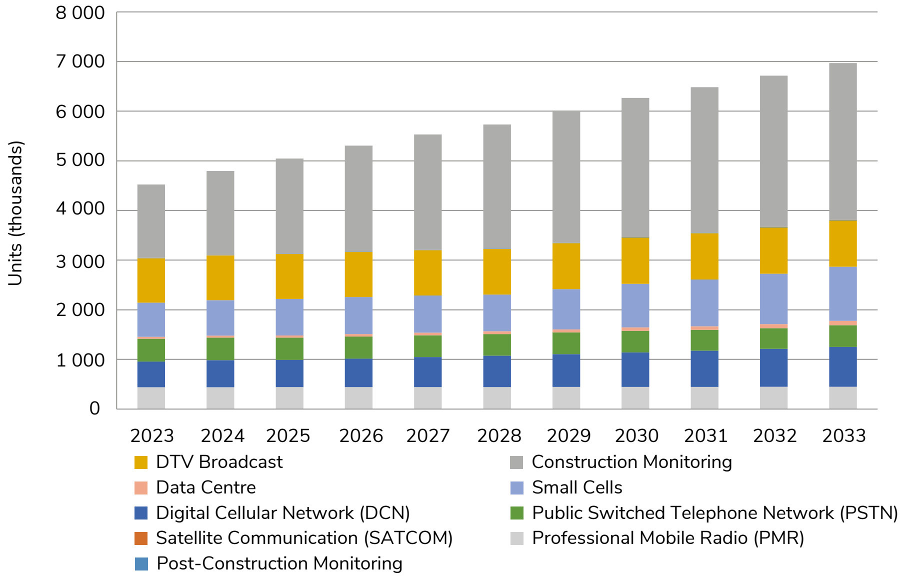
CHRISS will demonstrate a solution integrated into one device and resulting in increased time distribution service availability, accuracy and reliability.

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

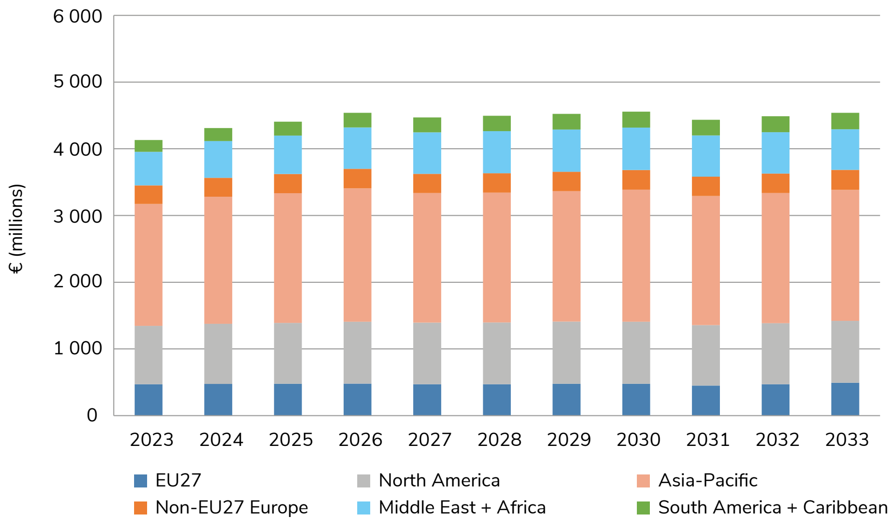
Installed base of GNSS devices by region



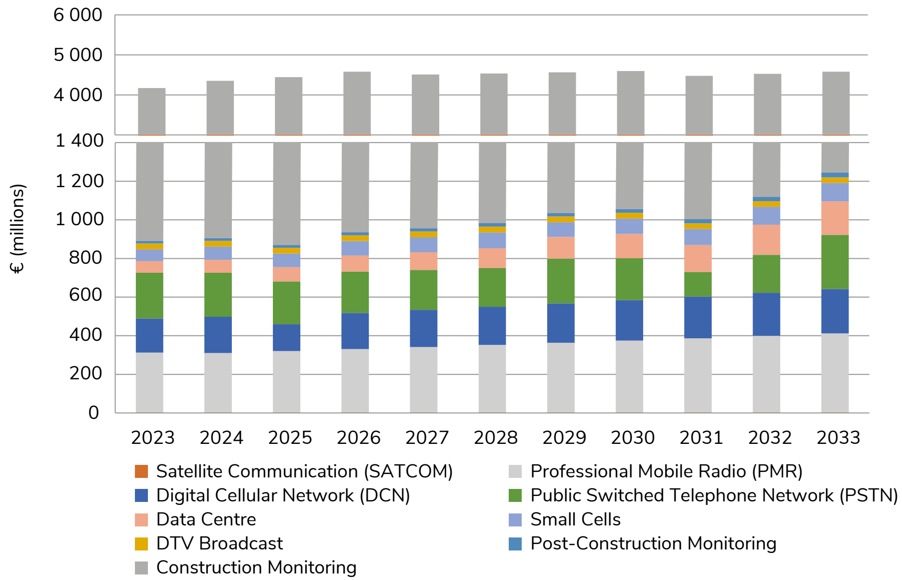
Installed base of GNSS devices by application



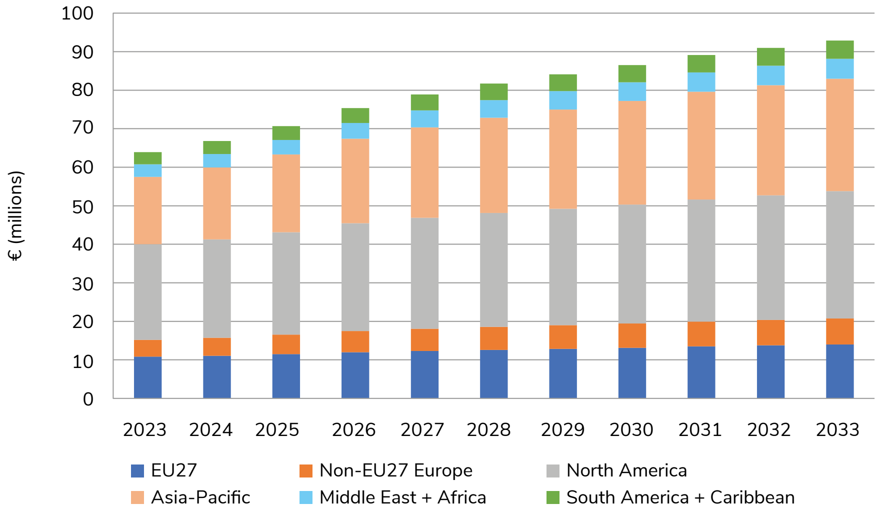
Revenue from GNSS device sales by region



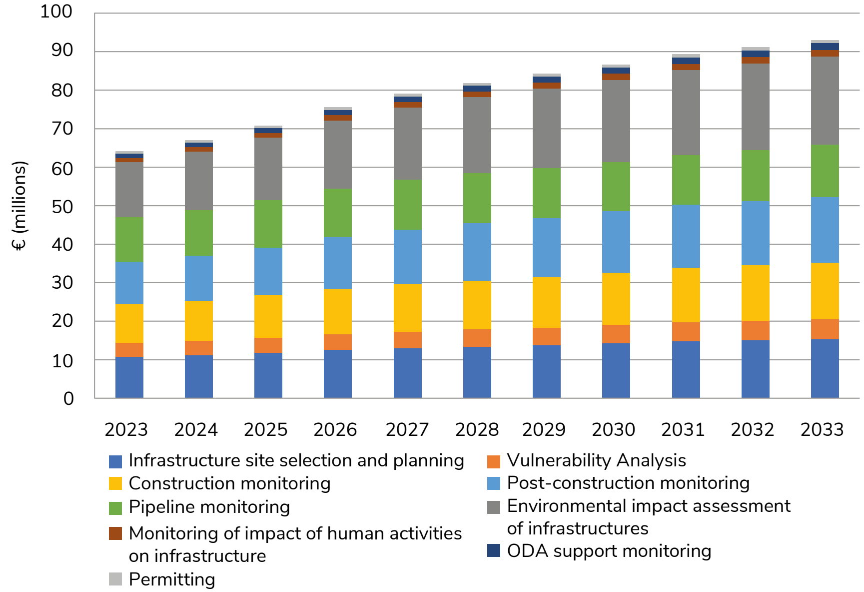
Revenue from GNSS device sales by application



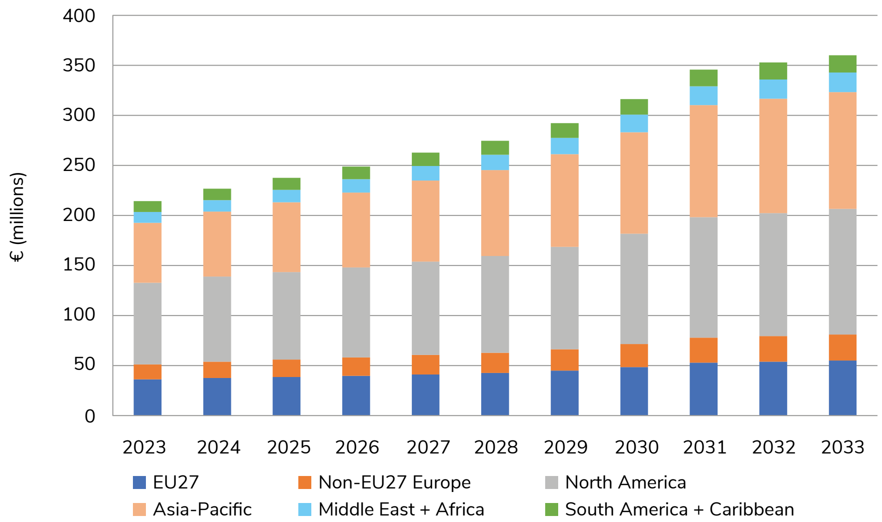
Revenue from EO data sales by region



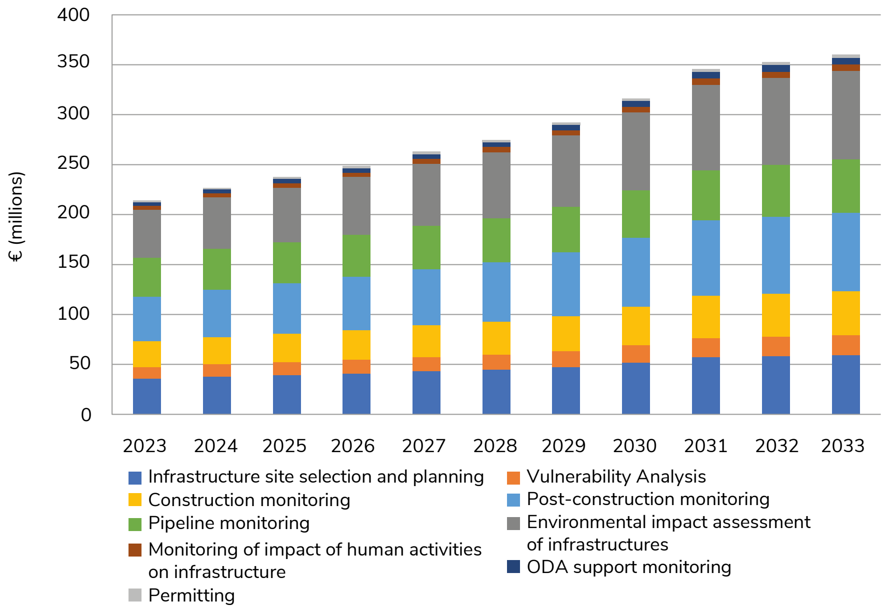
Revenue from EO data sales by application



Revenue from EO services sales by region



Revenue from EO services sales by application



INSURANCE AND FINANCE

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

Finance
- Commodities trading
- ESG Reporting
- 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 includes 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).

EO plays an important role in supporting insurance companies and financial institutions. In Insurance, EO is used to assess damage and claims management (Event Footprint), calculate indices for parametric products (Index Production) and support the prediction and severity of a weather event (Risk Modelling). In finance, EO data supports screening processes (i.e. risk assessments) undertaken by financial institutions for their investments. Additionally, it contributes to the monitoring of goods production and shipping at key locations. This provides investors/traders with information to predict supply and demand to develop their investment strategies.

Finally, EO can help to provide indicators supporting of sustainable investing considering environmental, social and governance factors to assess an investments financial returns and its overall impact (ESG reporting).

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.

Note: Topics mainly related to the **insurance** sub-segment are indicated with an **orange circle** , while the **finance** sub-segment topics are indicated with **blue circle** .

What you can read in this chapter

- **Key trends:** Space data is becoming an integral part of Insurance and Finance.
- **User perspective:** New Insurance and Finance policy and regulatory frameworks redefine users' needs.
- **Industry:** Insurance and finance value chains.
- **Recent developments:** Technological innovations pioneered by end-user's needs.
- **Future market evolution:** EO data & service sales for finance booming in the next decade.
- **European Systems and projects:** Copernicus and Galileo working together for more sustainable finance.
- **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.

Space data is becoming an integral part of insurance and finance

Key market trends

- Parametric Insurance: a growing trend increasing the potential for EO in hybrid insurance products combining Weather Indexes and Yield Index Insurances
- The rising role of EO in Commodity Trading and Risk Assessment in bringing more accurate forecasts
- The insurance world embracing machine learning and artificial intelligence to digitalise the sector and increase value for customers

Parametric Insurance: a growing trend increasing the potential for EO in hybrid insurance products

Index-based solutions have been steadily gaining momentum among prominent insurers and facilitate the creation of innovative and bespoke insurance policies. The combination of Weather Index Insurances (WII), leveraged by EO, with Yield Index Insurances (YII), creates **hybrid solutions bringing comprehensive coverage** to farmers. Consequently, these custom-built products with tailored requirements, enable insurers to provide support precisely when its needed most (during **natural disasters or extreme weather occurrences**).

A testament to its growing popularity is that in 2009, merely 3% of **total global agricultural insurance premiums catered to index-based crop and livestock insurance** products. However, in recent years, this figure has **surged to account for 12%** of the total global premiums. A key contributor to this advancement is EO, which furnishes both historical and near real-time data, thereby enhancing the technical quality of index insurance products.

These index-based solutions, which combine EO data with other data such as meteorological data or real-time data collected by loss adjusters in the field, **will further emerge**, involving more insurers and EO data providers to jointly search for solutions and address the needs of insured farmers. Their joint efforts will be directed towards crafting solutions that address the multifaceted needs of insured farmers. While this concept has deeply rooted itself in disaster management, its applicability is broadening. It now encompasses protection measures for businesses against challenges like infectious disease outbreaks, outages, emergent climate risks, and even non-damage disruptions to intangible assets.

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The rising role of EO in Commodity Trading and Risk Assessment

In the realm of commodity trading, satellite EO is becoming an increasingly important tool to furnish traders and investors with dependable and precise information before market fluctuations occur. By bringing an additional layer of information of production sites, goods transport, satellite EO data assist in the **forecasting annual yield estimations, crop prices, and projections on raw material and oil inventories**. Because of the introduction of new regulations, such as the **EU deforestation act**, there is more pressure on entities to meticulously monitor and trace the origins of various commodities like cattle, cocoa, coffee, palm-oil, soya and wood, as well as their by-products, including leather, chocolate, and furniture. EO stands as a pivotal resource in shedding light on the **sustainability impacts** of numerous globally traded commodities.

Service providers are already leveraging EO to aid companies in determining their **carbon footprint, curbing deforestation, and adhering to sustainability guidelines**. Example services include vegetation change alert systems, which illustrate one's journey toward zero deforestation, highlight high-risk areas, and assist in accurate reporting. EO data enables insurers and helps financial entities to perform more **precise risk assessments** and plan more informed, profitable and **sustainable trading strategies**.

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Synergising a myriad of technologies including machine learning and artificial intelligence

The insurance market is on the cusp of a transformative phase, aligning itself with the fourth industrial revolution by harnessing advanced analytical techniques such as **machine learning** and **artificial intelligence**. These sophisticated tools not only amplify big data processing but also pave the way for **heightened accuracy in estimations**, thereby delivering augmented value to customers. By synergising a myriad of technologies, including GNSS, Wi-Fi/Bluetooth, GSM, RF, connected sensors, and an underpinning cloud infrastructure, insurers are equipped to produce more offer (e.g., high precision forecasts supported by machine learning and based on EO data). This integrated approach facilitates a **continuous, data-driven situational awareness** by gleaning real-time and pinpointed information regarding loss exposure. Such a strategic move not only empowers insurers to carry out meticulous risk assessments, but also allows them to furnish customers with enhanced value through sustainable offers. It underscores the sector's commitment to fostering and marketing **environmentally-conscious insurance products** and fortifies their grasp on climate-associated risks.

New insurance and finance policy and regulatory frameworks redefine users' needs

Growing sustainability concerns in the financial world to push the use of EO

By establishing how financial market participants have to disclose sustainability information, recent contemporary **regulatory frameworks**, such as the Task Force on Climate-related Financial Disclosures (TCFD), the Taskforce on Nature Financial Related Disclosures (TNFD), Sustainable Finance Disclosure Regulation (SFDR), the EU Taxonomy for sustainable activities, EU Green Bond Standard, and the EU Action Plan on Sustainable Finance, are compelling financial institutions to precisely monitor and document ESG metrics. These frameworks drive companies to benchmark their **sustainability efforts and ethical commitments** in the context of its financial prosperity and overarching operations. With the growing requisites of investors and asset managers to access trustworthy sustainability data and risk management methodologies for producing ESG products,

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Earth Observation (EO) steps into the limelight. EO is pivotal in addressing fundamental shortcoming by offering:

- real impact measurements;
- ensuring transparency and impartiality;
- frequent update and access to consistent measures; and
- provide scientific standards.

The use of EO for **collecting sustainable finance data** and to close the data gap will be crucial for the implementation of data-driven, evidence-based policymaking in areas like micro-prudential supervision, financial stability, macroeconomic analysis, and risk and reserve management. EO, when paired with these emerging regulatory blueprints, promises a future where financial decisions are both sustainable and deeply rooted in verifiable evidence bringing unbiased calculated ESG scorings and allowing investors and consumers to have informed opinions about environmental performances.

The importance of space data for green finance and green bonds

The rising demand for green finance solutions highlights a shift towards loans or investments that champion environmentally-positive actions. These often encompass the acquisition of **eco-friendly goods and services** or the development of **green infrastructure**. Notably, **green bonds** dominate the landscape of **green financing**, as they encompass investments and returns derived from eco-conscious initiatives like renewable energy, clean transportation, and conservation. Further underlining the significance of sustainability in finance, the EU's sustainable finance taxonomy regulation mandates regulators to incorporate ESG metrics in discerning which sectors can be promoted as "sustainable investments". Traditional methods frequently fall short in adequately monitoring the environmental footprint of specific industries. In such scenarios, space data could emerge as a valuable tool, offering potentially enhanced resolution levels and helping in the decision-making process for investors. For instance, **the Spatial Finance Initiative** is tapping into the vast capabilities of EO data combined with machine learning with the objective to transform the access to information within the financial ecosystem. They aspire to generate asset-level data, poised to become a useful resource for investors, regulators, and civil society, allowing a deeper, more detailed perspective on environmental risks, implications, and prospects.

Sources of key EO and GNSS user requirements

The key EO and GNSS user requirements for the different applications within the **insurance** and **finance** are, at EU level, collected using a harmonised procedure. 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 Insurance and Finance user needs and requirements. User requirements for Earth Observation (EO) services and products – as well as their evolution – are now also collected through the UCP. The process covers the EO user needs and requirements of commercial users based on inputs from industry experts and user groups, mirroring the existing process implemented for GNSS.

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; and (iii) regular and structured exchanges among representatives of the Copernicus governance structure and Member States through the Copernicus User Forum.

The **2022 UCP Insurance & Finance discussions** made it clear that it was essential to include **ESG reporting as new finance application**. ESG reporting entails the disclosure on the operation of an organisation related to environmental, social and governance aspects. EO data can help providing indicators to improve ESG measuring, monitoring and reporting, assessing investment's overall impact and financial returns. Differently from ESG application analysed under the Climate, Environment, and Biodiversity segment which helps verifying the fulfilment of environmental requirements, ESG reporting in Finance specifically focuses on the economic perspective of ESG helping financial institutions to comply with regulation and supporting investment decisions that consider ESG factors to judge an investment's financial returns and its overall impact.

The application is currently quantified under the Environmental Monitoring segment as "Environmental Impact Assessment and ESG".

ESG reporting standards for insurance companies and financial institutions

Insurance companies and financial institutions face the imperative of **integrating sustainable reporting standards**, necessitating them to embed multiple steps focused on **ESG elements** within their regulatory project planning and operational activities. Given that these organisations have ownership of **vast asset portfolios**, there is an anticipation for these companies to align with a more environmentally conscious economy. The Corporate Sustainability Reporting Directive **(CSRD)** and its European Sustainability Reporting Standards **(ESRS)** are merely one in a series of mandatory reporting requisites entering into force, with notable examples in the EU including the SFDR and the EU taxonomy. Other international examples include the International Sustainability Standards Board (ISSB) and its S1 and S2 standards and the Securities and Exchange Commission (SEC) requirements in the US.

The **implications of ESG** can have a profound impact across entire business, investment and insurance functions. Examples of what investors and insurers can monitor and measure are the carbon emissions, deforestation, land use changes, water scarcity and air pollution. For instance, insurers can use information on natural disasters to determine whether an area presents a high insurance risk due to future climate conditions. Ultimately, access to more accurate data, **including EO**, allows financial institutions and insurers to better understand the environmental and social impacts of the companies they invest in or insure, which helps them make informed ESG-related decisions.

Insurance and finance GNSS Value Chain[1]

GNSS	COMPONENT AND RECEIVER MANUFACTURERS	DEVICE MANUFACTURERS	SYSTEM INTEGRATORS DESIGN CONSULTANCIES TESTING & MAINTENANCE	NETWORK OPERATORS
	• ALBEDO TELECOM* • ARBITER SYSTEMS • BODET* • BRANDYWINE COMMUNICATIONS • ELPROMA* • ENDRUN TECHNOLOGIES • FURUNO • GMV* • GORGY TIMING* • GUIDETECH • JACKSON LABS TECHNOLOGIES • MASTERCLOCK • MEINBERG* • MICROCHIP TECHNOLOGY • OSCILLOQUARTZ* • SAFRAN* • SEPTENTRIO* • STMICROELECTRONICS* • TALLYSMAN WIRELESS • TRIMBLE • U-BLOX*	• ARBITER • CHRONOS TECHNOLOGY* • ELPROMA* • ENDRUN • GORGY TIMING* • JACKSON LABS • MASTERCLOCK • MEINBERG* • MICROCHIP • OSCILLOQUARTZ* • SAFRAN*	• ACCENTURE • ARBITER SYSTEMS • CHRONOS TECHNOLOGY* • COMTECH DATA • IBM • SAFRAN*	BANKS AND STOCK EXCHANGES

European[2] GNSS industry in the global arena

GNSS receivers in insurance and finance are used for T&S applications, including networks using GNSS time and NTP and PTP servers. In 2021, Europe accounted for two thirds of the market shares for components and receivers.

LEGEND

- Commercial offering
- Public offering / entities
- 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.

Please refer to page 23 for a comprehensive description of the GNSS value chain and how to interpret them at segment level.
* European-based companies. The region is defined with respect to the headquarters of the company, though the actual area of activity might be wider

Insurance and finance EO Value Chain[1]

EARTH OBSERVATION

DATA PROVIDERS

Commercial offering:
- AIRBUS*
- BLACKSKY
- CAPELLA SPACE
- GEOSAT*
- E-GEOS*
- ICEYE*
- MAXAR
- PLANET
- SPIRE GLOBAL
- UMBRA

Public offering / entities:
- COPERNICUS SENTINELS*
- COSMO-SKYMED (ASI)*
- LANDSAT (USGS)
- METEOSAT (EUMETSAT)*
- NOAA AND GOES (NOAA)
- RADARSAT (CSA)
- RELEVANT IN-SITU NETWORKS
- OTHER RELEVANT EUROPEAN NATIONAL MISSIONS

INFRASTRUCTURE PROVIDERS

Commercial offering:
- AWS
- CLOUDFERRO*
- GOOGLE CLOUD PLATFORM
- IBM CLOUD
- MICROSOFT AZURE
- T-SYSTEMS*

Public offering / entities:
- FEDERATED INFRASTRUCTURE (E.G. GAIA-X)*
- SENTINEL COLLABORATIVE GROUND SEGMENT*

PLATFORM PROVIDERS

Commercial offering:
- CLEOS*
- CLOUDEO*
- CREODIAS*
- PLANET EXPLORER
- SENTINEL HUB* (SINERGISE)
- TERRADUE*
- UP42*
- VITO*

Public offering / entities:
- GEOHAZARDS TEP*
- WEKEO*

EO PRODUCTS AND SERVICE PROVIDERS

Commercial offering:

Insurance & Finance:
- EARTH DAILY ANALYTICS
- GEOVILLE*
- VITO*

Insurance:
- GAF*
- LUXCARTA*
- SKYTEK*

Finance:
- AGTUALL*
- KAYRROS*
- SATELLIGENCE*
- SPACEKNOW

Public offering / entities:
- COPERNICUS ATMOSPHERE MONITORING SERVICE (CAMS)*
- COPERNICUS CLIMATE CHANGE SERVICE (C3S)*

INFORMATION PROVIDERS

Commercial offering:

Insurance & Finance:
- ACCLIMATISE*
- ACCUWEATHER
- EARTHLAB AI SYSTEMS*
- ECOMETRICA*
- STORMGEO*

Insurance:
- GREEN TRIANGLE*
- VERISK ANALYTICS
- DESCARTES UNDERWRITING*

Finance:
- ASSET RESOLUTION*
- CHAI*
- FLINTPRO
- GEOSPATIAL FINANCIAL HUB*

Financial information providers:
- BLOOMBERG
- MOODY
- REUTERS
- S&P GLOBAL

END USERS

User segments:

COMMERCIAL/ INVESTMENT BANKS

RE/INSURANCE SECTOR
- AIG
- ALLIANZ*
- AXA*
- GENERALI*
- GUY CARPENTER
- MUNICH RE*
- SWISS RE*
- WILLIS TOWERS WATSON*

FINANCIAL INSTITUTIONS
- REFINITIV

INTERNATIONAL DEVELOPMENT ORGANISATIONS
- AFRICAN DEVELOPMENT BANK
- ASIAN DEVELOPMENT BANK
- EUROPEAN BANK OF RECONSTRUCTION AND DEVELOPMENT*
- EUROPEAN INVESTMENT BANK*
- INTER-AMERICAN DEVELOPMENT BANK
- WORLD BANK

TRADING COMPANIES

European[2] EO industry in the global arena

Europe maintains a leading position in the EO market for insurance and finance, with a significant portion of the total market shares on a total segment value, while North American companies account for roughly a quarter of the market. At the forefront of European leading companies, Airbus stands out as a significant frontrunner, followed by ICEYE and Kayrros.

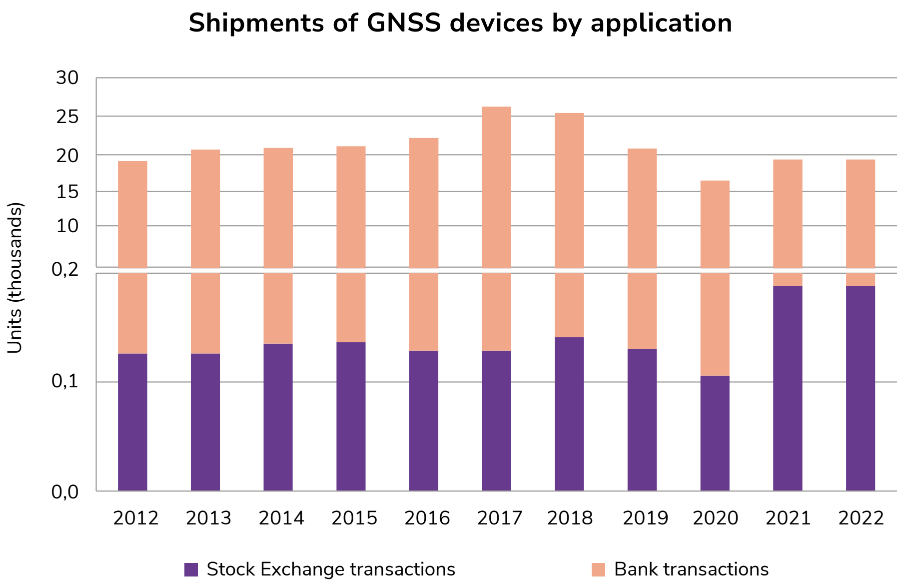
LEGEND
- Commercial offering
- Public offering / entities
- User segments

NOTES

[1] The value chain considers the key global and European companies involved in EO downstream activities. Please note that enterprises listed in the data providers step of the value chain often provide platforms as a service. For the sake of simplicity the data providers are not repeated in other stages of the value chain in which they are active.
[2] In the market share analysis, Europe is defined as EU27 plus Norway, Switzerland and the UK.

Please refer to page 13 for a comprehensive description of the EO value chain and how to interpret them at segment level.
* European-based companies. The region is defined with respect to the headquarters of the company, though the actual area of activity might be wider.

Technological innovations pioneered by end-user's needs



The rise of EO for commodity trading is driven by specific user needs

The current and future price of a commodity depends on the supply and demand, which in turn depends on physical assets that are involved in exploiting, producing or storing said commodity. **Traders benefit from making accurate predictions** on this market supply and demand by buying and selling future contracts.

Depending on the commodity, traders have **differing specific user needs** in order to monitor activities that provide meaningful information predicting the market. Traders can analyse imagery of physical assets on the ground. However, the needed imagery differs in terms of resolution, frequency and historical data depending on the commodity monitored. For example, in order to monitor a large agricultural field or the stockpiles of an urban recycling site for wood waste, the needed spatial resolution to distinguish assets on the ground differs quite a lot.

The use of satellite EO for commodity trading is on the rise as the **imagery offered is improving in terms of spatial resolution and temporal resolution** and increasingly meeting the needs of the traders in order to deliver credible and useful information.

Driven by regulations in Europe (MFiD II) and the US (Finra), the finance sector witnessed a steady **uptake of GNSS timing receivers** over the past decade. As specified in those regulations, **financial actors such as stock exchange and banks were required to ensure accurate time stamping** of each transaction which can be provided through GNSS receivers. In practice, each bank or stock exchange has installed one or, sometimes, multiple GNSS receivers to prove that they are following requirements from said regulations.

Analysing the distribution of GNSS device shipments across applications over the past decade, a predominant trend emerges. **The majority of shipments was related to Bank transactions**, with approximately 20 000 units deployed in 2022. This figure mirrors the numbers seen in 2012, barring a notable surge in shipments during the mid-decade period.

In contrast, the shipments pertaining to Stock exchange transactions remained consistently lower throughout the decade. Over the long term, no significant change is observed as the market is mature and saturated.

Blockchain in combination with EO and GNSS and its importance for Finance and Insurance applications

Blockchain is increasingly recognised as a pivotal instrument to propel the global digital economy forward. Its core strength lies in **facilitating secure data management** across a plethora of interfaces and stakeholders, ensuring **data remains uncompromised** in its integrity. Its applications span a wide spectrum, including identity management, underwriting, claims processing, fraud management, and guaranteeing reliable data availability, all while contributing to decreased operational costs. When Blockchain is integrated with **EO data**, a multitude of benefits emerge: a) it amplifies the **transparency and efficiency** in the movement of goods and financial services; b) it seamlessly **links the tangible environment to digital ledgers**; and c) it aids in crafting **organised data flows** applicable in diverse sectors, such as asset management, risk management, environmental management, logistics, and insurance, to highlight just a few.

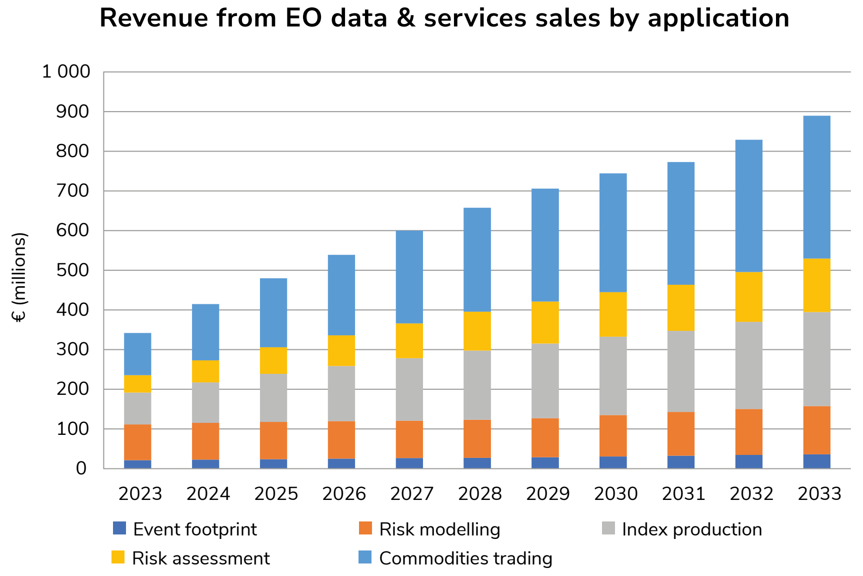
In May 2023, the European Parliament passed the regulation (EU) 2023/1114 or The Markets in Crypto-Assets Regulation (MiCA) to **trace crypto-asset transfers**, to manage crypto-assets that are not managed by current financial service legislation.

The regulation is intended to regulate as well as to foster user confidence in crypto-assets to allow the development of a market and innovative digital services. The tracing of crypto-assets within European boundaries will be enforced by geofencing, enabled by **GNSS technology**.

Innovative technologies in the **ecosystem** enable identification, monitoring, evaluation, and tokenization of verified carbon trading in credits, with **GNSS playing a role in geolocation verification**.

For instance, the IFC, a World Bank affiliate, supports a Blockchain-enabled platform called the Carbon Opportunities Fund platform for carbon offset exchange, enabling accurate valuation of environmental programs and projects.

EO data & service sales for finance booming in the next decade



The **insurance and finance segment is forecasted to be the largest EO downstream segment** within this market report, estimated to accumulate roughly 7 billion EUR in **cumulative revenues** between 2023 and 2033, trailed by the Urban Development and Cultural Heritage segment (see page 180). Important drivers behind this growth are the **advent of VHR satellite EO data**, bringing more opportunities to service providers to develop innovative EO products for commodity traders. VHR data will also enable EO data providers to sell more data products to basically all applications.

When analysing closely the five applications within the segment, in 2023, **commodities trading** is contributing for about **one third of the total revenues**. This application is also the one that is foreseen to yield the greatest CAGR of 30% by 2033, reaching a total of 360 million EUR of revenue. Accounting for roughly 240 million EUR in 2033, **index production** will witness a CAGR of 11% over the next years.

Minimum capital requirements for European banks should consider environmental risks

Since 2021, Environmental and other ESG risks have become increasingly integrated into **European banking supervision**. Currently, the focus on integrating environmental and ESG pillars within the **EBA (European Banking Authority)** prudential framework predominantly lies within supervisory reviews and disclosures.

However, the **EBA is now advocating for an expansion of this focus**, suggesting that the **analysis of environmental risks should also encompass credit risks**. EBA emphasises the necessity of incorporating new risk categories, notably environmental risks, and promotes the employment of internal models, external credit ratings, and the valuation of collateral and financial instruments. A distinctive emphasis is placed on adopting forward-looking methodologies by the EBA, recognising the long-term and non-linear characteristics of many environmental risks.

Banks face several pivotal challenges in this evolving landscape, including: 1) the procurement of **pertinent and trustworthy data** regarding environmental risks and their potential financial repercussions; 2) the creation of analytical instruments that can project the **future implications of these environmental risks**; and 3) the ongoing **monitoring** of the evolving **consequences** of climate-centric and environmental risks on an individual bank basis, as well as overseeing macroprudential capital buffers and accounting provisioning stipulations. EO could potentially play a big role by bridging current existing data gaps when assessing environmental and climate-related risks.

EO to enhance sustainable risk modelling

In response to **climate change** and emerging risks, insurance companies are increasingly recognising the value of Earth Observation (EO), incorporating it more prominently into their **risk models**. The changing climate actually makes current risk models less accurate prompting a **demand for more and accurate data inputs such as EO**.

When satellite data is integrated with other data sources, like **machine learning and GNSS**, it streamlines processes, ensuring they are more precise, swift, and efficient. This enhanced approach notably **improves risk modelling**, offering more accurate predictions concerning risks associated with assets and individuals. Such advancements furnish insurers with superior intelligence, optimising pricing strategies, risk portfolio management, and decision-making processes. Moreover, this integration presents an opportunity to foster greater resilience within households, businesses, and the broader society.

The importance of EO data for transparency in carbon markets

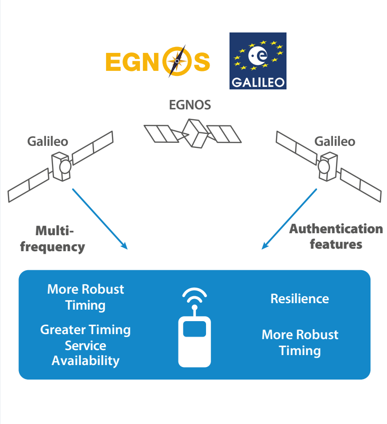
Carbon markets, having matured over time, stand as a pivotal mechanism to motivate the **reduction of GHG emissions** and address climate change. Credits are issued for each equivalent amount that is either curtailed or eliminated from the atmosphere. Yet, recent years have witnessed a diminishing trust in carbon markets, attributed to previously false or overstated claims. **EO** offers a promising avenue to bolster the dependability of these markets. By **ensuring accuracy and introducing uniformity to carbon projects**, EO can furnish dependable and autonomous validation of carbon project effectiveness. This, in turn, augments the credibility of carbon credits transacted in the market. Examples on the importance of the role played by EO might involve conducting **risk-based, transparent and universal carbon credit rating**, or the support given to companies to **identify, track and reduce their emissions**, as well as to develop and **monetise carbon credits**. Moreover, EO can also support in **conducting regular monitoring of forestry carbon projects**.

Copernicus and Galileo working together for more sustainable finance

Current usage of EGNSS

Across the world, financial institutions such as banks and stock exchanges rely on **GNSS timing receivers** for the accurate synchronisation and time stamping of financial transactions. The vast majority of such receivers put on the market by most receiver manufacturers (see page 139 for the industry value chain) are **Galileo-enabled**.

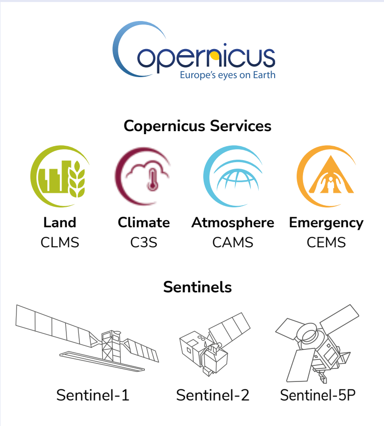
To address GNSS spoofing attacks, ongoing research is being done regarding the adoption of **Galileo OSNMA** as this authentication service would add an additional layer of robustness to the timing receivers. GNSS authentication through Galileo would also further strengthen the resilience of the finance market which is deemed by most nations across the world as a critical infrastructure.



Current usage of Copernicus

The **Copernicus Land Monitoring Service (CLMS)** provides geographical information on land cover, use changes over the years, vegetation, subsidences, etc. The information translated to indicators can be used by insurers and financial stakeholders in supporting risk management strategies, investment decisions, action preventions to climate-related risks, ESG investment/reporting, among others.

The **Copernicus Climate Change Service (C3S)** can support Insurance and Finance applications via an assessment of climate change impacts on biodiversity, risk management for commodity trading, and sustainable water management by providing reliable information to assess the past and to make informed decisions for the future.



The **Copernicus Atmosphere Monitoring Service (CAMS)** can support the insurance and finance sectors by providing up-to-date catalogue of windstorms and their associated impacts on the ground, and other historical events that help prediction calculations. It also supports to gain access to consisted information related to air pollution or climate forcing.

The **Copernicus Emergency Management Service (CEMS)** provides on-demand detailed information for selected emergency situations that arise from natural or man-made disasters anywhere in the world. CEMS helps insurers and financial institutions to identify risks and assess damages.

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

esa

FINANCE PROJECT: PSVE

The project **Port Stockpile Volume Estimation (PSVE)** looks to develop a module that seeks to quantify the volume of dry bulk commodities (e.g., iron ore, coal) held at large international commercial ports, critical for commodity trading. The intelligence on these collections of stockpiles is crucial to create predictions and estimations of the future commodities price fluctuations. Targeted users of the module are producers, end-users, physical merchants and financial players,

© PSVE

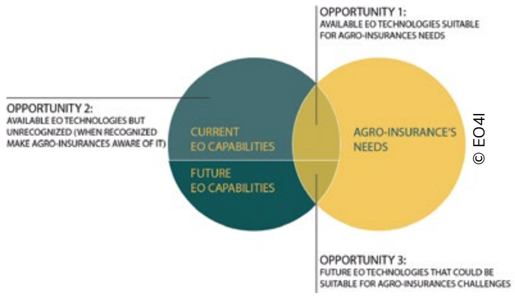
The developed module will use ML techniques to classify satellite imagery from Sentinel-2 MSI and PlanetScope and fuses the imagery with shipping data to increase the overall accuracy of the supply & demand market forecasts of commodity traders.

More information available at: https://business.esa.int/projects/psve

esa EO4I Earth Observation for Agro-Insurance

INSURANCE PROJECT: EO4I

The **Earth Observation Best Practice for Agro-Insurance (EO4I)** project brought together both sectors to find out more about Agro-Insurance needs and inform agricultural insurers about current and future EO capabilities. To find out about the needs and capabilities, the project involved key industry partners from the Agro-Insurance sector: Österreichische Hagelversicherung (AT), Schweizer Hagel (CH), and Vereinigte Hagel (DE); within the project's extension this user group was joined by two reinsurers, Munich Re (DE) and Swiss Re (CH).

