2019 / ISSUE 6

GSA GNSS Market Report

EDITOR'S SPECIAL

GNSS AND NEWSPACE

European
Global Navigation
Satellite Systems
Agency

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GNSS MARKET REPORT

ISSUE 6

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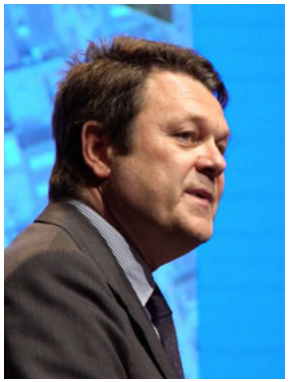
How to read this report

The GNSS Market Report is a continuously evolving publication that builds upon a similar structure and format used in previous issues. The 6th issue of GNSS Market is therefore structured into the following blocks:

- **General overview of the GNSS market** explains what GNSS is and what the user requirements are. It also presents quantification on future shipments, revenues and installed base for the GNSS market as a whole. The introduction also provides a global industry overview as well as focus on EGNSS and the synergies with Copernicus.
- **Macrotrends affecting GNSS** presents trends such as Climate Change & Circular Economy, Big Data, Artificial Intelligence, Silver Economy, etc. that lead to the development of new information-intensive services and impact the adoption of GNSS solutions.
- **GNSS market segments** forms the core of the report and follows the same structure used for each of the ten market segments (the only exception is a shortened new segment "Emergency response"):
  - To introduce the sector, a short summary of the **GNSS applications** is presented;
  - **Key** market segment **trend**s are illustrated with examples;
  - **User perspective** of the segment focuses on user needs and the use of GNSS from the users' point of view;
  - The **industry value chain** provides a non-exhaustive list of key stakeholders;
  - **Recent developments** focus on historical data of the shipments of GNSS devices by application, presenting initiatives and examples that have recently been implemented;
  - **Future market evolution** forecasts shipments or revenues over the next decade spanning 2019 to 2029. 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 GNSS** provides information on the current usage of Galileo, EGNOS and associated relevant projects within the particular segment;
  - **Reference charts** present a forecast of the installed base and revenues of the market segment by regions and by applications.
- In this issue **the Editor's special** introduces a new segment of GNSS receivers in satellites and it`s relation to an evolving space sector.
- **Annexes** close the report with a description of the methodology behind the data presented (Annex 1), definition of key performance parameters (Annex 2), list of acronyms (Annex 3) and information about the authors (Annex 4).



Dear Reader,

The global GNSS downstream market continues to grow rapidly and this year the global installed base of GNSS devices in use is forecast to reach almost 6.5 billion, while global GNSS downstream market revenues from both devices and services are set to reach an astonishing €150 billion. It is worth highlighting that out of 1.7 billion GNSS shipped units in 2019, more than 40% will be Galileo enabled, a remarkable and promising result for European GNSS programme.

In this context, it is more important than ever to keep on top of developments and trends on the GNSS market and this is what the GSA GNSS Market Report offers. Now in its sixth edition, the Report has established itself as the most authoritative reference document for information on the global GNSS market, and is regularly referenced by policy-makers and business leaders around the world.

The structure of this year's report follows the successful format of previous issues (for a detailed overview see the opposite page), while at the same time extending and updating the content and topics. Due to the evolution of market segments and trends, some segments (like LBS and Surveying) have been renamed to better reflect the solutions they contain. Moreover, two new segments have been added: the rapidly evolving Drones segment, following the huge interest of readers in the Editors' Special on drones in the previous edition; and Emergency Response, providing a thorough overview of all emergency beacons in one place, when previously this has been split between Aviation, Maritime and LBS.

"GNSS for NewSpace" has been chosen as the Editor's Special topic this year, featuring NewSpace and other drivers behind the growing number of GNSS space receivers. On top of shipments and the installed base of GNSS receivers, a classification of in-space applications is provided along with Galileo`s contribution to the Space Service Volume.

The Report is the result of thorough and continuous work by a team of 20 GSA experts from various market segments over the last two years, backed up by more than 50 external experts who helped to verify the data contained in more than 70 charts. I have witnessed the development of this report since its first edition and I am amazed to see how it has grown from a short document containing four segments into a fully-fledged report describing in great detail key trends, recent developments, value chains, user perspectives and future market evolutions covering ten segments.

When combined with other reports in the GSA Intelligence Reports series, such as the GNSS User Technology Report and Reports on User Needs and Requirements for Position, Navigation and Time, the GNSS Market Report provides a comprehensive overview of the GNSS landscape. I am confident that the latest edition of the GNSS Market Report will enable you to keep your finger on the pulse of the GNSS industry and reap the maximum benefit from the opportunities offered by this rapidly developing market.

Carlo des Dorides
Executive director

The European GNSS Agency (GSA)
Prague, October 2019

Asia-Pacific will continue to account for more than half of the global GNSS installed base

European Union (EU28)

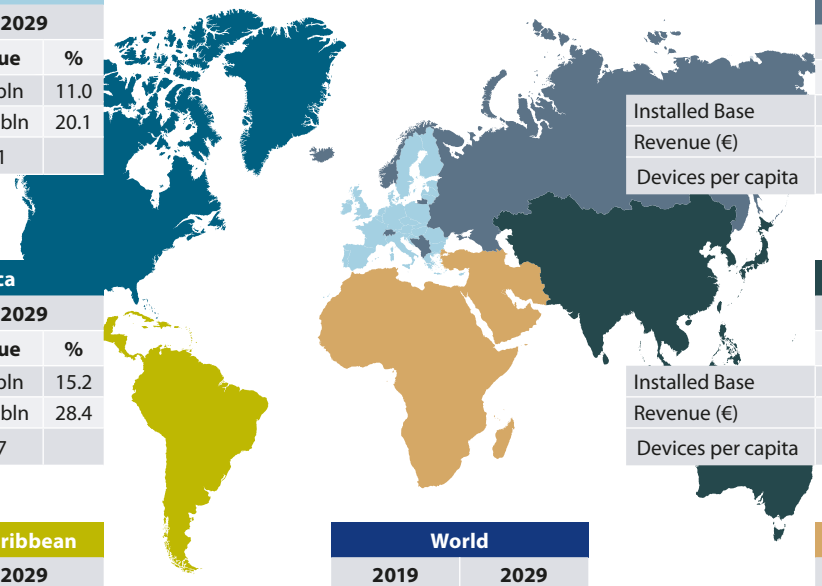
	2019		2029	
	Value	%	Value	%
Installed Base	0.7 bln	11.0	1.0 bln	11.0
Revenue (€)	38.4 bln	25.5	65.3 bln	20.1
Devices per capita	1.4		2.1	

North America

	2019		2029	
	Value	%	Value	%
Installed Base	1.0 bln	15.9	1.5 bln	15.2
Revenue (€)	40.3 bln	26.7	92.2 bln	28.4
Devices per capita	2.0		2.7	

South America + Caribbean

	2019		2029	
	Value	%	Value	%
Installed Base	0.6 bln	9.7	0.9 bln	9.3
Revenue (€)	8.1 bln	5.4	13.2 bln	4.1
Devices per capita	1.2		1.6	



World

	2019	2029
	Value	Value
Installed Base	6.4 bln	9.5 bln
Revenue (€)	150.7 bln	324.4 bln
Devices per capita	0.8	1.1

Russia and Non-EU 28 (Non-EU28 Europe)

	2019		2029	
	Value	%	Value	%
Installed Base	0.3 bln	4.0	0.3 bln	3.5
Revenue (€)	9.7 bln	6.4	16.3 bln	5.0
Devices per capita	1.1		1.5	

Asia-Pacific

	2019		2029	
	Value	%	Value	%
Installed Base	3.4 bln	53.2	5.1 bln	53.5
Revenue (€)	46.0 bln	30.5	106.0 bln	32.7
Devices per capita	0.8		1.1	

Middle East + Africa

	2019		2029	
	Value	%	Value	%
Installed Base	0.4 bln	6.3	0.7 bln	7.5
Revenue (€)	8.2 bln	5.4	31.4 bln	9.7
Devices per capita	0.2		0.4	

Consumer Solutions	The wearables market is on the rise, while dual-frequency and high accuracy are gaining traction in smartphones. Leveraging the hardware as a platform, software and apps provide endless opportunities to tailor the use of position to the needs of mass market users.
Road	As vehicles become more intelligent and automated, and the Mobility-as-a-Service business expands, the industry faces the challenge of introducing high-end GNSS solutions on a mass-market scale.
Manned Aviation	ICAO's Global Air Navigation Plan (GANP) provides a roadmap for the deployment of new operational concepts and technologies to improve the global efficiency of ATM.
Drones	GNSS is a key enabler for drones ensuring safe navigation and reliability for both consumer and commercial applications. As the industry matures, the supply chain is becoming increasingly specialised and in some cases the operator role is absorbed into end-user organisations.
Maritime	The use of satellite-based augmentation systems is becoming the primary source of accurate positioning across the maritime and inland waterway domains.

Emergency Response	Multi-constellation is the recognized paradigm by all major beacon manufacturers. Innovative features such as Return Link and Remote Activation are on the rise.
Rail	Railways are in the process of digitalization and GNSS is part of the game. GNSS based solutions for signalling applications will help reduce cost and enhance performance.
Agriculture	GNSS has become an integral part of smart, connected and integrated farm management solutions and a key driver for precision farming across the whole crop cycle.
Geomatics	The role of traditional GNSS surveying is transforming owing to the integration of emerging digital data collection techniques, high-precision GNSS services, cloud computing and sensor fusion.
Critical Infrastructures	Emerging paradigms such as Time-as-a-service (TaaS) and innovative applications are expected to drive growth in the GNSS Critical infrastructures segment. The market is stimulated by an increased need for resilience and improved accuracy, as well as by regulation.

With significant growth observed in recent years, the global **GNSS market will continue to expand in the next decade – both in terms of devices and services**.

This growth will be stimulated by global macrotrends such as **digitalisation, big data, sharing economy and artificial intelligence** that use GNSS for Position, Navigation and Timing. In combination with other technologies, **GNSS can also contribute towards tackling challenges such as climate change** by supporting environmentally friendly transport solutions, sustainable agriculture and meteorological monitoring.

"GLOBAL MACROTRENDS AFFECT THE USE OF GNSS BY INDUSTRIES AND INDIVIDUALS"

The global **installed base of GNSS devices in use** is forecast to increase from **6.4 bln in 2019** to **9.6 bln in 2029** with Asia-Pacific continuing to account for more than half of the global GNSS market. In terms of global annual GNSS receiver shipments, the market is forecasted to increase from **1.8 bln units in 2019 to 2.8 bln units in 2029**. Despite the increasing saturation of the mature EU28, North American and Chinese markets, **shipments of smartphones still outnumber those of all other devices**. Following smartphones, wearables has become the second most sold GNSS device, reaching 70 mln shipments in 2019. The **silver economy** is a key driver, mostly for health-related solutions but also following the trend of democratisation of sports & fitness equipment for all ages.

"DRONES HAVE BECOME 3RD GNSS MARKET SEGMENT FOR DEVICE SHIPMENTS"

Following the consumer platforms and automotive solutions, the **drones have become a significant GNSS market segment**, exceeding mature segments such as maritime, aviation and agriculture in terms of shipments. In fact in the last 3 years the shipments of drones have tripled and the growth will continue in the next decade for all drone categories, generating more than 2bln EUR revenues in 2029, both from device sales and services.

Though originally conceived for terrestrial use, GNSS has also proven its worth as a valuable tool for in-space applications. Formerly used mainly by governmental space entities, **GNSS now also serves an increasing number of commercial stakeholders within the 'NewSpace' paradigm**. The spacecraft segment is also notable for the highest value in terms of unitary receiver prices.

In terms of hardware supply, Asian manufacturers have become increasingly competitive in the mature markets of high-end receivers and professional applications, which has in turn **driven down the average price of professional receivers**. This pressure has forced manufactures to maintain competitiveness by delivering higher performance through less complex and more cost-effective solutions.

Leveraging improved receiver performance, the devices in use across various sectors have become platforms for an endless range of software solutions and services. In 2029, **GNSS added-value service revenues will account for 51% of the total global GNSS revenues**.

These solutions, ranging from connected and automated solutions for road transport to smartphone apps and surveying software, represent a major opportunity to mitigate against the competitive pressure on hardware.

"ADDED-VALUE SERVICES ACCOUNT FOR A HALF OF TOTAL GNSS REVENUES"

"THE EUROPEAN GNSS INDUSTRY ACCOUNTS FOR MORE THAN A QUARTER OF THE GLOBAL MARKET SHARE"

Overall, the GNSS industry's value creation is concentrated in three major geographic regions: **North America, EU28 and Asia** represented by China, Japan and South Korea. Component manufacturers from these three Asian countries altogether generate the largest amount of revenue, although considering individual countries, the Unites States continues to lead the global GNSS market (28%). Europe is following closely: **in 2017, European companies had an estimated share of 27% of the overall global GNSS market**.