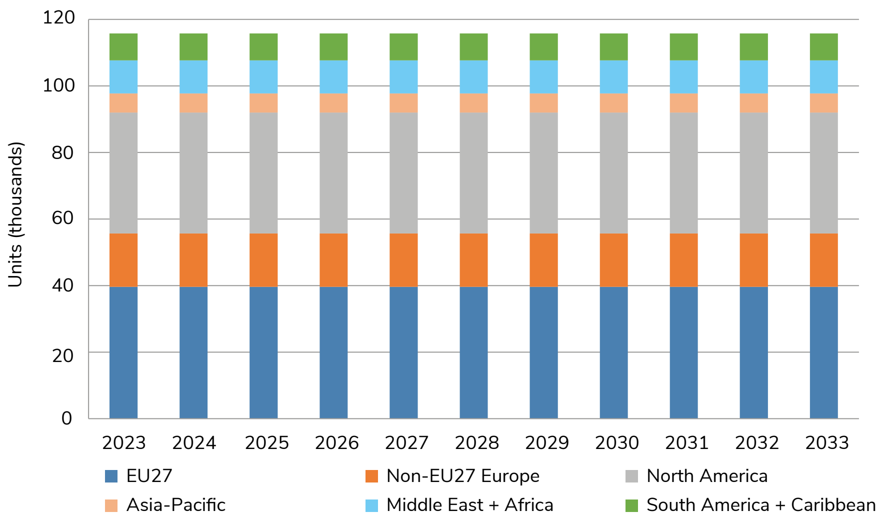


© EO4I

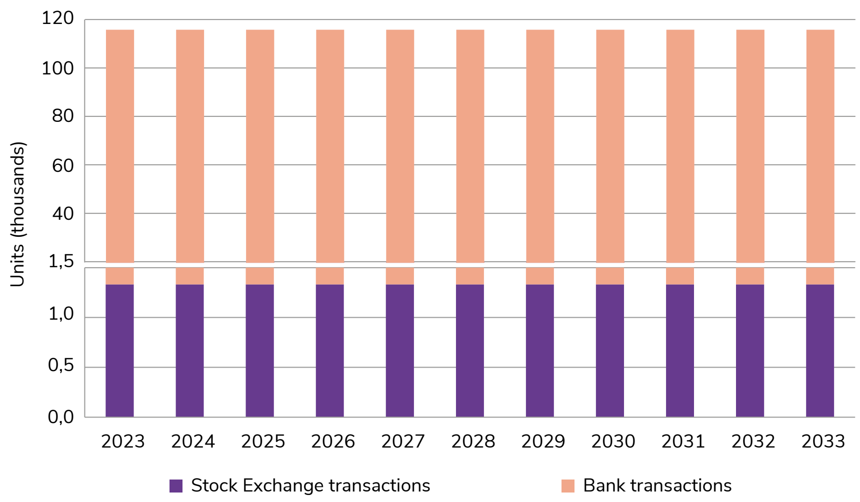
Several surveys, workshops and user meetings led to the best practice roadmap for the use of EO data by the agro-insurance sector. Three key opportunities were identified in the project, as shown in the figure on the right. The successful demonstration of three developed pilot services should serve as a workable model and solution to enhance the business processes of insurers and expand the regional application of these EO services in the future with other insurers and financial institutions.

More information available at: https://earsc-portal.eu/display/EO4I

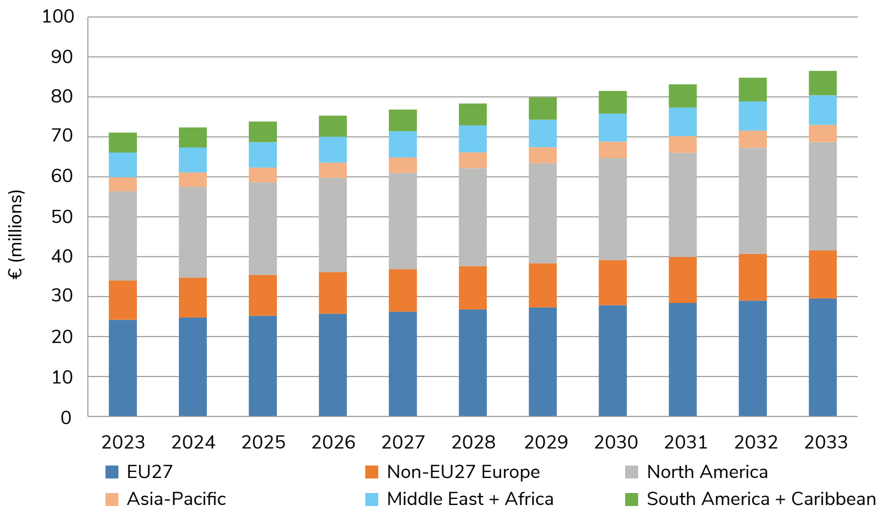
Installed base of GNSS devices by region



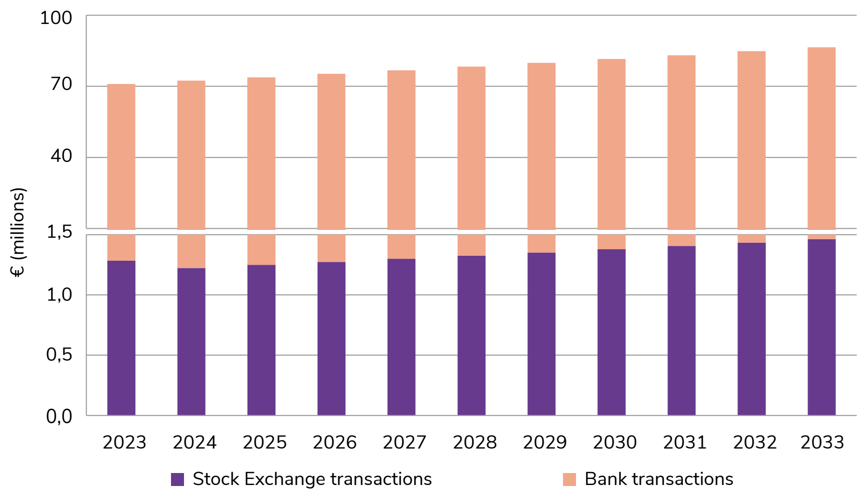
Installed base of GNSS devices by application



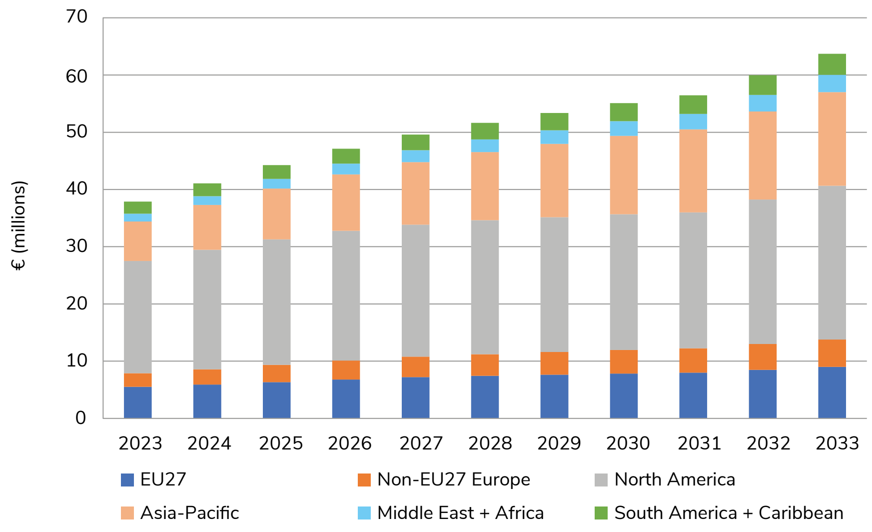
Revenue from GNSS device sales by region



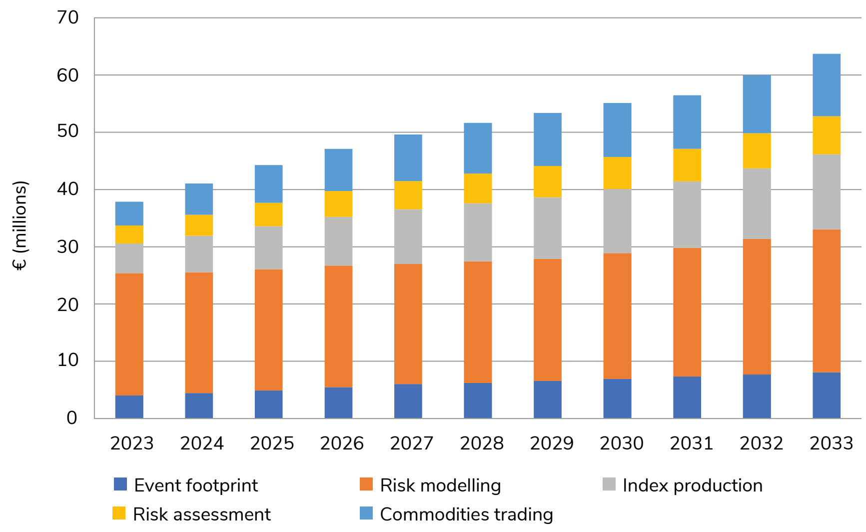
Revenue from GNSS device sales by application



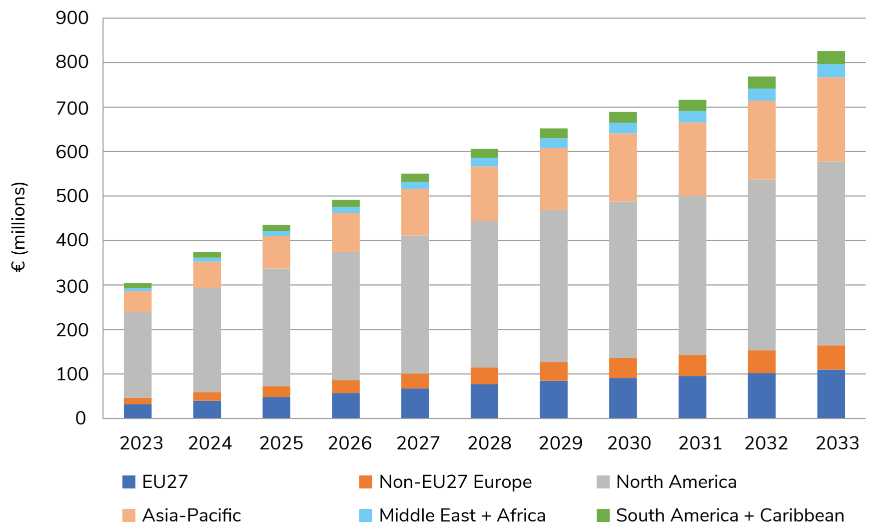
Revenue from EO data sales by region



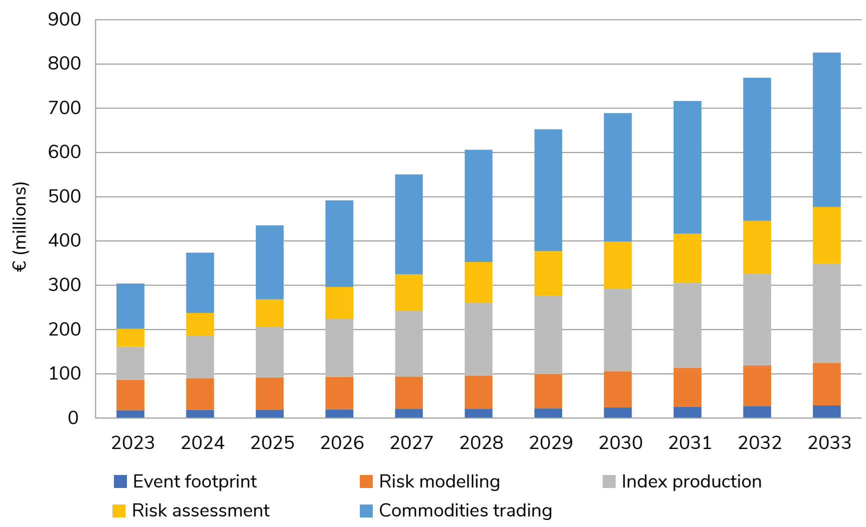
Revenue from EO data sales by application



Revenue from EO services sales by region



Revenue from EO services sales by application



MARITIME AND INLAND WATERWAYS

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

Inland Waterways
- Autonomous Surface Vessels
- Collision avoidance (AIS, VDES)
- GNSS vessel engine management system
- Inland waterways navigation

Maritime engineering
- Dredging
- Marine surveying and mapping

Merchant vessels
- Collision avoidance (AIS, VDES)
- GNSS vessel engine management system
- Maritime Autonomous Surface Ships
- Merchant navigation
- Navigation through sea ice
- Ship route navigation

Ocean and Environmental monitoring
- Marine pollution monitoring

Ports
- Automated port operations
- Piloting assist at ports
- Port Operations[1]
- Port safety
- Port security

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

The maritime sector relies significantly on GNSS and EO technologies, which have become indispensable tools in many maritime applications. In particular, they are helpful in achieving sustainability goals by reducing vessel emissions due to optimised navigation paths, the preservation of ecosystems by path avoidance, the facilitation of greater port security through advanced surveillance techniques as well as increasing maritime safety for vessel operators.

GNSS and EO are also crucial building blocks for upcoming innovative solutions such as autonomous and semi-autonomous vessels and have the potential to provide the same level of safety and security provided by the current state-of-the-art instruments of fully manned vessels.

Vessel-operators, port authorities, environmental agencies and recreational boaters are examples of stakeholders whose daily activities are improved by EO and GNSS technologies. Both EO and GNSS contribute to improving the efficiency, safety and security of various maritime operations, whilst the use of satellite-based information greatly improves decision-making as well as provides financially optimal solutions for the entire maritime sector.

Cross-reference: *GNSS-enabled Search and Rescue beacons, whilst used in this market segment, are presented and quantified in the Emergency Management and Humanitarian Aid market segment.*

What you can read in this chapter

- **Key trends:** Growing digitalisation and automation of vessels and ports, for a sustainable blue economy, and greater security.
- **User perspective:** Diversification of maritime activities with increasing emphasis on societal impact.
- **Industry:** Maritime and inland waterways value chains.
- **Recent developments:** GNSS services can reduce carbon footprint of goods-transport and increase port security.
- **Future market evolution:** EO steering the maritime sector through uncharted waters.
- **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.

Growing digitalisation and automation of vessels and ports, for a sustainable blue economy and greater security

Key market trends

- EO and GNSS technologies can help the maritime sector to advance on sustainability, utilising satellite-derived insights to minimise environmental impact and enable sustainable practices
- A rise in cyberattacks, including GNSS spoofing, prompts efforts to enhance GNSS security and explore alternatives
- The evolution of connectivity solutions and advancements in digitalisation help ports to achieve efficiency and security of operations
- Regulatory actions are preparing the ground to the future advent of autonomous ships

Space technologies help the maritime community to improve sustainability

A **clear trend** noted across all economic sectors is the implementation of modern technologies, not least of all, insights from satellite-derived data, to transition towards informed and fact-based choices that reduce the negative impacts of anthropogenic activities in the maritime sector. Overall, data collected from EO and maritime GNSS activities contribute towards a **greener and cleaner blue economy**.

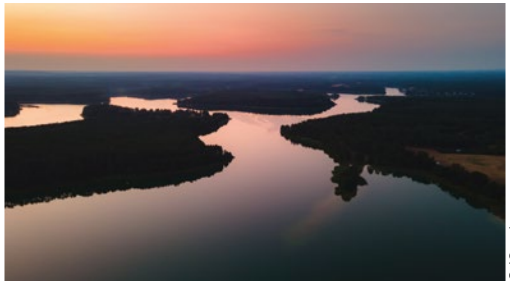
The **environmental impact** of shipping operations, maritime construction and renovation of ports **can be minimised** via the use of (near) real-time **satellite** data. Safety can be enhanced, and sustainable practices can be both enabled/monitored, by both EO and GNSS, supporting the achievement of **traceability** in **maritime value chains**.

The **EO component** of the EU's space programme is already being used for a wide range of land, sea and atmospheric monitoring purposes. Specific EO applications for the maritime sector include: marine pollution detection, biodiversity and ecosystem conservation and emissions monitoring. These are three areas in which EO is contributing to monitoring and protecting marine areas.

Improved connectivity and digitalisation are improving the efficiency and the security of port operations

Advanced **5G connectivity and the Internet of things (IoT)** enables greater adoption of autonomous port use cases. The growing **automation of port operations** is leading to increased emissions monitoring in ports and the evolution of **digital twins** of port structures such as quays for onloading and offloading purposes. IoT technology is also having a consequential impact on **smart containers** for tracking, loading and unloading and in port management systems. Key benefits of IoT enabled shipyards are minimising docked down time with automatic scheduling, as well as automatically tracking unloading times and reducing detention and management costs.

The Port of Algeciras has already implanted the use of GNSS with other technologies like 5G **to increase port security** with geolocation of assets. GNSS tracking systems pinpoint the location of cargo containers in real-time, and combined with virtual reality supported by 5G, it allows to handle security issues more effectively, track cargo and equipment accurately, and overall, streamline logistical operations.



© iStock

Cyber security and communications resilience in the maritime sector

Since February 2020, the maritime sector has experienced a **fourfold increase in attempted cyberattacks**, including GNSS spoofing and jamming, and there has been a staggering 900% rise in attacks on operational technology, such as ship management software, within shipping vessels between 2017-2020. Cyber incidents can arise as the result of loss of or manipulation of external sensor data, critical for the operation of a ship. IMO Guidelines on maritime cyber risk management provide high-level recommendations to safeguard shipping from current and emerging cyberthreats and vulnerabilities. It also includes functional elements that support effective cyber risk management.

The maritime sector recognises the importance of **resilient and secure GNSS positioning**. Efforts are being made to enhance the integrity and robustness of GNSS signals against spoofing and jamming threats. The adoption of **technologies like eLoran** (Enhanced Long-Range Navigation) is being explored as a backup or complementary system to GNSS.

EO has a growing role in supporting **greater maritime spatial awareness**. For instance, it enables the identification of suspicious activities by monitoring coasts and port surroundings. SAR constellations are promising **near real-time monitoring**, with services provided day or night and are not affected by inclement weather. The imagery can be used by coast guard **agencies to identify illegal activities ex ante and ex post**, but also by insurance companies to reconstruct timelines and MetOcean conditions at sea if ships encountered difficulties such as loss of containers.

Automation in the maritime sector: regulatory initiatives are paving the way for maritime autonomous surface ships

The International Maritime Organisation (IMO) **has been addressing the regulatory challenges of autonomous vessels at the international level**. The goal-based maritime autonomous surface ship **(MASS) Code** is **expected to be adopted** as a mandatory code under SOLAS in the future. The MASS Code will need to establish a robust safety regime for MASS that ensures safety of life at sea, as well as safety of cargo on board and the MASS itself. The non-mandatory, goal-based code for MASS could potentially enter into force on 1 January 2028 as a mandatory code.

At European level, the European Maritime Safety Agency (EMSA) has been involved in the development of **guidelines and regulations for the operation of autonomous ships**, through the project AUTOSHIP. Automation is also leading to **new applications** for **inland waterways shipping**, such as bridge collision warning, automatic guidance and mooring assistance, which need **higher precision** coming from on-board sensors and infrastructure.

Finally, **EUSPA is supporting the collection of GNSS user requirements for MASS** in the frame of the User Consultation Platform (see next page).

Diversification of maritime activities with increasing emphasis on security and environmental impact

Satellite EO supports all stakeholders of the blue economy through informed business decisions and increased efficiency of operations to minimise negative impacts

The world's oceans are experiencing an increasing presence of anthropogenic activities, which directly or indirectly impact the marine ecosystem due to ocean acidification, diffusion of (micro)plastics, debris, ship-related contaminants, eutrophication, and other harmful substances. The impact of these harmful activities on the ecosystem in turn generates a negative spiral on the economic activities.

To limit the negative impact on the maritime environment, there is an **increasing regulatory focus** on the blue economy to promote sustainable practices reducing environmental impact, ensure sustainable use of resources, and preserve marine ecosystems. Addressing this concern involves **enhancing maritime fleet efficiency, modernising ports towards zero-emissions, designating marine preservation areas**, thereby mitigating climate effects and yielding long-term economic benefits.

EO Satellite data, including SAR-based and optical imagery, **is playing an increasingly important role in tackling the above-mentioned challenges**, as it allows to monitor the global maritime environment at unprecedented levels. To support companies across the globe, Copernicus is offering several services to support decision-making in the maritime field.

The **Copernicus Marine Service (CMEMS)**, is a comprehensive global monitoring system for the world's oceans. It provides routine, high-quality information about the physical state, variability and dynamics of the ocean and marine ecosystems. The service supports multiple sectors, including maritime safety, marine conservation, fisheries management, coastal and marine environment, along with climate forecasting.

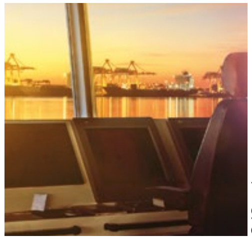
Dedicated user hubs have been developed such as the **Coastal Hub** and the **Arctic Hub**. These web portals provide dedicated data and information on coastal and Arctic environments, that can be explored through interactive maps and thematic use cases, with the aim to foster informed decision-making and promoting sustainable management strategies.

The **Copernicus Maritime Surveillance Service (CMS)**, part of the Surveillance Service (CSS), offers satellite surveillance information to all EU Member States' sea-related entities. System data is accessible within 30 minutes of a satellite overpass. The CMS value-added products help protect the environment, by supporting tasks such as vessel detection, activity monitoring, oil spill detection, incident tracking, and sea object monitoring.

The use of the different **Copernicus services is free of charge** and aims to meet the evolving needs of the different stakeholders.

Maritime operations depend on reliable systems

The **Galileo SAR (Search and Rescue)** service is a key component of the global Cospas-Sarsat distress alert system, designed to locate and assist people in distress situations at sea, in the air or on land. It reduces the time taken to detect a person equipped with a distress beacon after activation. This system also allows the transmission of return messages to the victims, assisting in the coordination of rescue efforts. More information is available on page 86.



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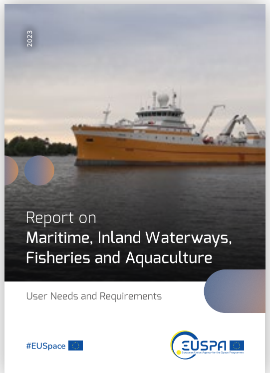
The **Galileo High Accuracy Service (HAS)** went live in 2023, the accuracy offered is expected to be less than 25 cm horizontally and 30 cm vertically, free of charge.[1] Galileo is the first constellation that provides such a service globally and directly through the **Signal in Space**. Stakeholders in the maritime sector have identified applications such as docking and ships navigating in ports and maritime engineering services such as construction and dredging, where safety of operations can be enhanced via a precise positioning service.

The **Galileo Open Service Navigation Message Authentication (OSNMA)** is an authentication service verifying the authenticity of the GNSS information and of the entity transmitting it, to ensure that it comes from a trusted source. OSNMA will help reducing the important amount of GNSS **spoofing** incidents currently occurring in the maritime domain, which are leading to erroneous data of a vessel's position, speed and direction, posing real threats not only to its own operations, but also to surrounding ships and especially those carrying dangerous goods. OSNMA will be made available free of charge to users.



Sources of key EO and GNSS user requirements

The key EO and GNSS user requirements for the different application groups within the **Maritime** segment are, at EU level, collected using a harmonised procedure.

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, Inland Waterways, Fisheries and Aquaculture user needs and requirements. User requirements for Earth Observation (EO) services and products – as well as their evolution – are now also collected through the UCP. The process covers the EO user needs and requirements of commercial users based on inputs from industry experts and user groups, mirroring the existing process implemented for GNSS.

Moreover, the collection of specific requirements for Copernicus services and products is supported by 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; and (iii) regular and structured exchanges among representatives of the Copernicus governance structure and Member States through the Copernicus User Forum.

[1] More information about HAS performance available at Galileo-HAS-SDD_v1.0.pdf (gsc-europa.eu)

Maritime and Inland Waterways Value Chains[1]

EARTH OBSERVATION

DATA PROVIDERS

- AIRBUS*
- BLACKSKY
- CAPELLA SPACE
- E-GEOS*
- GEOSAT*
- HAWKEYE 360
- ICEYE*
- KLEOS SPACE*
- MAXAR
- PLANET
- SPIRE GLOBAL
- UMBRA

- COPERNICUS SENTINELS*
- COSMO-SKYMED (ASI)*
- LANDSAT (USGS)
- METEOSAT (EUMETSAT)*
- NOAA AND GOES (NOAA)
- RADARSAT (CSA)
- RELEVANT IN-SITU NETWORKS
- OTHER RELEVANT EUROPEAN NATIONAL MISSIONS

INFRASTRUCTURE PROVIDERS

- AWS
- CLOUDFERRO*
- GOOGLE CLOUD PLATFORM
- IBM CLOUD
- MICROSOFT AZURE
- T-SYSTEMS*

- FEDERATED INFRASTRUCTURE (E.G. GAIA-X)*
- SENTINEL COLLABORATIVE GROUND SEGMENT*

PLATFORM PROVIDERS

- CLOUDEO*
- CREODIAS*
- EARTH-I
- EDS CEODE
- EURODATACUBE*
- GOOGLE EARTH ENGINE
- NORTH.IO*
- OPEN DATA CUBE
- OPENEO*
- PLANET EXPLORER
- SENTINEL-HUB* (SINERGISE)
- UP42*

- EMODNET*
- COASTAL TEP
- CODE DE*
- COPERNICUS DATASPACE ECOSYSTEM*
- NOAA ONESTOP (NOAA)
- WEKEO*

EO PRODUCTS AND SERVICE PROVIDERS

- ACRI*
- AIRBUS SE*
- BMT ARGOSS*
- BERRING DATA COLLECTIVE*
- CLS*
- DESCARTES LABS
- E-GEOS*
- EODC
- EOMAP*
- GMV*
- INDRA SISTEMAS*
- KSAT*
- MAXAR
- PIESAT
- RHETICUS (PLANETEK)*
- STORMGEO*
- VITO*

- COPERNICUS MARINE SERVICE (CMEMS)*
- COPERNICUS SECURITY SERVICE (CSS)*

INFORMATION PROVIDERS

COASTAL AND MARITIME EXPLOITATION AND PRESERVATION:

- BROCKMANN CONSULT*
- EOMAP*
- GEOOPTICS

SHIPPING AND MARITIME TRANSPORT:

- C-MAP
- DNV*
- EOMAP*
- ESRI UK*
- GLOBAL MARITIME*
- OCEANROUTE
- SAT-OCEAN
- STORMGEO

DATA ANALYTICS COMPANIES

END USERS

- PORT AUTHORITIES
- SHIP OPERATORS
- SURVEILLANCE AUTHORITIES (both national and international)

GNSS

MARITIME ORGANISATIONS

CIRM (International Association for Marine Electronics Companies)

EMSA (European Maritime Safety Agency)

IALA (International Association of Marine Aids to Navigation and Lighthouse Authorities)

IAPH (International Association of Ports and Harbors) **and ESPO** (European Sea Ports Organisation)

ICS (International Chamber of Shipping) **and BIMCO** (Baltic and International Maritime Council)

IMO (International Maritime Organization)

IMPA (International Maritime Pilots' Association) **and EMPA** (European Maritime Pilots' Association)

COMPONENT AND RECEIVER MANUFACTURERS

- ANALOG DEVICES
- ALPHATRON MARINE* (PART OF JAPAN RADIO CO)
- BEIJER ELECTRONICS*
- BEIJING BDSTAR NAVIGATION
- CHCNAV
- COBHAM*
- COBRA ELECTRONICS
- CYBERNETICA*
- FURUNO ELECTRIC
- GARMIN
- GMT CO.
- HEXAGON*
- INTELLIAN TECHNOLOGIES
- KONGSBERG MARITIME*
- NAVICO*
- NUVOTON
- ORBCOMM
- SEAS OF SOLUTIONS
- SEPTENTRIO*
- U-BLOX*
- UNISTRONG GNSS
- WARTSILA*

SYSTEM INTEGRATORS

- AB VOLVO*
- BEIBU GULF PORT GROUP
- COBHAM*
- FURUNO ELECTRIC
- GME
- HYUNDAI
- INMARSAT*
- JAPAN RADIO CO
- JOHNSON OUTDOORS
- KAWASAKI
- KONGSBERG MARITIME*
- LOCKHEED MARTIN
- MITSUBISHI
- OCEANEERING INTERNATIONAL
- PRONAV
- SAAB*
- SAMYUNG ENC
- UNISTRONG GNSS*
- VIASAT
- WARTSILA*
- XIAMEN YAXON NETWORK
- XINUO

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, including Navico, Kongsberg, and Wärtsilä, hold roughly 40% of the maritime market.

Europe has the largest share of the overall market for Earth Observation at close to 60%, followed by North America with just a quarter of the market. The biggest EU players are Leonardo (e-GEOS), Airbus, Acri, and CLS.

LEGEND

- Commercial offering
- Public offering / entities
- User segments

NOTES

[1] The value chain considers the key global and European companies involved in GNSS and EO downstream activities. Please note that enterprises listed in the data providers step of the value chain often provide platforms as a service. For the sake of simplicity the data providers are not repeated in other stages of the value chain in which they are active.

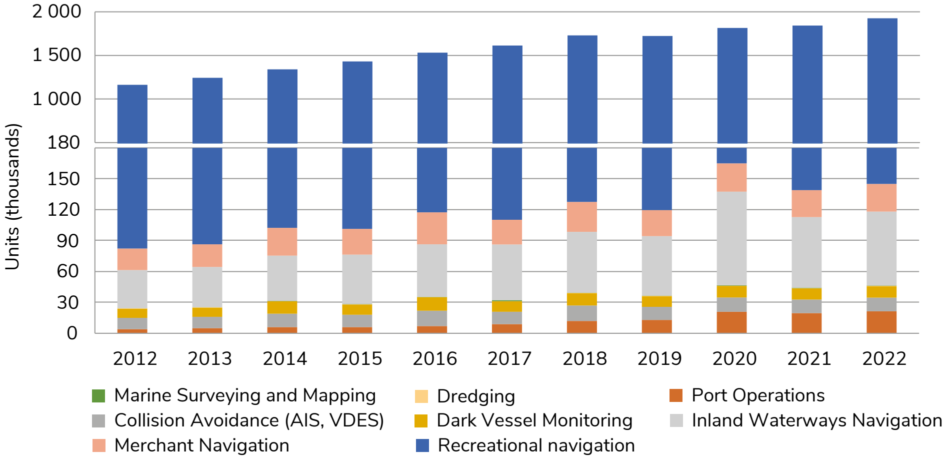
[2] In the market share analysis, Europe is defined as EU27 plus Norway, Switzerland and the UK.

Please refer to page 13 and 23 for a comprehensive description of value chains and how to interpret them at segment level.

* 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 services can reduce carbon footprint of goods-transport and increase port security

Shipments of GNSS devices by application



In 2022, the global size of GNSS shipments in maritime reached 1.9 million units across all applications used for positioning and navigation for maritime vessels and port operations. Maritime GNSS shipments have showed **constant growth**, from over 1.0 million units in 2012.

Recreational navigation continues to be the **largest application** in this segment. It is expected that shipments of GNSS devices for this application will grow from over a million to almost two millions of shipments between 2012 and 2022.

Aside from recreational navigation, **inland waterways navigation** is the largest application, recording almost 75 000 unit shipments in 2022. The shipments of GNSS devices for ports – including Portable Pilot Units (PPUs) – account for 21 000 units. The application registered the highest CAGR over the decade (18%), in line with the historical trend.

Merchant navigation shipments have remained stable across the past decade, in line with the market trends of the shipbuilding industry. They add up to around 25 000 units per year.

EO and GNSS enabling safety and autonomy at sea

The **emergence of autonomous or semi-autonomous vessels** signifies a **significant breakthrough** in the maritime industry, offering substantial **cost reduction opportunities** by minimising the reliance on marine manpower, a major component of shipping costs. This advancement enhances overall competitiveness in the maritime sector. Beyond traditional goods transportation, **autonomous marine vessels demonstrate versatility**, finding applications in marine monitoring, surveying for data collection, and supporting research initiatives.

The **integration of GNSS and EO** technologies in autonomous vessels reflects a promising evolution in maritime operations, fostering efficiency and environmental responsibility.

These cutting-edge technologies heavily depend on GNSS for precise positioning. Galileo's authentication and high-accuracy services can facilitate the operation of autonomous vessels in complying with safety regulations, by helping to meet the minimum safety requirements for autonomous vessels set in the relevant standards.

EO contributes to **strategic planning**, particularly for offshore renewable energy projects, aligning with the goals of the European Green Deal.

Projects and initiatives supported by the EUSPA **play a pivotal role in advancing autonomous shipping**. Consortia arising from EUSPA projects, like the National Technical University of Athens (NTUA) consortium, including Delft University of Technology, SINTEF Ocean, and others, are actively addressing challenges and opportunities in autonomous shipping. These endeavours aim to contribute to sustainability goals, aligning with the broader objectives of the European Green Deal.

Space data and drones are the future of port safety and security

Remote sensing plays a crucial role in bolstering **port safety** through vigilant surveillance. The **integration of drone technology and Earth Observation** contributes to an **extremely comprehensive approach to port safety**, ensuring a thorough understanding of both surface and underwater conditions for effective operational management. While **Earth Observation** techniques provide essential data on the bathymetry of sea floors adjacent to ports, this data has to be supplemented with **radar or drone surveying** techniques. Recent advancements in remote sensing have enhanced these capabilities, offering a more sophisticated solution for mapping and accurately estimating the dynamic evolution of the seabed within port areas.

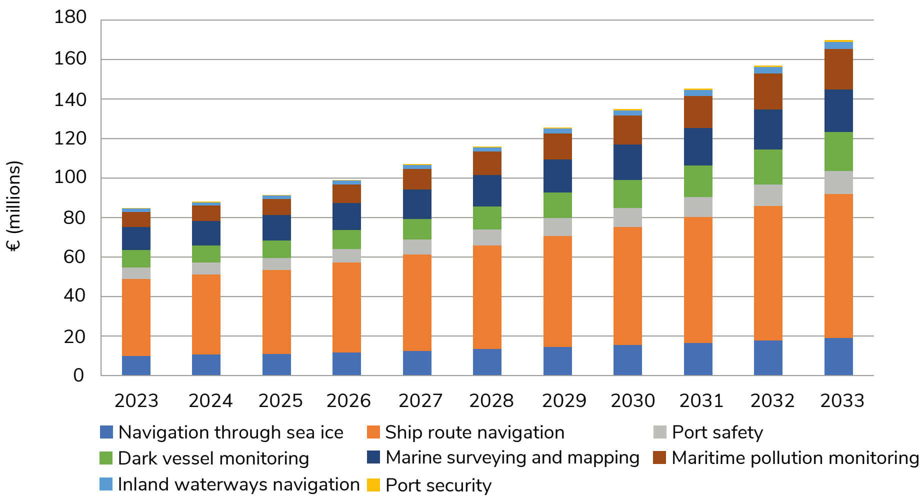
For example, the PASSport (Operational Platform managing a fleet of semi-autonomous drones exploiting GNSS high Accuracy and Authentication to improve Security & Safety in port areas) project **aims to engineer and qualify a solution that enhances situational awareness in port areas**. PASSport envisions activating commercialisation channels by leveraging the novelty of using a fleet of semi-automated drones integrated with Galileo services, and other sensors. Sentinel-2 supplies satellite imagery to bolster these techniques.

© PASSport project

Validation campaign on pollution monitoring - Kolobrzeg, Poland - https://h2020-passport.eu/

EO: steering the maritime sector through uncharted waters

Revenue from EO data & services sales by application



The **revenue generated from EO applications** in the maritime sector has been **steadily growing** over the years, reflecting the increasing importance of these services. Revenue in the maritime sector is primarily driven by a range of different applications, each contributing significantly to the industry's growth.

Revenue from ship route navigation services is estimated to increase from almost €40 million in 2023 to over €70 million in 2033. This application plays a crucial role in enhancing maritime efficiency and represents about 45% of the total market in this segment.

Marine surveying and mapping is currently the **second largest application**. Associated revenues are expected to grow significantly over the period considered. EO based services will grow from more than €11 million in 2023 to more than €21 million in 2033.

Maritime pollution monitoring is **increasingly prominent** as environmental concerns drive the demand for pollution control measures in maritime regions.

EO information supporting the safe **navigation through sea ice**, accounting for 12% of the market, **dark vessels monitoring** (10% of the market) and **maritime and pollution monitoring**, (almost 10% of the market), **jointly represent one third** of the revenue in the maritime domain. This remains true over the decade under analysis.

Autonomous ships seamlessly sailing through inland waterways

The development of **semi-autonomous or fully unmanned ships** stands as a major trend in the maritime industry, propelled by breakthrough innovations in digital technologies such as artificial intelligence, smart robotics, and advanced navigation systems.

Galileo authentication and **high-accuracy** features are **enablers** for the application in inland waterways. GNSS data, including Galileo, supports the identification and tracking of vessel traffic, ensuring safe navigation and collision avoidance. Additionally, **precise mapping of inland waterways, facilitated by EO**, contributes to the geospatial understanding necessary for effective route planning. In synthesis, the use of EU Space Data from Galileo, EGNOS, and Copernicus is pivotal for reliable positioning and harmonised imagery to facilitate safe and green automated operations.

In line with this, the European Parliament has allocated a budget to the European Commission to launch a study covering **EU Space Data for automated vessels in European waterways**. The study will analyse technical and regulatory barriers, industry value chains, and business models related to automated vessels, emphasising synergies between satellite-based navigation, imagery, and telecom. Furthermore, it will **develop a prototype of on-board** equipment utilising Galileo differentiators and **define a Copernicus safety** case for inland waterways, implementing pilot activities to demonstrate feasibility.

The general objective is to contribute to the development, demonstration, and deployment of holistic, smart, and automated shipping concepts in line with NAIADES III objectives.

European Marine Observation and Data Network (EMODnet) and the ocean floor

The **EMODnet broad-scale seabed habitat map** for Europe, also known as **EUSeaMap**, is a comprehensive and freely available **map of physical marine habitats** supported by EO data. It serves to harmonise mapping procedures and promote a common understanding among seabed mappers in Europe. The maps are generated with satellite derived bathymetric data. Copernicus Marine Service and EMODnet are working together on the European In Situ Marine Data Service Landscape.

Phase four of EMODnet Seabed Habitats ongoing efforts involves **the expansion and enhancement of Europe's sole extensive repository of habitat maps** derived from surveys and the accumulation of survey sample points. This expansion aims to broaden its scope to encompass coastal wetlands and crucial fish habitats. This update extends its coverage to include two new regions: the Caspian Sea and certain European territories situated in the Caribbean. These collective efforts seek to **enhance our understanding of Europe's marine habitats and their distribution**, promoting sustainable management and conservation practices.

© iStock

EMODnet also provides a **publicly accessible repository of coastal bathymetry** data in Europe. Accurate information about **potential underwater hazards**, as well as about the depth of water along shipping routes and while entering ports, is necessary for safe maritime transport, especially for large ships. EMODnet also offers the most complete worldwide bathymetric layout, which also boasts the highest resolution currently of such data.

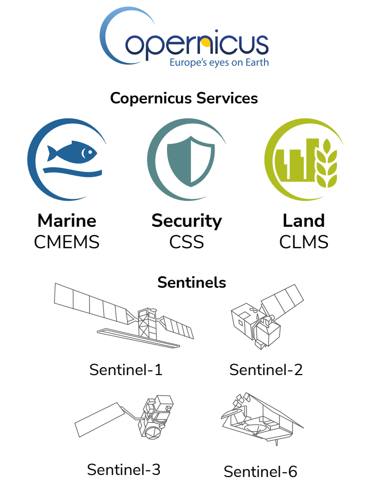
Enhanced devices and data for better performance in maritime activities

Current usage of Copernicus

The **Copernicus Marine Service (CMEMS)** provides free and open scientifically-assessed ocean data across the global ocean. More information is available on page 148.

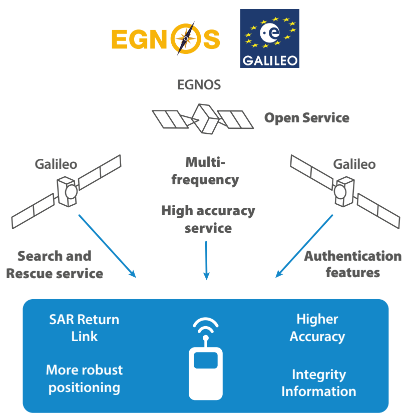
Under the CSS, there is a service called **Copernicus Maritime Surveillance Service (CMS)**. More information is available on page 148.

Under the **CLMS**, there is a service called **European Ground Motion Service (EGMS)**. The EGMS is capable of monitoring land subsidence, which is particularly important in the context of maritime ports many of which are partially built on land that is prone to subsidence. EGMS gives port-based stakeholders the ability to **monitor port protection infrastructure** and take action if subsidence poses a risk to the safety of port operators or traded goods.



New EGNOS service for maritime

The goal of the **EGNOS SoL assisted service for Maritime Users (ESMAS)** is to offer a service tailored to maritime users. It is based on the current EGNOS system, which augments **GPS L1 C/A signal** by providing corrections and integrity information for positioning and navigation applications over Europe via GEO satellites. The service will be declared operational in 2024 and will enable safe operations in ocean waters, harbour entrances, harbour approaches and coastal waters in line with the operational requirements included in the IMO Resolution A.1046 and in waters of the European Union Member States and EGNOS contributing countries, offering a solution to complement national DGPS services. ESMAS will be freely accessible without any direct charge and will be provided openly to suitably equipped maritime users using both the GPS L1 C/A signal and the **SBAS L1 augmentation signal**.



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

ASGARD Project - Operator-Centred Enhancement of Awareness in Navigation

The **Advanced shipborne Galileo receiver DFMC** (ASGARD) **receiver** is designed to leverage all the advanced features of the Galileo Open Service (OS), benefiting from enhanced performance and robustness through dual-frequency and OSNMA capabilities. This design ensures compliance with the regulatory frameworks governing maritime equipment at both the European Union (EU) and International Maritime Organization (IMO) levels. As part of the project, **various activities will be conducted to rigorously test and demonstrate the product's capabilities**, facilitating the dissemination and formulation of a business plan to maximize the adoption of shipborne Galileo receivers in the relevant market.

The EU **Maritime Security Strategy** (EUMSS) is dedicated to **advancing international peace, security and ocean sustainability**, aiming to ensure secure maritime operations. Despite its primary focus on sea-related matters, the effectiveness of the EUMSS relies significantly on space technologies. This includes leveraging Earth Observation data from Copernicus, the accurate positioning provided by Galileo and EGNOS, as well as the secure communication capabilities of IRIS² and GOVSATCOM.

More information available at: https://asgard.gmv.com/

IWETT- inland Waterway use of EGNOS for Tracking and Tracing

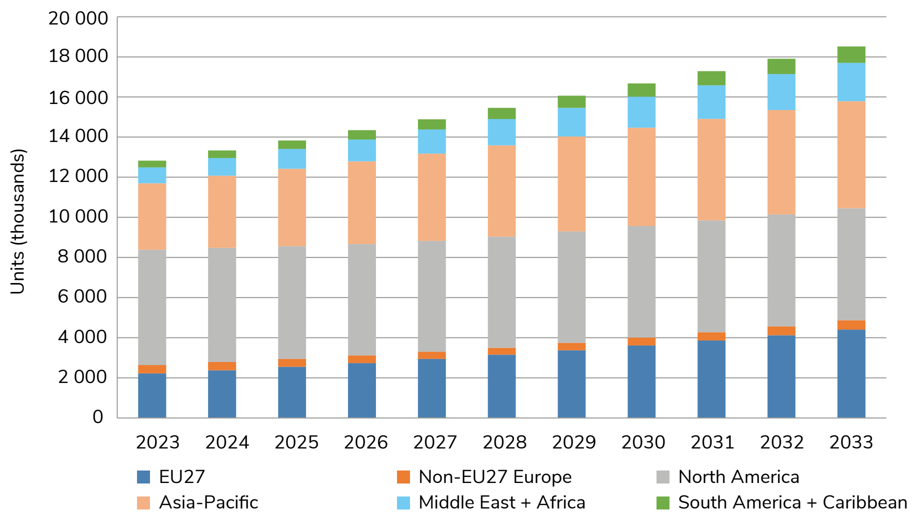
The **IWETT project** will achieve significant adoption of **EGNOS** in the inland waterway (IWW) transport sector, namely on the Danube in Hungary, on the Spree-Oder Waterway in Germany and on the Guadalquivir river in Spain. In these three countries, the authorities and organisations responsible for IWW information systems and services decided to execute final pilot tests and, after validation, use the **EGNOS based service as an important part of their River Information Services (RIS) system**.

IWETT will contribute to EGNOS adoption in IWW by implementing/upgrading the EGNOS based infrastructure in the three selected areas. A special IWW user terminal concept (INAV concept) will be elaborated and tested by the German responsible authority (WSV). The project ultimately seeks to bridge the gap between existing technologies and the adoption of advanced EGNOS-based systems, leading to more reliable, accurate, and comprehensive RIS.

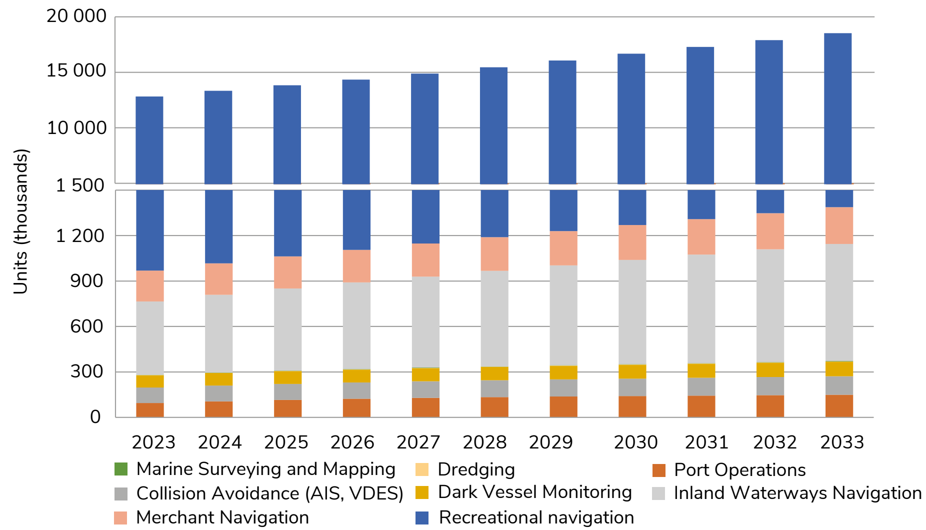
EGNOS improves the accuracy and reliability of GNSS positioning information, while also providing a crucial integrity message regarding the continuity and availability of a signal. The use of EGNOS as a source of differential corrections provides room for the rationalisation of the shore infrastructures by reducing onsite infrastructure as well as operational and maintenance costs.

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

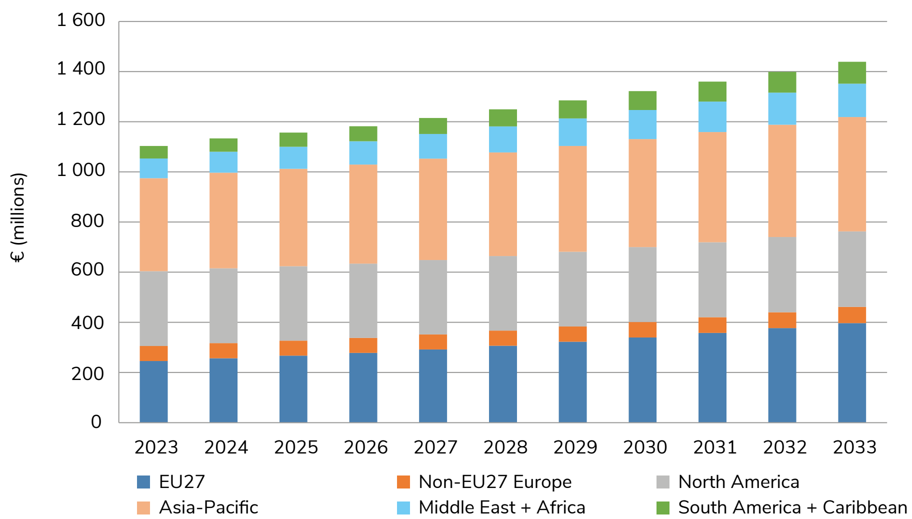
Installed base of GNSS devices by region



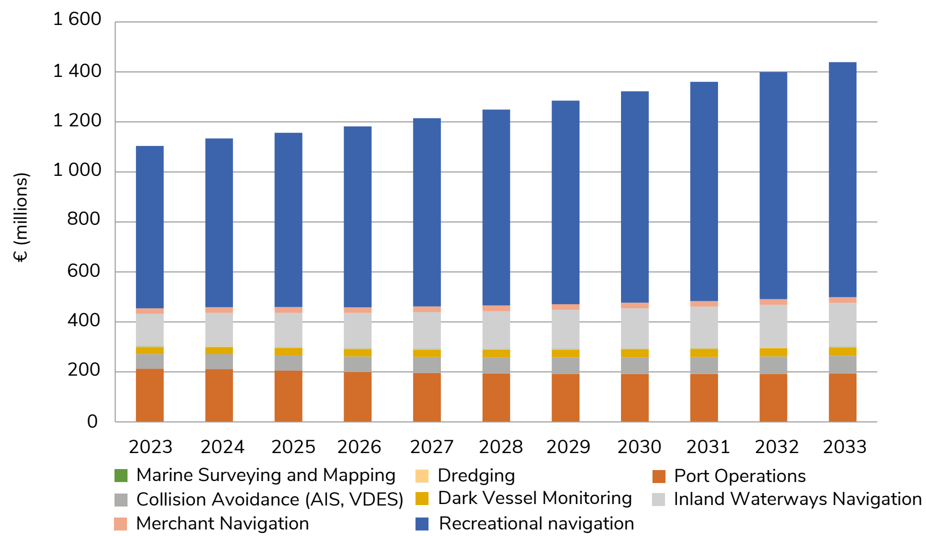
Installed base of GNSS devices by application

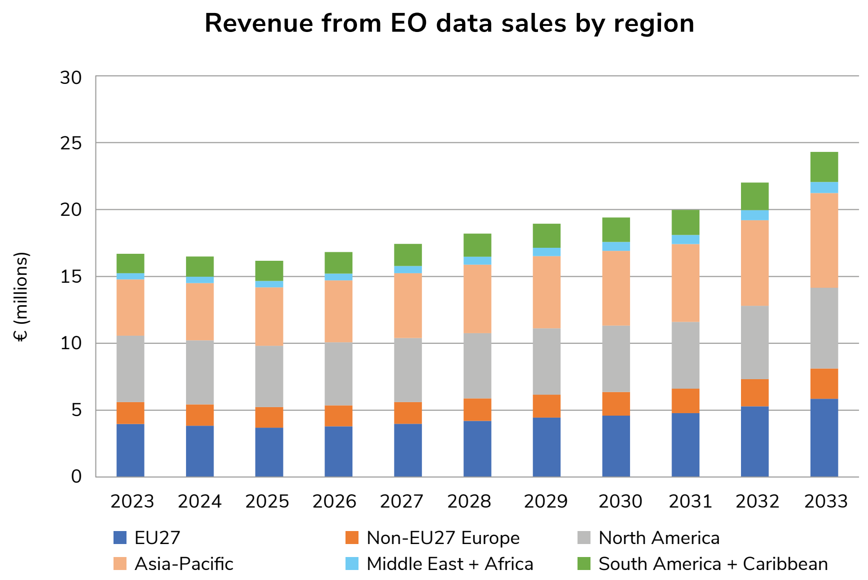


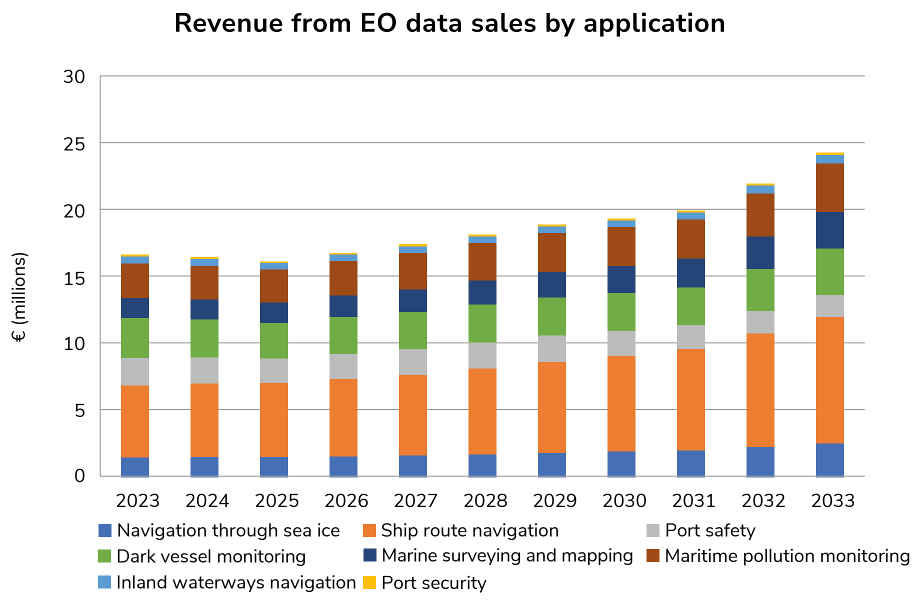
Revenue from GNSS device sales by region



Revenue from GNSS device sales by application




Revenue from EO data sales by region
€ (millions)
0
5
10
15
20
25
30
2023
2024
2025
2026
2027
2028
2029
2030
2031
2032
2033
EU27
Non-EU27 Europe
North America
Asia-Pacific
Middle East + Africa
South America + Caribbean


Revenue from EO data sales by application
€ (millions)
0
5
10
15
20
25
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2029
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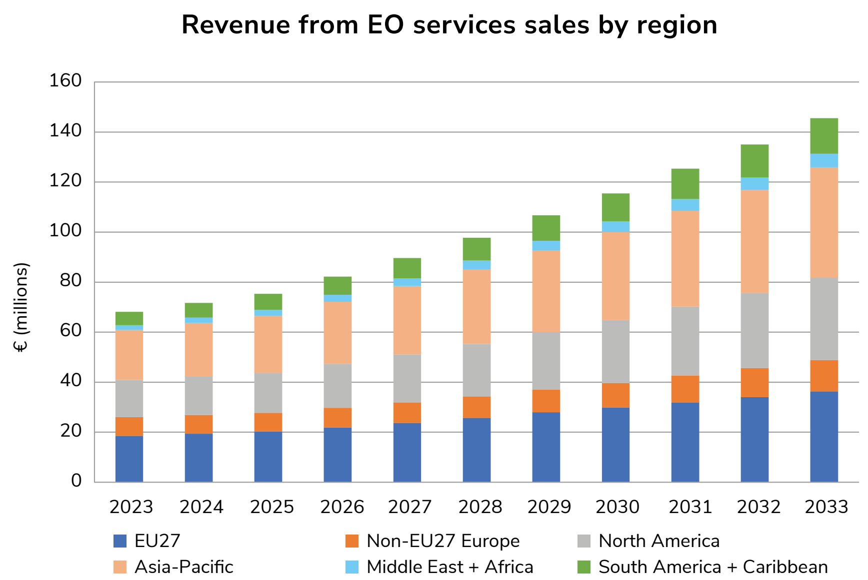
Navigation through sea ice
Ship route navigation
Port safety
Dark vessel monitoring
Marine surveying and mapping
Maritime pollution monitoring
Inland waterways navigation
Port security


Revenue from EO services sales by region
€ (millions)
0
20
40
60
80
100
120
140
160
2023
2024
2025
2026
2027
2028
2029
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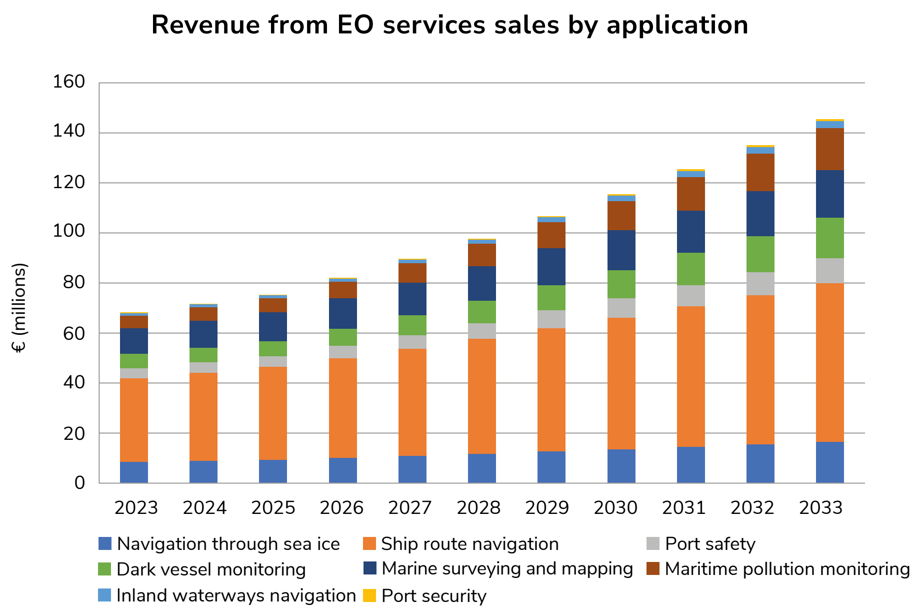
2031
2032
2033
EU27
Non-EU27 Europe
North America
Asia-Pacific
Middle East + Africa
South America + Caribbean


Revenue from EO services sales by application
€ (millions)
0
20
40
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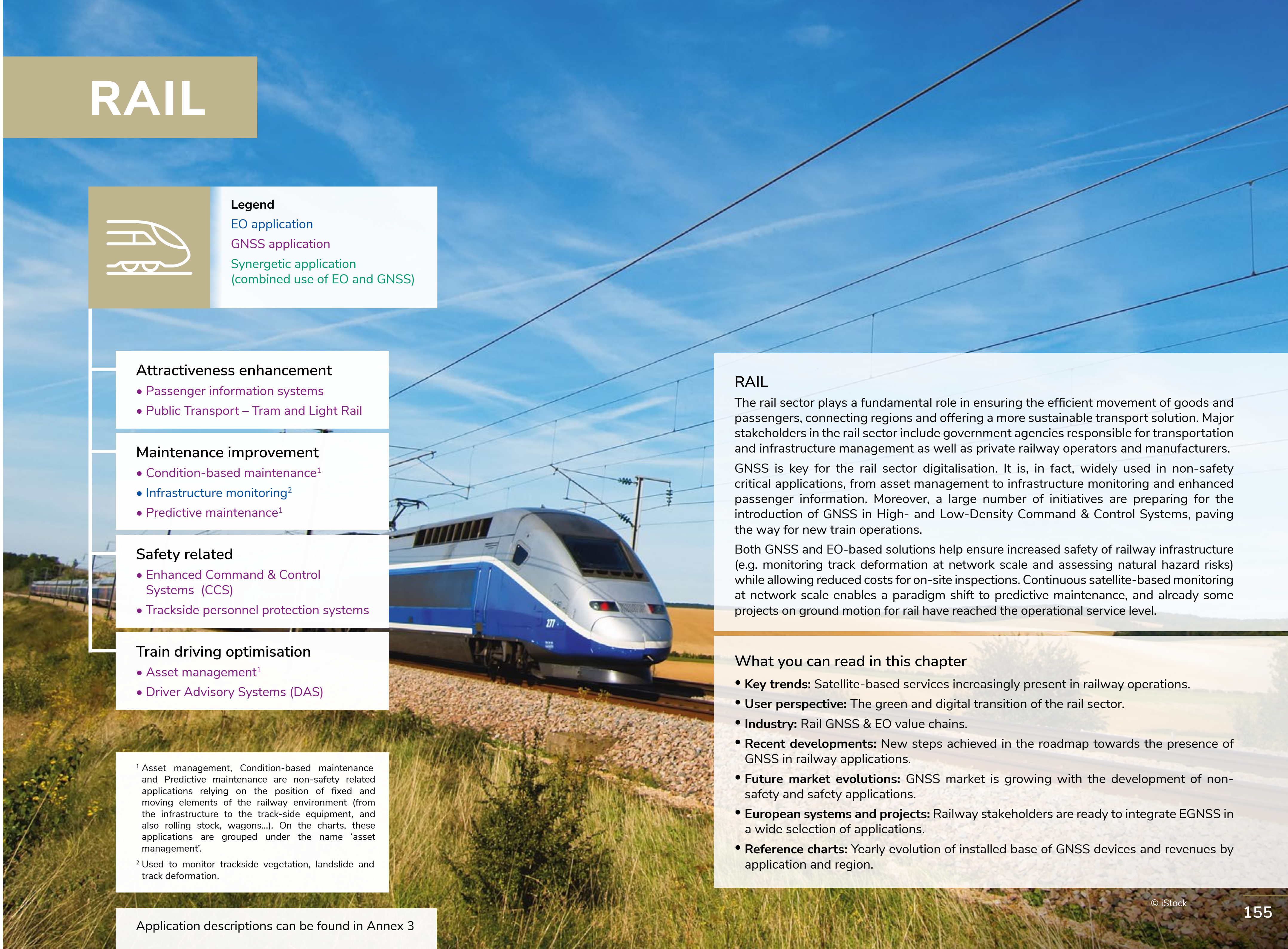
Navigation through sea ice
Ship route navigation
Port safety
Dark vessel monitoring
Marine surveying and mapping
Maritime pollution monitoring
Inland waterways navigation
Port security

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 (CCS)
- Trackside personnel protection systems

Train driving optimisation

- Asset management[1]
- Driver Advisory Systems (DAS)

[1] Asset 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

The rail sector plays a fundamental role in ensuring the efficient movement of goods and passengers, connecting regions and offering a more sustainable transport solution. Major stakeholders in the rail sector include government agencies responsible for transportation and infrastructure management as well as private railway operators and manufacturers.

GNSS is key for the rail sector digitalisation. It is, in fact, widely used in non-safety critical applications, from asset management to infrastructure monitoring and enhanced passenger information. 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.

Both GNSS and EO-based solutions help ensure increased safety of railway infrastructure (e.g. monitoring track deformation at network scale and assessing natural hazard risks) while allowing reduced costs for on-site inspections. Continuous satellite-based monitoring at network scale enables a paradigm shift to predictive maintenance, and already some projects on ground motion for rail have reached the operational service level.

What you can read in this chapter

- **Key trends:** Satellite-based services increasingly present in railway operations.
- **User perspective:** The green and digital transition of the rail sector.
- **Industry:** Rail GNSS & EO value chains.
- **Recent developments:** New steps achieved in the roadmap towards the presence of GNSS in railway applications.
- **Future market evolutions:** GNSS market is growing with the development of non-safety and safety applications.
- **European systems and projects:** Railway stakeholders are ready to integrate EGNSS in a wide selection of applications.
- **Reference charts:** Yearly evolution of installed base of GNSS devices and revenues by application and region.

Satellite-based services are increasingly present in railway operations

Key market trends

- An increasing number of rail freight wagons are equipped with EGNSS tracking devices enabling more digital freight services
- Enhanced infrastructure monitoring using AI for GNSS data processing is enabling proactive intervention during the initial stages of infrastructure deterioration
- The Rail sector is recovering from the COVID-19 impact and is bound for future growth and continuous modernisation of railways systems, including GNSS-based technologies

An increasing number of rail freight wagons are equipped with telematics including GNSS

EGNSS tracking devices are continuing to penetrate the freight market, with an increasing number of trains and wagons equipped across Europe. These devices are part of the strategy to **shift freight from road to rail** by enhancing its attractiveness.

Fleet operators develop **digital freight services** also by making wagons smarter, offering customers a better visibility of the cargos and its conditions. Parameters such as temperature, pressure, estimated time of arrival as well as accurate information of the transport itself are now provided – this includes information on the location of the cars, loading status, open/close condition of doors and hatches and health condition of bogies, braking system and wheelsets.

The total number of EGNSS tracking devices is estimated to be **more than 200 000**, and localised reports on assets are now extensively exchanging millions of messages each day. While the technology has reached maturity, the development of more services is continuing.

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For example, the **4F French coalition** just launched the MONITOR innovation project, which aims to support the development of digital freight trains by combining radio communication between wagons with brake and bogie monitoring sensors and automated brake testing. The aim is to reduce the risks of derailments and untimely brake applications and to reduce train preparation time.

Enhanced infrastructure monitoring is now using AI for GNSS data processing

Infrastructure, track inspection and maintenance are essential tasks to ensure safe and efficient railway operations. Increasingly, the monitoring of track geometry condition using equipped in-service trains is linked with **GNSS sensors** and allows for precise measurements and accurate location identification.

These technological solutions, combined with AI, offer valuable insights into predicting the emergence of defects, **enabling proactive intervention** during the initial stages of deterioration.

By implementing **AI-driven automation**, the railway system gains **enhanced flexibility** in managing varying peak travel times, mitigating operational disruptions caused by maintenance and staffing issues.

Furthermore, this automation enables upgrades to be carried out with minimal impact on rail services. Consequently, passengers benefit from an improved travel experience, as these advances **optimise overall efficiency and reliability**.

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Rail sector is recovering from COVID-19 impact and set for future growth

The rail sector has the potential to not only regain pre-pandemic passenger numbers but also expand its market share. This aligns with the growing consumer demand for **sustainability**, as rail travel offers a more environmentally friendly alternative to road and air transport. As **new mobility options** emerge, car usage for short to medium distances is projected to decrease by 20% to 70% over the next decade, creating an opportunity for rail to capture a larger share.

Additionally, various regions are actively modernising rail infrastructure and prioritising decarbonisation efforts. Notably, the **European Green Deal**, as a comprehensive sustainability initiative, aims to invest almost €90 billion in rail-related infrastructure upgrades.

The modernisation of the railway system includes the adoption of **GNSS-based technologies**; their introduction into signaling applications is increasing in Europe and could represent a major change in future markets.

The green and digital transition of the Rail sector

The importance of a modal shift towards the twin transition

A modal shift to rail is imperative for **reducing the environmental impact** caused by transportation. To achieve this, **innovation and digitalisation are key** and come in two main forms.

Firstly, for freight rail operations, competitiveness can be improved by a seamlessly integration into the logistics value chain, thereby strengthening the railway's role in the supply industry. Secondly, a comprehensive digital transformation, encompassing the automation of operations, can enhance overall performance and capacity in the rail sector.

Transformative innovations are expected from the new European partnership on rail research and innovation, named **Europe's Rail**. The partnership has defined different priorities where **digitalisation** plays important roles, including digital and automated train operations; the development of a competitive digital green rail freight and development of sustainable and digital assets.

Research and innovation along these priorities is expected to transform the rail sector providing truly **customer-centric services**, where mobility solutions fulfil passenger and logistic expectations, reducing costs, improving performance and creating immediate customer satisfaction.

Competitive digital green, automated train operations and rail freight contribute to the impacts presented in the figure below.

© Europe's Rail Joint Undertaking Master Plan

Towards network scale rail infrastructure monitoring with satellite and drone EO, GNSS

Safety of rail operations is the main concern for rail companies and must be ensured at large-scale networks comprising varied topographies, geological and climatic conditions.

The research and development project SIA developed **low-cost EGNSS solutions** for providing prognostic information on the health status of the railway assets. The project delivered a low-cost, real-time monitoring system using EGNSS localisation techniques providing high accuracy and high availability in the railway environment. The data collected feeds into infrastructure degradation models and predictive algorithms. In terms of added value offered, the new services developed are expected to reduce railway maintenance costs by 15%, maintenance costs linked to unscheduled events by 25% and the derailments associated to the rail-wheel interface by 15%.

The use of **satellite imagery** offers a valuable tool for authorities and infrastructure managers to identify crucial factors at network scale such as **vegetation levels** and their proximity to the rail tracks and **ground deformation and subsidence**. The latter should be managed to ensure the smooth and safe operation of rail systems, maintaining the reliability of rail travel. When it comes to monitoring ground stability at network scale, the large set of in-situ sensors necessary means that local scale remote sensing methods (e.g. LiDAR) may be too expensive due to the requirement to establish extensive measuring networks. By leveraging EO imagery, proactive measures can be taken to address issues concerning the infrastructure at a large scale before escalating, ensuring the smooth functioning of rail operations.

Drones can also provide a cheaper alternative compared with traditional monitoring methods, in particular **combined with GNSS and AI**, leading to **improved maintenance, increased operational efficiency, and enhanced safety** in the rail sector. Rail infrastructure managers such as SNCF Reseau and DB are already using drones to assist their monitoring and maintenance activities.

Sources of key EO and GNSS user requirements

The key **EO and GNSS user requirements** for the different application groups within the rail segment are, at EU level, collected using a harmonised procedure.

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 Rail and Public Transport user needs and requirements. User requirements for Earth Observation (EO) services and products – as well as their evolution – are now also collected through the UCP. The process covers the EO user needs and requirements of commercial users based on inputs from industry experts and user groups, mirroring the existing process implemented for GNSS. EO requirements are covered starting from the 2024 issue of the Rail report.

Moreover, the collection of specific requirements for **Copernicus services and products** is supported by 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.

Rail GNSS Value Chain[1]

GNSS	COMPONENTS AND RECEIVER MANUFACTURERS	SYSTEM INTEGRATORS	TRAIN MANUFACTURERS	RAILWAY UNDERTAKINGS	INFRASTRUCTURE MANAGERS
	• ALSTOM TRANSPORT* • AZD PRAHA* • CAF* • CATERPILLAR • CRRC CORPORATION • HITACHI • HUPAC* • JAPAN RADIO CO. • KAWASAKI • KINTETSU RAILCAR ENGINEERING • MERCITALIA RAIL* • MITSUBISHI • SICE* • SIEMENS* • THALES* • TRANSWAGGON* • VTG* • WABTEC • XIAMEN YAXON NETWORK	• ANALOG DEVICES • ANTCOM • BEIJING BDSTAR NAVIGATION • BROADCOM • COMNAV TECHNOLOGY • CORE CORPORATION • GLARUN TECHNOLOGY • GMV* • HITACHI • INTERMODAL TELEMATICS* • LANNER ELECTRONICS • MERMEC* • PANORAMA ANTENNAS* • SATEL* • SEPTENTRIO* • SIERRA WIRELESS • SYNTONY GNSS* • TE CONNECTIVITY* • TRIMBLE NAVIGATION • U-BLOX* • YAGEO	• ALSTOM TRANSPORT* • CAF* • CRRC CORPORATION • HITACHI • SIEMENS* • STADLER RAIL* • WABTEC	**TRAIN AND FREIGHT OPERATING COMPANIES:** • ARRIVA* • COLAS* • DB* • RENFE* • SBB* • SNCF* • STAGECOACH* • TRENITALIA* • URBAN TRANSPORT OPERATORS **ROLLING STOCK OPERATING COMPANIES:** • CONSORTIA • INVESTMENT BANKS • NATIONAL COMPANIES	• ADIF* • DB NETZE* • INFRAESTRUTURAS DE PORTUGAL* • NETWORK RAIL* • RFI* • SBB BAHNINFRASTRUKTUR* • SNCF RÉSEAU* • URBAN TRANSPORT OPERATORS

European[2] GNSS industry in the global arena

Looking at components and receivers manufacturers and system integrators in the rail industry, Europe, North America and Asia continue to largely dominate the market with European companies representing around a quarter of the market in 2021. Focusing on system integrators, their market share is distributed consistently among the primary regional players, with Europe retaining around one third of the global market share. Top European players in the segment include Alstom Transport, Siemens and Thales.

LEGEND

- Commercial offering
- Public offering / entities
- 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.

Please refer to page 23 for a comprehensive description of the GNSS value chain and how to interpret it at segment level.
* European-based companies. The region is defined with respect to the headquarters of the company, though the actual area of activity might be wider.

Rail EO Value Chain[1]

EARTH OBSERVATION	DATA PROVIDERS	INFRASTRUCTURE PROVIDERS	PLATFORM PROVIDERS	EO PRODUCTS AND SERVICE PROVIDERS	INFORMATION PROVIDERS	END USERS
Commercial offering	• AIRBUS* • BLACKSKY • CAPELLA SPACE • CGSTL • E-GEOS* • GEOSAT* • ICEYE* • MAXAR • PLANET • SATELLOGIC • UMBRA	• AWS • CLOUDFERRO* • GOOGLE CLOUD PLATFORM • IBM CLOUD • MICROSOFT AZURE • T-SYSTEMS*	• CLOUDEO* • CREODIAS* • EARTH-I • EURODATACUBE* • GOOGLE EARTH ENGINE • NORTH.IO* • OPEN DATA CUBE • OPENEO* • PLANET EXPLORER • (SINERGISSENTINEL-HUBE)* • UP42*	• BEIJING SUPERMAP SOFTWARE • CBC GEOSPATIAL • E-GEOS* • DARES TECHNOLOGY* • DETEKTIA* • GAF* • GEOFEM* • INTERMAP TECHNOLOGIES • LIVEEO* • PLANETEK* • SATSENSE* • SNC-LAVALIN • SPOTLITE* • TRE ALTAMIRA*	• ALTAMETRIS* • SNC-LAVALIN	
Public offering / entities	• ALOS-2 (JAXA) • COPERNICUS SENTINELS* • COSMO-SKYMED (ASI)* • RADARSAT (CSA) • RELEVANT IN-SITU NETWORKS • OTHER RELEVANT EUROPEAN NATIONAL MISSIONS	• FEDERATED INFRASTRUCTURE (E.G. GAIA-X)* • SENTINEL COLLABORATIVE GROUND SEGMENT*	• WEKEO*	• COPERNICUS EUROPEAN GROUND MONITORING SYSTEM (EGMS)*		
User segments						• ADIF** • DB NETZE** • INFRAESTRUTURAS DE PORTUGAL** • NETWORK RAIL** • RFI** • SBB BAHNINFRASTRUKTUR** • SNCF RÉSEAU** • URBAN TRANSPORT OPERATORS

European[2] EO industry in the global arena

The EO rail market is currently dominated by Asia-Pacific, which accounts for close to half of the market share. Beijing Supermap is the leading EO transportation service and solution provider globally. Europe follows closely behind, with Leonardo (e-GEOS) being the largest European company in this segment.

Rail is currently the smallest market segment when it comes to EO applications. However, many of the EO applications in the infrastructure segment overlap with those applicable to rail.

LEGEND

- Commercial offering
- Public offering / entities
- User segments

NOTES

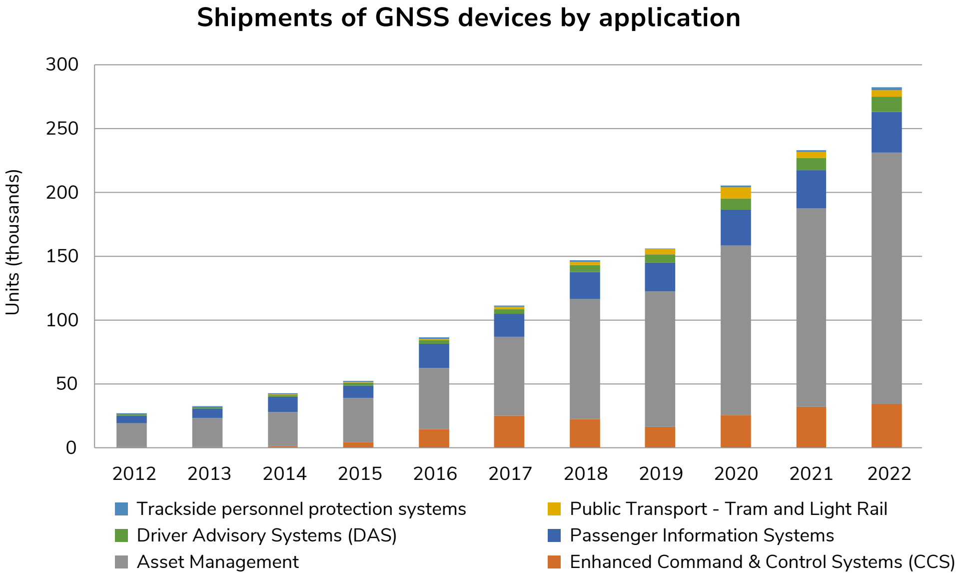
[1] The value chain considers the key global and European companies involved in EO downstream activities. Please note that enterprises listed in the data providers step of the value chain often provide platforms as a service. For the sake of simplicity the data providers are not repeated in other stages of the value chain in which they are active.

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

Please refer to page 13 for a comprehensive description of the EO value chain and how to interpret it at segment level.

* 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 steps achieved in the roadmap towards the presence of GNSS in railway applications



The annual shipments for **GNSS receivers** across the different rail applications have **grown from more than 25 000 in 2012 to over 250 000 units in 2022**. This trend was primarily driven by the overall digitalisation of railway assets, with GNSS data playing a crucial role in enabling this transformation. **Asset management** devices account for around 70% of these shipments. Asset management solutions allow the fleet performance to be assessed and the use of locomotives and railway cars to be optimised.

GNSS devices have been implemented into **CCS applications** since 2016, resulting in a steady growth over the past few years. While the market in 2012 was not yet mature, in 2022 shipments reached more than 30 000 units, making it the second largest application with almost 15% of total shipments of GNSS devices.

Rail users are driving the need for widespread **passenger information systems**, which are providing the information about the location, speed or arrival time of the train. With more than 20 000 shipments in 2022, this application is the third largest in terms of annual sales and accounts for 10% of total shipments.

GNSS for precision mapping in railway applications


© voestalpine

In a rapidly digitalising world, the railway sector's infrastructure mapping needs are evolving at an unprecedented pace. **Maps are key** for **infrastructure management, digital twins and travel information** systems. They will also **enable automatic train operations**, especially in future driverless applications, and facilitate track and catenary maintenance.

Moreover, maps will also act as a key enabler for automatic train operations related to the track axes and virtual or physical balises, light signals or markers, so that these can be integrated in a multisensor localisation system. **Digital maps** will enable and optimise current and future rail applications, which guarantee a safe and optimised rail traffic.

The **RAILGAP H2020 project** will contribute to the development of such maps, defining AI algorithms for detecting and localising railway assets starting from LIDAR and Camera point clouds.

EO for track measurements to predict ground movements

Europe's railway tracks are surrounded with all types of land cover such as forests, mountains, buildings and agricultural crop fields. **Changing moisture levels** in the soil or floods can **impact the railway infrastructure** – as the ground dries out or becomes saturated with water, it becomes prone to land subsidence possibly displacing rail tracks. Thus, measuring the soil moisture is a key activity of railway infrastructure managers to prevent damage and ensure safe and continuous activity on the tracks. Over the past few decades, several in-situ techniques have been developed to locally measure soil moisture such as gravimetric, time domain reflectometry (TDR) and frequency domain reflectometry (FDR). However, they have a low spatial representation and cannot capture soil moisture distribution across broader regions.

Advancements in EO technology aim to improve these field measurements, allowing for **monitoring at enhanced temporal and spatial resolutions**, and at a significantly **reduced cost**. The Copernicus programme is leading the way in this domain. For example, the **EO4Infrastructure project** aimed to develop specific EO applications to support rail infrastructure planning and monitoring. In the project framework, SNCF, along with RFI and DB NETZE, have developed medium resolution change detection maps that provide a weekly analysis of changes occurred over a specific land cover. Based on the monitoring of the Normalised Difference Water Index and fed into an update of the land cover map after a year of monitoring, it helped reduce the risk of damaged infrastructure, saving time and cost of labour-intensive manual ground measurements.

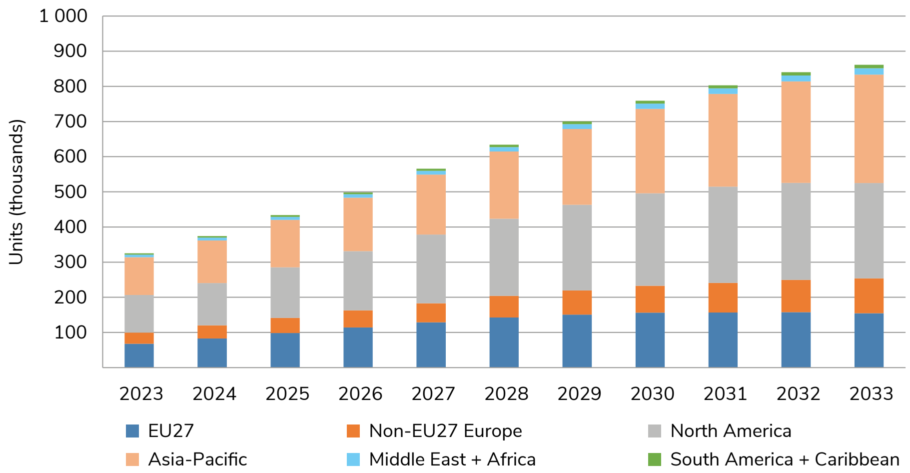

© Network Rail

Towards a EGNSS-based safety service

EUSPA is driving a roadmap towards the adoption of EGNSS in signalling applications. Recent EGNSS-R and IMPRESS mission studies contributed to close the gap of the technological readiness, by helping to define the European GNSS Navigation Safety Service for Rail. Starting with the identification of the operational requirements, then translated into a user-level integrity concept, the two studies covered an EGNSS-based safety service that enables continuous train localisation for safety-critical applications. Additional information about the project can be found at the following links for EGNSS-R and IMPRESS.

GNSS market is growing with the development of non-safety and safety applications

Shipments of GNSS devices by region



The global number of shipments of GNSS rail receivers is expected to **rise from more than 300 000 units in 2023 to over 850 000 in 2033**, mostly driven by the further growth of asset management solutions, which will account for the vast majority of shipments. Beyond asset management applications, driver advisory systems are expected to grow in the coming years, and account for most of the remailing market together with enhanced command and control systems and passenger information systems.

From a regional perspective, these shipments are mainly driven by **North America and Asia-Pacific** (each owning one third of the market) with **EU27** being the third with a share of about 20%. This trend is supported by the expected ambitious expansion and digitalisation of railway networks in these regions.

By 2033, Asia-Pacific is expected to increase its share to 35%, slowly increasing its relative share vis-a-vis **North America and EU27. Asia-Pacific** is forecast to reach sales of more than 300,000 units.

Despite only accounting for a marginal share of global shipments, **Africa and the Middle East** together with **South America and the Caribbean** are expected to triple their annual shipments of GNSS receivers. However, this last trend highlights the structural divide of rail development across the globe.

From trackside centric to train centric signalling

Since 2012, EUSPA has supported the railway industry, infrastructure managers and railway undertakings to adopt **EGNSS** and **EGNOS** for complex signalling applications, as well as integrating GNSS within the evolution of **European Rail Traffic Management System (ERTMS)**.

In the past few years, the **European Railway Agency (ERA)** has recognised the train-borne localisation function based on satellite positioning as a game changer, while the European Parliament in its recently adopted resolution on railway safety and signalling from July 2021 called for a joint effort towards the introduction of GNSS in the **ERTMS**, based on the anticipation that allowing a shift of the localisation function from trackside to on-board will result in a deployment and maintenance cost reduction, as well as in a faster ERTMS roll-out and enhancing of the ERTMS competitiveness outside the EU.

Different architectures are planned to be further demonstrated in an ERTMS context in the **FA2 programme** from Europe's rail and the **R2DATO** project. GNSS will also be part of the development of alternative innovative solutions needed to revitalise capillary lines and regional rail services. These solutions, developed in the **FP6 FUTURE** project, will feed passenger and freight traffic for the main/core network, ensuring the link to other public transport services and to first and last mile services.

More information available at:
https://projects.rail-research.europa.eu/eurail-fp6/

FP6-FutuRe
Cost effective regional lines

The role of EGNOS in the development of a common architecture for GNSS based solutions in signaling

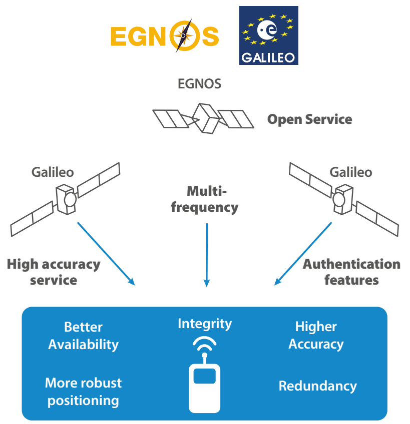
Through different programs funded by EUSPA, ESA, and notably Europe's Rail, **GNSS-based localisation units** are under development, relying on the use of multiple sensors such as IMUs, digital maps or odometers. These units will take advantage of tailored GNSS services for railway safety-relevant applications, which are currently being defined.

The development of the architecture is progressing well in terms of design, test and evaluation. The success of the demonstrations, scheduled in the coming years in the frame of the **Europe's Rail program**, is a prerequisite for GNSS inclusion within the future evolution of ERTMS.