The increasing market share of EU companies is linked with the development and use of Galileo, the European GNSS. For the announcement of Full Operational Capability, Galileo is preparing additional features that will differentiate the services from other GNSS and create additional value for the users. One of these additional features is the Open Service **Navigation Message Authentication (OS-NMA)**, which will contribute to the mitigation against spoofing attacks.

In addition users will be able to benefit from the **High Accuracy Service (HAS)**, which is foreseen to provide a target accuracy of 20 centimetres. For emergency response segment Galileo will provide the **Return Link Service**, an innovation that provides an acknowledgment that a distress signal has been received.

To enhance the benefits of the European Space Programmes, **European GNSS and Copernicus**, are often used in tandem to enable added value services for users in many different sectors and markets across the globe. Their **synergies** in applications such as crop productivity optimisation, livestock management, urban planning, infrastructure monitoring and disaster management have shown that European satellite systems adopted together can help users meet their challenges of daily life, while on a global scale they also **contribute to the achievement of the United Nation's Sustainable Development Goals** (SDGs).

"OPEN SERVICE NAVIGATION MESSAGE AUTHENTICATION AND THE HIGH ACCURACY SERVICE DIFFERENTIATE GALILEO FROM OTHER GNSS"

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Introduction to the GNSS market

What is GNSS?

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

- **Global constellations:** GPS (USA), GLONASS (Russian Federation), Galileo (EU), BeiDou (PRC).
- **Regional constellations:** QZSS (Japan), IRNSS (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).

GNSS market

This Market Report considers the GNSS market defined as activities where GNSS-based positioning, navigation and/or timing is a significant enabler of functionality.

The GNSS market presented in this report comprises device revenues, revenues derived from **augmentation**, and **added-value services** attributable to GNSS.

Augmentation services include necessary software products and content such as digital maps, as well as GNSS augmentation subscriptions. **Added-value** service revenues include data downloaded through cellular networks specifically for the purpose of running location-based applications (such as navigation), as well as the GNSS-attributable revenues of smartphone apps (sales revenue, advertisements and in-app purchases), subscription revenues from fleet management services, and a new quantification of drone service revenues across a range of industries.

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

- **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 (PLB) and Emergency Locator Transmitters (ELT), only the price differential between GNSS and non-GNSS devices is included.
- **Driver Advisory Systems:** Only the GNSS attributable functionality is considered, approximately 1/3 of the device price.

Key GNSS performance parameters

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

- **Availability:** The percentage of time the position, navigation or timing solution can be computed by the user. Values vary greatly according to the specific application and services used, but typically range from 95-99.9%.
- **Accuracy:** The difference between true and computed solution (position or time).
- **Continuity:** Ability to provide the required performances during an operation without interruption once the operation has started.
- **Integrity:** The measure of trust that can be placed in the correctness of the position or time estimate provided by the receiver.
- **Time To First Fix (TTFF):** A measure of a receiver's performance covering the time between activation and output of a position within the required accuracy bounds.
- **Robustness to spoofing and jamming:** A qualitative rather than quantitative parameter that depends on the type of attack or interference the receiver is capable of mitigating.
- **Authentication:** The ability of the system to assure the users that they are utilising signals and/or data from a trustworthy source, and thus protecting sensitive applications from spoofing threats.

Other parameters which do not directly relate to the GNSS performance are also important for GNSS-based technologies. Key requirements in this aspect comprise **Power consumption, Resilience, Connectivity, Interoperability** and **Traceability**.

Additional details on the GNSS performance parameters and other requirements are provided in **Annex 2**.

On charts and Methodology

Data from the years 2018 and 2019 contained within the charts are estimated and subject to update in the next edition of the GNSS 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.
- **Revenue:** The revenue from device/service sales in a given year.

For methodology and information sources see **Annex 1** and for any abbreviation used within the report, please refer to **Annex 3**.

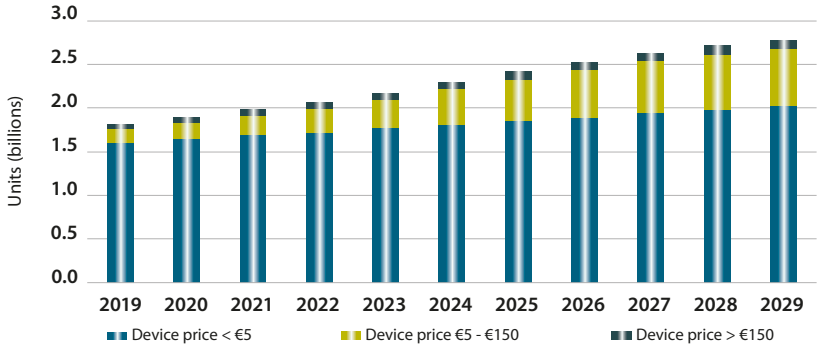
The GNSS market is set to grow steadily across the next decade

Global annual GNSS receiver shipments (graph top-left) are forecast to **grow continuously** across the next decade, from 1.8 bln units in 2019 to 2.8 bln units in 2029. The majority of **shipments is represented by** mass-market **receivers costing less than €5**. These account for more than 1.6 bln units in 2019 and are set to grow to more than 2.0 bln units by 2029. 90% of the receivers in this price segment are used for smartphones and wearables. The second GNSS receiver price segment (**between €5 and €150**) is on the rise, with an estimated annual growth of 6%. This type of GNSS receivers is **mainly used by unpowered assets**, **as well as** in Road and Drone applications. Although **high-end receivers** (more than €150) **account for less than 3% of the total GNSS receiver shipments**, they are used across all professional market segments. In particular, very high-end receiver shipments are forecasted to double in 10 years, from **around 1.5 mln units to more than 3.1 mln units**.

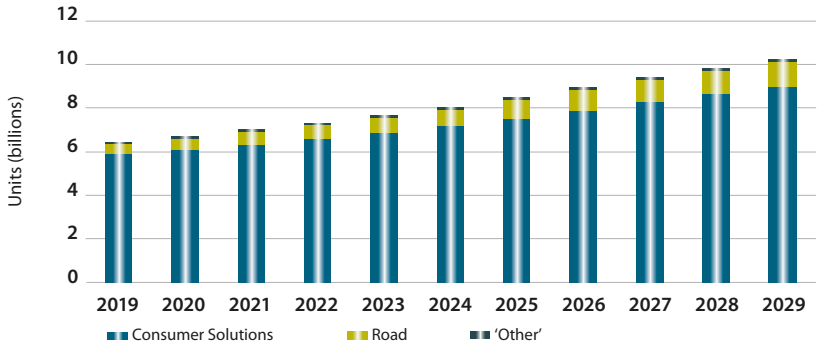
The average device price of professional high-end receivers (i.e. those priced at more than €1,000) (graph bottom-left) **will progressively drop**, from more than €6,000 in 2019 to less than €4,000 in 2029. This is primarily due to the high maturity of the professional GNSS market as well as the increasing competitiveness from Asian manufacturers, putting higher pressure on prices. This trend will contribute to a **more accessible market**, leading to a greater number of both professional and commercial end users having access to professional GNSS receivers.

The **overall installed base** will grow from more than 6 bln units in 2019 to 10 bln units in 2029. The current forecasts show a **slowdown** compared to the figures presented in the previous version of the Market Report. The primary reason is the global trend towards **extending the useful life of a smartphone**, which, in turn, has caused a decrease in smartphone shipments.

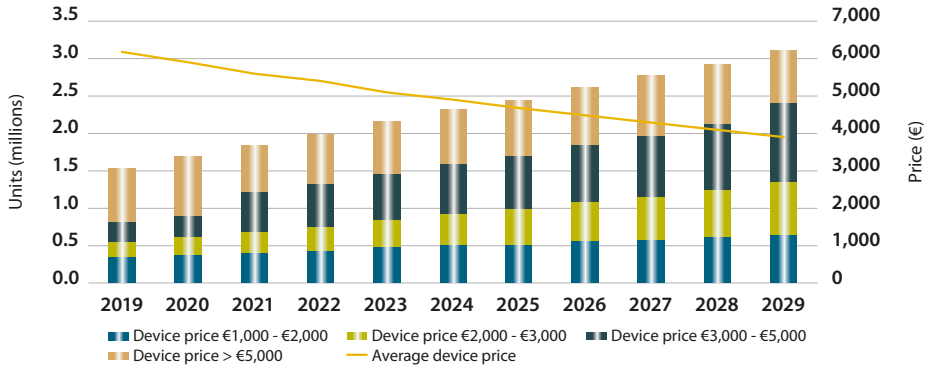
GNSS receiver shipments by price* categories



Global installed base by segment

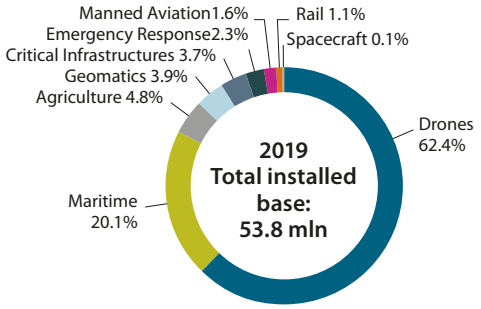


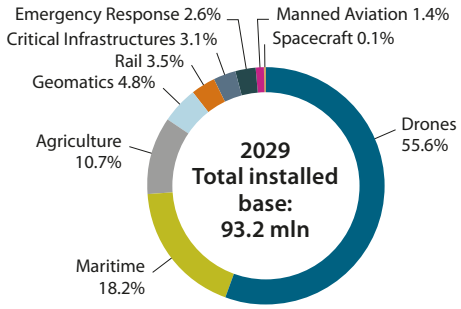
High-end receiver shipments by price* categories



* For multi-function devices, such as smartphones, the device price category refers to the value of GNSS functionality – not the full device price.

Installed base of 'Other' segments





Added-value services account for more than a half of the total GNSS revenues

Global GNSS downstream market

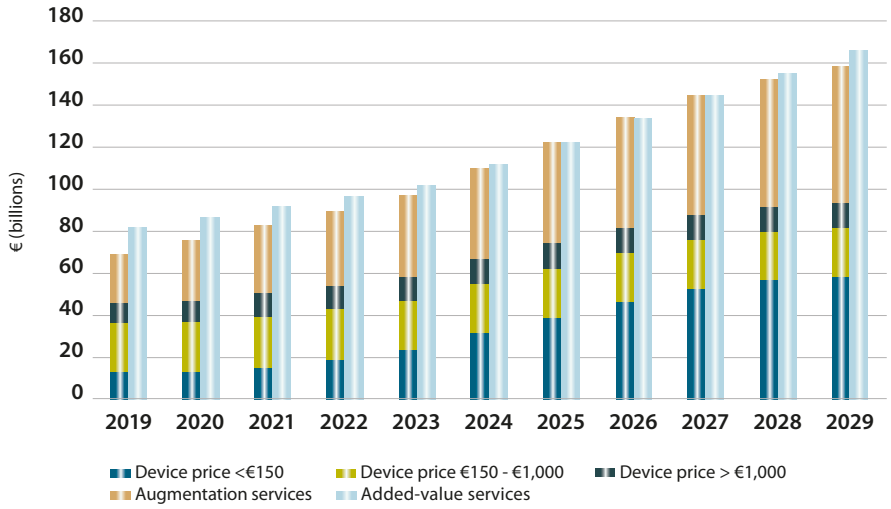
The **global GNSS downstream market** revenues from both devices and services will grow from **€150 bln in 2019 to €325 bln in 2029** with a CAGR of 8%.

The growth is mainly due to the revenues from **mass market and mid-end devices (<€150)** and from **augmentation services**. Low-end receivers will record a skyrocketing growth of 16% per year between 2019 and 2029, while revenues from augmentation services are set to grow steadily from €23 bln to nearly €65 bln in 10 years.

Although the shipments of **high-end receiver** (more than €1000) are less than 1% of total shipments, they contribute more than 10% of global receiver revenues (**€12 bln in 2029**).

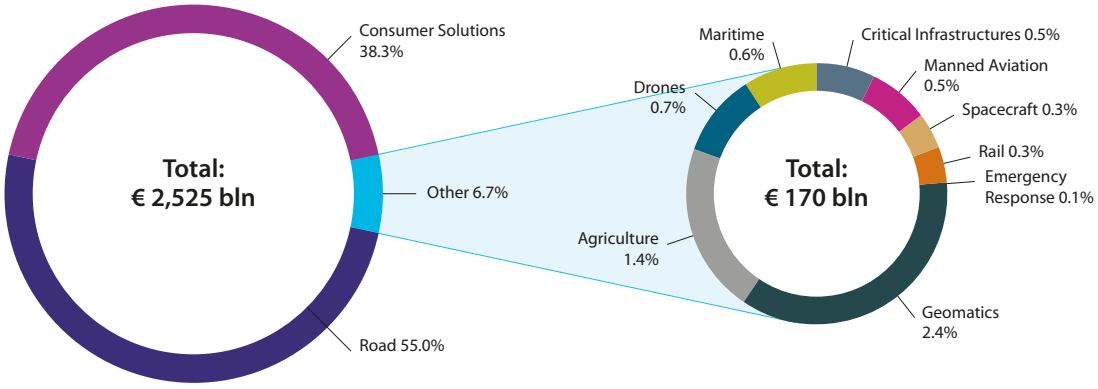
The **services** relying on GNSS technology to create added-value for users represent the biggest revenue stream for the GNSS market. In 2029, **added-value service revenues** will account for **€166 bln**, more than half of the total global GNSS revenues.

Total GNSS Revenues



Note: For multi-function devices, such as smartphones, the device price category refers to the value of GNSS functionality – not the full device price.

Cumulative Revenue 2019-2029 by segment



Road and Consumer solutions dominate total revenues

Road and Consumer solutions dominate by far all other market segments in terms of cumulative revenue with a combined total of 93.3% for the forecasting period 2019-2029.

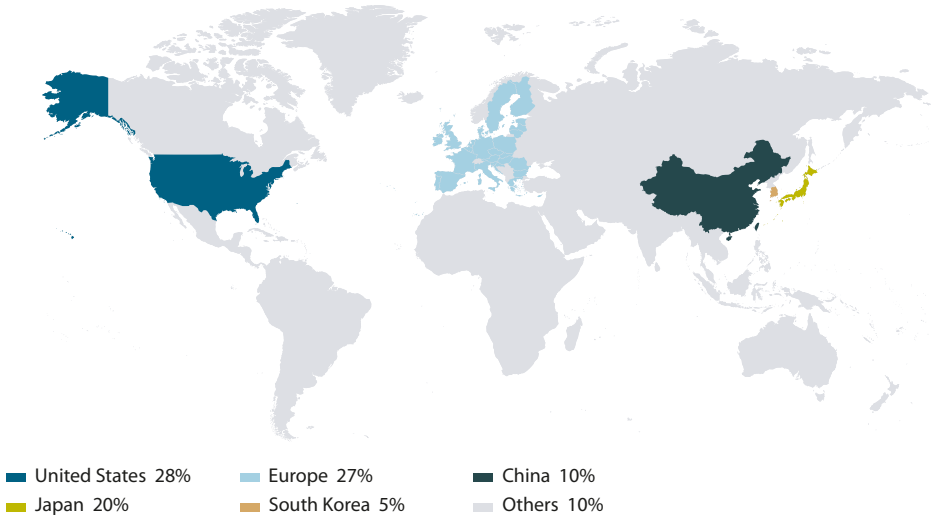
In the **Road sector**, most revenues are generated by In-Vehicle Systems (IVS), ADAS and fleet management, whereas **Consumer solutions** revenues mainly come from the data revenues of smartphones and tablets using location-based services.

Focusing on the remaining revenues, **more than 50% of these** will be generated by **Agriculture and Geomatics**. The main revenue-generating applications in Agriculture are Variable Rate Technologies (VRT) and automatic steering, while the primary sources of revenue in Geomatics is cadastral and construction surveying.

GNSS industry's value creation is concentrated in three major geographic areas

The map below shows the **comparison of the size of GNSS related revenues** associated with several key regions and countries, with a special focus on countries with a relatively large market share. These revenues are accrued based upon revenues generated from shipments of GNSS components and receivers, as well as those from added-value service provision[1].

Revenue generation in the GNSS industry by key domains (% split of revenues 2017)



The United States continues to lead the global GNSS market (at 28% of total industry revenues), thanks to key components & receiver manufacturers, system integrators and service providers.

However, **Europe[2] is closing the gap to the United States**, accounting for 27% of total industry revenues (compared to 25% in 2015). Regionally, **three Asian countries**, namely China, Japan and South Korea altogether represent the **largest revenue generation area**, as they sum up to 35% of the global industry revenues.

[1] Different methodology compared to the GNSS revenues calculated throughout this report as described in Annex 1 was used, and thus absolute values differ slightly from the total GNSS revenues. The methodology uses a bottom-up approach to quantify revenues attributable to GNSS of more than 1000 individual companies (including component and receiver manufacturers, system integrators and added-value service providers, as defined on this page), with turnover attributed to the country of domicile for each organisation. The analysis presented on this page only relates to companies for which financial data are available, i.e. those with turnover greater than the threshold relieving small firms from detailed financial reporting.

[2] In the market share analysis, Europe is defined as EU28 plus Norway and Switzerland.

Top 10 companies across the value chain based on 2017 revenues

The expanded table below reflects the ever **increasing diversity in the downstream GNSS industry**, which as of 2017 encompassed over a thousand companies globally for the first time. The whole value chain incorporates a range of participants, some with interests at multiple levels such as Trimble, whereas others specialise in a particular domain. The following three categories have been defined:

- **Components and receiver manufacturers** underpin the industry by producing chips, antennas and other inputs for receivers and receivers themselves (i.e. devices that allow users to access Position, Navigation and Timing information derived from satellite signals).
- **System integrators** incorporate GNSS receivers into multifunctional devices such as cars and smartphones. For these products GNSS represents only a small part of the product capabilities, but a highly valued one.
- Companies who provide capabilities to users, such as augmentation services and/or added-value services, designed to improve the performance of GNSS devices or use PNT for innovative products and services respectively, are classified as **Service providers**.

Component and receiver manufacturers		System integrators		System providers		Users
Avago (Broadcom)	US	Apple	US	Alphabet inc. (Google)	US	Users of consumer, transport and professional GNSS-based solutions
Garmin	US	Bosch	DE	Denso	JP	
Hexagon	SE	China First	CN	ESRI	US	
Honeywell	US	Ford	US	Garmin	US	
Mediatek	CN	General Motors	US	Here International	NL	
Qualcomm	US	Honda	JP	Hexagon AB	SE	
Rockwell Collins	US	Nissan	JP	Microsoft	US	
Tomtom	NL	Samsung Electronics	KR	Pioneer	JP	
Trimble Navigation	US	Toyota	JP	Radius Payment Solutions	GB	
U-Blox	CH	Volkswagen	DE	Trimble Navigation	US	

The European GNSS industry accounts for more than quarter of the global market share

European[1] market share

The right-hand table shows the **regional market shares for component & receiver manufacturers in 2017 for each market segment**. The underlying analysis is the same as described on previous page. The table shows the market shares of Europe, North America and Asia+Russia. Other regions are not shown in the table. **Detailed industry value chains can be found in each market segment**.

European industry

In 2017, **European companies have an estimated share of 27% of the global GNSS market**, an increase of 2 percentage points compared to 2015. Despite the stable position, the European GNSS industry has significant variation, depending on the market segments. It is driven by relative revenue growth of European firms, mergers and acquisitions, new market entrants and exchange rate fluctuations. In **Critical Infrastructures, Road, Maritime, Drones, Surveying and Emergency Rescue**, European manufacturing has an above average share of the component and receiver manufacturing marketplace.

[1] Market share analysis has been performed on the latest available financial information of the respective companies, namely the 2017 financial year. Europe is defined as EU28 plus Norway & Switzerland. Note: results presented are not readily comparable to those in Market Report V owing to a change to the definitions of each category for this report.

Components & Receiver manufacturers (Europe: 27%)

	Europe*	North America	Asia+ Russia		Europe*	North America	Asia+ Russia
	5%	50%	44%		25%	46%	29%
	49%	37%	14%		41%	28%	31%
	18%	80%	2%		51%	28%	19%
	16%	14%	70%		30%	33%	37%
	33%	37%	30%		33%	52%	13%

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

On top of this and focusing purely on system integrators, Europe's overall share is also 27%, driven by strong performance in **Rail (51%)**, **Agriculture (43%)**, **Road (33%)** and **Aviation (34%)**.

Europe is in **second best position** among GNSS augmentation and added-value service providers, accounting for **31%** of the global market in 2017 (compared to 22% in 2007), following North America, which has 49%.

Fundamental Elements and Horizon 2020 – From receivers to applications, EU supports European GNSS R&D

Fundamental Elements is an EU **R&D funding mechanism**. A total **budget** of **€101 mln** between 2015 and 2020 was devoted to support the development of EGNSS-enabled **chipsets**, **receivers and antennas**, to **facilitate** the adoption of EGNSS Systems, **improve** the competitiveness of EU industry, **address user needs** and **maximise benefits** to EU citizens.

The **Horizon 2020** programme, established for period 2014-2020, among many other topics, supports the development of new applications of **EGNOS** and **Galileo**. The past four calls have already provided innovators more than **€121 mln** of funding and the **5th call**, open from October 2019 to March 2020, will make an additional **€21 mln** available to support EGNSS innovation in different markets.

An up-to-date list including additional funding opportunities is available at: **www.gsa.europa.eu/opportunities/gnss-opportunities-database**.

MyGalileoApp: Piloting start-up programme to support EU innovation at app-level

The GSA's MyGalileoApp Competition challenges developers to design, develop, test and launch a **mobile application** providing a position and/or time fix using a Galileo-enabled smartphone, **showing** the **added value** of **Galileo's** improved **accuracy** and **availability** in a multi-constellation and multi-frequency solution.

The first edition was announced in January 2019 and will close in **November 2019**, when the first-place winner will be awarded with a **€100,000 prize**. The 30 teams selected in the first stage of the competition were free to choose among **many application areas**, including augmented reality, geo-marketing, smart navigation, social networking and many others.

Through this competition, the GSA is encouraging market adoption of Galileo by supporting the **development of mobile applications that address end user needs**.

EGNSS develops together with changing market trends and users' needs

Galileo is the European Global Navigation Satellite System, providing standalone navigation, positioning and timing information to users worldwide. Unlike other systems, it is under civilian control and has been designed in response to diverse needs of different user communities. The four Galileo services (Open Service, High Accuracy Service, Search and Rescue and Public Regulated Service) offer various levels of accuracy, robustness, authentication and security.

The **European Geostationary Navigation Overlay Service** (EGNOS) is a satellite-based augmentation system, that increases the accuracy of GNSS positioning and provides information on its reliability in Europe. EGNOS provides three services: Open Service, Safety of Life and EGNOS Data Access Service (EDAS). EGNOS is suitable for safety critical applications such as flying aircraft or navigating ships through narrow channels as well as applications where an accuracy of 1-2 meters is sufficient such as electronic tolling and tracking of dangerous goods.

EGNSS has a strong value proposition for diverse application domains

	Mass Market Consumer Applications	Workforce, Fleet, Traffic and Asset Management	Liability-critical Applications[1]	Safety-critical Applications	High Precision Applications	Timing Applications (Financial services, Energy and Telecom)
Relevant market segments	Consumer solutions, Road, VFR General Aviation, Recreational Maritime, and Rail (e.g. passenger info)	Consumer solutions, Road, Rail and Agriculture (including farm and livestock management)	Road (e.g tolling operators, insurance telematics), Consumer solutions (e.g. mobile payments) and Maritime (e.g. fisheries, marine park management)	Manned Aviation and Drones, Road (Connected and Automated Driving), Consumer solutions (E112) Rail and Maritime	Agriculture, Geomatics and Maritime	Timing & Synchronization of Critical Infrastructures
Galileo	Availability, better resistance to multipath, Accuracy, TTFF	Availability, better resistance to multipath, accuracy, TTFF, Authentication	Authentication, Availability, Accuracy, Continuity	Availability, Accuracy, Compliance with safety requirements and standards Dedicated SAR service with return link	Accuracy, Availability, TTFF	Accurate time, Authentication
EGNOS	Accuracy, especially in remote areas	Accuracy, Integrity	Integrity, Accuracy, Continuity	Integrity, Accuracy, Compliance with safety requirements and standard	Absolute and pass to pass Accuracy	Improved quality of synchronization

[1] GNSS position is linked with payment for services or fine in case of infringement

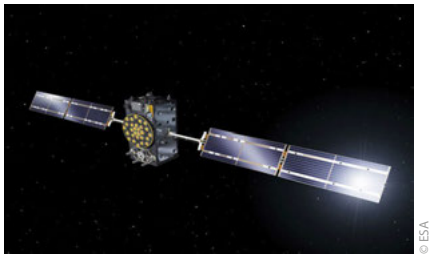
Placing user needs at the heart of EGNSS - The User Consultation Platform and the Reports on User Needs and Requirements

Continuing the pace set at the 2017 **User Consultation Platform (UCP)** in Madrid, the European Commission and the GSA organised the second edition of the UCP meeting just before the 2018 European Space Week in Marseille.