EGNOS was therefore pointed out as critical for the success of the demonstrations – the rail sector is now expecting from the space programme the delivery of an experimental EGNOS service for rail to enable a large scale demonstrator at the horizon of 2025 in Europe's rail activities.

The **EGNOS for rail demonstrator**, whose development activities shall start shortly, will be designed on the basis of the rail sector needs, with the underlying integrity concept relying on EGNSS integrity services at pseudo-range level and additional specific GNSS integrity parameters required by the usage of Kalman filtering, errors models and Fault Detection and Exclusion models.

Railway stakeholders are ready to integrate EGNSS in a wide selection of applications



EGNOS for RAIL

Thanks to the engagement of the railway undertakings, infrastructure managers and railway industry, progress has been achieved in defining the requirements for a potential EGNOS service in the rail sector. These advances may enable the EU Space Programme to create a new service that meets the specific safety requirements of the railways.

A demonstration of achievable performances, relying on **EGNOS**, enabling **train localisation** for **safety-critical applications** needs to be subsequently carried out within the framework of Europe's rail second phase to facilitate further adoption of satellite-based localisation in ERTMS.

Possible future applications of OSNMA and HAS

Galileo OSNMA is a service supporting navigation message authentication function provided for Galileo OS signals, ensuring that the information received is authentic and has not been tampered with – i.e., it comes from Galileo satellites and has not been modified in any way. This can be particularly useful in the rail sector for applications such as public transportation ticketing and critical functions like e-logistics, which require protection against spoofing.

Galileo HAS will offer real-time improved user positioning performances with a horizontal accuracy at decimeter level. Several rail related applications can benefit from Galileo HAS, more specifically applications linked to the rolling stock like asset management. Galileo HAS could support for example odometer calibration, shunting operations or applications related to the rail infrastructure monitoring and condition-based maintenance, such as infrastructure surveying including gauging surveys.

HORIZON 2020 CLUG RAILGAP

EUSPA supports research and innovation through H2020 and Horizon Europe grants to reach readiness of EGNSS integration in rail

The European Union has positioned rail as the backbone of people and goods transportation in the Union. The EU Space Programme and its components support rail operations and increase passenger safety. The **CLUG Project** (2019-2023) assessed the design of a "Certifiable Localisation Unit with GNSS in the railway environment", a failsafe on-board multi-sensor localisation unit using GNSS and EGNOS that will be interoperable across the entire European railway network. A follow-up project, **CLUG 2.0**, is ongoing to advance the development of the solution and to achieve a reliable demonstration of performance.

More information available at: https://clugproject.eu/ and https://www.clug2.eu/

The **RAILGAP** project (2020-2024) contributes to the roadmap for the application of new technologies in railway systems, developing methodologies and tools, for the evaluation and assessment of new, or enhanced, on-board signalling systems. These comprise a **Ground Truth and a Digital Map** which are not yet available with the required quality and performance attributes.

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

EUSPA European Union Agency for the Space Programme — Fundamental Elements — GALITS

Two EUSPA Fundamental Elements projects support the development of rail-compatible receivers

The **TREN**I project, led by Thales Alenia Space, is developing a railway GNSS receiver and antenna (TRL7) for use within a safe train positioning platform. The Galileo-based solution intends to be robust and capable of identifying failures, detect and mitigate interferences and spoofing.

More information available at: https://it.linkedin.com/in/treni-project

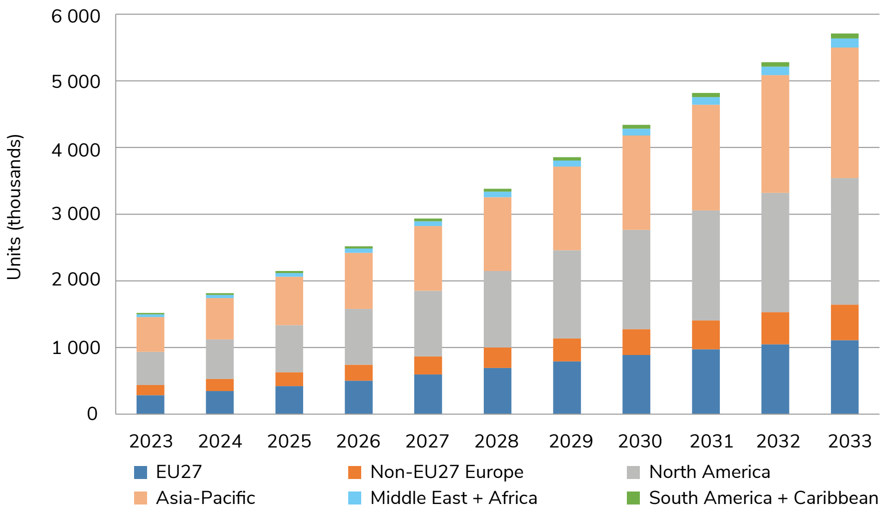
GALITS (GAlileo Localisation In Train Signalling), led by Qascom, is developing an innovative, flexible and customisable GNSS receiver and antenna. It intends to provide a cost-efficient solution for the train control system integrators.

Both consortia develop a **DFMC GNSS** receiver for safety-related railway applications designed to be integrated with additional sensors and compatible with on-board train control systems for various applications (i.e. the Virtual Balise concept for ERTMS, and absolute train positioning).

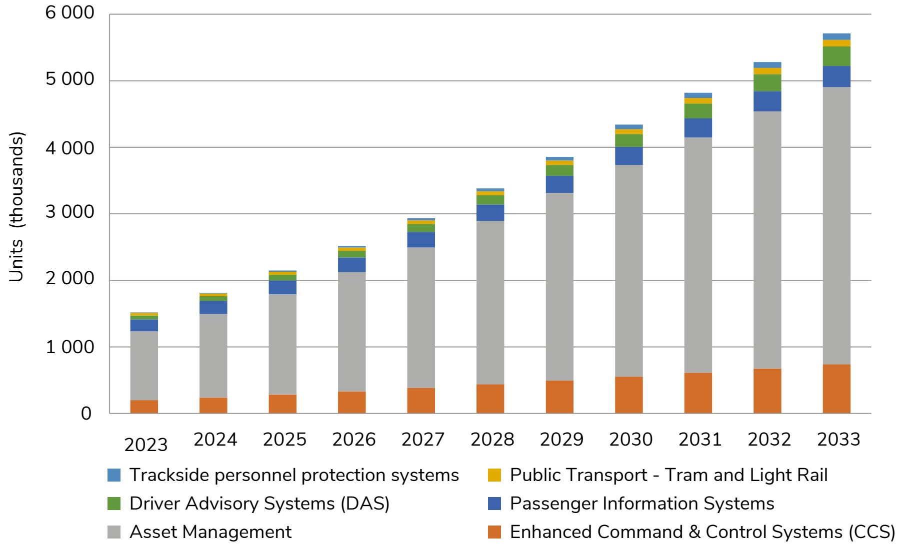
More information available at:
http://www.radiolabs.it/en/galits/

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

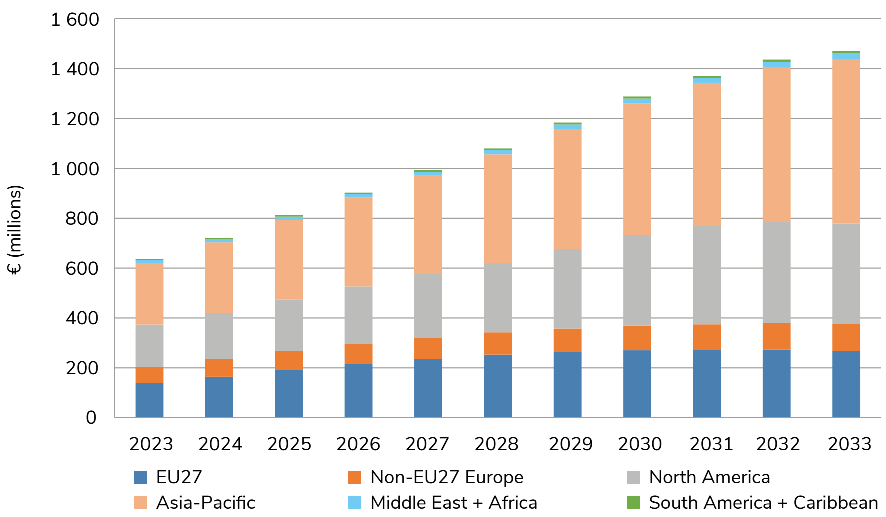
Installed base of GNSS devices by region



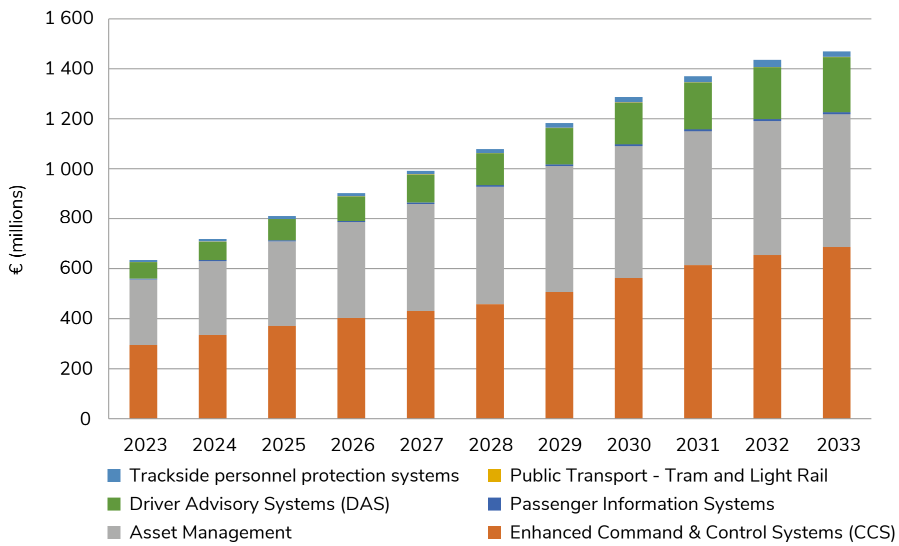
Installed base of GNSS devices sales by application



Revenue from GNSS device sales by region



Revenue from GNSS device sales by application



ROAD AND AUTOMOTIVE

Legend

EO application

GNSS application

Synergetic application (combined use of EO and GNSS)

Asset management

- Bike sharing
- Public transport - buses
- Road asset management[1]

Liability and enforcement

- Insurance telematics
- Road User Charging (RUC)
- Smart tachograph

Safety related

- Connected and Automated Driving (CAD)[2]
- Emergency assistance

Smart mobility

- Congestion control
- Infotainment services
- Navigation (IVS & PND)[3]

[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] Portable navigation devices (PNDs) and in-vehicle systems (IVS) built in cars support turn-by-turn navigation. Moreover, IVS support any location-based inputs for Advanced Driver Assistance Systems (ADAS) (SAE levels 2 and 3).

Application descriptions can be found in Annex 3

ROAD AND AUTOMOTIVE

Transport and mobility play a key role in today's world. The road and automotive market segment encompasses services and products involving not only the automotive industry, but also a range of service providers connected to mobility, logistics and the road transport network.

GNSS is used widely in roads across multiple applications. The GNSS applications can be categorised as safety related, where positioning information is used either to support safety-critical operations (e.g. connected and automated cars) or to support emergency assistance services such as eCall, liability and enforcement related (such as road user charging, smart tachographs), and asset management, where GNSS positioning is used to manage several types of vehicle assets and related operations.

In smart mobility applications, both GNSS and satellite imagery contribute to making mobility smarter, greener and more efficient thanks not only to navigation services for drivers, but also the collection and distribution of traffic information and the provision of contextual information to improve the driving experience.

The relevance of space for transport infrastructure: one of the enablers of mobility, transport and logistics is the transport infrastructure where space-based technologies have a role to play. GNSS empowers a range of different traffic management services, while EO supports the planning, design, construction and monitoring of the road infrastructure. This application is covered and quantified in the infrastructure segment. Go to page 123 for more information.

The role of HD maps: HD Maps represent an enabler for connected and automated driving, as they provide detailed information on the environment, necessary for determining driving instructions to automated vehicles. HD maps are a relevant space-enabled application because the basic layer of HD maps is derived from satellite imagery. Moreover, GNSS (absolute) positioning is used to locate the vehicle in such maps. In this edition of the Market Report, players active in HD maps are included in the analysis, but the application is not quantified.

What you can read in this chapter

- **Key trends:** The automotive industry recovers, urban mobility and automation push GNSS.
- **User perspective:** Users need performance, safety and security while keeping costs under control.
- **Industry:** Road and automotive value chains.
- **Recent developments:** In-vehicle systems, insurance telematics and emergency assistance pushed GNSS growth.
- **Future market evolution:** Growing automotive market, automation and smart mobility will boost GNSS sales.
- **European systems and projects:** HAS and OSNMA support more safe and secure road transport.
- **Reference charts:** Yearly evolution of installed base of GNSS devices and revenues as well as EO revenues by application and region.

The automotive industry recovers, urban mobility and automation push GNSS

Key market trends

- The automotive industry evolves in many directions to meet the demand for safer and more sustainable mobility and transport
- A range of micromobility solutions now complements traditional mobility and fuels Mobility-as-a-Service business models, enabled by GNSS for both user navigation and asset management
- Level 3 automated vehicles appeared at national level, while European safety regulations keep evolving, paving the way for level 4 automation

The automotive industry is rapidly evolving to meet the safety and sustainability challenges faced by transport and mobility

The automotive industry, after experiencing the disruptions to supply chains due to the COVID-19 pandemic, is undergoing a restart. Even though geopolitical issues and shortages in the supply of the rare materials used in the semiconductors still affect the industry, all major car-producing **European nations booked year-on-year growth** in production in 2022. The industry's focus on **electrification** is more significant than ever, driving innovations in electric vehicle manufacturing.

Smart cities are embracing this wave of change, **investing heavily in connected multimodality and electric infrastructure** to manage these new forms of transport and promote seamless, sustainable travel experiences. This revolution **in urban mobility** is being fundamentally shaped by green deal efforts and traffic optimisation objectives, leading to a seismic shift in the ownership paradigm.

The emphasis on sustainability and efficiency has given rise to **new business models** such as Mobility-as-a-Service (MaaS), Logistics-as-a-Service (LaaS), and Transportation-as-a-Service (TaaS), creating a **shared, integrated and on-demand ecosystem for urban transport and mobility.**

The efforts of the industry and the features of new models launched on the market show that there is an undeniable momentum in the **development** of **vehicle connectivity and automation**, also **supported by the progress of legislation**, which recognises the potential of connected, cooperative and automated mobility for increased safety and – combined with electrification – higher sustainability. Together, these transformations are shaping the future of automotive, directing us towards a safer, greener, and more integrated mobility and transport landscape.

Shared rides and electric micro mobility changing the future of urban transit and uptake of GNSS tech

Cities worldwide are actively addressing the issues stemming from the movement of people and goods, caused by increased urbanisation and concentration of people and economic activities in cities.

Novel mobility options are **helping cities** to become **more liveable and greener**. Micromobility solutions, such as scooters and e-bikes, as well as ridesharing, **have been gaining traction**. Their uptake will reduce CO_2 emissions, due to the lower number of vehicles on the roads, thanks to fleet pooling, as well as the smaller average vehicle size.

In turn, the **uptake of these** novel **solutions boosts** the market for **asset management services** that are required to manage and monitor the assets. Moreover, micromobility, combined with car sharing as well as traditional public transport solutions, represents the mobility building blocks of MaaS platforms. **In MaaS, GNSS represents an enabler on both sides of the business model**, i.e. the user and the vehicle.

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Level 3 automation just appeared at national level….

Based on the classification system defined by SAE (SAE J3016), the achievement of **the third level of automation marks a substantial technological jump** in the path to full automation of driving. From level 3 (L3) onwards, you are not driving – the system will.

The **necessary conditions to allow** the first operations of **L3** at national level **have been achieved**. In May 2022, Mercedes-Benz became the world's first manufacturer to obtain the certification by the German transport authorities for legal operation of its L3 Drive Pilot on the country's public roads. This was followed by a later announcement for certification of L3 use in the US State of Nevada.

….While European safety regulations lead the way for level 4 automation

On 15 September 2022, a milestone in automated vehicle regulation was reached with the **Commission Implementing Regulation 2022/1426**. The provision of procedures and technical specifications for the type approval of the automated driving system (ADS) of fully automated vehicles in the EU is a fundamental enabler for the deployment of L4 automation.

While this regulation is applicable to small series production, the EU aims to develop requirements for whole vehicle type approval of fully automated vehicles produced in unlimited series by July 2024.

The scope of the regulation **shows use cases that will benefit from using GNSS**, including fully automated vehicles and hub-to-hub for predefined routes.

Users need performance, safety and security while keeping costs under control

Road positioning applications to benefit from improved signal security

Road applications such as road user charging, smart tachograph, insurance telematics, asset management and automated driving all **need to ensure position security**, either to prevent frauds or to preserve the robustness of safety-of-life operations. Among potential threats, **spoofing** is a **sophisticated form of** interfering with and **falsifying satellite navigation signals**.

Authenticating the satellite navigation signals and data **can assure** the receiving **users** that **the signal is** coming from a **trusted** source and is correct.

The forthcoming Galileo Open Service – Navigation Message Authentication **(OSNMA)** is an **authentication mechanism** that **allows users** of the Open Service **to ascertain the validity of GNSS data**, thereby ensuring that the information they receive is genuinely from Galileo and remains unaltered in any form.

Receiver manufacturers have already started implementing OSNMA anti-spoofing security in their high-precision receivers ready for mass market in road applications.

Sources of key EO and GNSS user requirements

The key EO and GNSS user requirements for the different application groups within the **road and automotive** segment are collected using a harmonised procedure at EU level.

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 Road and Automotive and Public Transport. User requirements for Earth Observation (EO) services and products – as well as their evolution – are now also collected through the UCP. The process covers the EO user needs and requirements of commercial users based on inputs from industry experts and user groups, mirroring the existing process implemented for GNSS. EO requirements are covered starting from the 2024 issue of the Road and Automotive report.

Moreover, the collection of specific requirements for Copernicus services and products is supported by 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.

Performance requirements of automated vehicles drive the evolution of robust high precision services for automotive

With the advent of automated driving, **automakers are increasingly dependent on precise and high-performance positioning** technologies. Automated vehicles need to rely on instant, robust and accurate positioning (up to decimetre level), available at all times and **in all operational environments**.

To achieve this, the architecture of **positioning engines of vehicles** is based on the **data fusion paradigm** – inputs from inertial measurement units (IMUs), and sensors such as cameras, radar and LiDAR are used. Among the different sensors, GNSS enables, thanks to absolute positioning, ubiquitous and accurate contextual awareness within the road network.

The need for high accuracy and availability has **created a market need for novel correction services** offering up to centimetre-level accuracy and wide coverage and availability. Moreover, driven by user needs, captured in the safety-related requirements of the automated driving standards (e.g. ISO 26262), **the industry has also started to offer integrity** as part of their PVT solutions.

Finally, the importance of GNSS positioning is being leveraged by key industry players to **challenge the traditional paradigm of the industry**. Whereas GNSS players have historically covered the role of Tier 2 suppliers, they are now signing strategic partnerships directly with OEMs.

Road infrastructure planning, construction and monitoring facilitated by Earth Observation

Monitoring of road network and adjacent areas is essential along the whole infrastructure lifecycle – from **site selection, design, planning, construction to operation and maintenance**. Geohydrological conditions and hazards are monitored and forecasted for **tactical construction** and **maintenance decisions.** Decadal climate forecasts are needed to design resilient infrastructure with just the right performance and safety margins so as not to waste resources limit the impact on climate.

Earth Observation offers a **viable and effective solution**. In particular, the use of **SAR** images from EO satellites to support **SAR interferometry (InSAR)** techniques, **allows potential risks** connected to ground instability, landslides, subsidence, and deformation of road surfaces to be identified.

Copernicus has a significant role: data from **Sentinel-1**, together with other satellite imagery and data from other sensors, is used by service providers to **support solutions offering regular monitoring, alert services as well as decision-making support systems** to various stakeholders, including road authorities and operators, civil protection agencies and maintenance teams.

Thanks to EO-based services, the **final users are** then **able to assess the present exposure of assets to climate risks**, as well as the **expected exposure evolution**. It is the case of the the Italian Road Authority, ANAS, which uses EO services for ground displacement assessment during road design and construction, as well as for the regular monitoring of bridges and viaducts.

Road and Automotive GNSS Value Chain[1]

System Integrators

GNSS | **COMPONENTS AND RECEIVER MANUFACTURERS** | **TIER 1 SUPPLIERS** | **VEHICLE MANUFACTURERS** | **AFTERMARKET AND DEVICE VENDORS** / **SERVICE PROVIDERS** | **USERS**

COMPONENTS AND RECEIVER MANUFACTURERS

- AISIN
- AVAGO TECHNOLOGIES
- BEIJING BDSTAR NAVIGATION
- CADENCE DESIGN SYSTEMS
- FURUNO
- GARMIN
- HEXAGON*
- HITACHI
- HIRSCHMANN*
- JAPAN RADIO CO.
- KATHREIN-WERKE*
- LAIRD*
- MEDIATEK
- NIHON DEMPA KOGYO
- NUVOTON TECHNOLOGY
- NXP SEMICONDUCTORS*
- ORBCOMM
- QUALCOMM
- SIERRA WIRELESS
- STMICROELECTRONICS*
- TE CONNECTIVITY*
- TRIMBLE NAVIGATION
- U-BLOX*
- YAGEO
- ZHEIJANG JC

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*
- CHANGAN GROUP
- CHERY
- DAIMLER*
- DONGFENG
- FAW GROUP
- FORD
- GEELY
- GM
- GREAT WALL
- HONDA
- HYUNDAI
- MAZDA MOTOR
- NISSAN
- RENAULT*
- SAIC MOTOR
- SUBARU
- STELLANTIS*
- SUZUKI
- TATA MOTORS
- TESLA
- TOYOTA
- VOLKSWAGEN*

AFTERMARKET AND DEVICE VENDORS

- GARMIN
- MAGNETI MARELLI*
- MICHELIN (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 PROVIDERS**
- U-BLOX*, HEXAGON*, SWIFT, TOPCON, TRIMBLE
- **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 ST Microelectronics, u-Blox and Hexagon, European companies hold three of the five top spots of the components & receiver manufacturers market, where Europe is the main player with around 40% of the global market.

When it comes to system integrators, Europe accounts for over a third of global revenues. Bosch, Continental and Valeo are global leaders in the Tier 1 segment of the industry, while Volkswagen, Stellantis, Daimler, BMW and Renault represent the largest players of the global OEM arena.

LEGEND

- Commercial offering
- Public offering / entities
- 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.

Please refer to page 23 for a comprehensive description of the GNSS value chain and how to interpret them at segment level.
* European-based companies. The region is defined with respect to the headquarters of the company, though the actual area of activity might be wider.

Road and Automotive EO Value Chain[1]

EARTH OBSERVATION

DATA PROVIDERS

- AIRBUS*
- BLACKSKY
- CAPELLA SPACE
- CGSTL
- GEOSAT*
- E-GEOS*
- ICEYE*
- MAXAR
- PLANET
- SATELLOGIC
- UMBRA

MAP PROVIDERS:
APPLE, GOOGLE, MAPQUEST, MICROSOFT, OPENSTREETMAP*, OVERTURE MAPS*

HD MAP PROVIDERS:
GARMIN, HERE*, NAVINFO, NVIDIA, TOMTOM*

- ALOS-2 (JAXA)
- COPERNICUS SENTINELS*
- COSMO-SKYMED (ASI)*
- RADARSAT (CSA)
- RELEVANT IN-SITU NETWORKS
- OTHER RELEVANT EUROPEAN NATIONAL MISSIONS

INFRASTRUCTURE PROVIDERS

- AWS
- CLOUDFERRO*
- GOOGLE CLOUD PLATFORM
- IBM CLOUD
- MICROSOFT AZURE
- T-SYSTEMS*

- FEDERATED INFRASTRUCTURE (E.G. GAIA-X)*
- SENTINEL COLLABORATIVE GROUND SEGMENT*

PLATFORM PROVIDERS

- CLOUDEO*
- CREODIAS*
- DESCARTES LABS
- EARTH-I
- EURODATACUBE*
- GOOGLE EARTH ENGINE
- NORTH.IO*
- OPEN DATA CUBE
- OPENEO*
- PLANET EXPLORER
- SENTINEL-HUB* (SINERGISE)
- UP42*

- WEKEO*

EO PRODUCTS AND SERVICE PROVIDERS

- AFRY POYRY*
- AIRBUS*
- AVINEON*
- BEIJING DIGSUR SCIENCE AND TECHNOLOGY CO.
- DETEKTIA*
- E-GEOS*
- GAF*
- GEOFEM*
- MAXAR
- PLANETEK*
- SATSENSE*
- SPOTLITE*
- SNC-LAVALIN
- TRE ALTAMIRA*

- COPERNICUS ATMOSPHERE MONITORING SERVICE (CAMS)*
- COPERNICUS LAND MONITORING SERVICE (CLMS)*

INFORMATION PROVIDERS

- 1SPATIAL*
- ACCUWEATHER
- AFRY POYRY*
- ATKINSRÉALIS
- ZERO GRAVITY*

END USERS

- CAR OWNERS
- COMMERCIAL VEHICLES DRIVERS
- ENFORCERS
- FLEET OPERATORS
- FERROVIAL
- INSURANCE COMPANIES
- MEMBER STATES
- PRODUCERS OF INFOTAINMENT SYSTEMS
- ROAD NETWORK OPERATORS

European[2] EO industry in the global arena

In 2021, whilst North America remains in a leading position with about two-thirds of the global shares, Europe makes up almost 30% of the global market. The dominating European company remains Leonardo (e-GEOS), followed by Airbus and Avineon.

LEGEND

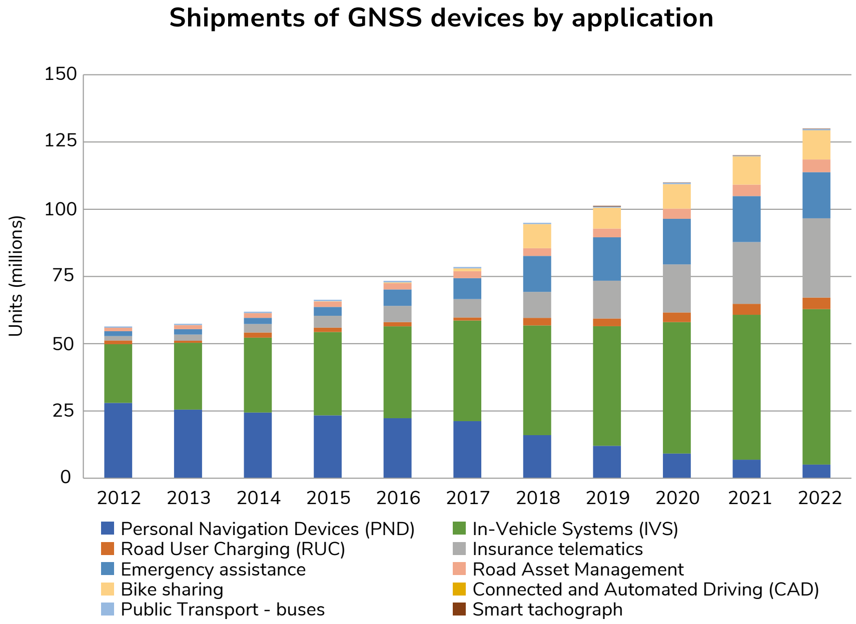
- Commercial offering
- Public offering / entities
- User segments

NOTES

[1] The value chain considers the key global and European companies involved in EO downstream activities. Please note that enterprises listed in the data providers step of the value chain often provide platforms as a service. For the sake of simplicity the data providers are not repeated in other stages of the value chain in which they are active.
[2] In the market share analysis, Europe is defined as EU27 plus Norway, Switzerland and the UK.

Please refer to page 13 for a comprehensive description of the EO value chain and how to interpret them at segment level.
* European-based companies. The region is defined with respect to the headquarters of the company, though the actual area of activity might be wider.

In-vehicle systems, insurance telematics and emergency assistance pushed GNSS growth



Following an overall stable phase in the first half of the 2010's, caused by the maturity of different applications and the decline of PNDs, the market entered a period of sustained growth, driven by the uptake of in-vehicle systems (IVS), insurance telematics and emergency assistance.

The **growth of IVS has first compensated the decline of PNDs and then boosted GNSS market uptake**, as automakers converged towards a trend of considering GNSS capabilities on a serial basis essential for embedding various services and applications, through the centralisation of the positioning function in the built-positioning engine of the vehicle. Shipments of IVS grew from 22 million in 2012 to almost 60 million in 2022.

Insurance telematics has also been growing steadily over recent years. The period of the COVID-19 pandemic has seen a shift on the side of insurers from the usual underwriting models to pay-as-you-drive and pay-how-you-drive models. Moreover, while Europe and North America historically represent established markets, Asia-Pacific is driving further growth thanks to increased demand in India, China and Japan.

Finally, the surge of **emergency assistance**, driven by regulation in Europe and supported by voluntary schemes worldwide, has led the market for the application to surge from 1.8 to 17 million units per year.

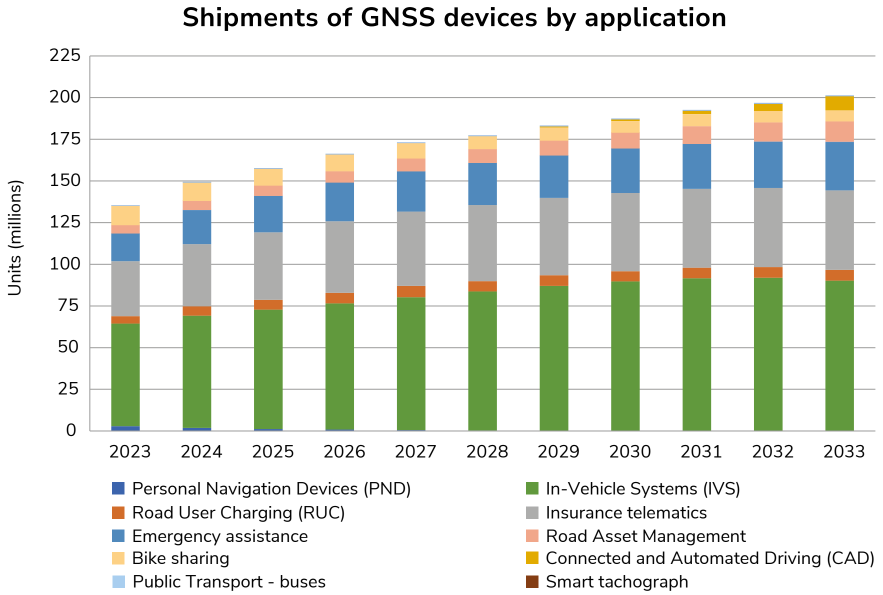
OEMs progress on automated driving

The **advent of automation is gradually materialising**, thanks to the **progress of vehicle technology** (including positioning and navigation), **standards**, the **development of legislation** (mandates for ADAS in the European legislations that include intelligent speed assistance) and the **deployment** of the necessary **infrastructure** (connectivity, correction services, road network).

Several **OEMs already launched** vehicles with **L2+ advanced driver assistance capabilities** and many more are expected to in the short term. L2+ systems let drivers to take their hands off the wheel for periods defined by local laws – often for several seconds.

Mercedes-Benz became the first OEM with L3 cars to receive approval by the German transport authority to legally drive on Germany's national roads as well as in one US state. BMW announced in 2023 that it will bring its L3 self-driving system into one of their models in the spring of 2024 and Stellantis is set to start rolling out Level 3 automated driving by 2024. It is expected that other OEMs such as Ford, Hyundai-Kia, GM, and Honda, will follow suit in the coming years – **deployment schemes are shaping**, with the 2025 timeframe expected to be an inflection point for L3 deployment in a variety of production models.

Growing automotive market, automation and smart mobility will boost GNSS sales



Progress in standards at European and ISO level paves the way for the uptake of space-enabled solutions

A range of different standardisation initiatives is contributing to the introduction of space-enabled technologies in road. As a selected example, ISO 26262 covers functional safety for autonomous vehicles, including a risk classification scheme (ASIL) to be complied by all components, including GNSS. **At European level**, the CEN CENELEC series of standards EN16803 addresses the use of GNSS technology for road Intelligent Transport Systems (ITS). Part 1 of the series defined the metrics for performance measurement, while part 2 and 3 started addressing the performance of the positioning terminals. Beyond this, additional efforts are taking place: the work on part 4 of EN16803 will complete the series by defining the procedures for the design and validation of test scenarios for performance measurement.

At international level, within ISO/TC20/SC14, a dedicated WG (WG8 - Downstream space services and space-based applications) was established to cover downstream standards. The scope of activities includes PNT/GNSS and Earth Observation, including in the automotive domain.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The future outlook of GNSS shipments in Road is positive and will be driven both by the growth of automotive sales and by the increasing uptake of applications.

The automotive market is expected to enjoy a long-term growth trend thanks to a **number of factors, including the increasing demand for personal and commercial vehicles worldwide** (in particular in Asia-Pacific), the **increasing maturity** of the new paradigms of **electrification and automation**, as well as the **higher awareness** among consumers **of safety and environmental aspects**.

As well as driving the automotive market, **these factors will expand the market of GNSS applications**. The **increasing demand for vehicles** will **drive the further growth of IVS**, which will soon become a common feature of new vehicles, to support all the positioning-based services and features offered by OEMs.

The **rise of automation**, coupled with the evolution of legislation and standards, will **create a market for CAD**, which will allow cars and their passengers to benefit from autonomous driving features (SAE level 4 and 5), while **increased awareness of safety** aspects will boost the demand for services such as emergency assistance, which will reach almost 30 million units per annum by 2033.

Finally, the **increased sensitivity of consumers to environmental issues** will further **support the rise of mobility business models** based on the service (e.g. MaaS) and sharing dimensions (e.g. car and bike sharing). These, in turn, will drive the need of **asset management solutions** by mobility providers and transport operators, with the application increasing to almost 15 million shipments in 2033, more than double the number of sales in 2023.

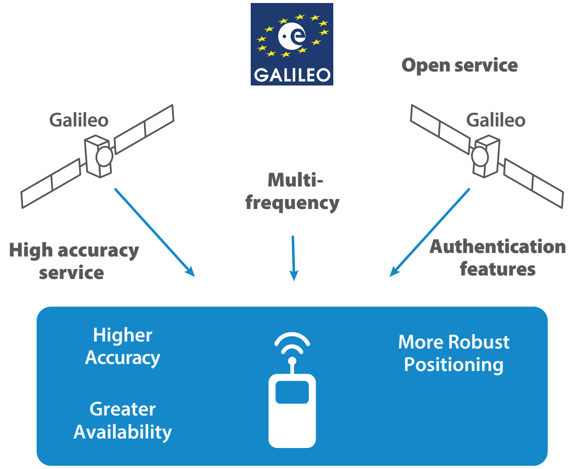
ITS Directive revision approved in October 2023 set to pave the way for Galileo and Copernicus in ITS

The ITS Directive (2010/40/EU) represents a "**toolbox directive**" to **harmonise** and **accelerate** the **adoption of ITS** (Intelligent Transport Systems) **in the EU**. The revision of the ITS Directive, adopted in October 2023, aims to **expand the initial scope to cover new challenges**, and **further promote the adoption of ITS services**. The revision also proposes to ensure the **compatibility of ITS services** relying on timing and positioning **with Galileo** navigation services (OS, OSNMA and HAS) **and EGNOS**, and to **ensure that**, where appropriate, **ITS services relying on EO use Copernicus data**, information and services. Accordingly, the revised directive will support the adoption of European GNSS and Copernicus in ITS and the related benefits for ITS users.

The CCAM Partnership: defining connected, cooperative and automated mobility of tomorrow

Formalised in 2021 and co-funded by the EU, **the CCAM Partnership aligns all stakeholders**' R&I efforts to **accelerate** the **implementation of innovative CCAM technologies** and services **in Europe**, including space-based ones. It aims to **design a mobility system** that is **user-centric and inclusive**, to enhance road safety, to minimise congestion, and to reduce environmental impact by fostering collaborative research, conducting testing and initiating demonstration projects on a European scale. The **strategic research innovation agenda (SRIA)** set by the partnership for the 2021-2027 period can be accessed here.

HAS and OSNMA support more safe and secure road transport



Galileo Open Service and OSNMA

The **Galileo Open Service** is **widely adopted** in road and automotive. In addition to **improving accuracy**, Galileo offers, in a multi-constellation environment, **better performance** in operational scenarios such as urban canyons.

The Open Service Navigation Message Authentication **(OSNMA)** provides receivers with the assurance that the received Galileo navigation message is coming from the system itself and has not been modified.

For road applications, **OSNMA can bring benefits mainly in liability or safety critical applications** that need authentication of GNSS data, such as road user charging, smart tachograph, insurance telematics, asset management and connected and automated driving.

Galileo HAS

The **Galileo High Accuracy Service (HAS)** has received **significant attention from the automotive industry**, which sees the potential from positioning performances down to a decimetre level.

Industry players are already working on the **implementation of HAS** for **non-safety critical use cases** such as lane manual navigation, as well as V2X functionalities, requiring **accurate positioning**.

HAS could also be used to **support** the positioning **automated driving** functions, as long as the positioning solution leveraged by the vehicle also includes the necessary integrity.

Galileo Emergency Warning Satellite Service

Galileo's Emergency Warning Satellite Service (EWSS) is designed to globally broadcast emergency warnings linked to natural or man-made disasters to smartphones, depending on the area in which the user is located. It has the major advantage of remaining operational when all terrestrial communication networks are down. EWSS is expected to be operational (initial services) in 2025 upcoming years.

Recently, the Traveller Information Services Association (TISA) has progressed on the development of the TPEG protocol family, covering the broadcast of traffic and transport information to end users. The TPEG2 Emergency Alerts and Warnings (EAW) technology now supports the distribution of official Emergency Alerts and Warnings as issued by public authorities and/or authorised agencies, without language barriers. In the future, it could represent a relevant dissemination protocol for Galileo EWSS.

HORIZON 2020 ESRIUM

ESRIUM project – Safe and efficient roads

ESRIUM is an international project **fostering safer and more efficient road maps** to achieve a smarter, safer and greener transport system. The key innovation covered in the project was an **EGNSS-based digital map of road surface damage and road wear**, containing unique information for road operators to enhance road maintenance planning and to provide route recommendations to automated vehicles.

The project, which has **demonstrated the use of OSNMA**, forseees that the **ESRIUM solution** captures the **status of the road surface through sensors and EGNSS-based** localisation **devices**. This **information** is then **sent** to the **platform operator, which** integrates it into a digital map and **generates safety warnings**. Based on these safety warnings, **road operators** can **communicate with CAD drivers and truck fleet operators** to avoid safety risks and improve the use of the road network.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ACCURATE project

Fundamental Elements Accurate

The **ACCURATE** project had the objective of **developing a high-precision positioning automotive system** for enabling the development and deployment of complex **automated driving functions**. In the framework of the Accurate project, a EGNSS-based precise positioning OBU (On Board Unit) has been developed. The system relies on an advanced GNSS-based positioning unit for absolute positioning, enhanced with sensor fusion. The ACCURATE solution was successfully demonstrated in Prague in October 2022, in the presence of the Czech transport minister.

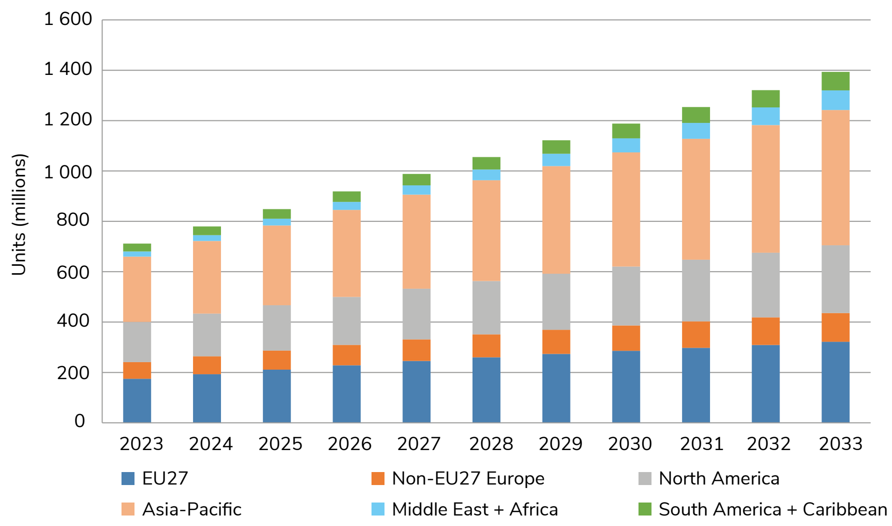
Additionally, ACCURATE focused on the processes required for EGNSS validation and certification, serving as a guideline for higher levels of automated driving.

Through this project, the **partners addressed market needs, gaining** invaluable **insights to inform their strategic directions**. The outcomes of the project, elevated the Technology Readiness Level (TRL) of **the products of the partners**, marking a **pivotal milestone** in their development. A further direct outcome was a noticeable increase in the visibility of the project partners within the market, together with an improved positioning in terms of addressing industry demands.