During the market segment-specific workshops, **user communities** presented a wide range of applications and services leveraging EGNSS and contributed to the discussion on the future of the European GNSS programmes. The outcome of the panel discussions can be found on the GSA's website.

One of the highlights of the second UCP was the announcement of the publication of the **sector-specific reports on User Needs and Requirements**. These reports cover all market segments presented in this Market Report and represent a comprehensive source of information on user needs related to expected GNSS performances. The reports can be downloaded from the European GNSS Service Centre (GSC) via the following link: https://www.gsc-europa.eu/electronic-library/gsa-publications.

The United States set to benefit from Galileo signals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Following a European Commission request for a waiver of the U.S. Federal Communications Commission (FCC) rules, the FCC decided to grant **partial access to the Galileo signals for devices in the United States**.

This means that consumers and professional users (e.g. automotive, aviation, rail, maritime, and agriculture) in the U.S. will be permitted to use **E1 and E5 Galileo signals** in combination with the U.S. Global Positioning System (GPS). Having access to these signals will allow consumers to benefit from **improved availability**, **reliability**, **and resiliency** of position, navigation, and timing services. It will also produce **public safety benefits** by reducing risks of accidents and disaster, aiding emergency response, and synchronising power grids and other critical infrastructure.

Being available for usage in the U.S., **Galileo** proves to be a **truly global positioning and navigation system**.

Open Service Navigation Message Authentication and High Accuracy Service set to differentiate Galileo from other GNSS

When close isn't enough, use Galileo

Premiering at the December 2018 European Space Week in Marseille, the European **"Accuracy Matters"** video campaign showcases the added-value brought by European GNSS to the daily lives of millions of users around the globe. It is intended to increase public awareness of Galileo's successes since the start of Galileo Initial Services and to showcase the benefits that Galileo brings to the mass market.

Such added value and benefits are already well recognised by the industry: the GSA-run www.useGalileo.eu website provides a documented overview of many Galileo-compatible products across different market segments. Launched in 2017, the website now covers **eleven categories** such as mass market, transport and professional use, including the recently added **timing**, **Internet of Things (IoT) and space application categories**.

Within each of these categories, a number of sub-categories enable users to narrow their search down to Galileo-enabled devices supporting specific applications, and where relevant to the GNSS chipsets enabling those applications.

Following the 2016 Declaration of Galileo Initial Services, Galileo officially moved from the testing phase to the provision of live services benefitting GNSS users worldwide.

One of the additional features to the Open Service, provided on E1 and E5 signals, will be the **Navigation Message Authentication** (OS-NMA).

In short, the OS-NMA will allow users to verify that a navigation message comes from a Galileo satellite and not a potentially malicious source. This feature will greatly contribute to the mitigation of spoofing attacks, offering a clear differentiator relative to any other GNSS available to the civil community for mass market applications.

On top of the Open Service, users across professional markets will be able to benefit from Galileo's **High Accuracy Service** (HAS) and Commercial Authentication Service (CAS) both to be provided on E6 signal, with HAS foreseen to provide a target accuracy of 20 centimeters. Both the HAS and the OS-NMA will come **free of charge** to the users and are set to **boost all sorts of business cases and solutions** across all market segments relying on accurate and reliable positioning and timing information.

While HAS will be provided through E6 signal data component (E6-B), CAS will make it possible to authenticate signals by giving access to the encrypted E6 signal pilot component (E6-C) codes. More can be found in Galileo **E6-B/C Codes Technical Note** at the Galileo Service Centre (GSC) website: https://www.gsc-europa.eu/electronic-library/programme-reference-documents.

Synergies between EGNSS and Copernicus contribute to achieve the SDGs

Copernicus and EGNSS contribute to the Sustainable Development Goals (SDGs)

More than 190 Member States of the **United Nations** have developed the 2030 Agenda for Sustainable Development with the aim to tackle many societal challenges to enhance human development. These challenges have been translated into **17 Sustainable Development Goals (SDGs)** with 169 specific targets.

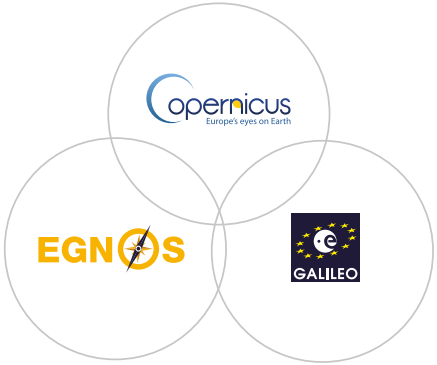
As **partnerships** are key to achieving these SDGs, and looking beyond borders, **space** has been used and is still being used by humankind to tackle daily challenges and to support development worldwide. Focusing on the contributions of the European flagship programmes, the 2018 report published by the **United Nations Office for Outer Space Affairs (UNOOSA) and GSA** showcases how synergies between telecommunication, GNSS and Earth Observation (EO) achieve common goals and meet clear user requirements to contribute to the achievement of the SDGs.

Galileo and EGNOS on the one hand and **Copernicus** on the other, positively contribute to the SDGs and out of the 169 specific targets, 65 of them directly benefit from using EGNSS and Copernicus data. A total of **13 SDGs are significantly impacted**, whilst the remaining 4 SDGs are categorised under the Limited Contribution Tier. EGNSS and Copernicus can be used to address a wide range of SDGs **either as stand-alone technologies or by leveraging synergies**. For example, crop productivity optimisation and livestock management can help address SDG 2: zero hunger; urban planning, infrastructure monitoring and disaster management can help meet SDG 11: sustainable cities and communities; and dozens of other applications and use cases have shown the international community the added-value and strength of space programmes to tackle daily life challenges.

The full report can be downloaded directly from UNOOSA's website or via the following link: https://www.gsa.europa.eu/space4sdgs.

Copernicus and EGNSS contribute to the enhancement of numerous applications

Earth Observation (EO) is often used in tandem with GNSS to enable added value services for users in many different markets across the globe. EO is used to analyse the properties of a given area, whereas GNSS enables efficient navigation, positioning and tracking of objects or people within this area. In this context, the joint exploitation of the unique features of EGNSS and Copernicus, gives rise to a wide variety of integrated applications. Additionaly, GNSS Reflectometry (GNSS-R) can be used together with EO data for applications such as farm management and prospecting of wind and solar farms.



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Agriculture is a prime example of a sector that strongly benefits from the synergies between the two space programmes. In the context of Smart cities, the joint use of EGNSS and Copernicus allows authorities to tackle key societal issues. An example linked with smart cities is the assessment of urban growth. EO is used to provide up-to-date urban maps, which allow the pinpointing of the current status of green areas and infrastructure alike. This information is essential for urban planning at city level, where GNSS is extensively used to support construction projects. Similarly, when **natural or manmade disasters** occur, EO and GNSS can greatly aid the efforts of disaster management authorities.

EO is offering near real-time information on the evolution and impact of the disaster (e.g. mapping of burnt areas, flood extent mapping), whereas GNSS is used to guide first responders – and increasingly drones, within the affected areas.

In maritime, integrated EO and GNSS applications, are deployed to enable more efficient and environmentally friendly ship routing. This is achieved by combining EO data (including oceanographic and weather information) with GNSS-enabled vessel navigation. In mining, EO is used as a tool for mine monitoring (e.g. active mines, abandoned mines, mining waste, man-made hazards), whereas very accurate GNSS positioning allows guidance of machinery (e.g. trucks) in open-pit mines.

Evolving user technologies are driving the future of positioning

The **2018 GNSS User Technology Report Issue 2** is the go-to source for comprehensive knowledge and information on the dynamic, global GNSS user technology industry and its latest trends. It follows the first Issue that was published in 2016.

Whereas the **GNSS Market Report** focuses on the market trends and drivers of the GNSS downstream sectors, the GNSS User Technology Report takes an in-depth look at the latest state-of-the-art GNSS receiver technology, along with providing expert analysis on the evolutionary trends that are set to redefine the global GNSS landscape.

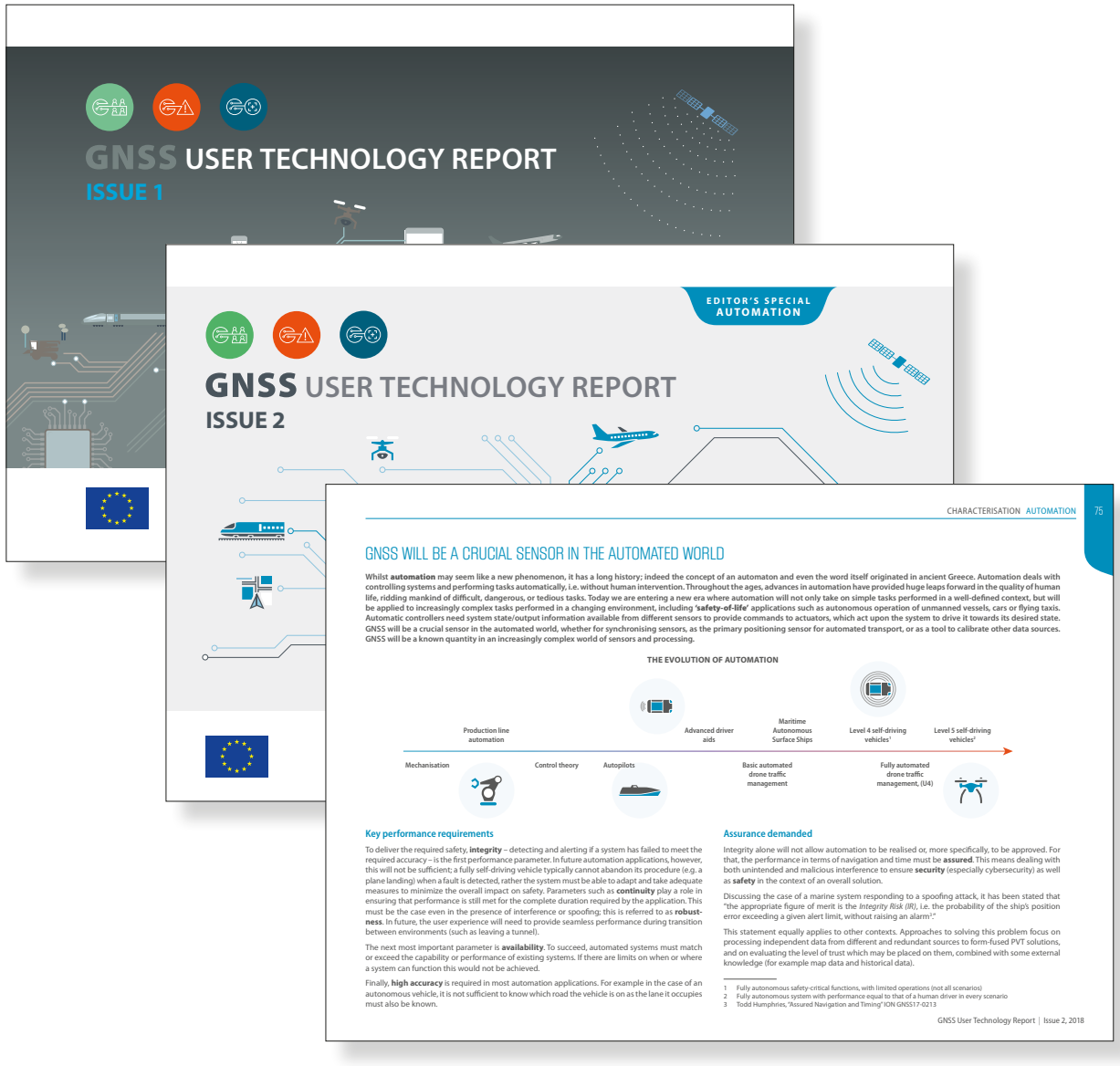
Building upon the first issue, the 2018 report kicks off with an overview on GNSS user technology before deep-diving into three macrosegments covering the receiver design for the different set of applications. The macrosegments are:

- Mass market solutions;
- Transport safety and liability-critical solutions;
- High precision, timing and asset management solutions.

The Report concludes with an Editor's Special on automation focusing on the role of GNSS, data fusion and AI across driverless cars and smart mobility, UAVs, autonomous vessels and automated procedures in Aviation, Rail and beyond the world of transport such as Agriculture, Surveying and grid management.

The current version of the GSA's GNSS User Technology Report **can be downloaded free of charge at**: https://www.gsa.europa.eu/european-gnss/gnss-market/gnss-user-technology-report.

While we are working on the forthcoming edition of the GNSS User Technology Report and constantly monitoring the technology trends, we are open to any suggestions and feedback.



MACROTRENDS AFFECTING GNSS ACROSS MARKET SEGMENTS

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Global macrotrends affect GNSS use by industries and individuals

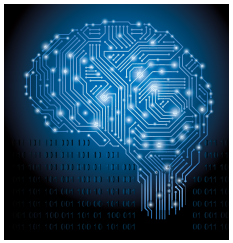
The world we live in is undergoing profound changes. The digital revolution is reshaping our everyday life, along with the business models and processes of companies. This change brings in **new opportunities**, in the form of new collaborative and AI-based services, but **also new challenges** such as ensuring the security of the digital "infrastructure" we heavily depend on. On a different scale, climate change and global warming have already produced impacts that need to be managed today to prevent further degradation. Finally, the economy and society are changing. Trends such as the ageing population in developed countries bring new challenges from a policy standpoint, but business opportunities arise linked to new requirements. As these "**macrotrends**" lead to the development of new information-intensive services, they also i**mpact the adoption of GNSS solutions when these services require positioning and timing data on a global scale**. The following macrotrends are covered in this chapter:

Climate change & circular economy

As rising global temperatures and sea levels as well as extreme weather events are all evidence of our **changing climate**, actions to stop this trend and reduce long-term effects are fundamental.

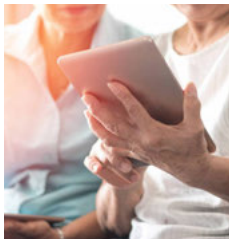
GNSS can contribute by supporting **environmentally friendly transport** solutions, **sustainable agriculture** as well as **meteorology** and climate change monitoring.

Digitalization and artificial intelligence



As the 4th industrial revolution blurs the boundaries between the physical, digital, and biological worlds, **artificial intelligence-based** business models leverage machine computing and learning to power data-intensive services in different sectors. As soon as these data include **outdoor positioning**, GNSS very often represents the preferred solution.

The silver economy



As the **economy** of the **population over 50 becomes larger** and **larger** in developed countries and regions, there are both the opportunity and the need for **new services**, including GNSS-enabled applications, capable of meeting the demand of the silver society, e.g. in terms of **mobile health** and **wellness**.

Big data

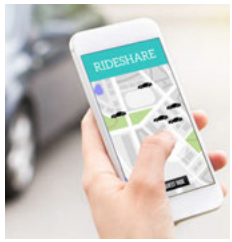
With traditional data processing unable to deal with the skyrocketing volumes of data that are produced every single day, **complex systems** are being created to allow for **big data processin**g.

GNSS is a major data source providing **location** and **timing information** to the world of Big Data. The proliferation of GNSS devices is boosting the quantity of location and timing data.

Cyber security

Cybersecurity is a big challenge that organisations and individuals will face in the next two decades, and a high-potential market at the same time. As it happened with many other connectivity-based technologies, our economy is now **depending on GNSS for the functioning of key industries and sectors**. This motivates the importance of addressing GNSS vulnerabilities as part of cybersecurity strategies.

The sharing economy



The paradigm shift from "**ownership of" to "access to"** is driving one of the fastest growing business trends in history. The sharing economy started from **ride** and **accommodation** sharing services and is now encompassing a plethora of other areas. **GNSS** is a key technology for all **service models** requiring **geographic information**.

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Acting now is the only way forward in a global effort to reverse climate change effects

Human activities are causing a rapid acceleration of climate change effects

Rising global temperatures and sea levels, warming oceans, shrinking ice sheets and more frequent extreme weather events are all manifestations of **climate change**. Human activities associated with increased industrialisation result in an ever increasing concentration of greenhouse gases in the atmosphere, inducing global warming.

Acting now is the only option to reverse climate change and **its long-term effects** on our planet's health, our economy and the next generations' livelihood. Climate change is our generation's greatest challenge; avoiding a "hothouse" Earth future will require global solidarity and immediate action at all levels – from each individual citizen, to multi-billion companies, to the most complex intergovernmental organisations.

Reversing the effects of climate change can only be achieved by a change of the strategic vision of nations and of the way people live, produce, consume, eat and commute. In that context, technological solutions such as **GNSS not only enrich our understanding and scientific evidence on human-made climate change; they also enable the needed changes in our everyday lives and our economic activities**.

The contribution of GNSS to limiting global warming

In the recent "IPCC Special Report Global Warming of 1.5° C" the world's leading climate scientists have issued a wake-up call to the world: The rise of global temperatures must be limited to 1.5 degrees Celsius (above the pre-industrial level) to avoid catastrophic consequences. Appropriate policies and regulation must be put in place and economic activities must follow suit to ensure the cutting of emissions by half by 2030 and reaching net zero emissions by 2050. GNSS contributes to this effort in many ways and across different sectors such as road transport, aviation, smart cities and agriculture. These are few examples out of many:

- **Reduced fuel consumption**: GNSS enables optimal routes for cars, buses, boats and airplanes by providing accurate positions. This allows significant reduction of the fuel required to go from A to B and thus contributes to the reduction of CO_2 emissions.
- **Sustainable agriculture**: As the centrepiece of precision farming, use of GNSS reduces the need for fertilisers. In turn, this means a reduction of greenhouse gases such as CO_2, nitrous oxide and ammonia in the atmosphere.
- **Smart Cities**: Connectivity and efficiency are fundamental concepts in the context of smart and more sustainable cities. GNSS contributes to the Internet-of-Things and empowers efficient urban public transport, eventually contributing to environmentally-friendly solutions.

GNSS in support of meteorology and climate change monitoring

As GNSS signals travel from the satellites to ground stations, they pass through the different layers of the Earth's atmosphere. Its lower part – the troposphere – contains water vapour, which introduces delays in the propagation of GNSS signals. These delays result in an offset of spatial accuracy.

By processing and analysing these effects, the Integrated Water Vapour quantity and the Zenith Total Delay can be evaluated. **As water vapour is the most abundant greenhouse gas in the atmosphere, the estimation of its concentration is important for weather forecasting** (both long-term and nowcasting) **and for climate change monitoring**.

In that context, **pan-European efforts to streamline the utilisation of GNSS as a tool supporting meteorology and climate change monitoring** are currently ongoing. The most prominent is the EU-funded COST Action – GNSS4SWEC. Running for 3 years already, it aims to develop new, advanced tropospheric products, exploiting the full potential of multi-GNSS water vapour estimates on a wide range of temporal and spatial scales, from real-time monitoring and forecasting of severe weather, to climate research.

GNSS is part of circular economy solutions

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Since the first industrial revolution humankind has been following a **linear approach** to the consumption of resources. Raw materials are used to make a product, which is then thrown away after its use. This results in tremendous amounts of waste affecting climate and nature. Adopting a circular economic approach by reusing resources and recycling is a promising step in the fight against climate change.

GNSS may provide added-value for the implementation of the circular economy via multiple innovative processes. For example, GNSS is used for waste management applications in smart cities. GNSS also contributes to precision agriculture in order to eliminate waste, optimise usage of machinery and increase crop yields, meeting the need for efficient and sustainable farming solutions.

GNSS adds value to Big Data analysis for optimization and prediction

What counts as big data?

In 2001, Big Data was defined by the power of 3 Vs: Big data is data that contains greater **Variety** arriving in increasing **Volumes** and with ever-higher **Velocity**. With the digital universe doubling every two years and new sources being added every day a fourth V has arised: **Veracity**. This related to the credibility and reliability of the data sources. As the Big Data Processing methods have evolved, a fifth V started to be circulated around the world of Big Data: **Value**. Having access to Big Data is useless unless we can turn it into something significant.

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The need for improved systems with very high storage capacity and processing power is crucial in the future as there are about 2.5 quintillion bytes of data being created globally every day. While the storage capacity can probably be fixed, the processing power is one of the key issues that can be tackled by combining Big Data with another macrotrend: Artificial Intelligence.

The main challenges for Big Data processing remain the ability to **store** and **process** the data at the same speed that the data is being produced. On top of these, new ones have arised like safety and security which both play a key role in ensuring data is used to preserve these two rather than compromise them.

GNSS and Big Data: a blessing or a curse?

The role of GNSS in day to day life keeps growing. Position and timing information is continually generated as new mobile devices are produced. Combining GNSS information with Big Data processing enables decisions to be made which uses these two technologies to cross-check results and ensure that data received about an object (vehicles, aircraft, people, animals, etc.) has veracity and value.

The data can be used to track anyone anywhere through data transactions from the various mobile applications that provide geolocation information (photos uploaded to the cloud), payments made using phones, travel guide applications, etc. The application of big data combined with GNSS in this way needs to be carefully considered given the possibilities for malicious use.

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More accurate location and timing support Big Data processing

The development and implementation of the Multi-GNSS environment enables the location and timing information to become more accurate and less prone to interference therefore improving the value that can be added through Big Data processing. The solution can **provide enhanced prediction and optimisation services to a wide range of industries** leading to improved efficiency of operations.

The GNSS segments in which Big Data processing brings the most value include Consumer Solutions, Road, Critical Infrastructures, Manned Aviation, Unmanned Transport: both Drones and Autonomous Cars and Agriculture.

Security is another area where Big Data can improve its efficiency by **broadening the scope of security oversight** and therefore, enabling the identification of trends and better detecting anomalies within the entire system of systems chain. The difficulty in such environment is to select the right data so Big Data processing can help alleviate this issue.

GNSS and Big Data improving businesses: Supply Chain Logistics

One of the biggest developments to come from big data science is the blockchain: an untamperable ledger of transactions. **Supply Chain Logistics is one area where combining GNSS data with Blockchain allows the end user or the manufacturer to trace their product through each production stage consistently without any gaps**. The company faizod produces a GPS Blockchain Tracker that determines the GPS coordinates and transfers them to any Blockchain.

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Multiple Blockchain connections are possible. The coordinates are continuously written as transactions in the decentralised database and are thus chronologically and precisely documented. This allows the end customer or manufacturer to check the location of the product at regular intervals and see through which production stations the product has passed. In addition to the tracking of a product through its manufacturing, warehousing and distribution, the technology also provides a measure against counterfeiting and a method for inventory control.

In the digital world, artificial intelligence takes the driving position

Everything has become digital…

The 4th industrial revolution is blurring the boundaries between the physical, biological and digital world. This trend generates countless opportunities to innovate by creating new and more competitive businesses models.

Nowadays, most of the operations and processes across the value chains serving sectors such as Healthcare, Finance, Energy, Mobility, Retail and Delivery, are largely **digitalised**, since digital approaches enable managing **more information** in a **more intelligent way**.

In this frame, over the past two decades GNSS technologies have progressively allowed digital systems to make use of positioning and timing information on a global scale.

… creating the necessary baseline for the uptake of artificial intelligence

Artificial intelligence (AI) enables computers to "think", thanks to routines that identify complex patterns, process information, draw conclusions, and enable the computer itself to learn along the process.

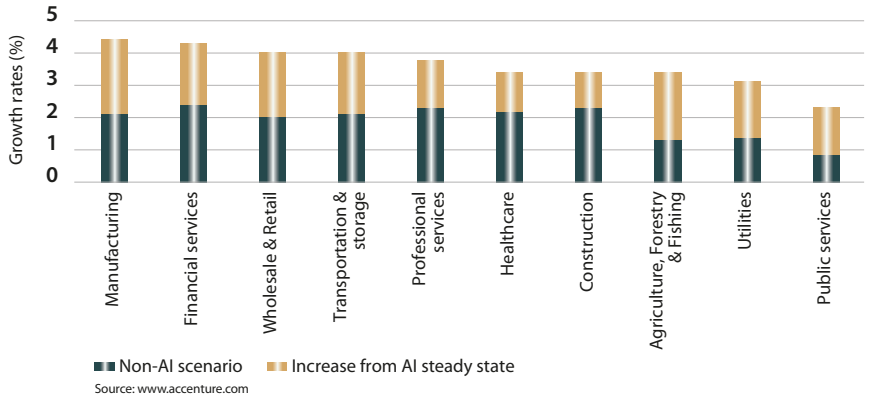
AI is being deployed at scale across different industries and sectors, although the automation potential can differ significantly, with manufacturing, financial services, wholesale & retail and transportation being the sectors with the highest potential.

The ability to capture and interpret data more efficiently and accurately than ever before is impacting the economic growth of these industries, by boosting profitability rates by almost 2 percentage points per year at least until 2035.

In each of these sectors, the way **AI can generate** this **growth** and benefits is manifold. Considering **transportation** as an example, artificial intelligence improves the safety and productivity of vehicle usage by enabling automation but can also reduce traffic congestion by predicting and managing traffic patterns. The same patterns can then be used to feed freight management systems supporting corporate decision making.

At the same time, as industries becomes more automated and data driven, a **shift in the workforce skills** will be necessary, to align with the disruptive impact of AI on businesses and their operations.

AI Impact on Gross Value Added (GVA) growth rates by industry in 2035



Source: www.accenture.com

Artificial intelligence enhances the impact of GNSS applications

There are many examples of how the introduction of artificial intelligence boosts the added value of GNSS enabled applications.