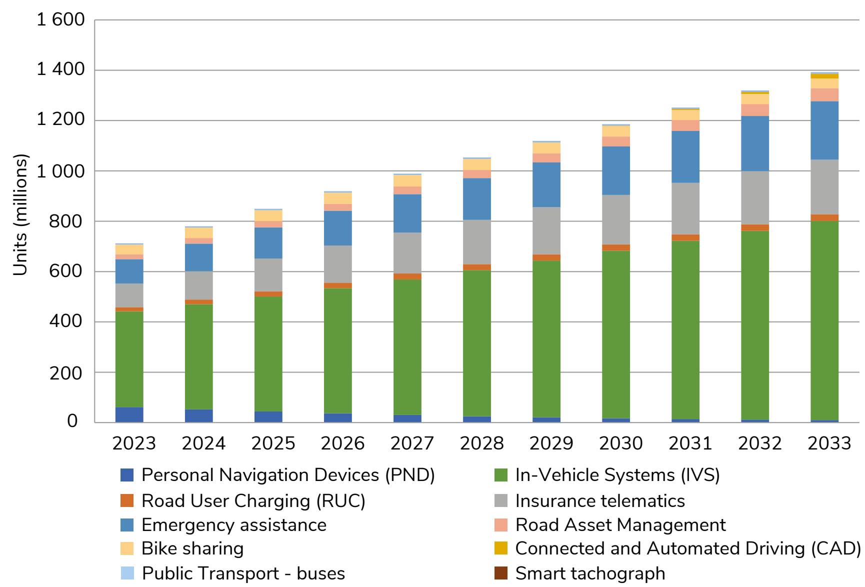
More information available at: https://www.accurate-obu.eu/about/

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

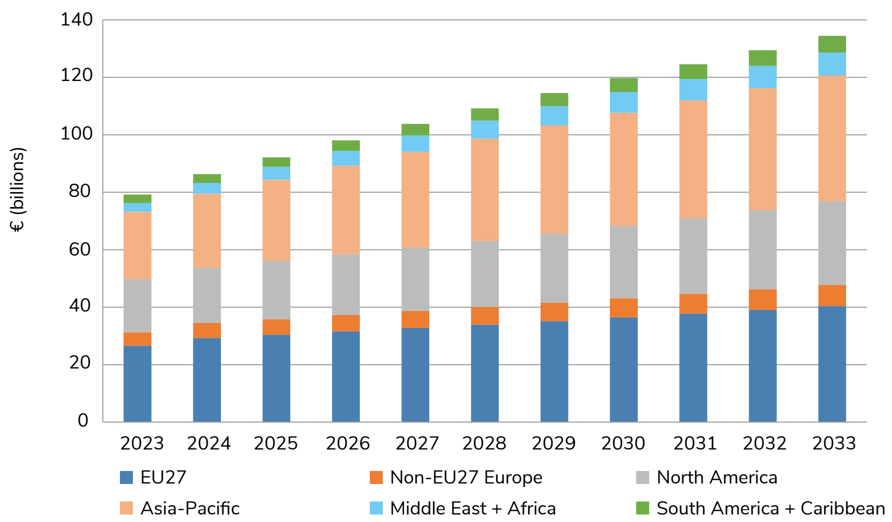
Installed base of GNSS devices by region



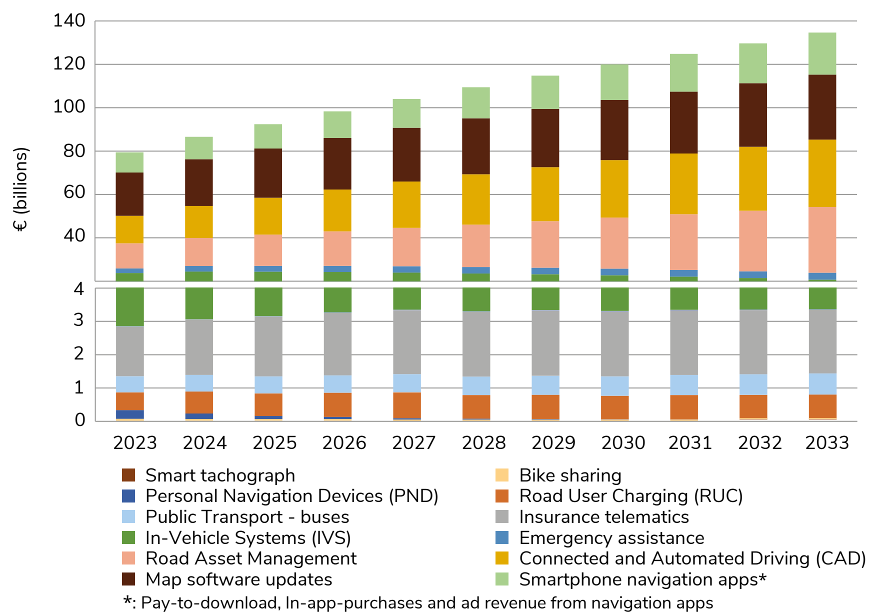
Installed base of GNSS devices by application

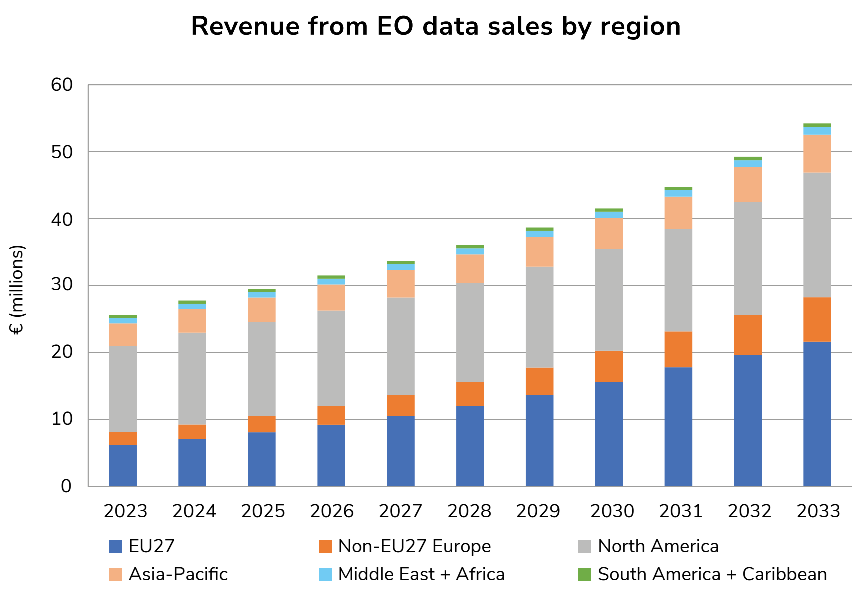


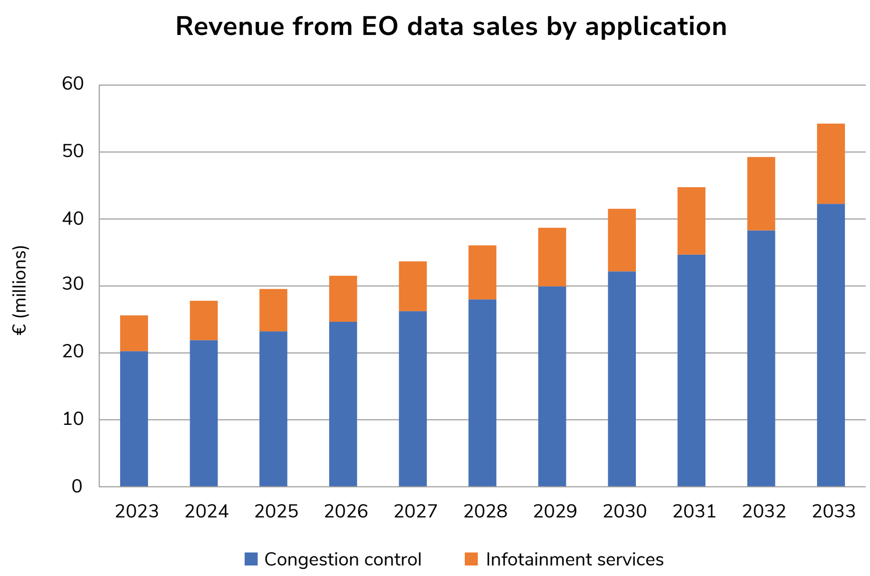
Revenue from GNSS device sales and services by region



Revenue from GNSS device sales and services by application




Revenue from EO data sales by region
€ (millions)
0
10
20
30
40
50
60
2023
2024
2025
2026
2027
2028
2029
2030
2031
2032
2033
EU27
Non-EU27 Europe
North America
Asia-Pacific
Middle East + Africa
South America + Caribbean


Revenue from EO data sales by application
€ (millions)
0
10
20
30
40
50
60
2023
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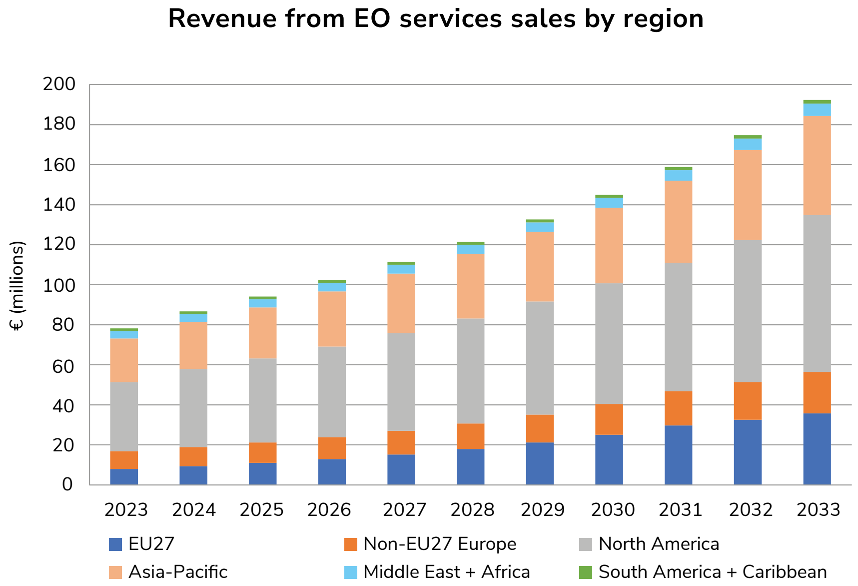
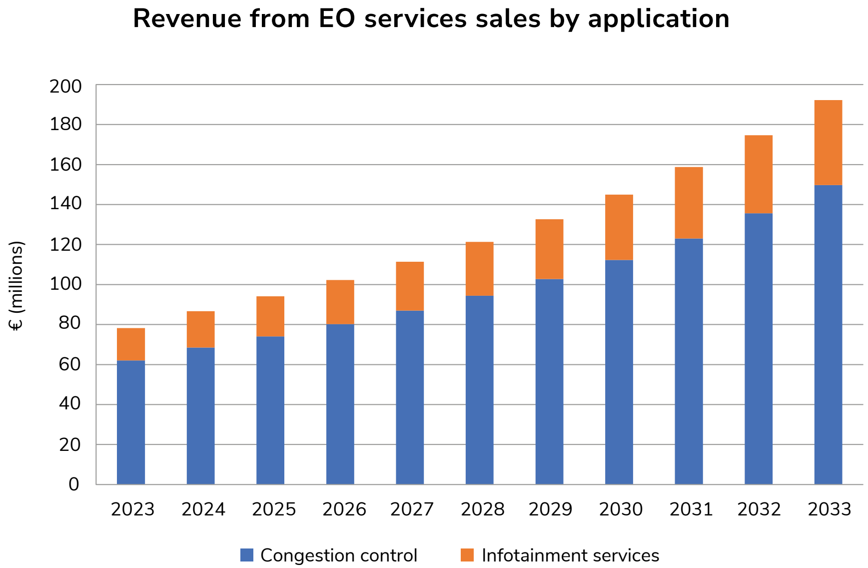
2029
2030
2031
2032
2033
Congestion control
Infotainment services


Revenue from EO services sales by region
€ (millions)
0
20
40
60
80
100
120
140
160
180
200
2023
2024
2025
2026
2027
2028
2029
2030
2031
2032
2033
EU27
Non-EU27 Europe
North America
Asia-Pacific
Middle East + Africa
South America + Caribbean


Revenue from EO services sales by application
€ (millions)
0
20
40
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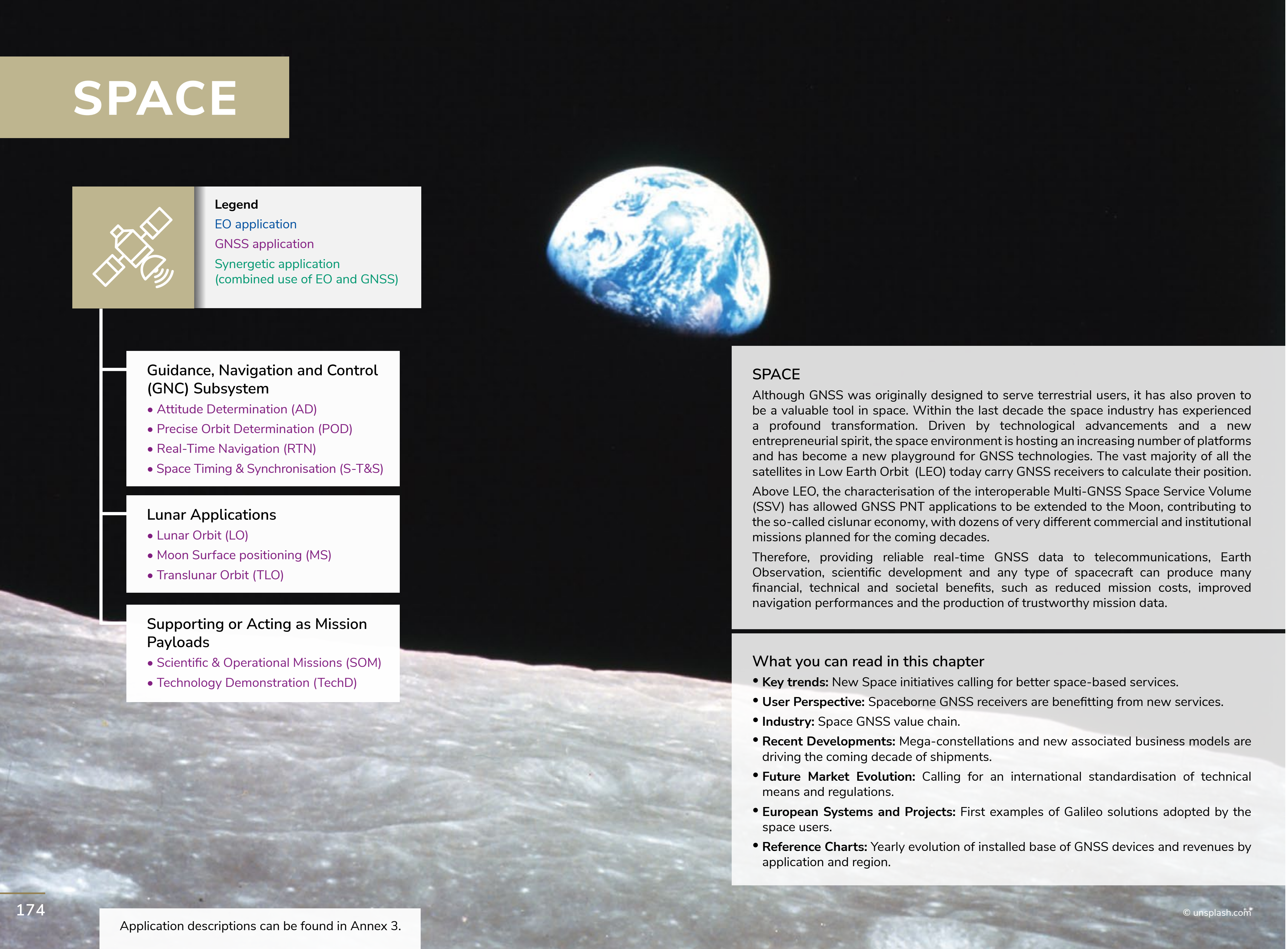
2032
2033
Congestion control
Infotainment services

SPACE



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

Guidance, Navigation and Control (GNC) Subsystem
- Attitude Determination (AD)
- Precise Orbit Determination (POD)
- Real-Time Navigation (RTN)
- Space Timing & Synchronisation (S-T&S)

Lunar Applications
- Lunar Orbit (LO)
- Moon Surface positioning (MS)
- Translunar Orbit (TLO)

Supporting or Acting as Mission Payloads
- Scientific & Operational Missions (SOM)
- Technology Demonstration (TechD)

SPACE

Although GNSS was originally designed to serve terrestrial users, it has also proven to be 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 hosting an increasing number of platforms and has become a new playground for GNSS technologies. The vast majority of all the satellites in Low Earth Orbit (LEO) today carry GNSS receivers to calculate their position.

Above LEO, the characterisation of the interoperable Multi-GNSS Space Service Volume (SSV) has allowed GNSS PNT applications to be extended to the Moon, contributing to the so-called cislunar economy, with dozens of very different commercial and institutional missions planned for the coming decades.

Therefore, providing reliable real-time GNSS data to telecommunications, Earth Observation, scientific development and any type of spacecraft can produce many financial, technical and societal benefits, such as reduced mission costs, improved navigation performances and the production of trustworthy mission data.

What you can read in this chapter

- **Key trends:** New Space initiatives calling for better space-based services.
- **User Perspective:** Spaceborne GNSS receivers are benefitting from new services.
- **Industry:** Space GNSS value chain.
- **Recent Developments:** Mega-constellations and new associated business models are driving the coming decade of shipments.
- **Future Market Evolution:** Calling for an international standardisation of technical means and regulations.
- **European Systems and Projects:** First examples of Galileo solutions adopted by the space users.
- **Reference Charts:** Yearly evolution of installed base of GNSS devices and revenues by application and region.

Application descriptions can be found in Annex 3.

New Space initiatives calling for better space-based services

Key market trends

- Mega-constellations in the Low Earth Orbit are already providing satellite-based and space data services, driven by New Space and the continuously increasing investment of the private sector
- Following the discovery back in 2018 of water ice in the polar regions of the Moon, over the coming years a growing roadmap of missions are planned to the Moon and beyond
- As space has become a critical domain for national security, governments are investing in increasing resilience and autonomy, particularly through Space Situational Awareness and secured communications
- Precise Orbit Determination of satellites is increasingly dependent on the use of GNSS, with Galileo being a major contributor thanks to the unrivalled quality of its services

Low-Earth Orbit Mega-constellations

The launch of Low Earth Orbits (LEO) mega-constellation projects has become a symbol of this new era, with new projects continuously arising to provide many types of space-based services.

In satellite communications and broadband applications, and driven by the needs of global coverage and low latency, **hundreds or even thousands of satellites** are being launched to compete with large GEO satellites. Pico-satellite (<1kg) constellations have already conducted In-Orbit Validation (IoV) for **Internet of Things (IoT) applications**, with use cases such as providing connectivity to monitoring sensor stations located in remote areas. Indeed, **small satellites accounted for about 95%** of spacecraft launched in 2022.

GNSS has a major role to play in this evolution, thanks to the financial and technical benefits it brings, including a reduction in the number of instruments, a reduced dependence on ground-based stations and improved navigation performances, as well as its applicability to both historical and emerging stakeholders. New business models based on a rapid prototyping, production and deployment of small satellites are today driving down the costs-to-orbit, particularly on LEO. In fact, LEO-PNT initiatives are also benefiting from the more agile New Space approach. There are several projects to set-up these constellations of smaller satellites, which will supplement GNSS ones and will bring new services and better resilience.

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-based European critical infrastructures

In 2022, EU identified space as a strategic domain in the Strategic Compass and called for an **EU Space Strategy for Security and Defence**, where EU is taking action to protect its space assets. The EU's new strategy marks a paradigm shift, aimed at bolstering EU resilience in and from space. The strategy proposes actions to strengthen the resilience and protection of space systems and services in the EU. The communication satellites such as those to be deployed as part of IRIS², the navigation satellites from Galileo and the Earth Observation Copernicus satellites are a core part of this context.

The Strategy proposes the launch of two pilots: one for the delivery of initial **Space Domain Awareness (SDA)** services building upon the capacities of Member States, and another for a new **Earth Observation governmental service** as part of the evolution of Copernicus, complementing existing assets.

The strategy also commits to better connect space, defence and security at EU level and ensure synergies and cross-fertilisation, notably in terms of research and development.

In this context, the EU SST Collision Avoidance service is already safeguarding Galileo's satellites and its services, while the Union Secure Connectivity Programme IRIS² should satisfy space sustainability criteria and be an example of good practice in Space Traffic Management (STM) and in SST, contributing to the reduction of the amount of space debris produced, and the prevention of on-orbit break-ups and on-orbit collisions.

To the Moon and beyond

The **space economy** has traditionally existed up to the geostationary (GEO) belt, comprising around 560 satellites currently operating. Below this belt, the GNSS constellations can be found in Medium Earth Orbit (MEO) and in Low Earth Orbit (LEO), where most of the Earth observation satellites operate, as well as a growing swarm of Cubesats, telecom constellations and the International Space Station.

However, interest in another segment of the space economy has grown significantly in recent years: **the cislunar economy** that is built up between the Earth and the Moon space. A key factor for this has been the demonstrated presence of iced water on the lunar south pole.

The international space community, led by UNOOSA, has already characterised the Multi-GNSS Space Service Volume (SSV), but **more efforts are being dedicated to extend GNSS PNT applications to the Moon**. Starting with the use of the already existing Earth-GNSS constellations via high-sensitivity space receivers, leveraging the use of GNSS signal side lobes, a new communications and navigation infrastructure is planned to be settled via **ESA's Moonlight initiative**, with dedicated lunar orbiting satellites and lunar beacon ranging sources for the benefit of lunar missions.

On the spacecraft side, the US launched the most powerful to date space vehicle in December 2022, the Space Launch System. Adopting this system, the **Artemis Missions will establish a long-term presence on the Moon**. The experience gained will be used to send the first crewed missions to Mars.

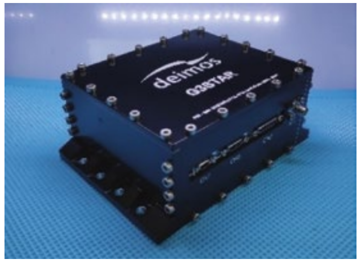
GNSS in support of space-based EO services

Precise Orbit Determination (POD) consists of the estimation of the position and velocity vectors of an orbiting spacecraft with the highest possible accuracy. POD has typically been performed on the ground, in **post-processing**, making use of the best available auxiliary data. Indeed, the evolution of POD to achieve the best results in terms of orbital accuracy has mostly been driven by EO mission requirements in LEO such as SAR, Altimetry, Radio Occultation and others.

More recently, the use of GNSS to determine POD has grown in importance and established itself as one of the common techniques to determine the trajectories of satellites in LEO.

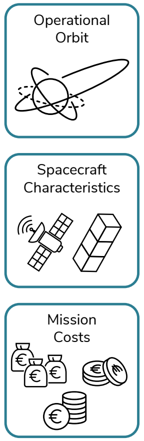
The broadcast of high-quality ephemeris by Galileo is expected to permit **real-time POD** with accuracies (3D RMS) below 15cm in LEO. Beyond that, the more recent declaration of the Galileo High Accuracy Service (HAS) in January 2023, as the first global in-orbit source of precise positioning data, will help achieve greater accuracy.

This free-of-charge capability fits well with the needs of the New Space community, as suggested by the typology of spaceborne GNSS HAS-capable receivers already on the market or under development.



Space GNSS HAS-enabled receiver
© Deimos

Spaceborne GNSS receivers are benefitting from new services



Operational drivers for the use of GNSS receivers onboard spacecraft

Although all space users operate in a similar environment – i.e. outer space – many variables come into play when identifying case-to-case GNSS requirements.

Depending on their mass, designed lifespan or mission type and costs **characteristics**, for example, **and the orbit** they are targeting, with variable geometrical constraints and GNSS signal availability, **spacecraft** are indeed **not expected to be equipped with the same kind of spaceborne GNSS receivers**.

At relatively low altitudes, between 3 000 and 8 000 km, GNSS receivers generally benefit from a good signal-in-space availability. By contrast, high-altitude orbits at 36 000 km and above are much more challenging as the receiver must cope with a significantly reduced GNSS signal availability and therefore needs to be ultrasensitive and able to exploit GNSS signals' side lobes. Also, large satellites can install relatively heavy receivers, up to a few kilos, 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 the system's robustness.

Lastly, when considering the smaller satellite groups, such as the picosatellites, power constraints will impact not only the choice of the receiver, but also the percentage of time the receiver will be 'on' and providing PVT information to the mission.

Receivers to navigate 'above' GNSS satellites

Most GNSS space users have been located at low altitudes (i.e. LEO orbits), where GNSS signal reception is similar to that on the ground.

However, over the past few years GNSS has become a common solution for GEO satellites, which are making increased use of **low-thrust electric propulsion**; the use of this technology during geostationary transfer orbits and circularisation manoeuvres can lower the necessary propellant mass and reduce the launch cost. The drawback is the obligation to extend this phase of the mission by several months. During such a long period, **GNSS-based**, free-of-charge, real-time navigation allows mission costs associated with **ground tracking and positioning services** to be avoided.


© iStock

Launched in September 2022, EUTELSAT Konnect VHTS is an example of a telecommunications, all-electric GEO satellite equipped with GNSS, which also uses this kind of propulsion to maintain its position after entering mission orbit.

When looking **beyond GEO, GNSS** is also **envisaged** as at least a transitory navigation means for certain space missions to reach the Moon.

Key GNSS user requirements

The key GNSS user requirements for the different application groups within the **space** segment are collected using a harmonised procedure at EU level.

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 space user needs and requirements** which will be issued in 2024.

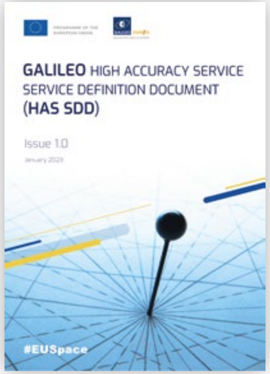
Galileo's High Accuracy Service: adding value for space users

Galileo's High Accuracy Service (HAS) was declared operational in January 2023. It is a global, free-of-charge and standalone service that is operational 24/7. Its precise satellite orbit, clock and signal biases corrections are provided **via the Galileo satellites** E6-B signal and via the Internet Data Distribution. It thus provides users with decimetre level positioning accuracy when using a PPP processing algorithm.

The first results of Precise Orbit Determination (POD) showed that the accuracies obtained with HAS were marginally worse than those achieved with third-party hourly ultra-rapid GNSS orbit and clock products, although **reduced latency and greater independence of the ground segment were observed**[1], with associated economic savings in some cases.

As such, **HAS is already being adopted by space receiver manufacturers**, obviously based on the use of the E6-B signal channel, to provide satellite operators with autonomous and highly accurate real-time navigation products. The availability of accurate orbit information will support advanced mission concepts and EO missions with onboard and near real-time data processing requirements.

Additional details about HAS description, interface channels, characteristics and Minimum Performance Levels (MPLs) can be found on the European GNSS Service Centre website.



[1] Hauschild, A., Montenbruck, O., Steigenberger, P. et al. Orbit determination of Sentinel-6A using the Galileo high accuracy service test signal. *GPS Solut 26, 120 (2022). https://doi.org/10.1007/s10291-022-01312-5*

Space-borne GNSS Value Chain[1]

GNSS	COMPONENTS AND RECEIVER MANUFACTURERS	SPACECRAFT MANUFACTURERS & DEVELOPERS	SPACECRAFT OPERATORS	PROVIDERS OF SERVICES GENERATED IN SPACE	FINAL USER COMMUNITIES
	• AIRBUS* • ANALOG DEVICES • BEYOND-GRAVITY* • BLILEY TECHNOLOGIES • CAES • CHINA GREAT WALL INDUSTRY* • COBHAM* • DEIMOS SPACE* • DLR* • GENERAL DYNAMICS • HEXAGON* • HONEYWELL • NEC • NEWSPACE SYSTEMS* • OHB* • RAKON • MOOG • QASCOM* • SAFRAN* • SKYFOXLABS* • SPACEMANIC* • SPACE PNT* • SPACEX • SYNTONY GNSS* • SYRLINKS* • THALES* • U-BLOX*	• AIRBUS* • BOEING • CHINA GREAT WALL INDUSTRY • HEXAGON* • ICEYE* • LOCKHEED MARTIN • MAXAR TECHNOLOGIES • NORTHROP GRUMMAN • SPACEX • SPIRE GLOBAL • THALES* • SMALL SATELLITES DEVELOPERS (E.G. AAC CLYDE SPACE*, REDWIRE, DEIMOS SPACE*, GOMSPACE*, SATREV*, ISISPACE*) • UNIVERSITIES	Public: • ARMED FORCES • ESA (ESOC)* • EU* • NASA • NATIONAL SPACE AGENCIES • NON-PROFIT ORGANISATIONS (E.G. AMSAT) • RESEARCH CENTRES • UNIVERSITIES Commercial: • ARIANEGROUP* • EUTELSAT* • HISDESAT* • HISPASAT* • ICEYE* • INMARSAT • INTELSAT* • ONEWEB • SES* • SPACEX • STARLINK • VIASAT	Public: • EU (E.G. COPERNICUS)* • GOVERNMENTAL INSTITUTIONS • RESEARCH CENTERS • UNIVERSITIES Commercial: • PROVIDERS OF EO SERVICES • PROVIDERS OF TELECOM SERVICES	• EARTH SCIENCES RESEARCHERS • EMERGENCY SERVICES • ENVIRONMENTAL MONITORING AGENCIES • GEOSPATIAL INTELLIGENCE AGENCIES • INFRASTRUCTURE OPERATORS • LAW ENFORCEMENT BODIES • PUBLIC SAFETY INSTITUTIONS • TERRITORY PLANNERS

European[2] industry in the global arena

In 2021, Europe significantly contributed to the market for GNSS components and receivers, together with North America, Russia and China. Europe's positioning benefits from a combination of both historical stakeholders and new actors answering New Space needs. Airbus, Safran, Thales, Hexagon, U-Blox and Beyond Gravity are the largest European manufacturers in the market segment.

LEGEND

- Commercial offering
- Public offering / entities
- User segments

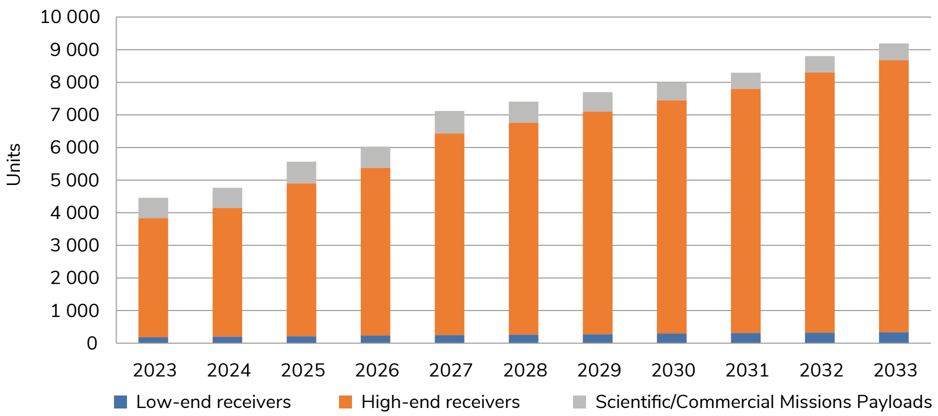
NOTES

[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.

Please refer to page 23 for a comprehensive description of the GNSS value chain and how to interpret it at segment level.
* European-based companies. The region is defined with respect to the headquarters of the company, though the actual area of activity might be wider.

Mega-constellations and new business models are driving the coming decade of shipments

Shipments of GNSS devices by receiver category



Receiver category \ Applications	Attitude Determination (AD	Precise Orbit Determination (POD)	Real Time Navigation (RTN)	Space Timing & Synchronisation (S-T&S)	Lunar Orbit (LL)	Moon Surface positioning (MS)	Translunar Orbit (TLO)	Scientific & Operational Missions (SOM)	Technology Demonstration (TechD)
Low-End	Early Stage	Early Stage	Used	Used	-	-	-	Used	-
High-End	Used	Used	Used	Used	Early Stage	Early Stage	Used	Used	Used
Payload/ Scientific	-	-	-	-	-	Early Stage	-	Used	-

Whether it is for real-time on-board autonomous navigation, supporting specific scientific or operational satellite missions, or enabling deep-space activities such as a translunar orbits, user needs and associated priorities vary. Three categories of receivers are defined.

While **'Low-End' receivers** encompass Commercial-Off-The-Shelf (COTS) New Space 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, must respond to specific needs, not necessarily navigation-related.

The availability and use of **more GNSS satellites** and of **dual-frequency receivers** (even triple in certain cases) and of advanced navigation algorithms provides superior positioning accuracy. The increase in accuracy has, indeed, been supported by the quality of the **ephemerides provided by Galileo constellation**, which show smaller orbit and clock offset errors.

Mega-constellations boost the number of GNSS devices in outer space

In 2000, around 800 satellites were orbiting the Earth. That number has increased to around 7 000, with 2 500 new satellites estimated to be launched each year over the next decade.

The number of mega-constellation projects is increasing and the plans for launches of LEO as well as MEO satellites are in the tens of thousands. This is shown by the chart on the left, as well as the charts on page 181.

The chart presents EUSPA's estimation on the number and types of space GNSS receivers to be shipped over the next decade. Having validated key assumptions with industry, such as the number of GNSS devices per different type of satellite, projections show that **the demand for components and hence for space GNSS receivers is already a fact, and that such growth will continue over the next few years**, even if with a slightly reduced trend from 2028.

Revenues from GNSS device sales are forecast to peak around 2027 and slightly decrease after this point, with the predicted increase in the installed base of GNSS devices expected to no longer compensate for the decrease of unit prices expected in space GNSS receivers.

It should be noted that source data for satellite launches were compiled from existing databases and press releases of all the major space players. Data were only used when launch dates were also available.

Unique features developed for New Space users

The New Space opens the space sector to an economic model in which satellites are manufactured in batch, launches occur every month, parts and units are mass-produced and processes are industrialised. Projects are launched rapidly, adopting a more trust-based and risk-tolerant approach.

A major trend conceived under the New Space industry era is the **change from large and expensive satellites to constellations of smaller, cost-optimised satellites**.

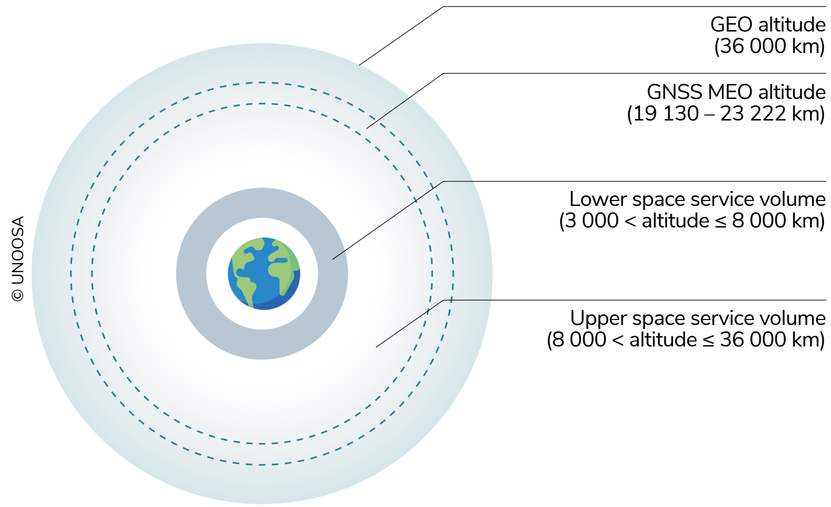
The reduction of mission costs is being achieved, on the one hand, thanks to economies of scale, where unitary production costs are optimised by increasing production. On the other hand, product development and design requirements, applicable as well to the GNSS receivers, include **features not yet developed by this industry**. These could be:

- The use of Commercial-Off-The-Shelf (COTS), non-space qualified, components utilised to manufacture the spacecraft. Under this mass-production model, satellites are designed with a lifespan of less than five years. This allows the use of components with lower requirements to resist the effects of space radiation.
- The use of software-defined receivers (SDR), offering features such as re-programmability (i.e. upgradeability) in the form of over-the-air (OTA) software updates, a feature quite unique from the mobile devices industry until very recently.

These and other ground-breaking innovations have made it possible to **reduce prices of space GNSS receivers by an order of magnitude**, in line with the overall New Space philosophy.

Calling for an international standardisation of technical means and regulations

The GNSS space service volume and its regions



Address the need for global collaboration in defining the Multi-GNSS SSV

The **United Nations International Committee on GNSS (UN ICG)** was established in 2005 as a cooperative framework upon which current and future international providers of GNSS could work together to ensure greater compatibility, interoperability and transparency of their systems.

Published in September 2021 and collecting the outcomes of its Working Group B, the most notable accomplishment of ICG in recent years has been the release of the second version of the **Interoperable Multi-GNSS Space Service Volume (SVV)** booklet.

By characterising the Interoperable Multi-GNSS SSV, space users can assume a scenario where **all navigation constellations operate together**; the signal reception is dramatically improved in higher orbits and hence there is continuous navigation support, thus promoting the development of new applications and protecting the use of GNSS.

The **development of spaceborne receivers** is expected to further **leverage**, at its own pace, the **multi-constellation and multi-frequency developments** achieved in terrestrial ones, driven by the evolution and adaptation of these devices to the needs of New Space entrants.

Ultimately, several ongoing public and private initiatives around the concept of LEO-PNT are increasingly the focus of the committee.

Aviation and Space getting closer: High-Altitude Operations (HAOs) and Space Traffic Management (STM)

The dynamic, integrated management of air traffic through the provision of facilities and seamless services is known as **Air Traffic Management (ATM)** and is a pillar of aviation since decades. Recently, the creation and definition of the **Unmanned Traffic Management (UTM)** is addressing the challenges posed by the rising number of drones operating below typical manned aviation altitudes.

In addition, higher airspace or the area near or above FL 600/FL660 is becoming a new frontier for flight. Although there is not yet any predominant user type and the numbers are rather low compared to orbiting altitudes, there are many initiatives ongoing worldwide such as suborbital flights and **High-Altitude Operations (HAOs)**. This evolving environment narrows the **frontiers between the aerial and orbiting worlds** with new airspace management challenges to be addressed.

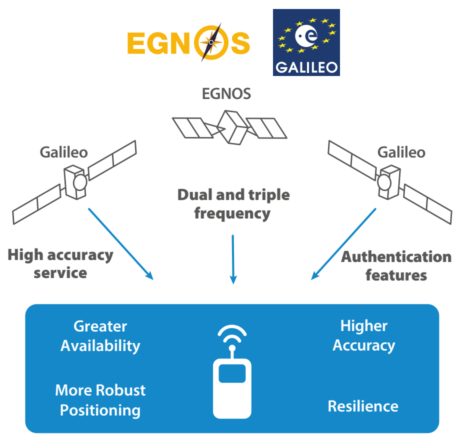
In this context, **ECHO and ECHO 2 (European Concept for Higher Altitude Operations)** are two consecutive research projects led by Eurocontrol aimed, firstly, at developing a Concept of Operations (CONOPS) for European Higher Airspace operations, and secondly, at introducing a module on space launch real-time monitoring and packages covering ground and air-ground operational integration procedures. EASA has in parallel published a Proposal for a Roadmap on Higher Space Operations (HAO).

Above HAO altitudes, the expansion of space users and NewSpace activities can overwhelm current space flight safety processes, putting at risk space infrastructure and human spaceflight. Today, space traffic is mainly addressed by the Outer Space Treaty, which establishes that no nation may claim sovereignty over outer space (article II), and the IADC space debris guidelines, which aim to limit the generation of space debris. No 'highway code' has been established in outer space by the international community so far, and business-as-usual will cease to be valid at some point.

As a consequence, and with the launch into orbit of new LEO satellites, the enforcement of **Space Traffic Management (STM)** policies is needed. In that respect, the European Commission issued in February 2022 a Joint Communication to the European Parliament and the Council titled "**An EU Approach for Space Traffic Management**", supported by the space regulation of year 2021, aimed at paving the way towards an international approach to STM. STM "*encompasses the means and the rules to access, conduct activities in, and return from outer space safely, sustainably and securely*" and is dependent upon a foundation of continuous **Space Situational Awareness (SSA)**, of which **Space Surveillance and Tracking (SST)** is a component. In the Joint Communication, EU SST is considered the operational pillar of STM and therefore must be reinforced with new services, such as space debris mitigation and remediation, and technologies. The EUSPA has been responsible for operating the EU SST front desk since 1 July 2023.

The question of the role GNSS solutions could play in this long-lasting process is legitimate. But Galileo should allow, from the navigation infrastructure perspective, a seamless transition between the ATM and STM context.

First examples of Galileo solutions adopted by the Space users



Added value brought by EGNSS

The **increase of the overall number of GNSS satellites** provides **significant improvements** in terms of PNT availability for spacecrafts orbiting at MEO and beyond.

The **superior quality of Galileo orbits and clocks**, when compared to other GNSS constellations, has also **brought improved accuracy** for spacecraft orbit determination. Together with dual-frequency capacities, it guarantees better performances for lower orbits.

Moreover, **Galileo HAS** goes one step further. With triple-frequency antennas and receivers to access the E6-B signal, it **provides a source to conduct real-time decimetre-level PPP** without the need to rely on commercial correction services.

Finally, although still in its early stages, the use of **Galileo OSNMA is already being** explored as a way of providing more navigation in space.

EU Space Programme services and features for space applications

The **EU Space Programme comprises several flagship components** that work in harmony.

In space applications, Galileo will complement the SSA and secured satellite connectivity (GOVSATCOM and IRIS^2) initiatives to **open up more opportunities for synergies**.

For example, Galileo PNT will support the evaluation and eventual performance of Collision Avoidance Manoeuvres (CAMs), providing benefits to all users of the EU SST. It will also support the future 'automation' of CAMs.

On the other hand, the EU secured satellite connectivity initiatives will find applications in supporting EU space infrastructures or in providing connectivity to satellites, up to providing intersatellite communication links.

NewSpace PPP Receiver

Fundamental Elements

Funded as part of the Fundamental Elements scheme, the **NewSpace PPP Receiver** (NEWSPAPER) project allowed Beyond Gravity to evolve their Precise Point Positioning (PPP) software and conceive a GNSS receiver able to revolutionise the concept of **Real-Time Precise Orbit Determination** (POD).

Thanks to the adaptations performed in their PPP engine, the EU-made PODRIX spaceborne receiver is expected to become a game changer: the **first space receiver leveraging Galileo's High Accuracy Service (HAS)** transmitted on the Galileo E6 signal, providing real-time positioning accuracy in **the low decimetre or even centimetre range**. The Software Defined Radio (SDR) leveraged from the previous PODRIX generation has allowed the RF frontend to be returned to support E6 band.

The model has undergone extensive testing on the ground, and one unit is embarked for **in-orbit demonstration on the Copernicus Sentinel-1C**, a 2 000 kg polar orbiter situated at an altitude of 700 km.

The target 3D accuracy to be achieved is of 20 cm.

From a market perspective, the receiver attacks the Low Earth Orbit satellites and constellations in the 50–500 kg class for space applications.

Beyond Gravity's next step in this area is to apply the lessons learnt and the developments of the NEWSPAPER project into their **NavRIX PinPoint, a HAS-capable GNSS receiver for New Space LEO applications** that makes use of COTS components.

PODRIX receiver and antenna.
© Beyond Gravity

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

Galileo Cyber Space Receiver

Fundamental Elements

After the successful outcomes achieved in the Enhanced Navigation in Space (ENSPACE) project, Qascom and its consortium engaged in **GalilEo cYber SpacE Receiver** (GEYSER).

Launched in 2021 by EUSPA, the project has **developed an innovative close-to-market GNSS space receiver for LEO orbits and Launchers**. Indeed, its compactness and low weight (<1 kg) enables its use in CubeSats and small LEO satellites, such as mega-constellations and LEO-PNT concepts.

The developed product benefits from various **Galileo differentiators** and advantages, including others **authentication** (OSNMA), robust navigation against **interference** or **dual frequency** L1/L5 E1/E5a GPS and Galileo capability, among others.

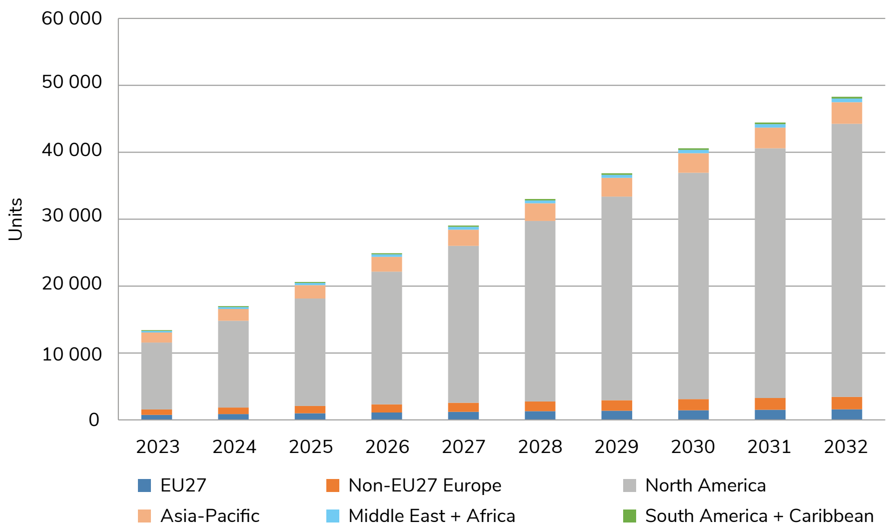
Through a Dual Frequency Precise Orbit Determination (POD) plugin, GEYSER aims to offer high accuracy positioning for satellites, enabling space debris collision avoidance and "station keeping" as an additional added value.

GEYSER prototype
© Qascom

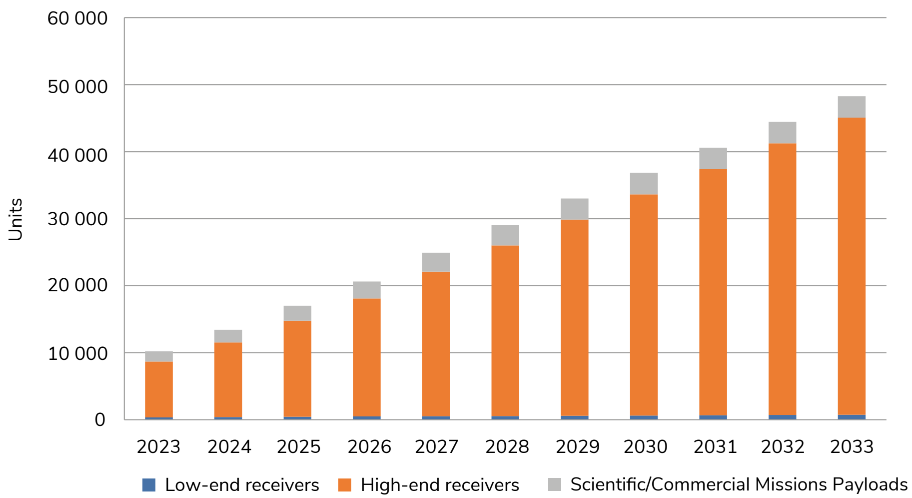
The product meets the **emerging needs of the New Space users**, requiring spaceborne GNSS payloads to provide accurate and robust navigation and timing: 3D position accuracies below 3 m in LEO satellites and a timing accuracy below 50 ns are achieved.

A **Software Defined Radio** approach has been followed, allowing over-the-air firmware updates. It has also been validated in collaboration with NASA in sounding rockets, CubeSats and aboard the International Space Station. In this way, the GEYSER project contributes to Qascom's roadmap on GNSS space receiver developments, including **future missions in lunar scenarios**, such as the Lunar GNSS Receiver Experiment (LuGRE).

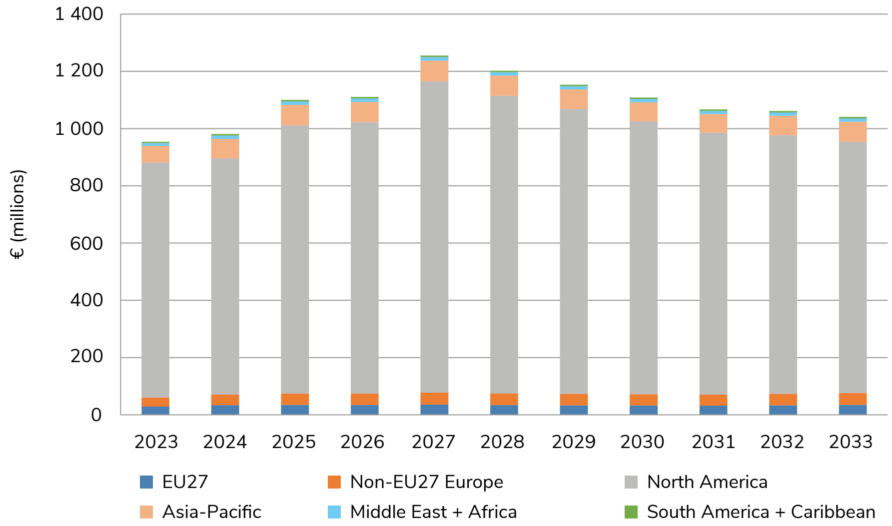
Installed base of GNSS devices by region



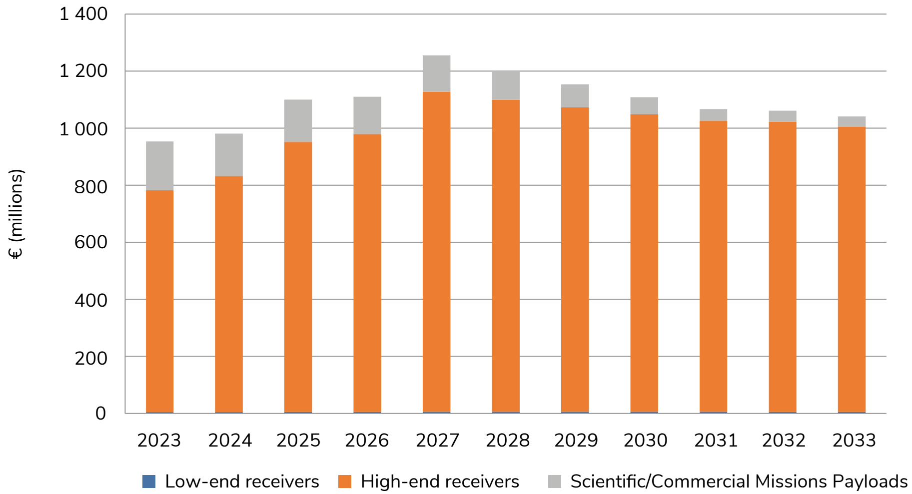
Installed base of GNSS devices by application



Revenue from GNSS device sales by region



Revenue from GNSS device sales by application



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
- Informal dwellings
- Real estate*
- Surveying and mapping of urban areas*
- Urban modelling, 3D modelling, Digital Twins*
- Urban planning*

* applications with particular relevance for cultural heritage monitoring

Application descriptions can be found in Annex 3.

URBAN DEVELOPMENT AND CULTURAL HERITAGE

Earth Observation (EO) and Global Navigation Satellite Systems (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.

EO provides valuable information in support of urban planning, monitoring of informal dwellings, and informing the progress and state 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 endanger these sites.

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:** EO and GNSS data and services enable sustainable and resilient cities.
- **User perspective:** Advanced mapping, modelling, and simulation enable informed decisions and efficient and effective planning.
- **Industry:** Urban development and cultural heritage value chains.
- **Recent developments:** Advanced technologies improve the precision and versatile applicability of GNSS, and EO and GNSS data support monitoring and planning of urban areas for improved resilience and sustainability.
- **Future market evolution:** Integration of GNSS with further sensors and signals will increase precision and availability of location-based services and information. EO data forms the basis for applications supporting the sustainability of urban spaces and preservation of cultural heritage sites.
- **European systems:** The EU Space Programme presents a strong value proposition for urban development and cultural heritage applications.
- **European projects:** Several European-funded projects combine EO and GNSS to propose solutions in support of the urban development & cultural heritage sector.
- **Reference charts:** Yearly evolution of installed base of GNSS devices and revenues as well as EO revenues by application and region.

EO and GNSS data and services enable sustainable and resilient cities

Key market trends

- In light of growing populations and increasing urbanisation, efforts to make urban spaces more sustainable, but also resilient and inclusive are underway
- Efforts putting cities at the forefront of sustainability and resilience are largely driven by the growing awareness for changes in the environment, the role of human activities contributing to these, and the impact of these changes on the planet and life on it
- Policies and initiatives such as the EU Green Deal, the Urban Agenda for the EU, or the United Nations' Sustainability Development Goals (SDGs) are targeting resilience, sustainability, and recovery and regeneration with urban areas in focus. Enforcing these policies is enabled by means of digitalisation and increasingly so by geospatial data, with the European Space Programme's assets on the forefront

Satellite data enabling the '15-minute city', where most necessities and services are in walking distance

In today's world, characterised by growing populations, urbanisation, and the pressing challenges of climate change and sustainability, urban planning is crucial to live up to these challenges. Developments and trends in urban planning are influenced by significant policy initiatives like the EU Green Deal and the UN Sustainable Development Goals (SDGs), which emphasise the need for more **sustainable and resilient cities**.

One emerging urban planning concept gaining renewed attention is the **15-minute city**. This idea revolves around creating urban environments where all essential amenities are conveniently accessible within a **short walking distance** or a quick bicycle ride. This concept is not new, but it has regained prominence due to its alignment with the goals of sustainability and resilience.

To turn this vision into reality, cities must embrace **integrated urban design and transportation planning**. This holistic approach seeks to reshape urban areas, ensuring that they are more efficient, equitable, and environmentally friendly.

In this transformation journey, **satellite imagery** and **GNSS** play a crucial and growing role. They aid in redesigning and operating cities efficiently. Satellite imagery helps with **mapping** and **geospatial planning**, providing valuable insights into urban landscapes and potential areas for improvement. GNSS technology facilitates **precise navigation** and **location-based information**, enabling **urban mobility** and location-based services to thrive.

EO data guides the resilient design of urban spaces, and provides information for early warning and response to disasters

In the face of **climate change** and the increasing frequency of **extreme weather events**, urban areas must adapt to these evolving challenges. Here, urban development carries a dual responsibility: not only must it support the **mitigation** of such events, but it also must take proactive steps towards **prevention** through the design and the implementation of **robust information systems**.

EO data emerges as a vital asset in this effort. It facilitates the **assessment of vulnerability** in urban spaces to a range of natural hazards, including **floods** and the formation of **urban heat islands**. EO data is instrumental in identifying high-risk areas and offering valuable insights into the potential impact of these hazards on urban communities.

The wealth of information stemming from EO data aids in the creation of resilient urban spaces that can withstand, or even minimise, the impact of natural disasters. Furthermore, this data supports informed decision-making during **disaster response** and **recovery** efforts, ensuring that resources are allocated efficiently and effectively to aid affected communities in a timely manner.

Urban regeneration benefits from satellite imagery in identification, planning, and monitoring areas of concern

In the wake of **urban deprivation** and the aftermath of armed conflicts, many large urban areas can find themselves in a state of disrepair, decline or even significant destruction. However, within these challenges lies a unique opportunity for **transformation**. Urban planners and developers can seize the chance to redesign entire neighbourhoods, establish new public spaces, and repurpose existing structures to adapt to evolving realities and needs.

In this transformative process, EO data has a key role. Collected through satellites, drones, or on-site sensors, this data serves as a valuable source for **detecting** signs of urban decline, **mapping** the extent of destruction, and providing essential geospatial information for **effective urban planning and development**. When combined with GNSS data, it offers a comprehensive understanding of the urban landscape, empowering urban planners and stakeholders to make informed decisions, **driving sustainable recovery and development**.

In this context, the demand for EO data is on the rise due to the imperative nature of **recovery plans** and **development aid**. These initiatives drive the need for accurate and up-to-date information for both **initial planning** as well as **ongoing monitoring** of progress and impact. Simultaneously, the integration of EO data can lead to cost savings for local municipalities by enhancing their ability to monitor, plan and manage their urban assets efficiently.

EO-based geospatial data help manage Cultural Heritage

"Make cities and human settlements inclusive, safe, resilient and sustainable" is one of the 17 Sustainable Development Goals (SDG) defined by the United Nations in its "2030 Agenda for Sustainable Development". To achieve this goal, it is necessary to **ensure adequate protection and management of the tangible cultural heritage**, which is an inherent component of the urban landscape and has a role to play in urban **regeneration** and **sustainable** development.

To this respect, cultural heritage managers can count on geospatial information. In particular, beyond the role they can play in **discovering** new archaeological sites, satellite-based EO data enable the provision of services informing Cultural Heritage managers about the **environmental conditions** surrounding the sites they are responsible for (e.g. air pollution, vegetation growth), about the **risks** they are exposed to, whether natural (e.g. ground motion, extreme weather events) or anthropogenic (e.g. urban sprawl, mass tourism), and about their evolution in time.

Advanced mapping, modelling, and simulation enable informed decisions and efficient and effective planning

Building Information Modelling (BIM) plays a crucial role in the development and management of smart cities

For **visualisation and analysis of spatial data** in urban areas, for example, as well as for the management of urban spaces, Geographic Information Systems (GIS) have many established applications in, for example, urban planning, emergency management, or real estate management. Managing spaces and built structures and the complex systems they create however benefits from additional information on building level. **Building Information Modelling (BIM) is an emerging tool** which, when integrated with GIS and geospatial data, has the potential to enhance modelling of urban spaces and the applications that rely on such data and information.

BIM is an increasingly important tool in modern urban development. It revolves around creating **digital representations of physical spaces**, complete with their unique characteristics. These Building Information Models are instrumental in streamlining **urban design processes**, offering efficient solutions.

Given the ongoing digitalisation of areas such as architecture, construction and engineering, new constructions already come with rich data describing their properties. By means of digitalisation, BIM can also be applied to existing buildings and built structures though. The models created provide a foundation for the development of **smart cities** and enable in-depth analysis and **automation**, paving the way for more intelligent and responsive urban environments.

To elevate BIM's capabilities further, the **integration of EO and geospatial data into BIM tools** adds a new dimension of **accuracy** and **detail**. This combination provides essential and more holistic information for urban planning and analysis, enabling cities and their stakeholders to make **informed decisions** and optimise their development strategies.

EO supports decision-making for cultural heritage management

In most countries, the challenges posed by the geopolitical and economic situation on the one hand, and global warming on the other hand, reduce available budgets and human resources devoted to the preservation of cultural heritage. In this context, cultural heritage managers often have to establish **priorities** for the preservation and restoration of the sites under their responsibility. These priorities may have to be established at different levels, from local to national. To make informed decision, managers need **reliable information** not only on the **current status** of cultural heritage settlements but also on the **risks** threatening those settlements. With its global coverage and the wide variety of parameters it monitors, satellite-based EO enables a comparison of the conditions and risks between different sites (e.g. comparison for several Cultural Heritage sites throughout a country or a region, of the risks related to, for example, subsidence, erosion, drought or floods). By doing so, EO helps managers to better plan conservation operations while optimizing the use of resources.

Key EO and GNSS user requirements

The key EO and GNSS user requirements for the different application groups within the **urban development and cultural heritage** segment are, at EU level, collected using a harmonised procedure.

Information is collected through extensive interactions with user groups, providers and experts in a continuous process culminating at the User Consultation Platforms (UCP). Requirements relevant for the Urban Development & Cultural Heritage segment are documented in detail within the Reports on Infrastructure, Emergency Management, or Consumer Solutions. User requirements for EO services and products – as well as their evolution – are now also collected through the UCP. The process covers the EO user needs and requirements of commercial users based on inputs from industry experts and user groups, mirroring the existing process implemented for GNSS.

Moreover, the collection of specific requirements for Copernicus services and products is supported by 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; and (iii) regular and structured exchanges among representatives of the Copernicus governance structure and Member States through the Copernicus User Forum.

The Copernicus Land User Event is another example of formats through which user feedback is collected in its 2023 urban applications session, revealing needs such as customised data for specific applications, more interaction between solution developers or guarantees for reliability and availability of data.

Urban Development & Cultural Heritage EO & GNSS Value Chain[1]

EARTH OBSERVATION

DATA PROVIDERS

- AIRBUS*
- BLACKSKY
- CAPELLA SPACE
- CONSTELLR*
- GEOSAT*
- ICEYE*
- E-GEOS*
- MAXAR
- PLANET
- SATELLOGIC*
- UMBRA

- COPERNICUS SENTINELS*
- LANDSAT (USGS)
- METEOSAT (EUMETSAT)*
- RADARSAT (CSA)
- RELEVANT IN-SITU NETWORKS
- OTHER RELEVANT EUROPEAN NATIONAL MISSIONS

INFRASTRUCTURE PROVIDERS

- AWS
- CLOUDFERRO*
- GOOGLE CLOUD PLATFORM
- IBM CLOUD
- MICROSOFT AZURE
- T-SYSTEMS*

- FEDERATED INFRASTRUCTURE (E.G. GAIA-X)*
- SENTINEL COLLABORATIVE GROUND SEGMENT*

PLATFORM PROVIDERS

- CLOUDEO*
- CREODIAS*
- EARTH-I*
- EDS CEODE
- EURODATACUBE*
- GOOGLE EARTH ENGINE
- NORTH.IO*
- OPEN DATA CUBE
- PLANET EXPLORER
- SENTINEL-HUB* (SINERGISE)
- UP42*

- CODE-DE*
- COPERNICUS DATASPACE ECOSYSTEM*
- ESA TEP (URBAN)*
- OPENEO*
- WEKEO*

EO PRODUCTS AND SERVICE PROVIDERS

- AIRBUS*
- ESRI
- GAF*
- GAMMA REMOTE SENSING*
- GEOVILLE*
- KSAT*
- OHB*
- PLANETEK*
- SINERGISE (PLANET)
- TESSELO*
- VITO*
- WORLD FROM SPACE*

- COPERNICUS ATMOSPHERE MONITORING SERVICE (CAMS)*
- COPERNICUS CLIMATE CHANGE SERVICE (C3S)*
- COPERNICUS EMERGENCY MANAGEMENT SERVICE (CEMS)*
- COPERNICUS LAND MONITORING SERVICE (CLMS)*, INCL. COPERNICUS EUROPEAN GROUND MONITORING SERVICE (EGMS)*
- COPERNICUS SECURITY SERVICE (CSS)*

INFORMATION PROVIDERS

- 21AT
- CGI
- CONSTELLR*
- GAF*
- GENEGIS GI*
- KERMAP*
- LUXCARTA*
- NAIS*
- SATSENSE*
- SPACEKNOW
- TETRA TECH
- TRACASA*

END USERS

- URBAN PLANNERS
- ARCHITECTS
- CONSTRUCTION COMPANIES
- URBAN PUBLIC TRANSPORT PROVIDERS
- PUBLIC AUTHORITIES (HEALTH, ENVIRONMENT, CULTURE)
- ENGINEERING COMPANIES
- CITIZENS
- UTILITY COMPANIES
- REAL ESTATE AGENCIES
- INSURANCE COMPANIES
- INTERNATIONAL ORGANISATIONS (E.G. UNITED NATIONS, UNESCO)
- TAX AUTHORITIES

GNSS

AUGMENTATION SERVICE PROVIDERS

- HEXAGON (LEICA GEOSYSTEMS, NOVATEL)*
- SPACEOPAL*
- SWIFT NAVIGATION
- TERIA*
- TOPCON
- TRIMBLE NAVIGATION
- U-BLOX*

- NATIONAL AND REGIONAL RTK NETWORK PROVIDERS

COMPONENT AND RECEIVER MANUFACTURERS

- BEIJING UNISTRONG SCIENCE & TECHNOLOGY
- CHCNAV
- HEXAGON*
- HI-TARGET SURVEYING INSTRUMENT
- SATEL*
- SBG SYSTEMS*
- SEPTENTRIO*
- TOPCON
- TRIMBLE NAVIGATION
- U-BLOX*

SYSTEM INTEGRATORS

- ALLSAT*
- CHCNAV
- EATON*
- HEXAGON*
- RACELOGIC*
- STONEX*

SOFTWARE, APPLICATIONS AND ADDED VALUE SERVICES

- CARLSON
- HEXAGON*
- JAVAD GNSS
- SEPTENTRIO*
- TOPCON
- TRIMBLE NAVIGATION

PROFESSIONAL USERS

- CONSTRUCTORS
- EDUCATORS
- ENGINEERS
- ENVIRONMENTALISTS
- PRESERVATIONISTS
- SCIENTISTS
- SURVEYORS

CUSTOMERS OF SURVEYING SERVICES

- ARCHITECTS
- CONSTRUCTION COMPANIES
- INSURERS
- CITIZENS
- PUBLIC AUTHORITIES
- URBAN UTILITIES

LEGEND

- Commercial offering
- Public offering / entities
- User segments

NOTES

[1] The value chain considers the key global and European companies involved in GNSS and EO downstream activities. Please note that enterprises listed in the data providers step of the value chain often provide platforms as a service. For the sake of simplicity, the data providers are not repeated in other stages of the value chain in which they are active.
[2] In the market share analysis, Europe is defined as EU27 plus Norway, Switzerland and the UK.

Please refer to page 13 and 23 for a comprehensive description of value chains and how to interpret them at segment level.
* European-based companies. The region is defined with respect to the headquarters of the company, though the actual area of activity might be wider.

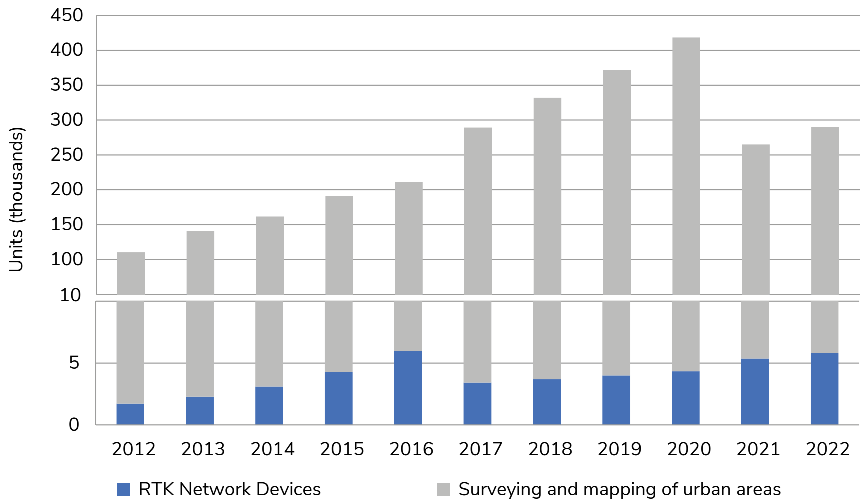
European[2] EO and GNSS industry in the global arena

While EO data processing markets are dominated by North American and Asian companies with increasing market shares, European countries still account for over a quarter of the market. Here, leading European companies include Airbus and Leonardo (e-GEOS).

GNSS receivers in urban development and cultural heritage are used for mapping and cadastral purposes, while the infrastructure segment covers devices for post-construction purposes. Companies such as Hexagon, SBG Systems and Septentrio are leaders in Europe for components and receivers, and systems integration.

Cutting edge technologies are enhanced with GNSS information and vice versa to improve the precision and versatile applicability of GNSS

Shipments of GNSS devices by application



Shipments of GNSS receivers for surveying and mapping have grown **from over 110 000 units in 2012 to more than 290 000 in 2022.**

A drop of shipments can be seen **after 2020** (where shipments peaked at around 418 000 devices), with continuous recovery since. This drop can likely be attributed to the COVID-19 pandemic which resulted in both a **strong decline in constructio**n in 2021 as well as disruptions of supply chains.

Shipments of **RTK network devices have tripled since 2012** to around 5 800 devices in 2022. With a median of around 3 700 units per year between 2010 and 2022, shipment numbers of such devices are relatively low.

Fewer unit sales of RTK network devices meant that prices were maintained at a high level and lifetimes were increased in order to maintain moderate growth rates.

Augmented Reality enhances decision-making and public engagement in urban planning and transportation

High-precision design overlays in real-world urban settings offer the ability to create **precise visualisations of planned construction projects**. Georeferenced models are seamlessly positioned using measurements relative to property boundaries or other site reference points.

This flexibility allows for on-site adjustments and reorientations of models as needed. Cutting-edge Augmented Reality (AR) solutions empower engineers, architects, and construction professionals **to plan and execute projects on-site** with remarkable precision. These tools not only enhance accuracy but also streamline the entire construction process, ensuring that urban development projects align seamlessly with their intended designs.

Furthermore, AR can integrate real-time data feeds, such as traffic information, public transportation schedules, and environmental data, into the urban environment. These data can be presented as overlays on devices, helping commuters and planners make **informed choices about transportation options, routes, parking etc., reducing congestion and improving overall mobility**. Here, GNSS provides the geospatial context in terms of accurate positioning, alignment with real-world surroundings and proximity alerts, for example.

Floating Car Data (FCD)-based traffic services offer benefits for transportation and urban planning

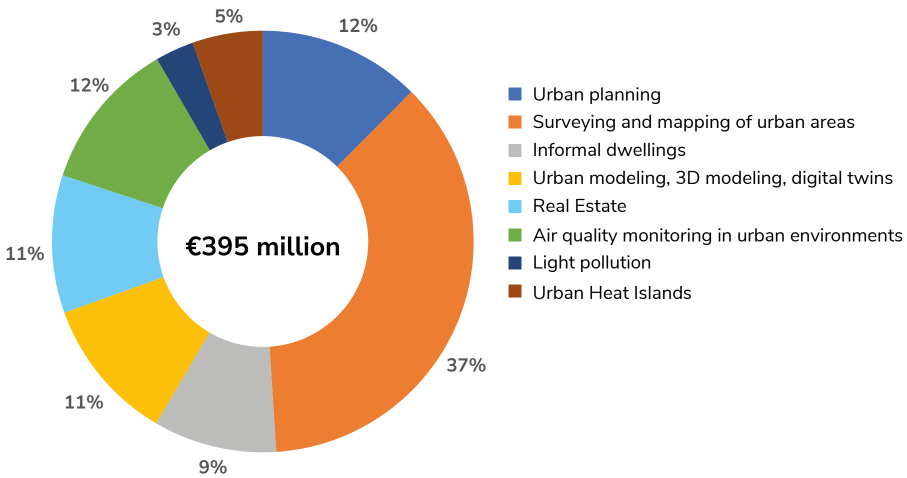
Anonymous location data collected from various mobile sources, including apps, cars and devices, can be seamlessly integrated into urban planning, traffic information systems and other urban applications. Integrated with GNSS information, it provides precise location details, real-time environmental monitoring, **disaster response** capabilities, infrastructure assessment and valuable insights for urban expansion. This integration serves as a powerful tool for **enhancing urban mobility and traffic management,** while also contributing **to smarter urban planning**.

By harnessing this wealth of data, traffic information systems can provide users with real-time travel times for routes they have defined. This means that individuals can make **informed decisions** about their journeys based on current traffic conditions, helping to **reduce congestion and improve overall urban transportation efficiency**. Moreover, real-time floating car data integrated with GNSS information, empowers traffic management authorities to take **proactive measures**. These measures may include automatically adjusting signal plans, redirecting traffic flow or implementing other strategies to **optimise urban mobility and minimise congestion**, all of which are critical components of effective urban planning.

This integrated approach supports data-driven decisions, promoting sustainability, resilience and efficiency in cities while addressing a wide range of urban planning challenges beyond traffic management.

Satellite data supports monitoring and planning of urban areas, contributing to improved resilience, sustainability, and preservation of cultural heritage

Revenues from EO data & services sales by application 2022



For 2022, revenues from EO data & services sales have reached almost €400 million. By far the **largest share** of these revenues (over 35%) stems from applications in **surveying and mapping**. This is followed by urban planning and air quality monitoring applications, both of which had a slight growth in shares and total revenues compared to the year before. The **increase in shares of applications other than surveying and mapping** indicates a **wider adoption of EO by new user groups. Urban heat is another strong trend**, with many municipalities appointing heat officers. Light pollution applications are also on the rise, serving as indicators for different thematic areas such as energy or cultural heritage.

About 75% of the revenues are generated by services, only 25% by data. One of the drivers of this is a **trend of more open data availability** due to which the **proportional value of services is expected to further increase**.

Urban resilience monitoring and planning is improving preparedness, safety, sustainability, and cost

The intersection of urban land use, climate change, and other factors exposes vulnerabilities, particularly in the context of extreme weather events like heatwaves, droughts and floods. EO capabilities and applications offer holistic solutions to address these challenges.

EO-enabled monitoring solutions not only provide **timely response** capabilities, empowering **emergency** services to react swiftly during crises but also enable in-depth analysis of conditions. EO data plays a pivotal role in **predicting** events and guiding longer-term interventions. For instance, it aids in strategic planning related to water bodies, green spaces, urban layout adjustments, and even the potential relocation of communities to safer areas.

Leveraging existing EO capabilities like the European Ground Motion Service, which offers insights into natural and human-induced **ground motion**, and the Global Human Settlement Layer, which provides global geospatial information on human settlements, supports comprehensive **risk assessment** and **crisis management** efforts. These tools, coupled with EO data, collectively contribute to building more **resilient** and adaptable urban environments in the face of evolving challenges, ensuring the **safety** and **well-being** of urban populations.

EO contributes to the restoration of cultural heritage in conflict areas

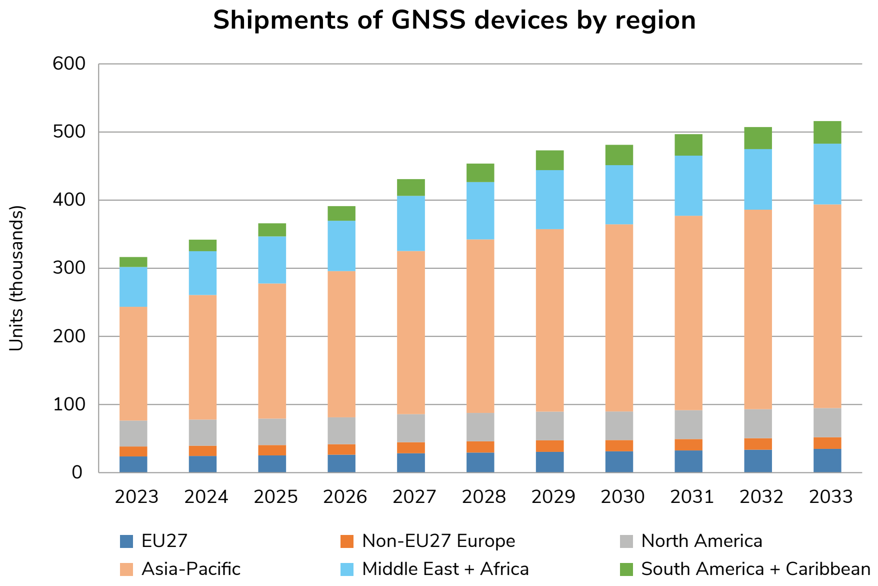
During armed conflicts, tangible cultural heritage is very often part of collateral damages and suffers looting and degradation, if not complete destruction.

An emerging EO application is the creation of **digital inventories** of cultural heritage sites in war zones (which UNESCO is currently doing to keep track of damage to Ukraine's cultural heritage sites).

The comparison of satellite images **before and after malicious acts** in areas affected by conflicts, enables the identification of damaged or destroyed areas as well as the **assessment** and **classification** of the level of **degradation**. Several initiatives are also springing up to supplement the information obtained via space-based observations with local information provided either by specialists on site or by citizens taking pictures.

Increasingly used by national and international organisations, this type of application makes it possible to **document damages**, serve as **evidence** and constitute a **basis for post-conflict reconstruction**, from local-scale to country-scale. It also helps to raise awareness among the general public.

Integration of GNSS with further sensors and signals will increase precision and availability of location-based services and information



The anticipated growth in unit shipments is scaling from approximately 316 000 in the year 2023 to more than 500 000 units by 2033. A **substantial portion** of devices is expected to be deployed for applications in **surveying and mapping**.

However, it is noteworthy that **this growth projection is lower compared to prior forecasts**. The recalibration takes into consideration updated assumptions regarding the **extended life expectancy** of the devices.

Asia remains the biggest market for GNSS devices. Over the span of the next decade, it is anticipated to grow from nearly 167 000 shipped units in 2023 to an estimated 300 000 units in the year 2033. For comparison, shipments in the **EU27 are expected to see a more moderate growth**, reaching an estimated 35 000 units by 2033.

Enhancing location-based services – Tightly-Coupled Inertial Visual GNSS leads the way

Buildings and other structures in cities can create "urban canyons" that pose challenges to GNSS signals, potentially affecting positioning and navigation accuracy. To mitigate these issues, the integration of GNSS-RTK or PPP with inertial navigation systems (INS) is considered a viable solution. The inclusion of a **visual** component can further **enhance the accuracy** of these systems.

Tightly-coupled solutions, which consolidate multiple data sources into a **single optimisation problem**, are crucial for robust urban navigation. This fusion of data can include GNSS, inertial sensors and visual data.

LiDAR-based simultaneous localisation and mapping (SLAM) approaches are effective but often come with high costs and power consumption, making them less practical for some urban applications. As a more cost-effective alternative, monocular visual inertial SLAM systems have been proposed.

Moreover, the utilisation of various **visual sensors** such as cameras is gaining traction. These sensors can improve the overall performance of tightly-coupled inertial visual GNSS systems.

When applied to urban planning, tightly-coupled inertial visual GNSS systems can overcome service interruptions caused by urban canyons, substantially increase positioning **precision**, and enhance the availability of location-based services. Additionally, these systems play a critical role in enabling the development of **autonomous** vehicles and aerial systems within urban environments, contributing to safer and more efficient urban transportation.

Preserving the past and paving the future: LEO-enhanced 3D mapping-aided GNSS for Smart Cities and cultural heritage

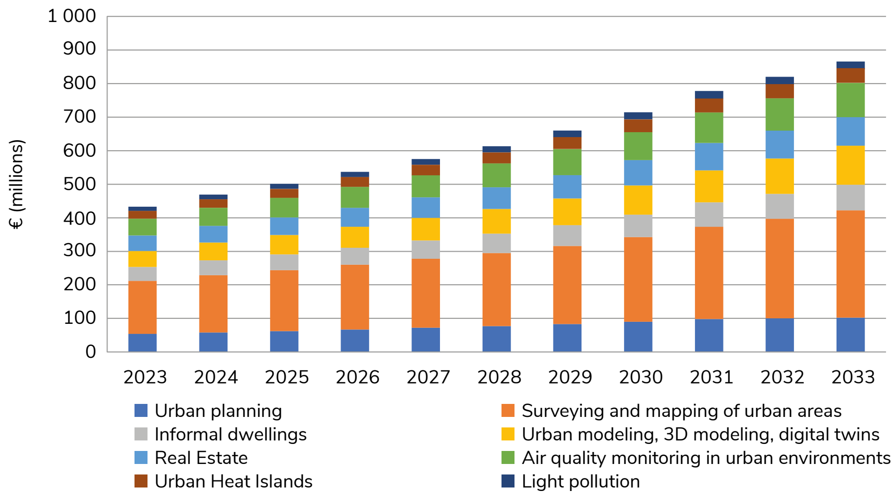
3D mapping-aided GNSS integrates information from 3D building models to **anticipate the visibility of satellites**. In an urban environment, such information can **improve the precision of low-cost receivers**. Measuring sky visibility in real-time can be achieved by tracking Low Earth Orbit (LEO) and GNSS satellite constellations.

The integration of 3D building models with GNSS technology offers significant advantages for urban planning. By anticipating satellite visibility and optimising GNSS signal reception through 3D mapping-aided GNSS, urban planners can make **informed decisions** about infrastructure development, zoning and land use. This real-time sky visibility data supports **disaster response planning**, sustainable urban design, and smart city initiatives, enhancing the efficiency and liveability of urban areas.

Additionally, it aids in historical preservation efforts and fosters public engagement by visualising urban changes. In short, this integrated approach empowers urban planners to create more efficient, resilient and engaging cities.

EO data forms the basis for applications supporting the sustainability of urban spaces and preservation of cultural heritage sites

Revenues from EO data & services sales by application



Estimated **revenues from EO data and services sales are expected to grow** from about €430 million in 2023 to up to €870 million in 2033. By far **the largest share of these revenues** (on average 35%) stems from applications in **surveying and mapping**.

This is followed by **urban planning** and **air quality monitoring** applications, both of which will see continuous growth in total revenues and also in the shares of revenues across applications. This shift of larger shares in other applications than surveying and mapping, indicates a **wider adoption of EO by new user groups. Urban heat** is a strong trend with many municipalities appointing heat officers in need for reliable information.

Light pollution applications are also **on the rise**, serving as indicator for different thematic areas such as energy or cultural heritage.

Around **75% of the revenues are generated by services**, but only 25% by data. This is partly due to the trend towards more open data, while the proportional value of services is expected to further increase.

Preserving the past with EO-enabled Digital Twin

Digital Twins have the potential to advance the **monitoring, management and preservation** of our cultural heritage, especially when integrated with EO data. This synergy offers a transformative approach to safeguarding our cultural legacy.

Digital Twins, which are **virtual replicas of physical assets**, can play a crucial role in this transformation. They allow for **simulations**, providing real-time insights and enabling **predictive** analytics. Through this, Digital Twins empower decision-makers to make **informed choices** that contribute to more sustainable and resilient cities.

Crucially, EO data, sourced from satellites and in situ measurements, constitutes a valuable resource of information about urban environments, both past and present. Through their integration, highly detailed digital models of cities can be constructed, which not only account for modern infrastructure but also preserve the historical and cultural heritage that defines a city's unique identity.

Data fusion solutions seamlessly integrate various data sources, including satellite imagery and on-site measurements, to create comprehensive and up-to-date representations of urban landscapes. Through this fusion, the Digital Twins become enriched with insights into cultural heritage, ensuring that historic buildings, archaeological sites, and culturally significant landmarks are meticulously preserved within the digital realm and, more importantly, provide the required information to ensure their physical preservation.

Growing greener cities: Urban agriculture and gardening for sustainability

Urban agriculture, encompassing traditional farming, vertical gardens and rooftop cultivation, is a **catalyst for social and economic benefits**, with its potential spanning food security, resource efficiency, and sustainability. It addresses challenges such as **pollution reduction** and **energy conservation** by streamlining delivery and storage practices.

EO plays a pivotal role in **monitoring** and **optimising** these diverse urban cultivation methods. It provides valuable insights into **crop health, water usage and land utilisation patterns**, empowering urban farmers to adopt more **efficient** and **sustainable** agricultural methods, whether they are growing in soil or in vertical systems.

Furthermore, Geographic Information Systems (GIS) and EO data, including local climate and weather information, assist in **site selection** for these varied urban cultivation projects. By leveraging these tools, **urban planners can identify ideal locations** that align with climate conditions and resource availability, further enhancing the sustainability of urban farming and vertical gardening initiatives.

Urban agriculture, with its diverse forms and enabled by EO technology, transforms cities into hubs of sustainable food and greenery production, promoting resilience and environmental stewardship.

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**).

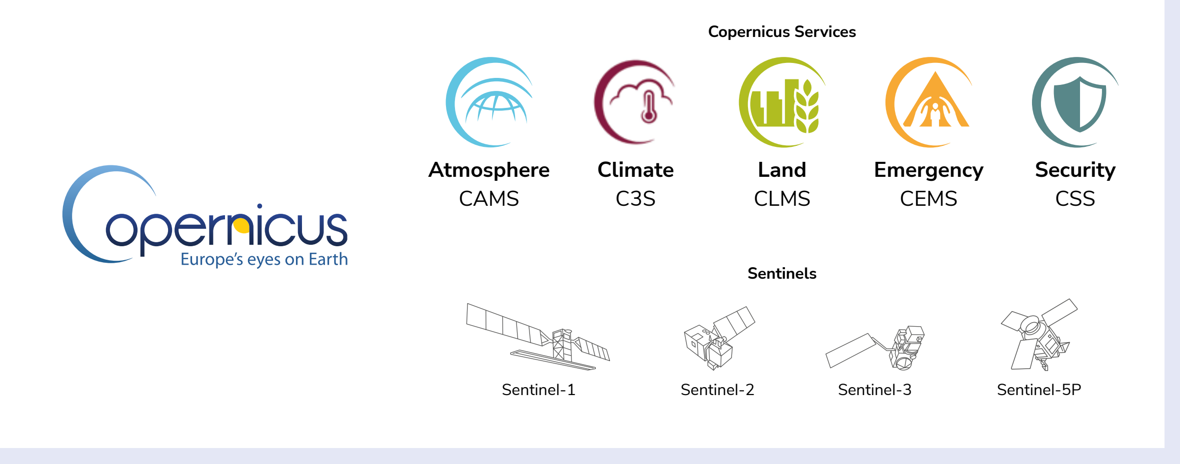
The CLMS is also critical for monitoring of cultural heritage, identifying and mapping risks such as coastal erosion or ground subsidence. CLMS' European Ground Motion Service (EGMS) for instance enables investigation of ground motion affecting buildings and linear infrastructures.