In **Agriculture**, beyond automation of steering and input application, Deep learning algorithms use data from drones and satellites to predict crop outputs and help detect crop diseases before they spread.

In road **transport**, AI enables self-driving cars to use GNSS navigation and fleet management algorithms previously fed by human decisions. The same is happening in other transport sectors, such as maritime with autonomous vessels. While in the road domain GNSS data can also feed traffic management algorithms, in maritime machine learning enables the optimisation of fishing vessel operation by identifying where the vessels have been, their activities and productivity.

The same logic applies to many other sectors, such as **energy**, when deep learning processes are used to optimise the operation of drones for inspecting power lines.

Improving GNSS cyber security yields huge economic opportunities

GNSS security will benefit from the cybersecurity market growth

Cybersecurity is **one of the biggest challenges** that organisations and individuals will face in the next two decades. The **cybersecurity market is therefore one of the fastest growing** markets in the ICT sector and is increasingly seen as an economic opportunity. For instance, Market & Market estimate that the automotive Cybersecurity Market would be worth €5.17 billion by 2025 growing at a CAGR of 23% between 2018 and 2023.

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Similar to the Internet, GNSS has become a **pillar of our economy** and is therefore a possible target for cybercriminals. GNSS security is consequently increasingly part of all **cybersecurity strategies** and is expected to benefit from the intense cybersecurity market growth.

Strong suspicions of GNSS spoofing at 2019 Geneva Auto Show reinforce the importance of GNSS authentication solutions

A recent example of GNSS spoofing happened at the **2019 Geneva Motor Show** reinforcing the case for GNSS spoofing protection in mass market products.

Indeed, several car manufacturers were affected by GNSS spoofing resulting in their cars' GNSS units displaying a location in the UK and a date in 2038. This event echoed the experiment made by security researchers in 2018 who managed to spoof a smartphone turn-by-turn navigation system with low cost hardware components.

Improving robustness against GNSS spoofing is therefore increasingly put on the agenda of all car makers and of the entire GNSS automotive value chain.

GENEVA INTERNATIONAL MOTOR SHOW
7-17 MARCH 2019

© Images: Getty images

Threats to GNSS may affect a wealth of vertical market segments

GNSS spoofing and jamming are raising concerns for applications where Position Velocity and Time (PVT) is either the **basis for legal decisions, imply safety considerations, has a potential environmental impact or is involved in an economic transaction**. This includes for instance Cooperative, Connected and Automated Mobility (CCAM), telecommunication networks synchronisation but also illegal fishing, energy distribution, logistics, emergency services, drone operations, data centers and many other applications.

Several initiatives launched to combat the issue

Improving GNSS security has become a priority for most GNSS stakeholders. Device manufacturers have increased their R&D effort to improve receiver robustness and security. The topic is also taken very seriously by GNSS programme managers. The European Union has been a pioneer in the field offering a **portfolio of authentication** capabilities through **Galileo OS-NMA, SAS and PRS**.

Improving PVT security may also be ensured through the use of complementary technologies at receiver level (e.g. through sensor fusion) or even with other satellites-based systems such as Satellite Time and Location (STL) based on the Iridium system. All these technologies have been developed in the recent years as a response to GNSS vulnerabilities.

Finally, co-operation and exchange of information between GNSS stakeholders and end users has led to a better understanding of the GNSS cyber threat allowing users to fully exploit the benefits of GNSS while mitigating against the corresponding risks.

The ageing society brings in challenges and opportunities for smart health services

The silver economy – a global trend

The so called "**Silver Economy**", i.e. the economy generated by the population over 50, has **progressively gained relevance** over the past decades. According to the European Commission data, the **European Silver Economy** would currently be the third largest **economy** in the world, following USA and China. This is by no means a regional trend, as between 2015 and 2050, the proportion of the world's **population over 60 years will nearly double** from 12% to 22%, as an effect of people living longer.

All countries need to ensure that their health and social systems are ready for this demographic shift, since this part of population needs to be in good health to be able to learn, work, travel and be able to live independently.

To meet these challenges, the **health sector** is **turning towards digitalisation** and the adoption of new technologies to deliver better services and new healthcare and wellness products. The scope of **Health-tech** applications is rather wide, encompassing, among others, the use of **artificial intelligence** for drug discovery and diagnostics, as well as the introduction of **digital platforms** to manage the patient journey from diagnosis up to post-treatment care.

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GNSS is an enabler for m-health applications

All the Health-tech services that have a mobility component represent interesting opportunities for the adoption of positioning technologies. On top of supporting "preventive" applications connected to fitness and wellbeing, GNSS plays a significant role by enabling services such as **emergency caller localisation, and senior citizen monitoring**.

Considering the first category, on top of public emergency caller systems, commercial applications such as **PulsePoint Respond** enables individuals to provide life-saving assistance to victims of cardiac arrest. Users trained in cardiopulmonary resuscitation (CPR) are notified through a location-based service approach if someone nearby is having a cardiac emergency.

Moving to the second category, companies such as **Weenect** produce dedicated devices for tracking the elderly, connected to a smartphone app that allows for remote monitoring and tracking. The service also establishes geo-fencing areas and alerts users if the tracked subject leaves a defined area. This helps locating, reaching and taking care of loved ones that are subject to medical emergencies or might get lost because of conditions such as Alzheimer's.

Positioning information is key for sharing economy services

Sharing economy platforms are growing quickly in volume and value

The **sharing economy** is one of the fastest growing business trends in history based on the characteristics of **"access to" rather than "ownership of"**. While back in 2014 the value of the sharing economy worldwide was estimated to be worth €12 bln, the business is set to reach a staggering value of €300 bln by 2025, according to Statista[1].

Why and how sharing economy services have developed?

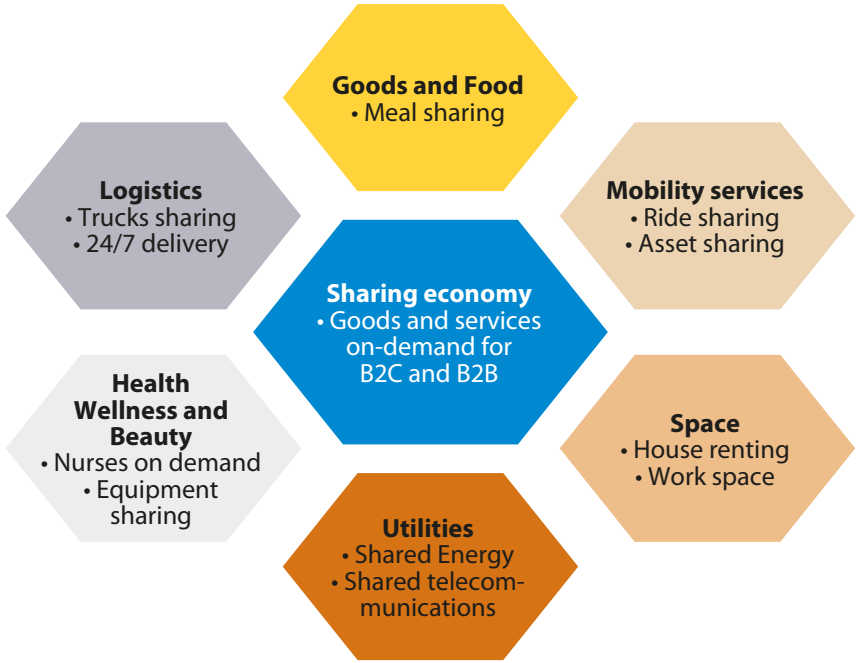
Technology has reduced transaction costs, making sharing assets cheaper and easier, therefore possible on a much larger scale. **Increased availability** of data about people and things allow physical assets to be disaggregated and consumed as services.

Platforms and applications are at the centre of the sharing economy business models, making it possible to network a large pool of providers with the audience of potential users.

Who are the main actors?

The sharing economy **started in the mobility and housing sectors**. Most of the first sharing-economy companies are in the sector of ride sharing (BlaBlaCar, Lyft, Uber) or accommodation sharing (Airbnb). Nevertheless, the trend has **quickly extended to other sectors**, often disrupting the competition in impacted markets: shop and office sharing (We Are Pop Up); Meal sharing (EatWith, Meal Sharing, Traveling Spoon); Solar-energy sharing (Yeloha).

Among these sectors and markets, all the sharing economy **business models that involve geographic information** on the user side, the provider side, or both, typically **represent use cases for GNSS technologies**. This applies to all mobility-related services, but to some extent also to all business where an asset (or accommodation) needs to be located by users.



GNSS enables mobility sharing services

© Getty Images

Different type of mobility sharing services make use of GNSS positioning for asset localisation and transaction calculation, including **asset sharing and rides as a service** solutions. When these services involve sharing an **asset** (e.g. bike, scooter, car), different business models exist – they can broadly be categorized into **station based** vs. **free float** schemes, with the latter giving users more freedom when it comes to dropping the asset after use.

Focusing on **rides as a service**, these include commercial "on-demand" ride sharing solutions such as Uber and **car pooling** services enabling users with a common path and/or destination to share travel costs.

Over the past years, it has become clear that **GNSS is a key enabler** for all these service and business models, thanks to the positioning accuracy, availability and reliability of GNSS that is essential for users to find the assets and for service providers to manage them.

[1] https://www.statista.com/statistics/830986/value-of-the-global-sharing-economy

CONSUMER SOLUTIONS

GNSS applications

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

Consumer Solutions devices

GNSS-enabled Consumer Solutions comprise a multitude of applications, tailor-made to satisfy different usage conditions and needs. These applications are supported by several categories of connected devices: mainly smartphones and tablets, but also specific equipment such as personal tracking devices, wearables, digital cameras and portable computers. Nowadays, with a combination of technologies such as GNSS, 5G, and IoT, any physical device can become a connected device, enabling new applications to facilitate the end user's day-to-day life. On top of this, Artificial Intelligence (AI) provides an additional layer to this connectivity enabling greater capabilities and sophistication to these devices.

What you can read in this chapter

- **Key trends:** Intelligent connectivity is proliferating with increasing numbers of platforms and apps.
- **User perspective:** Smarter connectivity calls for better GNSS performance.
- **Industry:** Consumer Solutions Value Chain.
- **Recent developments:** Asia-Pacific continues to dominate the market, accounting for half of global shipments in 2018.
- **Future market evolution:** Wearables and tracking devices are boosting the GNSS market, whilst smartphone shipments are maturing.
- **Focus on European GNSS:** Connectivity becomes more reliable with Galileo.
- **Reference charts:** Yearly evolution of GNSS devices' installed base and revenues by device type and region.

NEW **Low-powered asset trackers** have been added to the reference charts and overall statistics data.

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Intelligent connectivity is proliferating with increasing numbers of platforms and apps

Key market trends

- After smartphones have made our lives more digital and interconnected, augmented reality applications are bringing the virtual to the real world
- Enhanced smartphones and new wearable devices push the performance of GNSS to new levels to improve the user experience
- Due to the evolution of receiver technology, dual-frequency and high accuracy in smartphones is on the rise and is here to stay

Smartphones are constantly evolving …

© Samsung

In 2020, the number of smartphone users is forecasted to reach almost 3.5 bln, making smartphones the most used electronic device worldwide. Looking to the overall market, the biggest players according to the 2018 market shares in terms of shipments of units are Samsung (20.7%), Huawei (14.3%), Apple (13.3%), Xiaomi (9.3%) and OPPO (7.7%). To stay ahead of the stabilisation of the market, the **mobile industry is investing into truly innovative smartphones**.

The new generation of smartphones will rely on fast and highly reactive 5G network and their models are adopting new flexible designs, imitating wearables. The **foldable smartphone** model was first issued by Samsung (Galaxy Fold) but other brands such as Huawei and Xiaomi are also producing their own flexible smartphone devices. Also thanks to GNSS multi-constellation and now multi-frequency, manufacturers are constantly improving smartphone capabilities, providing the software and application developers with ever-growing opportunities for new businesses and use cases.

… supporting a continuously increasing ecosystem of apps

The **software is becoming a key differentiator to transform the smartphone into a hyper-personalised device**. With a total of 5.5 mln apps available for download in 2018 on the main app stores (Google Play, Apple App Store, Windows Store, Amazon Appstore, BlackBerry World), smartphones serve as a music, lifestyle, social media, entertainment, games, productivity, travel and navigation enabler. Integrated location-based service applications like Apple's iBeacons and Google Beacon are enabling personalised marketing.

Mobile app revenues are forecasted to continue growing, reaching nearly €160 bln worldwide in 2020, almost entirely running on the Android or iOS operating systems. Digital media usage also continues to rise, with approximately 3.5 hours of mobile use on daily basis and around 260 bln mobile app downloads worldwide by 2022.

Wearables: our digital lives are dressed in technology

Wearables represent the beginning of the separation between smartphones and end users, as an increasing number of smartphone services and apps are now accessible via new interfaces (smartwatches, fitness trackers, smart glasses, clothing, etc.). According to Statista[1], connected wearable shipments are expected to reach €64 bln by 2022, representing 1 bln connected devices. Currently, wearables are mostly used for fitness, health and entertainment.

© Getty Images

Fitness wearables, the biggest segment of the market, reached a global market size of €13 bln in 2018 and an annual growth of about 5.2% through to 2023 is foreseen. Focusing on GNSS-enabled products, Multi-GNSS is one of the most valuable technology of the high-end devices. The leaders of the wearables market leverage multi-GNSS to provide enhanced location and navigation information to their customers. Recently, the offer of wearables started to evolve from bracelets and watches to other objects. In the case of **smart glasses**, the possibility to record and store location stamped videos and photos, in combination with advanced Augmented Reality features and affordable prices, could boost the growth of the market. Professional, sport and entertainment are deemed to be the most prominent usage domains.

[1] https://www.statista.com/statistics/487291/global-connected-wearable-devices/

AR Gaming: an attractive playground for geolocation apps

Mobile gaming represents 75% of global app store revenues, which accounted for €81 bln in 2018 also thanks to the ubiquity of smartphones. Along with the latest trends such as Augmented Reality (AR) and Virtual Reality (VR), gaming app developers take advantage of the GNSS capabilities of the phone to integrate the real-time location of the user, allowing the player to interact with its surroundings. Looking at the potential for AR games and their software, conservative forecasts suggest a 2020 market value of over €30 bln.

GNSS helps making augmented reality games even more immersive, providing the players with high accuracy and availability even in areas with no phone coverage or Internet. Also thanks to accurate positioning capabilities, these games have become hugely popular, with few examples being Pokémon Go, Geocaching, Resources and Geoglyph. **At this stage, GNSS is present in 64% of the latest AR games.**

Smarter technologies call for better GNSS performance

GSA GNSS Raw Measurements Taskforce promotes wider use of GNSS raw measurements

As of Android 7.0, access is available to the GNSS raw measurements, allowing developers to use the carrier and code measurements, as well as the decoded navigation messages from mass-market devices. This allows for the creation of advanced GNSS positioning algorithms that enable the development of more ambitious smartphone-based applications.

In 2017, **a GNSS Raw Measurements Task Force** was launched, to bridge the existing knowledge gap among potential raw measurement users. Since then, the Task Force has expanded to a group of more than 100 agencies, universities, research institutes and companies. As part of its mission, the Task Force is also organising various fora and annual workshops to reach an even wider audience.

To support these activities, a **White Paper** on the subject has been published. It provides in-depth information on how to access these raw measurements and highlights which mass-market application areas are most likely to benefit from improved positioning performance.

Besides this White Paper, two additional tools are available, namely a dedicated **discussion forum** and a **measurement database** where members can upload data logs and relevant documents.

Awareness of cybersecurity on the rise

Considering the increasing number of connected devices and the increasing reliance on digital platforms, the **protection against potential cybersecurity threats has now become of critical importance.**

The global presence of and access to positioning and navigation information from GNSS opened up plenty of possibilities for people to enhance their daily activities: from receiving more accurate information during their outdoor activities, to ordering food or sharing different transport modes. In line with the increased digitisation and connectivity, the smartphone has become a digital hub for a wide range of personal data such as addresses, preferences, health information and financial data. The protection of these data is becoming increasingly important for users, and cybersecurity companies are starting to use new technologies such as blockchain (e.g. Forcepoint) for monitoring and managing systems.

Companies and individuals relying on asset trackers for the tracking and tracing of valuables (such as equipment and vehicles) have similar concerns given that their GNSS-enabled devices could be vulnerable to spoofing attacks. Emerging technologies and new features (e.g. Galileo OS-NMA) are giving vulnerable information security systems a required upgrade.

GNSS as an enabler for connectivity and automation

The table below presents the key user requirements from the GSA's Report on User Needs and Requirements in the Consumer Solutions segment. The report, updated on regular basis, contain detailed and quantified requirements. Only high priority requirements are shown in the table, i.e. other requirements might also be relevant for considered applications. Information on the parameters definitions is provided in Annex 2.

Applications	**Traditional applications:** Navigation, Sports, Tracking, Social networking, Enterprise applications, Infotainment, Games	**Innovative applications:** Augmented Reality, Robotics, mHealth, Geo marketing and advertising, Fraud management and billing, Safety and emergency
Key GNSS requirements	Availability (in all environments) TTFF	Accuracy (high) Authentication Availability (in all environments) TTFF
Other requirements	Connectivity (including short range) Interoperability Power consumption	Connectivity (including short range) Interoperability Power consumption

Consumer Solutions Value Chain

COMPONENTS AND RECEIVER MANUFACTURERS

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

OPERATING SYSTEM DEVELOPERS

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

DEVICE INTEGRATORS AND VENDORS

Smartphone/Tablets: APPLE, BLACKBERRY LIMITED, BQ*, DORO, HTC, HUAWEI, LENOVO, LG, MALATA, MICROSOFT, OPPO, SAMSUNG, VIVO, XIAOMI, ZTE, ONEPLUS, SONY, NOKIA

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

People Tracking: GARMIN, POCKET FINDER, SPOT, TELTONIKA

Original Design Manufacturers: AVNET, COMPAL ELECTRONICS, FOXCONN, PEGATRON, WISTRON

Cameras: CANON, NIKON, SONY

PCs: ACER, APPLE, ASUS, DELL, HP, LENOVO

SERVICE & CONTENT PROVIDERS

Map Providers:
- APPLE
- GOOGLE
- HERE
- MAPQUEST
- MICROSOFT

Mobile Network Operators and Assistance Data Providers:
- AT&T MOBILITY
- ORANGE*
- RXNETWORKS
- TELEFÓNICA*
- VERIZON WIRELESS
- VODAFONE*

APP DEVELOPERS/ RETAILERS

General App Developers: APPLE, FACEBOOK, FOURSQUARE, GOOGLE, IAC, MICROSOFT, NIANTIC, NOKIA, TRIPADVISOR, YELP, ZYNGA, and many small app developers

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

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

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

APP STORES

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

USERS

END USERS

European[1] GNSS industry in the global arena

The segment is dominated by non-EU players. With a market share of 53% in 2017, **North American** companies were leading in the chipset market, compared to a market share of 2% held by European companies with u-blox as the biggest player. **Asian system integrators** (e.g. smartphones, wearables, etc.) solidified their strong lead amongst the top 20 companies in 2017, generating almost 65% of global revenues.

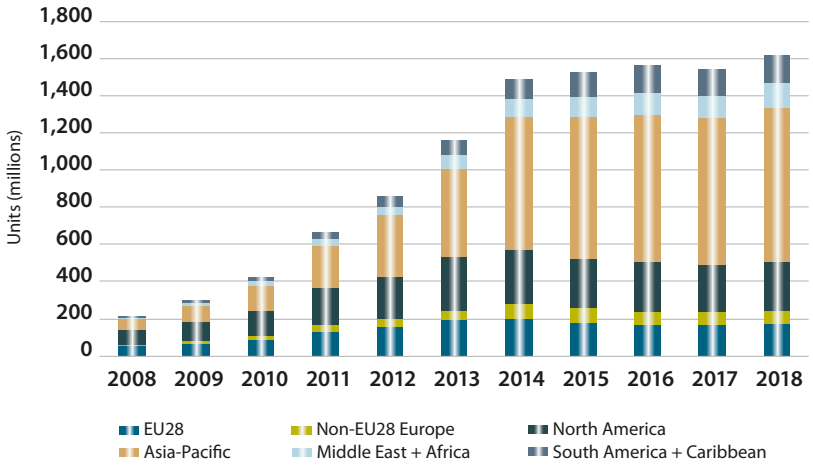
[1] In the market share analysis, Europe is defined as EU28 plus Norway and Switzerland.

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

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

Asia-Pacific continues to dominate the market, with half of global shipments in 2018

Shipments of GNSS chips by region



Asia-Pacific, the largest regional market for Consumer Solutions devices since 2011, accounted for more than 50% of global GNSS device shipments in 2018 with a total of 830 mln units. **North America** and the **EU28** accounted for 255 mln and 175 mln device shipments respectively.

Smartphones still outnumber other devices in terms of shipments. Due to the increasing saturation of the mature EU28, North American and Chinese markets and slowing global economic growth, the rise in global smartphone shipments has been gradually attenuating. The slowdown in the smartphone market is also due to the fact that smartphone users are keeping their phones longer, extending the replacement cycle. The **tablets** market is also slowly maturing (i.e. 150 mln unit shipments of tablets worldwide in 2018 compared to 175 mln in 2016); however GNSS shipments have remained constant owing to increased GNSS chipset penetration (approximately 40m devices shipped per year). Currently, the greatest level of demand for tablet devices comes from Europe, although the Asia-Pacific region is forecasted to overtake Europe as the biggest regional market.

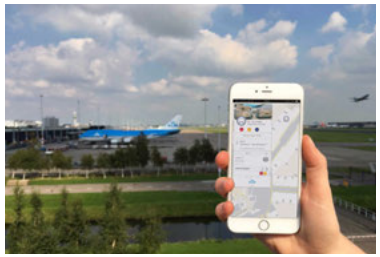
Consequently, the reason for the slight growth of shipments of GNSS devices in 2018 can be explained by the booming wearables market, as the high-end devices are GNSS-enabled. In 2018 overall **wearables** represented more than 170 mln shipments worldwide (51 mln GNSS-enabled) compared to 30 mln in 2014 (12 mln GNSS-enabled). In 2018, the wearable device unit sales were led by North America followed by Asia Pacific and Europe.

GNSS and low-powered asset trackers help to keep track of our valuables

From the 1960s onwards, companies and individuals started to track their assets using computers and a variety of IT systems. Since then, technology has taken many steps forward. **GNSS-enabled trackers enable position tracking of all valuable objects**, ranging from vehicles, heavy equipment and materials to individuals, smaller devices and even pets.

These GNSS-enabled devices are progressively becoming more miniaturised. Their usability is improving due to the **advancements in both GNSS technology and battery life**.

For example, in the case of high value assets in transit, one of the key drivers for the adoption of GNSS is the increasing need for improved accuracy and availability, leading to the increasing adoption of multi-constellation solutions. As the required level of accuracy cannot be reached with for example LTE networks, manufacturers foresee the uptake of GNSS across low-powered asset trackers to increase over time.


© Undagrid

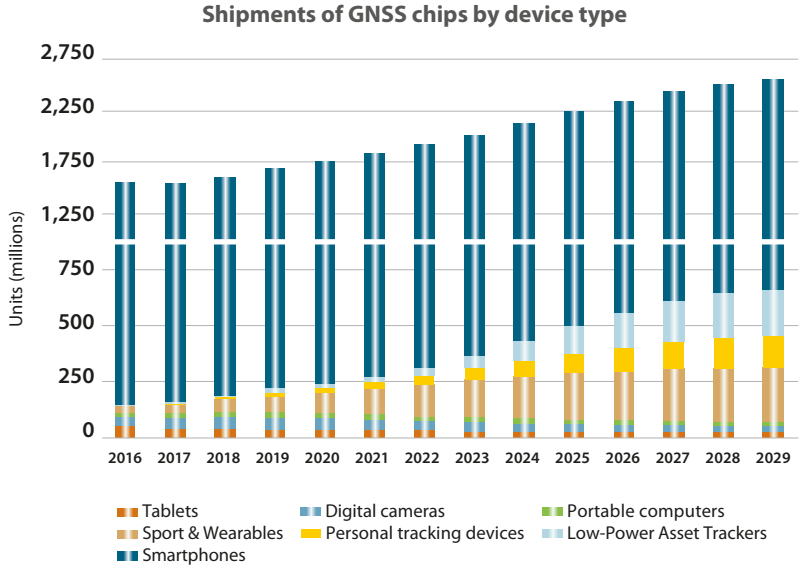
Digitalisation and connected devices are enhanced by Artificial Intelligence and no longer limited to a handheld device

Combined with the ubiquitous presence of smartphones, the network coverage creates the perfect scenario for maximising the usability and benefits of apps, including GNSS-enabled ones (mHealth, fitness, navigation, gaming, personal information, etc.). **Advances in AI will improve the capabilities of applications and services**, providing improved experiences to all users.

AI-enabled machine learning is used to improve the GNSS data processing to provide even greater performances. For example, both Google and Apple navigation services use artificial intelligence to interpret the large amount of data points that they receive to give real-time traffic information.