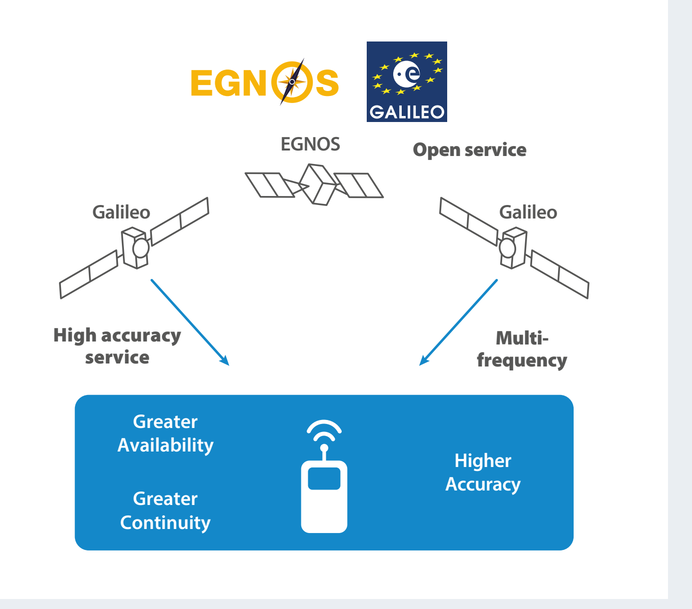
In addition, the Copernicus Emergency Management Service **(CEMS)** provides a **range of products related to natural and man-made disasters that can affect the urban environment** (e.g. floods, landslides).

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 regarding climate change effects (e.g. heat waves, sea level rise).

The Copernicus Service in Support to EU External Action **(SEA)** – a service of the Copernicus Security Service (CSS) – among other provides support in **monitoring damages to world cultural heritage** in areas affected by armed conflicts. The service can assess potential damage to cultural heritage sites over areas of conflict inaccessible to the international community. The Copernicus SEA Service can only be activated by authorised users.

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. Sentinel-3 provides Land Surface Temperature (LST) data, applicable to the detection of urban heat islands; Sentinel-2 surface reflectance data can further improve LST resolution. Finally, Sentinel-5P measurements support the monitoring of air quality in urban environments.





Current usage of EGNSS

Galileo services and features have proven to be **crucial tools for urban planners** and **cultural heritage management** professionals in ensuring precise positioning, safety, integrity, and efficient coordination of activities within urban areas and historic sites.

The **High Accuracy Service (HAS)** of Galileo can be **beneficial for urban planning** and documenting cultural heritage sites by providing improved accuracy for creating detailed topographic maps, identifying property boundaries, and conducting land surveys.

Urban planners can benefit from this technology by quickly and accurately assessing the impact of proposed construction projects or existing infrastructure. In addition, **Galileo improves accuracy of surveying in urban canyons**, where high buildings may obstruct visibility of satellites.

The system's **navigation** features can assist in **navigating through urban areas and cultural heritage sites** by providing accurate positioning, route planning, and real-time guidance.

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

Several European-funded projects combine EO and GNSS to propose solutions in support of the Urban Development & Cultural Heritage sector

Galileo Improved Services for Cadastral Augmentation Development On-field Validation – GISCAD-OV

Cadastral surveying focuses on establishing and re-establishing property boundaries, tracking changes due to construction or demolition, and updating cadastral maps. It plays a crucial role in legally defining property rights and maintaining national land registries.

The **GISCAD-OV project** aimed to **improve cadastral surveying** by involving the entire industry chain. It developed a **cost-effective high-accuracy service** (HAS) using GPS+Galileo E6 HAS and precise point positioning-ambiguity resolution (PPP-AR) techniques. It further aimed to establish a GISCAD-OV Service Operator Centre, integrating existing infrastructures to enhance Cadastral operations' efficiency and reduce citizen-facing procedure times.

GISCAD-OV's approach included upgrading commercial GNSS receivers, utilising low-cost augmentation services, and developing a viable business model for widespread Cadastral HAS implementation.

GISCAD-OV intends to create new business opportunities in cadastral surveying by leveraging Galileo's HAS corrections broadcasting for improved service differentiation.

More information available at: http://www.giscad-ov.eu

Community-Based Smart City Digital Twin Platform for Optimised DRM operations and Enhanced Community Disaster Resilience – PANTHEON

Horizon Europe, a programme of the European Union

PANTHEON aims to create a community-based digital ecosystem for disaster resilience using Smart City Digital Twin technology and cutting-edge innovations. The project focuses on improving risk assessment, reducing vulnerability and enhancing community disaster resilience.

It will achieve this by establishing a community-based smart city digital twin environment for simulations, training, and evaluating subsystem behaviour and threats.

PANTHEON also includes early detection and situational awareness tools, collaborative sensing from earth observations, and UAVs for disaster assistance.

The PANTHEON platform integrates IoT infrastructure and multi-source data to assess risks, inform decision-makers and the public, engage stakeholders, and promote comprehensive disaster risk assessments, all while fostering international cooperation and data sharing.

The Smart City Digital Twin technology will facilitate collective community behaviour analysis concerning exposure to urban multi-hazards over time and space.

More information available at: https://cordis.europa.eu/project/id/101074008

HYPERION – Decision support system for improved resilience & sustainable reconstruction of historic areas

HYPERION is a four-year EU-funded project which provided tools enabling a **better understanding of the effects of climate change**, extreme weather conditions, the ravages of time and intense geological phenomena **on Cultural Heritage monuments**.

Based on the hygrothermal, structural and geotechnical analysis of cultural heritage sites and on the combination of monitoring and simulated data, the project provided proper adaptation and mitigation strategies, and supported sustainable reconstruction plans for damaged sites.

The vulnerability maps produced by HYPERION have helped local authorities assess climate change threats, visualise the built heritage and cultural landscape under future climate scenarios, model the effects of different adaptation strategies, and ultimately prioritise any rehabilitation actions.

The outcomes of the project were demonstrated in four historic areas located in Greece, Italy, Norway and Spain and having different climatic characteristics.

More information available at: www.hyperion-project.eu

SIGNATURE – Mapping endangered cultural soilscapes in post-conflict through EO, AI and geoarchaeological signatures

Horizon Europe, a programme of the European Union

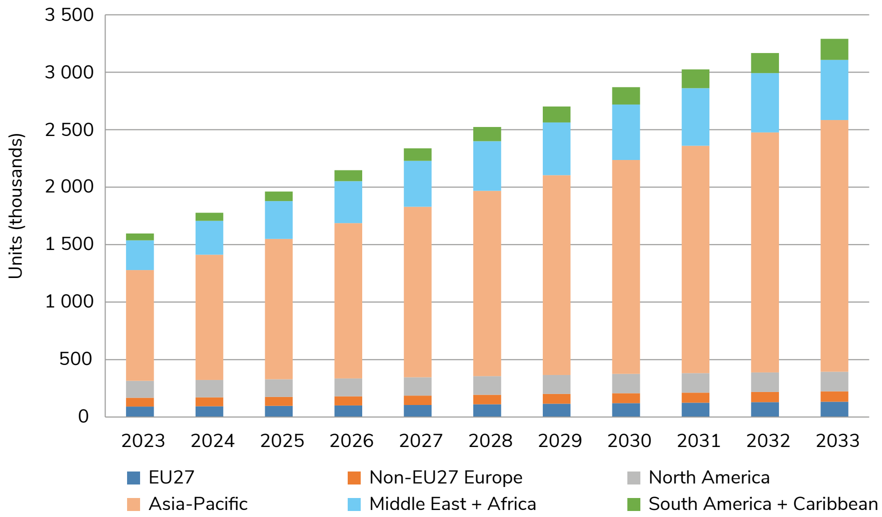
SIGNATURE is a two-year EU-funded project which **investigates the long-term settlement and land use dynamics that shaped the cultural soilscapes of the Levant** with the objective to identify archaeological sites subject to recent agricultural encroachment or abrupt land disturbances.

The project combines EO big data, AI and geoarchaeological signatures to accurately map and predict the location of anthropogenic soils and landforms, monitor historical and present-day land use trends, and identify acute landscape transformations endangering the preservation of vulnerable archaeological and heritage assets.

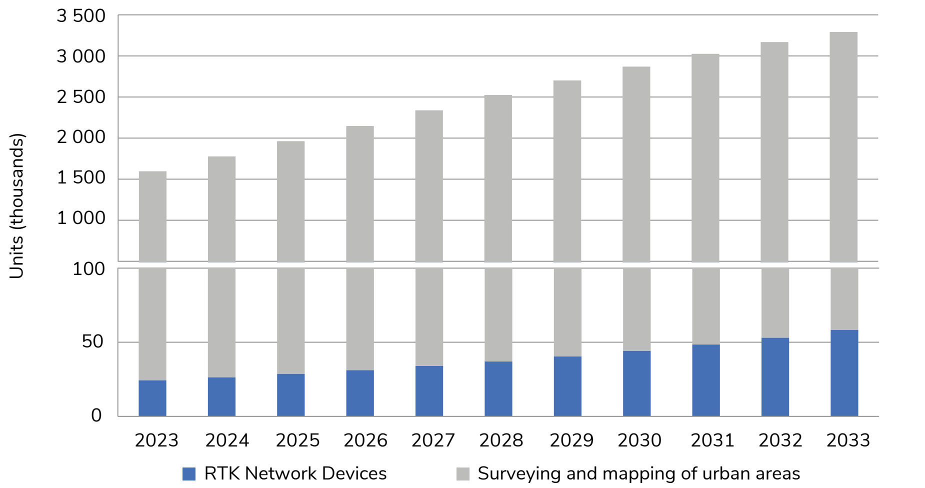
SIGNATURE will produce and share a comprehensive set of comparable data and reproducible tools for the study and management of endangered cultural landscapes, likely to be adapted and implemented by scholars and cultural heritage practitioners working in conflict and post-conflict regions.

More information available at: https://cordis.europa.eu/project/id/101067100

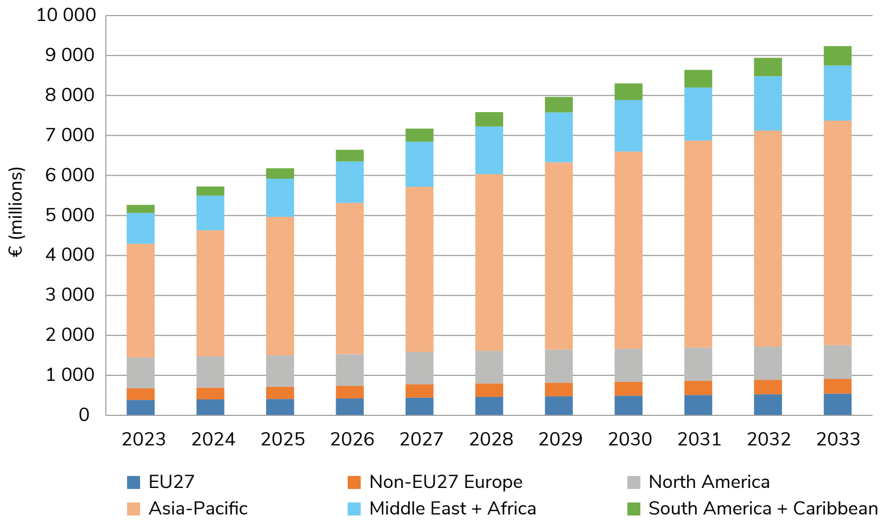
Installed base of GNSS devices by region



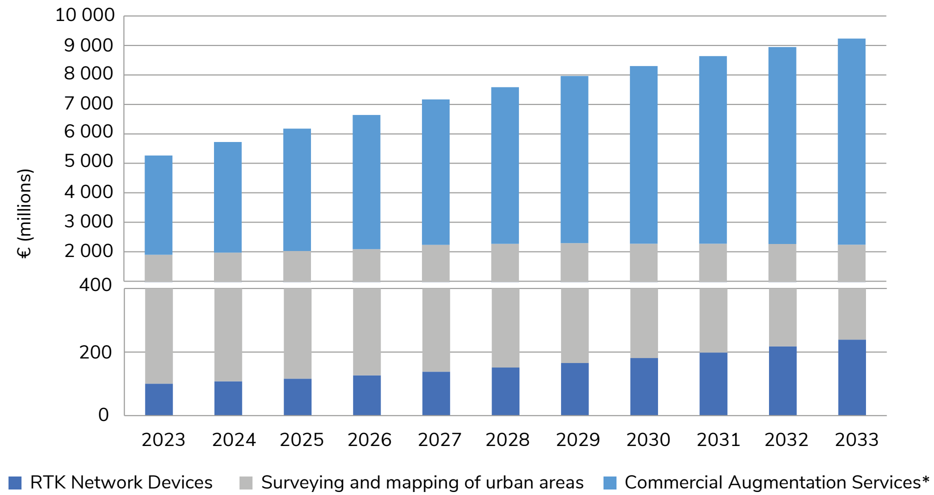
Installed base of GNSS devices by application



Revenue from GNSS device sales and services by region

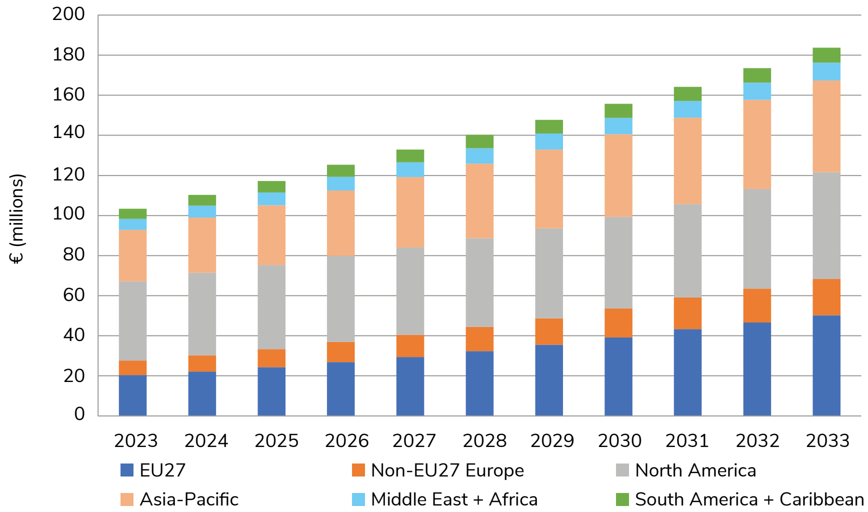


Revenue from GNSS device sales and services by application

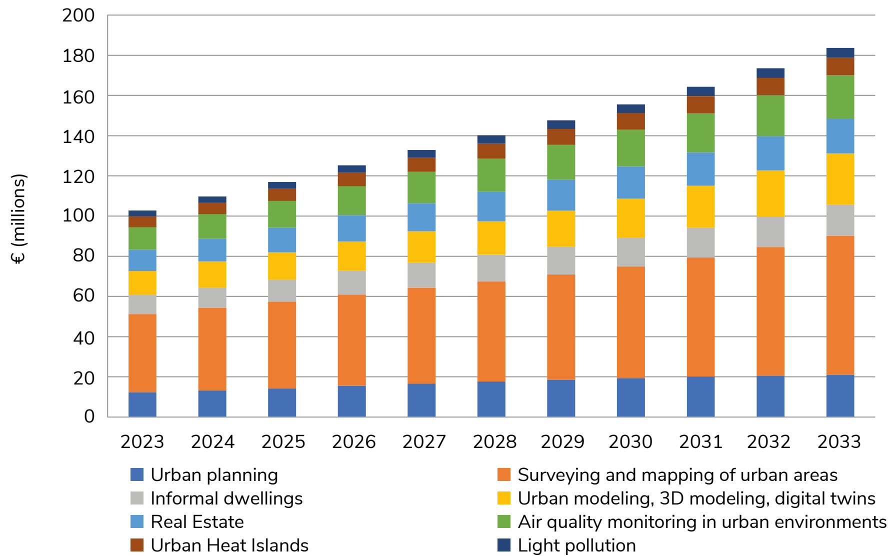


* Commercial Augmentation Services also include revenue from applications in Energy and Raw Materials and Infrastructures segments. Commercial Augmentation Services from applications in Agriculture segment are captured in the chart for Agriculture.

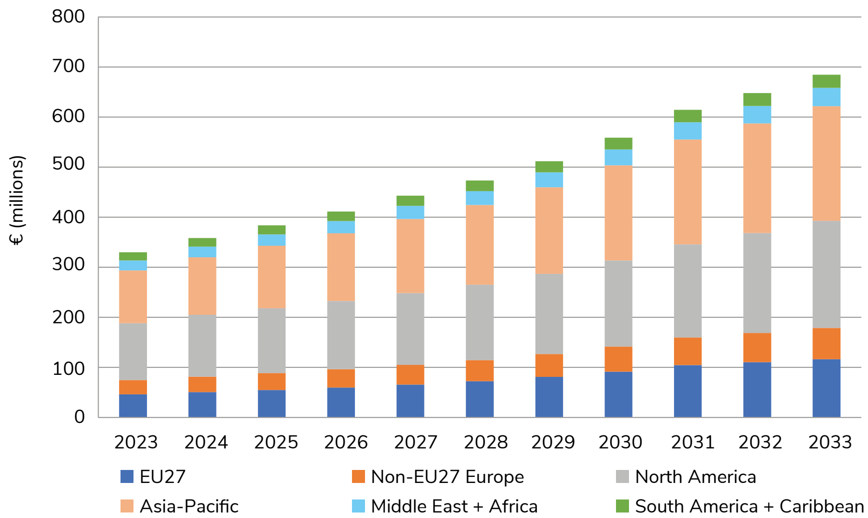
Revenue from EO data sales by region



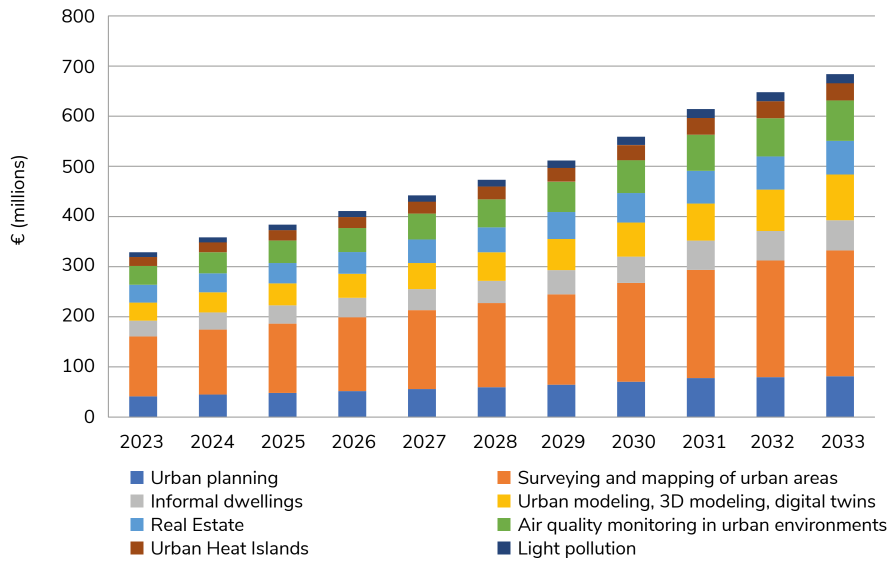
Revenue from EO data sales by application



Revenue from EO services sales by region



Revenue from EO services sales by application



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EDITOR'S SPECIAL: RESILIENT SOCIETIES

"Space systems and services in the EU contribute to the strategic autonomy of the EU and its Member States. They are key assets that will contribute to shaping the future competitiveness, prosperity and security of the EU for next generations."

"The functioning of economies, citizens and public policies increasingly relies on space-related services and data, including those in the field of security and defence."

In line with these citations from the **EU Space Strategy for Security and Defence** (SSSD), this year's Editor Special will explore the concept of **resilient societies** and illustrate through a limited selection of example use cases how EO and GNSS, but also EU Space Programme Components – EGNSS and Copernicus[1] – are contributing to building a more resilient society.

The concept of "resilient societies" as defined in this chapter encompasses all non-military activities aimed at safeguarding people, their possessions, the environment, the economy and the organisation of our societies against hostile or rogue actors, as well as managing other threats, risks and hazards that could imperil life or belongings.

Such activities, which are not discussed in the previous chapters of this report, typically fall within the remit of several government entities and can be identified across multiple domains, including border management, maritime surveillance, justice actions, diplomacy and international relations and police operations.

The following pages present a small selection of use cases that illustrate the versatility and potential of space technologies in supporting resilient societies. While these examples are by no means exhaustive, they serve to emphasise the broad utility of these technologies and to highlight opportunities for further development.

[1] The GNSS and EO report does not discuss the valuable contributions that Satcom, including secure Satcom, can provide to resilient societies. For further information on this matter, please consult the EUSPA Secure Satcom User Technology Report discussed on page 24.

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Customs operations: at the heart of international trade

Borders – land, sea, physical or digital – constitute the interface between distinct national legislations and identities, and border crossing points are convenient places at which to control the movement of goods and people in order to protect the territory, citizens and the economic and financial interests of a country.

Customs operations predominantly focus on the management of goods[1], yet customs operate in the broader context of border management and often contribute to tasks other than the management of international trade. In particular, they often participate in the surveillance of land and sea borders, the control of irregular migration and the fight against smuggling and trafficking.

This expanded role requires customs to work more closely with other relevant policy areas and organisations, both nationally and internationally.

Customs operations are essential to ensure legitimate cross-border trade and combat fraud and trafficking

Customs operations enable international trade by allowing the legitimate import, export and transit of goods. In many countries, customs are the responsibility of the ministry of finance, in line with their traditional tax collection role. In addition to this focus on **taxation**, the role of customs has evolved over time to become a more general approach to controls related to the **safety** and **security** of citizens.

In cooperation with other national or international agencies, modern days customs operations include the protection against terrorist activities, the application of restrictions on the import or export of specific products, the detection and seizure of prohibited articles, the application of sanitary and phytosanitary measures, the protection of endangered species and intellectual property rights, the implementation of foreign exchange restrictions and the monitoring of suspicious cash movements.

The traditional process of assessing and collecting trade taxes relies on the physical inspection of consignments at points of entry. This task can be complicated by old legislation – often requiring 100% inspection – and by trade tax policies that involve highly differentiated rates and widespread exemptions.

Procedures governing routine operations, such as establishing accurate import values and checking the (mis)use of exemptions, can be time and labour-intensive, leading to considerable and unpredictable delays in clearing consignments through customs. This situation is further complicated by non-tariff verifications. In short, customs operations can often be a barrier to international trade, resulting in administrative costs for government and compliance costs for business.

GNSS and EO role in Customs operations

Role of GNSS

GNSS technology contributes to, improves and even enables several customs activities whether in their core role of managing goods crossing the border - including the enhancement and modernisation of the relevant procedures - or in their modern expanded role mentioned above.

GNSS enables the **tracking and tracing** of goods along the supply chain, especially in transit at borders. It contributes to **pre-clearance** procedures (FCA - Incoterm Free Carrier - pre-clearance procedures), the creation of **fast corridors** facilitating import operations and the implementation of currently paper-based procedures through **electronic data exchange** (dematerialisation of procedures). Overall, GNSS can facilitate trade between partners by avoiding duplication of customs procedures and facilitating the clearance of goods for import, export and transit.

In the context of the digitalisation of customs clearance procedures, and in particular of eFTI (electronic Freight Transport Information), GNSS authentication can allow the **automatisation of goods clearance, green lanes** or **fast corridors**, although this capability and potential are not currently being fully exploited.

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Role of Earth Observation

Despite their potential, Earth Observation (EO) services are currently under-utilised for the core operation of goods clearance at the border. However, EO has proven its value for other operations, particularly in international cooperation to combat illegal activities, e.g. trafficking. For example, the Maritime Analysis and Operations Centre (Narcotics) (**MAOC (N)**), in which several European customs agencies participate, is already using the Copernicus Maritime Service.

Future use of space data

The challenge for customs administrations is to optimise or reduce the necessary clearance procedures to the minimum compatible with the country's international trade policy, while ensuring that the rules are correctly applied with a minimum of impediments and with **no increase of risk of fraud**.

Digitalisation and dematerialisation of customs operations is one response to this challenge, involving the use of complementary elements and technologies to further automate customs clearance processes. These include electronic filing systems, a single window system, risk management, use of GNSS and EO in combination with electronic seals and cargo tracking and tracing systems.

In the short term, **authenticated GNSS** can become a key enabler of further automated processes. EO services used more widely – e.g. for supply chain risk assessment – could ensure more streamlined clearance procedures and more effective fight against counterfeiting and illicit traffic.

[1] The control of the movement of people across borders is generally the function of a distinct immigration service or border guard.

Prevention and suppression of trafficking and smuggling: a global challenge

Organised crime – such as trafficking and smuggling – is a transnational problem calling for transnational solutions. With increased mobility of people, goods and capital, organised crime has greatly evolved and now leverages advanced technologies to strengthen and further its activities, including cybercrime.

Prevention and suppression of trafficking and smuggling can benefit from space technologies

Combating organised crime is a major challenge for the international community. Along with terrorism, it is now considered the greatest non-military threat to internal security and international economic stability. Although it is difficult to estimate, the overall proceeds of organised crime total around €1 trillion per year, according to French authorities.[1]

In a context where crime knows no national borders or sovereignty, it is essential to adopt a global strategy to tackle it and to reinforce international collaboration, especially between law enforcement agencies and judicial bodies. The **United Nations Convention against Transnational Organized Crime** (Palermo Convention), which contains protocols against trafficking persons, the smuggling of migrants and the trafficking of firearms, acknowledges this situation and provides a global legal framework for such required multinational efforts.

At the global level, the United Nations Office on Drugs and Crime **(UNODC)** and the World Customs Organization **(WCO)** manage the Container Control Programme **(CCP)** aimed at building capacity in countries seeking to improve risk management, supply chain security and trade facilitation in seaports, land borders and airports to prevent the cross-border movement of illicit goods. In Europe, the Global Illicit Flows Programme **(GIFP)** aims at strengthening international cooperation and capacities to tackle transnational organised crime.

Fighting efficiently against trafficking implies actions all along the supply chain, from the point of origin to the final destination. This includes detection of illegal crop cultivation, poaching, logging and mining, control of exit and entry points in a territory, control of transport of the cargo – including maritime surveillance – and eventually prevention of distribution.

Agencies involved in this fight include police, environmental agencies, anti-drug agencies, navies, coast guards, port authorities, border guards, and customs authorities.

Notable international or European actors include the International Criminal Police Organization **(ICPO-Interpol), Frontex** (European Border and Coast Guard Agency), **EFCA** (European Fisheries Control Agency), **EMSA** (European Maritime Safety Agency) and Europol, facilitating information exchanges between Member States and carrying out criminal analysis and assessing threats. Alongside its judicial sector counterpart, Eurojust, Europol is a keystone in Europe's arsenal to combat transnational organised crime.

GNSS and EO role in suppression of trafficking and smuggling

Role of GNSS

GNSS is used all along the Illicit trafficking supply chain by criminals and law enforcement agencies alike, as standard equipment for navigation and reporting purposes (for the platform transporting the goods). Governmental agencies, however, may be using secure governmental services such as Galileo PRS or GPS PPS. Additionally, the cargo itself can be traced by a standard GNSS tracker, but also by additional concealed trackers in case of suspected trafficking.

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Role of Earth Observation

Earth Observation is an essential tool to identify the production sites of illegal goods (origin of the supply chain) which are often located in remote and difficult-to-access areas. This early detection can range from areas of illegal crop production, mining and poaching to suspicious activities on archeologic sites.

It is also invaluable for surveillance of the maritime routes used by traffickers for detection, identification, and tracking of suspicious targets. Comparing positions reported by the mandatory (GNSS-enabled) VMS, AIS, or LRIT systems with EO observations allows detection of anomalies or unreported actions (e.g., a rendezvous with a smaller boat escaping AIS regulation).

The **Copernicus Security Service (CSS)** is particularly relevant as it provides information that helps the European Union to improve crisis prevention, preparedness and response, and to address security-related challenges in the areas of **Maritime surveillance, Border surveillance** and **Support to EU External and Security Actions (SESA)**. The European Commission has entrusted the operation of these three components of the CSS to the European Maritime Safety Agency **(EMSA)**, the European Border and Coast Guard Agency **(Frontex)** and the EU Satellite Centre **(SatCen)**.

Future use of space data

Transnational crime exploits a variety of asymmetries created by differences in legislation, law enforcement capabilities, economic cycles, the presence of organised crime and vulnerabilities such as corruption. Illegal actors take advantage of the opportunities presented by these factors, creating a tendency to exploit vulnerable geopolitical areas and weak law enforcement. Unfortunately, economic or geopolitical instabilities and crises regularly occur, creating new vulnerabilities that criminal actors are prompt to exploit. Reducing crime displacement is a priority requiring rapid adaptation and strong international cooperation between agencies. Faced with such challenges, law enforcement agencies strive to improve their early situational awareness by employing a variety of surveillance means, including space services.

[1] Source: www.diplomatie.gouv.fr/en/french-foreign-policy/security-disarmament-and-non-proliferation/fight-against-organized-criminality/

Evidence of law violations: satellites as impartial witnesses

The digitalisation of our lives and the widespread use of information and communication technologies (ICT) have created new challenges for law enforcement and judicial authorities and have profoundly changed the way they conduct their criminal investigations or proceedings. The European Commission has noted in 2018 that "E-Evidence in any form is relevant in around 85% of total criminal investigations".

Satellite information is a distinct kind of digital evidence that brings exclusive advantages, including global access, widespread availability and seemingly irrefutable proof.

Satellite data is a new and very powerful form of scientific evidence

Digital and scientific evidence are very powerful tools to support judicial proceedings and have long been admitted in courts. However, there are several factors to consider when using such data in legal procedures.

New technologies are inevitably ahead of the **legal framework** that allows them to be used as evidence, which can be a problem at times. A recurring issue is the balance between privacy and surveillance technologies.

Competence is also an important factor to consider. Legal practitioners, including judges, must call on expert witnesses to explain the significance of the data as it may be unclear by itself.

Legal admissibility: The issue of admissibility means that there is a need to ensure that data presented as evidence in court are acquired legally, free from manipulation, authentic and of the desired quality and accuracy.

To cope with such questions, special guidelines known as the **Daubert Standard**[1] – first developed in the US but adopted in many countries and in international law – exist for admitting novel scientific evidence based on expert testimony in court, including satellite products. This standard sets out additional requirements for assessing the scientific maturity and acceptance of the proposed evidence, compared to those applicable to physical evidence (authenticity, completeness, reliability, credibility and proportionality).

The use of data generated by space services (GNSS, EO) as evidence in court and other legal proceedings is not new and has become increasingly common. In 1986. For example, the International Court of Justice (ICJ) used satellite images in a border dispute between Burkina Faso and Mali.

These technologies are critical for rapid responses to developing crises, long-term monitoring of adherence to post-conflict or environmental agreements and in prosecuting violators of human rights. Moreover, during international law disputes, such as territorial and maritime disputes, parties can use satellite-based data in the proceedings to present support for their claims. The data can be used both as hard material evidence and as corroborative evidence that enhances the quality of other evidence. The use of such data is not limited to courts within national jurisdictions, but also in international tribunals, as illustrated in the ICJ case mentioned above.

[1] See e.g. https://www.law.cornell.edu/wex/daubert_standard

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GNSS and EO role in evidence of law violations

Role of GNSS

GNSS data are often used to investigate or document crimes and offences, for example to add location metadata and timestamps to photo or video recordings, to reconstruct crime or accident scenes, or to create a chronology of locations and events. However, they are less commonly used as evidence because they do not have the intrinsic qualities required to be directly admissible in court, as discussed below.

Role of Earth Observation

EO provides insight into otherwise inaccessible (dangerous or remote) areas and enables large-scale or historical analysis. It is also often the only tool with such capabilities and may have been used in the discovery and investigation of the case before being used as evidence in the prosecution. High-resolution optical images are the easiest to present in court, although other data may also be of interest.

Common benefits and challenges

EO and GNSS technologies are an **independent and objective** form of reporting and provide **scientific corroboration** of on-the-ground reporting. In both cases, the information is stored digitally and transmitted electronically. Space-derived data must therefore meet the standards for digital evidence discussed above, and in particular their acquisition, custody, control, transfer, analysis and disposition must form a proper chain of custody (CoC).

This last point is particularly important: since the processes used to extract information presented as evidence from raw EO or GNSS data are very complex and usually beyond the competence of judges or juries, expert witnesses must educate them during their testimony. This situation is complicated by the **lack of protocols and standardised methodologies** accepted by the courts.

Satellite data are processed, filtered, enhanced and interpreted for release by people who may or may not bring their own biases to bear.

Furthermore, the digital nature of this data makes it susceptible to manipulation: in the case of digital images, which are a combination of 0s and 1s, the data can be altered without the possibility of detecting forgery. In the case of GNSS, self-spoofing examples (e.g. vessels trying to circumvent embargoes) have also been widely reported.

Future use of space data

Despite the challenges discussed above, the use of GNSS and EO data as evidence in legal proceedings will continue to grow, thanks to their unique power and reach, and to the ongoing efforts of space service providers to increase confidence in their products. **GNSS authentication**, pioneered by **Galileo**, is just one example of such efforts.

The development of open standard methodologies and protocols, which are currently lacking, will facilitate the acceptance of GNSS or EO data by courts and their consideration in national and international laws and regulations. The use of **open standard products**, such as those provided by **Copernicus**, is a good example of such recognition in a legal framework, allowing EU Member States, for example, to use them to automate the acceptance of claims for agricultural subsidies and fish catches.

Election observation: an important tool for building peace and democracy

Election observation is a vital EU activity aiming to promote democracy, human rights and the rule of law worldwide. It contributes to strengthening democratic institutions, increasing public confidence in electoral processes and helping to deter fraud, intimidation and violence. It also reinforces other key EU foreign policy objectives, in particular peacebuilding.

Working alongside the **European External Action Service** (EEAS), the service for **Foreign Policy Instruments** (FPI) is responsible for operational expenditures in the crucial area of EU external action. The FPI acts as a first responder to EU foreign policy needs and opportunities in several domains, including election observation.

The European Union deploys Election Observation Missions (EOMs) to countries all around the world, with the exception of the regions covered by the **Organization for Security and Co-Operation in Europe** (OSCE). In the EU Member States, election processes are observed by the OSCE.

Election observation is a demanding task that can be facilitated by the use of space data

International election observation is a valuable tool for improving the quality of elections. Observers help to build public confidence in the integrity of electoral processes. Election monitoring helps to promote and protect the civil and political rights of voters, to prevent manipulation and fraud, and to expose such problems when they occur. When observers issue positive reports, they build confidence in the democratic process and the legitimacy of the governments that emerge from elections.

Any election can be improved by independent observation, but in-depth monitoring is particularly useful in countries where a significant proportion of the population lacks confidence in the electoral system, such as post-conflict countries where groups that fought on the battlefield may have strong suspicions about the political system and the electoral process. The same applies to countries that have held very few elections or those adopting electoral reforms.

In such cases, election observation makes an important contribution to peacebuilding, because building confidence in the electoral process is a prerequisite for peace.

Election observation by the United Nations or other intergovernmental organisations can be particularly useful where domestic observer organisations do not have sufficient power or resources to organise effective monitoring, or where their impartiality may be questioned. International observer missions are organised by a wide range of actors, such as the **European Union**, **OSCE**, the **Carter Center**, the **African Union, OAS and the Council of Europe**.

Comprehensive observation requires an examination of the entire pre-election period and post-election developments, as well as what happens on election day.

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GNSS and EO role in support for elections observation

The ability of observers to reach remote locations or to cover an entire country to fulfil their mission is often limited, intentionally or otherwise. Furthermore, access to some places may involve an element of risk.

Role of GNSS

To ensure the **safety** of observation missions, Satcom-enabled GNSS trackers provide 'track and trace' capabilities for personnel and assets in the field, allowing a control centre to monitor their position and stay informed of the situation. Such missions may take place in contested environments, which may require specific capabilities in terms of **resilience** and **trustworthiness**, but only standard open GNSS services are currently used.

Role of Earth Observation

When direct, ground-level observations are challenging or unfeasible, **EO** data can provide valuable assistance. Satellite imagery is an important means of detecting the movement and number of people, and can be used for gauging electoral participation levels or to identify anomalous patterns (for instance, unoccupied polling stations in an otherwise well-attended election) that may indicate disruption of the electoral process.

Future use of space data

The recent increase in political instability on several continents is evidence that sound democratic practices are more necessary than ever.

Election observation missions can contribute to this, even though their task is made more challenging by an unfavourable environment, which may even call into question the credibility and relevance of their assessments.

In addition, the role of observers has been greatly complicated by the emergence of **digital technologies** in elections (e.g. voting machines, Internet voting), which require new skills and new monitoring tools.

In this context, it is more important than ever to improve the quality and reach of election observation, and the full potential of space services can be effectively used to help meet such challenges.

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, while 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. This methodology attributes the size of the EO and GNSS market to the region where, devices, data or services are sold and used.

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 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. In particular, quantitative data and forecasts of GNSS devices shipments, installed base and the deriving revenues presented 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. In the same way, quantitative data and forecasts of EO revenues presented throughout the Market Report are given for all applications listed in the charts of each market segment, carefully cross-checked in order to avoid overlaps and double-counting. The revenues attributed to the EO applications in the different segments are to be interpreted as the best estimation of relative proportion between them. The authors adopted a best-effort approach to ensure achieving the best possible accuracy.

A **different methodology** was used **to calculate EO and GNSS revenues** presented **on pages 13, 14** and **23, 24 respectively**, compared to the rest of the report. This methodology measures the size of the EO and GNSS industry from a supply perspective based on a bottom-up approach which quantifies revenues attributable to EO and GNSS of more than 1 500 individual companies. The analysis presented on those pages only relates to 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 for some regions and not others). Companies are allocated to a single region based on the registered headquarters of the company (or its ultimate parent), which indicates the regions in which the revenues deriving from EO data, GNSS equipment and related services are generated. Changes in market share are driven by general market trends, mergers and acquisitions, and exchange rate fluctuations.

Not all companies are obliged to report their financial information, so inaccuracies in revenues for individual organisations may exist. In the case of missing financial figures for 2021, especially for relevant players, revenues were extrapolated from available information. The authors are aware that the accessibility of information on the companies' revenues might differ in different world regions, potentially leading to inaccuracies and biases. In particular, there may be vertical integration in the Chinese and Russian governments. This means that activities, which in Europe are procured by the government from industry on market terms, are delivered internally by those governments. This implies that companies from those countries might appear underrepresented in the analysis. The **authors adopted a best-effort approach** to ensure achieving the best possible accuracy and completeness. The revenues of the companies included in the analysis are allocated to the different segments of application and the different steps of the value chain according to the best knowledge available to the authors, which is based on official sources (e.g. companies' annual reports) and other secondary sources, including databases and reports and interviews with the companies of interest and industry experts. Concerning EO, data and data processing services can be used in any market segment, making it difficult to delineate the companies to the different segments of application. Therefore, data acquisition and distribution is not quantified per segment in this study.

Disclaimer

The EUSPA EO and GNSS Market Report issue 2 was carried out by the European Union Agency for the Space Programme in cooperation with the European Commission and with the support of EY Belgium, Egis, Evenflow, FDC and LE Europe.

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Any comments to improve the next issue are welcome and should be addressed to: market@euspa.europa.eu

Sources

The model makes use of publicly available information and additional data and reports purchased from private publishers. Primary sources include:

Euroconsult (EO Data & Services Market, 2022), 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; Orbis; 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.

Annex 2: Definition of GNSS performance parameters

The definitions given below are to explain the GNSS performance parameters as referenced throughout the report, in order to support the reader in gaining full understanding of the report content. Although universally accepted definitions for the performance parameters do not always exist, the terminology adopted in this report is based on converging definitions by influential sources and publications.

Key GNSS performance parameters

Availability is the 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 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: 0-10 cm; decimetre level: 10-100 cm; metre-level: 1-10 metres.

Calibration only relates to 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 the 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).

Traceability is the 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 timestamp.

Annex 2: Definition of EO performance parameters

The definitions given below are to explain the EO performance parameters as referenced throughout the report in order to support the reader in gaining full understanding of the report content. Although universally accepted definitions for the performance parameters do not always exist, the terminology adopted in this report is based on converging definitions by influential sources and publications.

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 metre means that each pixel corresponds to a 1 by 1 metre 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 28=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).

Spectral range refers to the wavelength range of a particular channel or band over which remote sensing data must be collected.

Latency is the difference between the reference time of the satellite measurement and the time the final product (e.g. optical or radar image) is made available to users (e.g. value-added service providers).

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 follows 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 helps 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, through various types of practical, operational and financial data aimed to improve 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 synchronisation 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

Drone navigation (uncertified): An uncertified navigation tools capable of PVT and other capabilities related to drone navigation providing horizontal/vertical accuracy, integrity (integrity risk, time to alert and alert limits), continuity and availability for different phases of flight and environments.

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 200 ft. 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.

Performance Based Navigation (PBN) for drones: An umbrella term for navigation based on a specific and certified standard. An equivalent of PBN for manned aviation.

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 operations 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 optimisation 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: GNSS 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.

Drone operations planning: Includes the use of EO data to understand the environment close to planned flight trajectory and consequently to support ground risk assessment. EO data supports inclusion of terrain/surface model into route planning in order to apply ground clearance. EO data can also support operators in identifying alternative landing site. GNSS (SBAS) enables precise route planning and increased integrity of positioning signal thus ensuring that positioning and navigation performance is known and acceptable.

Monitoring terrain obstacles: EO assists airport operators in monitoring and managing potential threats to aviation safety from changes to airport surroundings and helping to secure safe flight take-off and landing. Outside of airport's protected areas, EO is also capable to provide high accuracy terrain models supporting airspace users operating close to the ground.

U-space services: The precise positioning and integrity enabled by EGNOS can support U-space services serving both manned and unmanned airspace users. Such services include network identification, geo-awareness or conformance monitoring. It is important to note that network identification only applies to drones. EO can support geo-awareness (post-processing).

SURVEILLANCE

Electronic Conspicuity (certified): 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 numerous non-certified solutions used for situational awareness of the operator.

Electronic Conspicuity (uncertified): Provides self-reporting of position from an aircraft or drone to other aviation actors providing means to learn about position and speed vectors. The information is derived from GNSS and covers numerous certified solution used mostly for Air Traffic Management.

GADSS: 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 aircrafts and provide services to facilitate conflict free traffic flows. All systems in use today rely on GNSS for timing, and often synchronisation as well, for example in Wide Area Multilateration systems that use multiple synchronised 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 to a reduction in the number of safety incidents and increased flight efficiency.

Annex 3: List of applications

CLIMATE, ENVIRONMENT, AND BIODIVERSITY

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.

Ecosystems monitoring: Includes coastal, snow and ice, terrestrial and water ecosystems. For coastal ecosystems monitoring, EO provides information on multiple parameters, 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. For snow and ice ecosystems monitoring, EO provides data on snow and ice cover (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. For terrestrial ecosystems monitoring, EO data provides information on plant species which 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. Other relevant data derived from EO relate to air/water quality completing the information for the status/forecasting of the ecosystem. With regards to 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: Various types of EO data can be used to aid formation of short and long-term climate change mitigation and adaptation strategies.

Climate monitoring and forecasting: Many types of EO data can be used in climate monitoring and forecasting. Air quality, land temperature, cloud cover and several other parameters relevant for the climate can all be understood with EO data, which in turn can be built into relevant models and contribute to climate forecasting.

EO-based climate 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 behaviour used for various purposes.

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

ENVIRONMENTAL MONITORING

Environmental auditing: EO data aids in the assessment of the impact of human activity across four different environments: atmosphere, coasts, land, and water and oceans. For 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. 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. With regards to 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. 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 impact assessment and ESG: EO plays a vital role in conducting impact studies and implementing ESG policies across four distinct environments. For the atmosphere, EO satellites and sensors are deployed to monitor atmospheric conditions, encompassing air quality and greenhouse gas emissions, facilitating both short- and long-term forecasting. Along coastlines, EO data provides insights into wetland loss, land-use changes, wetland mapping, coastal geomorphology, and water properties, including chlorophyll-a levels and littoral and subtidal habitats. On land, EO applications extend to land-use changes, vegetation, biomass, soil monitoring, and the assessment of human impacts like waste disposal, construction, and infrastructure development. In water and ocean environments, EO data captures parameters such as temperature, transparency, water depth, tides, and currents, while also offering insights into flora, fauna, and human activities, including the monitoring of infrastructure and waste.

Environmental resources management: The use of EO satellites and data enables effective environmental resource management in four environments. Firstly, for the atmosphere, multiple EO satellites and sensors monitor air quality and greenhouse gas emissions, providing both short and long-term forecasting capabilities. Secondly, along the coasts, EO satellites track coastal wetland loss, land-use changes, wetland mapping, coastal geomorphology, water properties, and nutrient levels, aiding in erosion and sedimentation mapping, and compliance monitoring for water quality. On land, EO applications encompass land-use changes, vegetation, biomass, soil monitoring, and the assessment of human impacts like construction and waste. Lastly, in water and oceans, EO data measures various parameters to assess the impacts of human and natural activities on aquatic environments, including temperature, transparency, water depth, tides, currents, flora, fauna, and human activities such as waste disposal.

Annex 3: List of applications

CONSUMER SOLUTIONS, TOURISM & HEALTH

CORPORATE

Location-based 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.

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 through a variety of fitness applications. It records data such as real-time distance, speed/pace, location, elevation, travelled distance, and step counters to monitor users' performance. Speed and elevation charts are provided (including 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).

Tourism fruition: GNSS data can be used to enhance navigational capacities for tourists, including in reaching destinations and exploring the destination areas, as well as providing information on the destinations, such as restaurants, hospitals, ATMs, banks, petrol stations, etc.

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 into consumer electronics for localisation and navigation purposes. For example, for gardening robots, delivery robots, security and surveillance robots, personal assistant robots, painting robots, and 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.

Annex 3: List of applications

EMERGENCY MANAGEMENT & HUMANITARIAN AID

HUMANITARIAN AID

NGO's asset management: Through smartphones or other devices, GNSS functionalities can be helpful for NGOs in managing and tracking resources, including real-time personnel and asset tracking, route optimisation particularly for disaster relief or healthcare delivery missions, data collection and effective resource allocation for areas of need.

Welcome applications to people in need of humanitarian aid: GNSS provides accurate location information that can be accessed through smartphones or other mobile devices for recipients and aid distribution points and improves the efficiency and effectiveness of humanitarian efforts. The location information can improve coordination, speed up the delivery of relief supplies to those in need, and ensure the safety of the personnel involved.

Health and medicine response and coordination: EO data can be used to monitor the spread of diseases and the environmental risk factors associated with certain diseases, thus, helping with public health mitigation measures. GNSS, meanwhile, can be used to locate and navigate relief efforts and help patients transport, as well as track the movement of healthcare supplies, especially as the data is easily accessible from smartphones or other mobile devices.

Anticipatory humanitarian action: Anticipatory action is commonly defined as acting ahead of predicted hazards to prevent or reduce acute humanitarian impacts before they fully unfold.

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 displacement monitoring: Monitoring of displacement patterns due to conflict or disaster aimed at, for example, planning humanitarian responses. EO data can be used to monitor migration routes, as well as for the identification of temporary dwelling structures.

PREVENTION AND MITIGATION

Impact exposure analysis and proactive mitigation measure: EO data can assist in preparing for potential disasters by helping identify and monitor natural hazards, such as floods, wildfires, earthquakes and hurricanes, and map high-risk areas that may require special attention in disaster planning.

PREPAREDNESS

Early warning emergency applications: GNSS and EO technologies perform the systematic monitoring and alerting of various environmental hazards. This includes drought monitoring, early-warning surveillance of forest fires, landslides and terrain deformation monitoring, earthquake and tsunami monitoring, floods monitoring, storm surge monitoring, and volcanic activity monitoring. Leveraging GNSS and EO technologies enables real-time data collection, analysis, and timely dissemination of alerts, enhancing the capacity for early detection, preparedness, and effective response to mitigate the impact of natural disasters and emergencies.

Early-warning surveillance of forest fires: EO thermal imaging can detect the heat signatures associated with active fires, as well as smoke and aerosols that may appear. As an early warning system, EO can provide a risk assessment and vulnerability mapping of forest fires by assessing land cover, vegetation types, and proximity to urban areas.

Hazards monitoring: Hazards monitoring, facilitated by GNSS and EO technologies, encompasses the systematic observation and analysis of various environmental phenomena. This includes the monitoring of landslides and terrain deformation, locust swarms, drought monitoring, earthquake and tsunami occurrences, floods, storm surges, vector-borne diseases, volcanic activity monitoring, and early-warning surveillance of forest fires. Utilising GNSS and EO technologies enables the real-time tracking, assessment, and early detection of these hazards, contributing to enhanced disaster preparedness, risk mitigation, and timely response efforts.

Landslides and terrain deformation monitoring: EO data can be used to detect changes in the Earth's surface that may indicate potential landslides and monitor ground displacement over time (in conjunction with similar applications in Infrastructure or Rail that are more specifically focused on the infrastructures themselves). GNSS can provide real-time data on ground movement, allowing for an early warning system and a rapid response to landslide threats.

Earthquake and tsunami monitoring: EO satellites can detect and monitor surface deformations caused by tectonic activities, including land and coastal changes. GNSS can provide early warning signals from ground motion or sea-level changes.

Drought monitoring: In parallel to soil condition and vegetation monitoring applications used in Agriculture (that are more specifically focused on plant health), EO can also provide data to assess and manage drought conditions, including monitoring vegetation health, soil moisture, rainfall and water bodies and weather forecasts.

Volcanic activity monitoring: EO can provide thermal imaging to monitor the movement and temperature of lava flows and volcanic gasses and ash clouds. GNSS technology can be used for ground deformation monitoring and eruption early warning systems.

Floods monitoring: EO and GNSS can provide critical data for flood prediction, early warning, and response efforts. EO can provide flood extent mapping and damage assessment, as well as weather forecasts and water bodies and coastal monitoring, while GNSS can provide real-time water-level tracking.

Storm surge monitoring: EO satellites can track the formation, movement, and intensity of storms, as well as changes in ocean temperature and levels, to mitigate storm surge events.

Monitoring of vector-borne diseases: EO can provide environmental data monitoring temperature, humidity, precipitation, vegetation cover and other factors that may influence the spread of vector-borne diseases.

Monitoring of locust swarms: EO satellites can detect the presence of locust swarms and track changes in vegetation cover, as well as monitor environmental conditions that influence movement and breeding patterns. GNSS can provide real-time swarm tracking.

RESPONSE

Crisis area assessment: EO data can provide damage assessment and monitor changes in land and vegetation cover. Simultaneously, GNSS can provide real-time tracking of affected populations and relief supplies and personnel.

Operational wildfires modelling: EO data equipped with thermal imaging can be used to model fire spread, as well as provide assessment of the flammability of vegetation and potential hotspots.

Annex 3: List of applications

SEARCH AND RESCUE

SAR operations - at sea: 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).

SAR operations - aviation: Aircraft should be equipped with Emergency Locator Transmitters (ELTs) or a PLB that helps 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.

SAR operations - land: Climbers and hikers are advised to equip themselves with a PLB in case they find themselves in distress.

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

POST-EVENT RECOVERY

Post-crisis damage assessment and building inspection: EO data can be used to map the extent of the damage, including to infrastructures, while GNSS can provide accurate locations of damaged buildings and enable field teams to navigate the impacted areas for inspection.

Restoration of supply chain and infrastructure services: EO data can provide damage assessment to critical infrastructures and transportation networks, including vegetation and land cover, while GNSS enables precise location tracking and mapping of infrastructure damage and repair efforts, in addition to assisting in finding optimal routes for the transportation of goods and resources.

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 raw materials: 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).

Mineral exploration, site planning/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.

Mining vehicle management and control: Augmented GNSS solutions enable the accurate guidance of heavy mining machinery.

Annex 3: List of applications

RENEWABLE ENERGY

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.

Renewable energy 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 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 visualisation. 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.

Risk assessment for renewable energy assets: Energy assets are exposed to a variety of natural risks which can put at danger the people working on site, 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 (including 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.

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., biogeochemical 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.

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

Fishing 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.

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.

Fish provenance and ecolabelling: GNSS-enabled data from vessels can be used to monitor the location and intensity of fishing effort. This can form an independent and reliable source of data for fish provenance certification and ecolabelling.

Illegal, unreported and unregulated fishing (IUU) control: Satellite data has surveillance capabilities for monitoring IUU fishing activities and can 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., 15 m for AIS, 12 m for VMS), the GNSS receiver in these applications is different to the receiver used for general navigation.

Annex 3: List of applications

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.

FOREST RESOURCES 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. Meanwhile, GNSS technology can be used to monitor parameters related to forest vegetation health, such as in mapping forest cover or measuring tree height.

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.

Forest asset management: GNSS provides insightful telematics data from forestry assets to help increase traceability/efficiency, monitor workforces and reduce costs.

Forest certification: EO can help in the verification and certification of forestry management and production activities.

Forest machinery guidance: GNSS positioning can assist drivers of forest machinery in following the optimal path when conducting activities, thus minimising risks of overlaps.

INFRASTRUCTURE

ENVIRONMENTAL IMPACT MONITORING

Environmental impact assessment of infrastructure: 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. This application focuses on the infrastructures themselves in contrast to similar applications in Climate, Environment and Biodiversity that are more focused on natural or geologic changes.

INFRASTRUCTURE CONSTRUCTION AND MONITORING

Construction monitoring: Thanks to its capacity to detect surface changes, EO can support the monitoring of ground deformations in the vicinity of construction sites as well as the monitoring, in near-real-time, of the progress achieved anywhere on the construction 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 infrastructure: EO enables the monitoring of the impact on buildings and infrastructure of land subsidence caused by a variety of human activities (e.g. aquifer overexploitation in urban areas).

Official Development Assistance (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.

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.

Post-construction monitoring: Critical infrastructure 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.

Annex 3: List of applications

INFRASTRUCTURE PLANNING

Infrastructure site selection and planning: EO 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 applications like 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.

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.

Vulnerability Analysis: EO can contribute to the vulnerability assessment for locations prone to natural hazards for infrastructure planning purposes (in contrast to similar applications in Emergency Management that focus more on natural disaster preparedness). Relevant EO-based products and services include historical data on ground deformations, floods, droughts, and fires as well as climate projections enabling the assessment of the evolution of risks.

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 synchronisation 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.

DTV Broadcast: GNSS timing receivers provide the means to ensure a continuous and tight synchronisation of the different media data. Timing and synchronisation, delivered by GNSS, is essential for a smooth and uninterrupted broadcasting experience.

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 the 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 analogue telephone systems, the PSTN is now almost entirely digital in its core network and in this report it consists of fixed telephone networks. GNSS is usually a backup to atomic clocks to provide time slot management.

Satellite Communication (SATCOM): Telecom operators require accurate and consistent time and synchronisation, as well as 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 cell networks.

INSURANCE AND FINANCE

FINANCE

Commodities trading: Commodity trading involves the monitoring of goods production, natural resources (e.g. oil and gas, mineral resources) and shipping at key locations, providing investors/traders with information to predict supply and demand to develop their investment strategies. EO can contribute by providing more information on the calculation of indicators which can help to develop logistics and financing strategies. Beyond goods and natural resources, there is a growing interest in the food commodity market for which EO can provide vital information on crop conditions (e.g. the AMIS tool by the FAO).

ESG reporting: EO data can help providing indicators to improve ESG (Environmental, Social, Governance) measuring, monitoring and reporting, assessing investment's overall impact and financial returns. Differently from ESG application analysed under the Climate, Environment, and Biodiversity segment which helps verifying the fulfilment of environmental requirements, ESG reporting in Finance specifically focuses on the economic perspective of ESG and can help financial institutions to comply with regulation, assess risks and monitor physical assets. The revenues of this application are quantified in the Climate, Environment, and Biodiversity segment under the application Environmental impact assessment and ESG.

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 with this new business and 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. For Bank Network Operations, GNSS equipment is used for Time Stamping functions, to log events chronologically 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. Meanwhile, for 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 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. GNSS provides positioning for drones used for pre- and post-event for analysis and data gathering in the case of insurance claim assessments.

Index production: Computation of numerical indexes (part of parametric insurance products as a certain index level triggers a payment) 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 the 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 can 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.

Annex 3: List of applications

MARITIME & INLAND WATERWAYS

INLAND WATERWAYS

Autonomous Surface Vessels: ASVs rely on a combination of EO and GNSS data to navigate and perform various tasks. GNSS can provide precise positioning and autonomous navigation capabilities, while EO satellites can capture data related to water conditions and monitor the weather. As of now, this application is still under development and not fully operational yet.

Collision avoidance (AIS, VDES): Alongside the receivers for navigation, all vessels above 300 GT 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), in order to improve the traffic management and safety of navigation. VHF Data Exchange System (VDES) builds upon the capabilities of AIS and is currently in plan to succeed AIS.

GNSS vessel engine management system: GNSS supports remote monitoring of the ship's condition (e.g. engine diagnostics). This provides the vessel operators with the necessary information to perform routine checks on the engine and improves the overall maintenance of vital elements of the vessel.

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.) whose outcomes are key 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

Maritime Autonomous Surface Ships: MASS refers to a ship which, to a varying degree, can operate independent of human interaction (i.e. degrees of automation are defined from Degree-1 to -2 by the IMO). The MASS are typically larger than AVS and are designed for ocean-going transport with different sets of requirements and equipment needed.

Collision avoidance (AIS, VDES): *Similar with Inland Waterways. However, for Merchant Vessels, the technology is more complex and advanced as this would be required for ocean transport, as well as to comply with international regulations.*

GNSS vessel engine management systems: *Similar with Inland Waterways. However, for Merchant Vessels, as it entails a larger vessel and system, additional sensors and systems may be needed, especially with regard to long-distance ocean transport.*

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, and cargo ships larger than 500 gross tonnage or larger than 300 tonnes if engaged on international voyages are regulated and heavily rely on GNSS to support navigation activities. At least three devices are typically fitted on vessels for redundancy reasons.

Navigation through sea ice: Combined with GNSS positioning information, ice maps generated using EO data enable navigation applications that 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 navigation: 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 optimisation of maritime transportation.

OCEAN AND ENVIRONMENTAL MONITORING

Marine pollution monitoring: SAR-based and optical satellite data can detect and monitor 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. This application is similar, although with due differences, to the coastal and water ecosystems application in Climate, Environment, and Biodiversity that encompasses a wider scope for ecosystem monitoring.

PORTS

Automated port operations: GNSS positioning supports the 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 devices - PPU) provides pilots with greater control, safety and accuracy during port approach and manoeuvres.

Port Operations: GNSS-based technologies enhance safety, efficiency and precision during port operations. This application includes port navigation devices used for monitoring transit progress, docking and loading-unloading operations; Portable Pilot Units (PPUs) which are professional devices used by maritime pilots for navigating vessels through narrow passages; and vessel docking systems that offer necessary precision in positioning and speed, facilitating efficient manoeuvring within the port area, improved vessel trajectory, and constant monitoring for moored or docked vessels.

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 caused 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, using collision avoidance devices.

Port security: EO data contributes to enhanced situational awareness with the goal of preventing crime or any illicit good entering or exiting the country. High-resolution SAR data for instance enables port authorities to access the most recent information on changes in cargo and passenger ports, tracking vessels, and estimating the amount of stored goods.

Annex 3: List of applications

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.

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

Asset 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.

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.

Annex 3: List of applications

ROAD & AUTOMOTIVE

ASSET MANAGEMENT

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 asset management: Asset management on-board units (OBUs) and systems transmit GNSS positioning information through telematics to support transport operators in monitoring the logistics activities and their performance, as well as to help monitoring vehicles. 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 AND ENFORCEMENT

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 sensor data, GNSS positioning information is used by insurance companies to monitor the distance driven as well as driver's behaviour and related 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 potentially 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

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.

Emergency assistance: The pan-European eCall and other systems, such as the ERA-GLONASS in Russia, as well as non-regulated solutions developed by OEMs and device vendors send a message including location to emergency response centres in case of accident, accelerating assistance to drivers.

SMART MOBILITY

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.

Infotainment services: Mobility platforms combine various data sources to provide real-time information and predictions to road users, enabling them (through the vehicle navigation system) to plan and navigate the most optimal routes. EO supported information include road condition status, real-time traffic and congestion updates, and weather information.

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.

Annex 3: List of applications

SPACE

GUIDANCE, NAVIGATION AND CONTROL SUBSYSTEM

Attitude Determination (AD): Space missions' success often rely on the pointing accuracy and the stability of its payloads (e.g. precise communication data link among satellites, precise pointing direction of a camera to acquire images of a determined area, etc.). Being accurately aware of the vehicle's orientation in space allows to apply – if needed – the necessary torques to obtain the desired attitude. As primary attitude sensor, GNSS can be an excellent option for satellites whose accuracy requirements are not so stringent. GNSS is also used to complement, or serve as back-up, of more precise systems such as star trackers.

Precise Orbit Determination (POD): the most accurate 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 precise trajectories of satellites in LEO. Such GNSS-based information can also be used to perform "Rendezvous & Docking", "Formation Flying" or "GEO Station keeping".

Real-Time Navigation (RTN): Real-time navigation onboard an orbiting vehicle is based on the use of an orbit propagator; a model that allows predicting the orbital characteristics of the vehicle given the current orbital characteristics. GNSS is an enabler of real-time navigation by feeding these orbital propagators with its PVT information, contributing to an increased autonomy and orbital accuracies in the decametric range when based on multi-constellation and multi-frequency receivers.

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.

DEEP SPACE APPLICATIONS

Lunar Orbit (LO): Past the TLO, GNSS will be used to obtain position fixes and velocity vectors once the vehicles will be established in lunar low orbits. GNSS can reduce tracking and operations costs, provide a backup/redundant navigation means, or support hosted payloads if it is used as a timing source.

Moon Surface Positioning (MS): Although still to be tested "in-orbit" but with demonstrating missions in the horizon, GNSS might be used as a source of coarse positioning on the Moon's surface (or part of it), at least until the currently conceptualised GNSS-like constellations around the Moon become a reality.

Translunar Orbit (TLO): GNSS can be used as a means of orbital monitoring and determination during Translunar Orbits (or Moon Transfer Orbits), during which the spacecraft is manoeuvred via propulsive injections to raise it from a circular Earth orbit to a highly-eccentric orbit, and later to a lunar orbit.

SUPPORTING OR ACTING AS 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.

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, for example, 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 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, for example, as a means to alert health authorities of related risks for specific demographic groups.

SMART CITIES OPERATIONS

Smart streetlights: Smart street lights combine precise GNSS positioning data with other sensors (e.g. Cameras, photocells) to remotely control the output of individual streetlights, detect faults, or 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 CULTURAL HERITAGE MONITORING

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

Real estate: EO data is enabling increased situational awareness for real estate actors as part of the planning and/or monitoring phases. This includes supporting valuation of land or property, monitoring the evolution of real estate property projects, or developing analyses and risk assessments for hazard-prone locations.

Surveying and mapping of urban areas: Using satellite imagery and precise GNSS positioning, comprehensive geographic data can be collected and analysed, enabling the creation of accurate maps and spatial information for urban planning, infrastructure development, cultural heritage monitoring and management, and resource management in cities.

Urban modelling, 3D modelling, Digital Twins: Leveraging digital information, including satellite imagery and GNSS, to create comprehensive digital representations of urban environments, helps facilitating urban planning, infrastructure management, and real-time simulations for improved decision-making in city development and management.

Urban planning: EO empowers urban planning through data-driven insights on various aspects for sustainable and resilient urban development. EO can measure urban sprawl, density, and sealed surfaces, as well as change such as increase or decrease of urban deprivation.

Annex 4: List of acronyms

2D	Two-dimensional
3D	Three-dimensional
3GPP	3rd Generation Partnership Project
4D	Four-dimensional spacetime
5D	Fifth-dimensional - Real-time extraction in virtual model
5G	Fifth-generation of mobile telecommunications technology
6G	Sixth-generation of mobile telecommunications technology
A4E	Airlines for Europe
AAQS	Ambient Air Quality Standards
ACI	Airport's Council International
AD	Attitude Determination
ADS	Automated driving system
ADS-B	Automatic Dependent Surveillance - Broadcast
ADS-L	Automatic Dependent Surveillance - Light
AED	Automated External Defibrillator
Agtech	Agricultural technology
AI	Artificial Intelligence
AIRE	Airlines International Representation in Europe
AIS	Automatic Identification System
AIS-MOB	Automatic Identification System Man Overboard Beacon
AIS-SART	Automatic Identification System Search and Rescue Tran-smitters
AMC	Acceptable Means of Compliance
AMIS	Agricultural Market Information System
ANAS	The Italian Road Authority
AQGs	Air Quality Guidelines
AR	Augmented Reality
ARAIM	Advanced Receiver Autonomous Integrity Monitoring
ARI	Advanced Air Mobility (AAM) Reality Index
ASC	Aquaculture Stewardship Council
ASI	Agricultural Stress Index
ASIL	Automotive Safety Integrity Level
AsSiSt	Aircraft Support & Maintenance Services
ATC	Air Traffic Control
ATIS	Alliance for Telecommunications Industry Solutions
ATM	Air Traffic Management
AUV	Autonomous Underwater Vehicles
B2B	Business-to-Business
BBNJ	Biodiversity Beyond National Jurisdiction
BDPS	Beacon Distress Positioning Sharing Service
BDS	BeiDou Satellite System
BIM	Building Information Modelling
BSGN	British Space Group Network
BVLOS	Beyond Visual Line of Sight
C3S	Copernicus Climate Change Service
C4EC	Copernicus for EC
CAD	Connected and Automated Driving
CAGR	Compound Annual Growth Rate
CAMS	Copernicus Atmosphere Monitoring Service
CANSO	Civil Air Navigation Service Organisation
CAP	Common Agricultural Policy
CAS	Cooperative Applications Satellite
CAS	Commercial Authentication Service
CASA	Centre for Advanced Spatial Analysis
CAT 1	Category 1
CCAM	Cooperative, connected and automated mobility
CCM	Copernicus Contributing Missions
CCO	Continuous Climb Operations
CDO	Continuous Descent Operations
CDSE	Copernicus Data Space Ecosystem
CDS	Climate Data Store
CEMS	Copernicus Emergency Management Service
CEN	European Committee for Standardisation
CENELEC	European Electrotechnical Committee for Standardisation
CFP	Common Fisheries Policy
CH	Cultural heritage
CI	Critical Infrastructure
CIMR	Copernicus Imaging Microwave Radiometer
CIS	Common Information Services
CISP	Common Information Services Provider
CLMS	Copernicus Land Monitoring Service
CLUG	Certifiable Localisation Unit with GNSS
CMEMS	Copernicus Marine Environment Monitoring Service
CNS	Communication, navigation and surveillance
CO2	Carbon dioxide
CO2M	Copernicus Anthropogenic Carbon Dioxide Monitoring
cOBC	Constellation On-Board Computer
CODA	Copernicus Online Data Access
COP	Conference of Parties

Annex 4: List of acronyms

COP15	Conference of the Parties to the United Nations Convention on Biological Diversity	EASA	European Union Aviation Safety Agency	EMSA	European Maritime Safety Agency
COP27	Conference of the Parties to the United Nations Framework Convention on Climate Change	EBA	European Banking Authority	EN	European harmonised standard
COSPAS--SARSAT	Cosmicheskaya Sistyema Poiska Avariynich Sudov/Search And Rescue Satellite Aided Tracking	EBAA	European Business Aviation Association	ENSPACE	Enhanced Navigation in Space Project
COTS	Commercial-Off-The-Shelf	e-bikes	Electric bicycle	ENVISAT	ENVIronmental SATellite
COVID19	Coronavirus disease	EC DRMKC	European Commission Disaster Risk Management Knowledge Centre	EO	Earth Observation
CRMA	Critical Raw Materials Act	EC	European Commission	EO4EA	Earth Observation for Ecosystem Accounting
CSCDA	Copernicus Space Component Data Access system	EC	Electronic Conspicuity	EO4I	Earth Observation Best Practice for Agro-Insurance
CSRD	Corporate Sustainability Reporting Directive	ECA	European Compliance Assurance		
CSRISTAL	Copernicus Polar Ice and Snow Topography Altimeter	ECARO	EGNOS Civil Aviation Roadmap	EO4SD	Earth Observation for Sustainable Development
CSS	Copernicus Security Service	ECMWF	European Centre for Medium-Range Weather Forecasts	EPIRBs	Emergency Position Indicating Radio Beacons
DAA	Detect & Avoid	EDAS	EGNOS Data Access Service	ERA	European Regions Airline Association
DAS	Driver Advisory Systems	EDO	European Drought Observatory	ERCC	Emergency Response Coordination Centre
DCN	Digital Cellular Network	EEA	European Environment Agency	ERTMS	European Railway Transport Management System
DEM	Digital Elevation Model	EFAS	European Flood Awareness System	ESA	European Space Agency
DFMC	Dual Frequency Multi-Constellation	EFCA	European Fisheries Control Agency	ESG	Environmental, Social, and Governance
DG MARE	Directorate-General for Maritime Affairs and Fisheries	EFFIS	European Forest Fire Information System	ESMA	European Securities and Markets Authority
DIAS	Data and Information Access Services	EFRAG	European Financial Reporting Advisory Group	ESRS	European Sustainability Reporting Standards
DLR	German Aerospace Center (Deutsches Zentrum für Luft- und Raumfahrt)	EGMS	European Ground Motion Service	ETC	Electronic Toll Collection
DLT	Dominant Leaf Type	EGNOS	European Geostationary Navigation Overlay Service	ETC/CCA	European Topic Centre on Climate Change Impacts, Vulnerability and Adaptation
DLT	Distributed Ledger Technology	EGNSS	European Global Navigation Satellite System	ETCS	European Train Control System
DO	Drought Observatory	EHA	European Helicopter Association	EU	European Union
DSM	Digital Surface Model	EIA	Environmental Impact Assessment	EU SatCen	European Union Satellite Centre
DSRC	Dedicated Short-Range Communications	ELT	Emergency Locator Transmitter	EUDR	European Union Deforestation-Free Products Regulation
DTSC	Digitial Twins of Smart Cities	ELT-DT	ELT Distress Tracking	EUMETSAT	European Organisation for the Exploitation of Meteorological Satellites
E112	GNSS-supported emergency call	EMAid	Emergency Management and Humanitarian Aid	EUROCAE	European Organisation for Civil Aviation Equipment
EARSC	European Association of Remote Sensing Companies	EMODnet	European Marine Observation and Data Network		

Annex 4: List of acronyms

EUSPA	European Union Agency for the Space Programme
EV	Electric Vehicle
eVTOL	Electric Vertical Take-off and Landing
EWS	Emergency Warning System
FA	Flagship Area
FADA-CATEC	Fundación Andaluza para el Desarrollo Aeroespacial (Andalusian Foundation for Aerospace Development) Spain
FAO	Food and Agricultural Organisation of the United Nations
FCC	Federal Communications Commission
FCD	Floating Car Data
FFO	Full, Free and Open
FINRA	Financial Industry Regulatory Authority
FIs	Financial Institutions
FISE	Forest Information System for Europe
FLARM	Flight alarm
FMC	Fishing Monitoring Centre
FMS	Farm Management System
FP6	Sixth Framework Programme
FRAC	Final Review and Comment
FRONTEX	European Border and Coast Guard Agency
FTY	Forest Type
GADSS	Global Aeronautical Distress and Safety System
GAGAN	Indian SBAS
Galileo SAR	Galileo Search and Rescue
GALITS	Galileo Localization In Train Signalling
GAST	Ground-Airborne System Test
GAST-D	GBAS Approach Service Type D
GAST-F	GBAS Approach Service Type F
GBAS	Ground-Based Augmentation System
GBFF	Global Biodiversity Framework Fund
GDO	Global Drought Observatory
GDOP	Geometric Dilution of Precision
GDPR	General Data Protection Regulation
GEF	Global Environment Facility
GEO	Group on Earth Observations
GEO	Geosynchronous Equatorial Orbit (geostationary orbit)
GEOSAR	Geostationary Orbit Search and Rescue
GEOSS	Global Earth Observation System of Systems
GERICS	Climate Service Center Germany
GHG	Greenhouse Gases
GIEWS	Global Information and Early Warning System on Food and Agriculture
GIS	Geographic Information System
GloFAS	Global Flood Awareness System
GLONASS	Global'naya Navigatsionnaya Sputnikovaya / GNSS by the Russian Federation
GLU 2100	Ground & Landing Unit (Multi Mode receiver)
GM	Guidance Material
GMES	Global Monitoring for Environment and Security
GMP	Global Methane Pledge
GMR	Governmental Market Report
GNC	Guidance, Navigation and Control
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
GSM	Global System for Mobile Communications
GTOS	Global Terrestrial Observing System
GVA	Gross value added
GWIS	Global Wildfire Information System
H2020	Horizon 2020 (Research and Innovation Programme by the European Commission
H2H	Hull-to-Hull
HAB	Harmful Algae Bloom
HAOs	High-Altitude Operations
HAPS	High Altitude Platform Systems
H-ARAIM	High Availability Advanced Receiver Autonomous Integrity Monitoring
HAS	High Accuracy Service
HEMS	Helicopter Emergency Medical Services
HERA	Health Emergency Response Authority
HPC	High Performance Computing
HQ	Headquarters
HR	High Resolution
HRAP	Holistic Resilience Assessment Platform
HR-VPP	High Resolution Vegetation Phenology and Productivity
HVAC	Heating, ventilation and air conditioning

Annex 4: List of acronyms

IACA	International Air Carrier Association
IADC	Inter-Agency Space Debris Coordination Committee
IAGOS	In-service Aircraft for a Global Observing System
IAM	Innovative Air Mobility
IATA	International Air Transport Association
ICAO	International Civil Aviation Organization
ICD	Interface Control Document
ICT	Information and Communication Technology
IDD	Internet Data Distribution
IDPs	Internally displaced persons
IEC	International Electrotechnical Commission
IEEE	Institute of Electrical and Electronics Engineers
IFC	In-flight Connectivity
IGS SSR	International GNSS Service standards
IIoT	Industrial Internet of Things
IISD	International Institute for Sustainable Development
ILS	Instrument Landing System
IMO	International Maritime Organisation
IMPEL	Implementation and Enforcement of Environmental Law
IMUs	Inertial Measurement Units
INI	Own-Initiative Procedure
INS	Inertial Navigation System
InSAR	Interferometric Synthetic Aperture Radar
IOC	Initial Operational Capability
IOPA	International Aircraft Owners and Pilots
IoS	In-Orbit Satellite
IoT	Internet of Things
IoV	In-Orbit Validation
IPCC	Intergovernmental Panel on Climate Change
IPM	Integrated Pest Management
IRIDeS	International Institute of Disaster Science
ISO	International Organization for Standardization
ISSB	International Sustainability Standards Board
ITS	Intelligent Transport Systems
ITU	International Telecommunications Union
IUCN	International Union for Conservation of Nature
IUU	Illegal, Unreported, and Unregulated fishing
IVS	In-Vehicle Systems
IWES	Fraunhofer Institute for Wind Energy Systems
IWW	Inland waterway
JARUS	Joint Authorities for Rulemaking on Unmanned Systems
JRC	Joint Research Centre
KIC	Knowledge and Innovation Community
L3	Level 3
LaaS	Logistics-as-a-Service
LANDSAT	"land" and "satellite."
LDACS	L-band Digital Aeronautical Communications System
LEO	Low Earth Orbit
LEOSAR	Low Earth Orbit Search and Rescue
LGBTQ+	Lesbian, gay, bisexual, transgender, queer or questioning, intersex, asexual, and more
LiDAR	Light Detection and Ranging
LO	Lunar Orbit
LPV	Localiser Performance with Vertical Guidance
LSTM	Copernicus Land Surface Temperature Monitoring
LTE	Long Term Evolution
LUCAS	Land Use/Cover Area frame Survey
LuGRE	Lunar GNSS Receiver Experiment
MaaS	Mobility-as-a-Service
MASS	Maritime Autonomous Surface Ships
MBDs	Mosquito-Borne Diseases
MEO	Medium Earth Orbit
MEOLUT	Medium Earth Orbit Local User Terminal
MEOSAR	Medium Earth Orbit Satellites Search and Rescue System
Metop-SG	Meteorological Operational Satellite - Second Generation
MiFiD II	Markets in Financial Instruments Directive
ML	Machine Learning
MOB	Man OverBoard
MODIS	Moderate Resolution Imaging Spectroradiometer
MOPS	Minimum Operational Performance Standards
MoU	Memorandum of Understanding
MPLs	Minimum Performance Levels
MS	Moon Surface positioning
MSAS	Japanese Satellite Based Augmentation System
MSC	Maritime Safety Committee
MSP	Maritime Spatial Planning
MTG-S	Meteosat Third Generation (Sounding)

Annex 4: List of acronyms

MUAC	Maastricht Upper Area Control Centre
MUGG	MUlti-mode Global positioning system (GPS) and Galileo
NASA	National Aeronautics and Space Administration
NavIC	Navigation with Indian Constellation/Indian Regional Navigation Satellite System
NBS	Nature-based Solutions
NDVI	Normalized Difference Vegetation Index
NEO	Near-Earth Objects
NeRF	Neural Radiance Field
NFMS	National Forest Monitoring System
NG112	New Generation of E112
NGO	Non-Governmental Organisation
NIR	Near-infrared
NOAA	National Oceanic and Atmospheric Association
NPA	Notice of Proposed Amendment
NRT	Near real-time
NSP	Navigation System Panel
NTN	Non-Terrestrial Networks
NTRIP	Networked Transport of RTCM via Internet Protocol
OCHA	United Nations Office for Coordination of Humanitarian Affairs
ODA	Official Development Assistance
OEMs	Original Equipment Manufacturers
OS	Open Service
OSNMA	Galileo Open Service Navigation Message Authentication
OT	Operational technology
OTA	Over-the-air
PBN	Performance-based navigation
PDOP	Position Dilution of Precision
PHAR	PBN for HEMS in the Italian Apulia Region
PinS	Point-in-Space
PLB	Personal Locator Beacon
PMR	Professional Mobile Radio
PMU	Phasor Measurement Unit
PND	Personal Navigation Device
PNT	Positioning, Navigation, and Timing
POCs	Proof-of-Concepts
POD	Precise Orbit Determination
PPAs	Power Purchase Agreements
PPP	Precise Point Positioning
PPPs	Public-Private Partnerships
PPU	Power Processing Unit
PPUs	Portable Pilot Units
PRC	People's Republic of China
PRS	Public Regulated Service
PSD2	Directive of Payment Services
PSTN	Public-Switched Telephone Network
PVs	Photovoltaics
PVT	Position, Velocity and Time
QNH	Question Nil Height (measurement; pressure at sea-level; aviation)
QZSS	Quasi-Zenith Satellite System/regional navigation satellite system commissioned by the Japanese Government
R&D	Research and Development
R&I	Research and Innovation
RACE	Rapid Action on COVID-19 and EO
RAS	Researchlab Autonomous Shipping
RBA	Remote Beacon Activation
RES	Renewable Energy Sources
RF	Radio Frequency
RFI	Radio Frequency Interference
RIN	Royal Institute of Navigation
RIS	Reconfigurable Intelligent Surfaces
RLM	Return Link Message
RLS	Return Link Service
RLSP	Return Link Service Provider
RNP3	Required Navigation Performance
RNSS	Radio Navigation Satellite Services
RNTF	Resilient Navigation and Timing Foundation
ROV	Remotely Operated Vehicles
ROSE-L	Copernicus L-band Synthetic Aperture Radar
RTCA	Radio Technical Commission for Aeronautics
RTCM	Radio Technical Commission for Maritime Services
RTK	Real-Time Kinematics
RTN	Real-Time Navigation
RUC	Road User Charging
SaaS	Synchronisation-as-a-Service
SAE	Society of Automotive Engineers
SaaS	Synchronisation-as-a-Service
SAE	Society of Automotive Engineers

Annex 4: List of acronyms

SAE levels	Society of Automotive Engineers setting levels for autono-mous driving	SOC	Security Operation Centre	TLO	Translunar Orbit
SAR	Search and Rescue	SoL	Safety of Life Service	TPEG	Transport Protocol Experts Group
SAR	Synthetic Aperture Radar	SOM	Scientific and Operational Missions	TPEG-2-EAW	Emergency Alerts and Warnings technology
SARPs	Standards and Recommended Practices	SORA	Specific Operations Risk Assessment	TSI	Technical Specifications for Interoperability
SARSAT	Search and Rescue Satellite Aided Tracking	SRTM	Shuttle Radar Topography Mission	TSN	Time-Sensitive Networks
SATCOM	Satellite communications	SSA	Space Situational Awareness	TTFF	Time To First Fix
SB	Service Bulletin	SST	Space Surveillance and Tracking	TWC	Two-Way Communication
SBAS	Satellite-Based Augmentation System	SSV	Space Service Volume	UAM	Urban Air Mobility
SCADA	Supervisory Control and Data Acquisition	S-T&S	Space Timing and Synchronisation	UAS	Unmanned Aircraft Systems
SDA	Space Domain Awareness	STC	Supplemental Type Certificate	UAT	Universal Access Transceiver
SDCM	System for Differential Corrections and Monitoring (Russian SBAS)	STM	Space Traffic Management	UAV	Unmanned Aerial Vehicle
SDG	Sustainable Development Goals	SUGUS	Solution for EGNSS U-Space Service	UCP	User Consultation Platform
SDI	Spatial Data Infrastructures	SVS	Synthetic Vision Systems	UHI	Urban Heath Island
SDR	Software Defined Radio	SWE	Space Weather	UITP	International Association of Public Transport
SDRs	Software-defined Receivers	SWIR	Short-Wave Infrared	UK	United Kingdom
SEA	Copernicus Service in Support to EU External Action	T&S	Timing and Synchronisation	UN ICG	United Nations International Committee on GNSS
SEC	U. S. Securities and Exchange Commission	TaaS	Transportation-as-a-Service	UN	United Nations
SESAR	Single European Sky ATM Research	TaaS	Time-as-a-Service	UNCLOS	United Nations Convention on the Law of the Sea
SFDR	Sustainable Finance Disclosure Regulation	TAWS	Terrain Awareness Warning Systems	UNEA	United Nations Environment Assembly
SIS	Sectoral Information System	TCD	Tree Cover Density	UNESCO	United Nations Educational, Scientific and Cultural Orga-nisation
SiS	Signal-in-Space	TCFD	Task Force on Climate-related Financial Disclosures	UNIDO	United Nations Industrial Development Organisation
SLAM	Simultaneous Localisation and Mapping	TechD	Technology Demonstration	UNOOSA	United Nations Office for Outer Space Affairs
SME	Small and Medium-sized Enterprise	TEWS	Tsunami Early Warning Systems	UNWTO	United Nations World Tourism Organization
SNAS	Satellite Navigation Augmentation System (PRC)	TGV	High-Speed Train	US	United States
SNCF	Société Nationale des Chemins de Fer Français	TISA	Trade in Services Agreement	USA	United States of America

Annex 4: List of acronyms

USGS	United States Geological Survey
U-space	Unmanned Aircraft Systems Airspace Management
USSPs	U-space Service Providers
UTC	Universal Time Coordinated
UTM	Unmanned Traffic Management
UV	Ultraviolet (UV) radiation
V2X	Vehicle to everything
VAAC	Volcanic ash advisory centres
VAS	Value-added Service
VBDs	Vector-Borne Diseases
VDES	Very High Frequency Data Exchange System
VFR	Visual Flight rules
VHF	Very High Frequency
VHR	Very High Resolution
VHTS	Very High Throughput Satellites
VIIRS	Visible Infrared Imaging Radiometer Suite
VLL	Very Low Level
VMS	Vessel Monitoring System
VR	Virtual Reality
WAAS	Wide Area Augmentation System
WAM	Wide Area Monitoring
WFD	Water Framework Directive
WG- C	Working Group C
WG	Working Group
WHO	World Health Organisation
Wi-Fi	Wireless Fidelity
WWF	World Wide Fund for Nature

Annex 5: About the authors

The European Commission

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.

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

EUSPA is the operational European Union Agency for the Space Programme. It adopts a user-oriented approach to promote sustainable growth and improve the security and safety of the European Union. EUSPA's mission revolves around three core principles: service provision, market growth, and security.

The EU Agency for the Space Programme:

- Provides state-of-the-art, safe and secure positioning, navigation and timing services based on Galileo and EGNOS, cost-effective satellite communications services for GOVSATCOM and soon IRIS², and Front Desk services of the EU Space Surveillance Tracking whilst ensuring the systems' service continuity and robustness.
- Promotes and maximises the use of data and services offered by Galileo, EGNOS, Copernicus, GOVSATCOM and soon IRIS² across a broad range of domains.
- Fosters the development of a vibrant European space ecosystem by providing market intelligence, and technical know-how to innovators, academia, start-ups, and SMEs. The agency leverages Horizon Europe, other EU funding, and innovative procurement mechanisms.
- Implements and monitors the security of the EU Space Programme components in space and on the ground with the aim to enhance the security of the Union and its Member States; EUSPA operates the Galileo Service Monitoring Centre.

The Security Accreditation Board established within the Agency is the security accreditation authority for all of the Programme's components, where Member States take accreditation decisions in a strictly independent manner from the Programme.

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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.

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The European Union Agency for the Space Programme: linking space to user needs.

market@euspa.europa.eu
www.euspa.europa.eu

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