The concept of **extended reality (XR)** is a mix of all the technologies which combine real-virtual environments and human-machine interactions. In terms of GNSS, XR has stringent requirements when it comes to accuracy, availability and timeliness. XR applications are still in early stages but the leading technology companies (e.g. Microsoft with HoloLens) see a lot of potential for devices that can be controlled remotely through completely separate physical spaces in real time (drones, surgical robots, etc.).

Wearables and tracking devices are boosting the GNSS market, whilst smartphone shipments are maturing



In 2020, almost 1.8 bln units of GNSS devices will be shipped, with annual shipments set to exceed 2.5 bln units in 2029. The growth of the global GNSS market in Consumer Solutions devices will continue until 2029, including periods of attenuated growth due to increasing saturation in the **EU28**, **North American** and **Chinese** markets, mostly due to the maturing smartphone market.

Despite contributing 1.5 bln units in 2019, increasing to reach 1.9 bln units in 2029, the share of **smartphones** in the overall size of GNSS shipments is forecasted to decrease from 87% to 76% over the next decade. This can be explained by the maturing market as well as the shift from the smartphone towards **sports & wearables** (see Key Trends). From 2019 to 2029 the sport & wearables CAGR is forecasted to be 13%, leading to 240 mln shipments.

Personal tracking devices and Low-Power Asset Tracking devices have an estimated CAGR of 23.7% and 24.2%, respectively. This trend is mainly driven by the demand for accurate tracking solutions, a demand which is met by the improving GNSS performances.

Despite the overall smooth growth, the shipments in segments such as **portable computers**, **tablets and digital cameras are foreseen to decrease between 2019 and 2029** as they are reaching their market maturity.

How robots could become an integral part of our work and daily life

© Stanley robotics

From distribution centres, warehouses and even parking lots, **mobile robots** are becoming a natural part of the working environment. As these robots move increasingly outside their indoor environments, there is a **need for ubiquitous and accurate positioning**. Integration of GNSS and advanced sensors into robots have improved their performance, allowing **safe** and **synchronised operations between humans and robots.**

This is the case of **Kiwibot**, the advanced delivery robot system, as well as **Stan**, the first outdoor robotic parking service in the world. Further to these applications, **gardening or personal assistant robots** are gaining popularity, as well as **humanoid robots such as REEM** built to guide, provide dynamic information or even make presentations and speeches.

Although the need for positioning information will differ from one category to another, GNSS is expected to play a crucial role in providing robots with high accuracy positioning and navigation information.

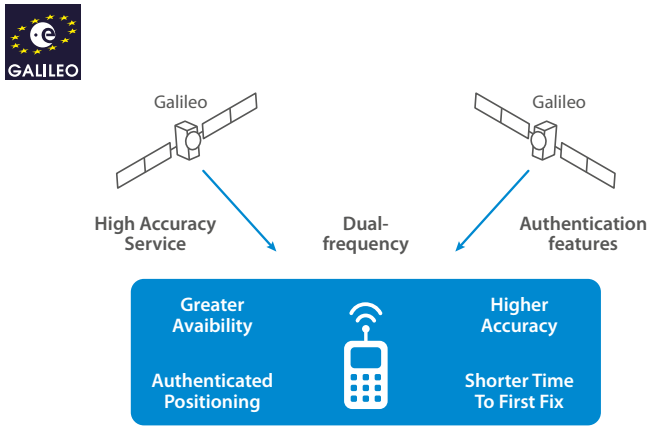
GNSS-enabled Smart clothing expected to boost beyond 2020

One of the most prominent areas of further development for smart fabrics is the **sport sector**, where tracking data is used to support coaching and exercise guidance applications. **Connected clothes** can correct the posture of the user with vibrations (Nadi X yoga pants) or detect numerous parameters via sensors (UV level in swimsuits, steps and distance travelled in socks, etc.). Beyond sports, smart clothing is conquering **fashion**, as several brands are working on the integration of Consumer Solutions functionalities.

© Nadi X

Thanks to GNSS, with a single touch or swipe across the sleeve of a jacket, users will not only be able to answer, but also to obtain directions and participate in location-based games. Smart clothes will leverage higher integration of chips and sensors to translate positioning and other data into added-value features for users. A market of 20 mln shipments is forecasted in 2022, up from the 7 mln units shipped in 2019.

Connectivity becomes more reliable with Galileo



Current usage of Galileo

At the beginning of 2019, a total of **126 different Galileo-compatible smartphone models** were available on the market. These are estimated to represent a global installed base of 600 mln units.

With leading GNSS chipset providers producing Galileo-ready chipsets and over 25 global smartphone brands already integrating these chipsets in their latest smartphone models, this number is bound to soar over the years to come.

Galileo services and features to be explored

With Galileo's Open Service Navigation Message Authentication, users of various Consumer Solutions applications will be assured of the trustworthiness of the information they receive.

On top of this, Galileo's High Accuracy Service will provide access to sub-metre accuracy to enhance innovative user applications such as Augmented Reality and Robotics applications.

E112 emergency call will leverage Galileo for improved location accuracy

Following the publication of the Commission Delegated Regulation (EU) 2019/320, new smartphones placed on the European market will have to be capable of **transmitting the caller location information**, **based on Wi-Fi and GNSS data, during emergency calls** to the common European emergency number 112. The new rules will start to apply as of March 2022.

With the requirement for the GNSS data to be at least **compatible and interoperable with the Galileo system**, the aim is to improve the average positioning accuracy of the caller, given by the cellular network, from some kilometres to a few metres. This will **greatly improve the effectiveness and efficiency of emergency services to locate people in distress**. More accurate positioning will lead to the reduction of the number of fatalities and the consequences of injuries, as the emergency response will benefit from a far more reliable location information to respond to the emergency.

One of the technologies to implement the Regulation is **Advanced Mobile Location** (AML), which is used to transmit the GNSS/Wi-Fi/cell-ID information available from the smartphone via SMS to the Public Safety Answering Points (PSAPs).

First dual-frequency smartphones hit the market

Xiaomi has launched the world's first dual-frequency GNSS smartphone, which provides high accuracy for location-based services and vehicle navigation. With the first mass-market launch, it is **expected that dual-frequency GNSS devices will account for more than a billion chipset shipments in 2023**. Brands such as Huawei, Honor, OPPO, Lenovo and others followed the Xiaomi example.

Users of dual-frequency GNSS-enabled smartphones will be able to benefit from a better positioning and navigation experience in urban environments due to the unique shape of the E5/L5 signal provided by Galileo satellites, which makes it easier to distinguish real signals from the ones reflected by buildings. This greatly reduces the multipath effect, which contributes to inaccurate positioning and navigation information in urban environments.

In addition, the enhanced positioning accuracy also creates opportunities for new applications in areas such as augmented reality, vehicle navigation, and mapping. It will also support the potential use of smartphones as tools for professional activities, as an alternative to existing dedicated devices.

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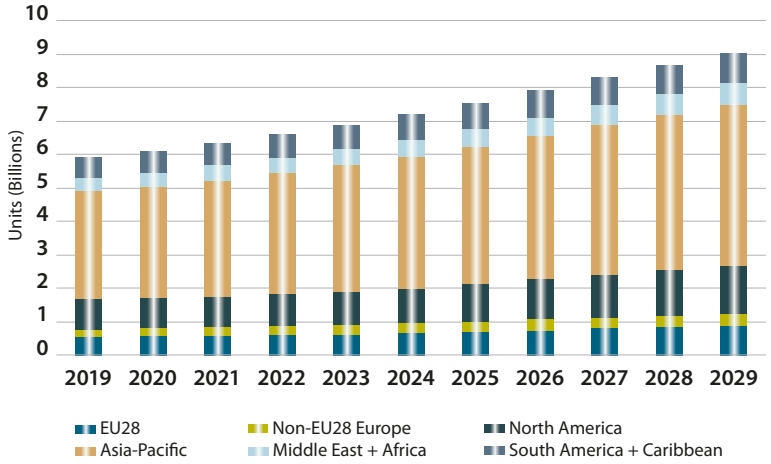
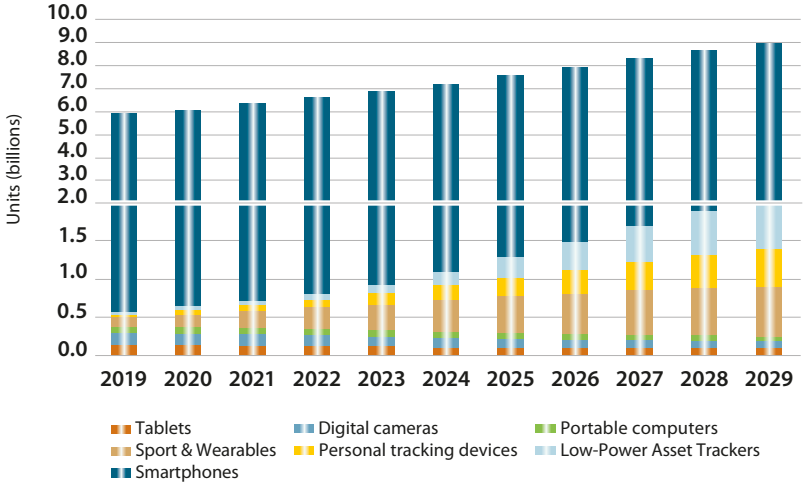
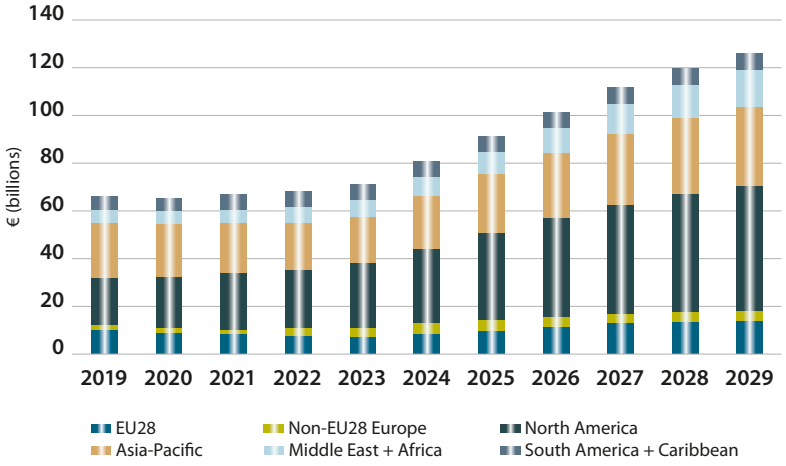
Installed base of GNSS chips by region



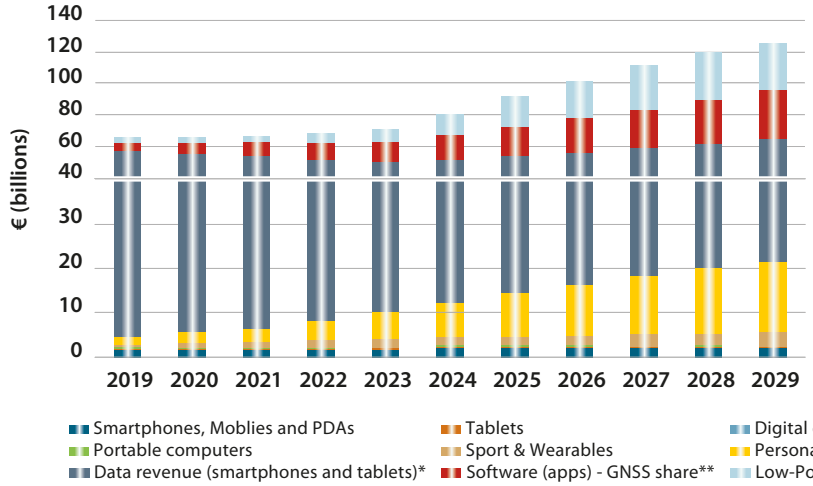
Installed base of GNSS chips by device type



Total revenue of GNSS chip sales and services by region



Total revenue of GNSS chip sales and services by type



* Only data revenue arising from the use of location-based consumer solutions considered
** Pay-to-download, In-app-purchases and ad revenue from social, tracking, search and gaming apps

ROAD TRANSPORTATION AND AUTOMOTIVE

GNSS applications

Smart mobility applications improving efficiency, effectiveness and comfort of road transportation:

- **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.
- **Fleet management** on-board units (OBUs) transmit GNSS positioning information through telematics to support transport operators in monitoring the performance of logistics activities.
- **Satellite road traffic monitoring** services collect floating car location data from vehicles through PNDs, IVS and mobile devices, then process traffic information to be distributed to users and other interested parties.
- **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.

Safety-related applications leveraging on accurate and secure positioning to scenarios of potential harm to humans or damage to a system/environment:

- **Connected and Automated Driving (CAD):** Connected and Automated Driving enabled by GNSS positioning information feeds technologies allowing road vehicles to exchange information between other vehicles and everything around them. 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.
- **eCall:** the pan-European eCall and other systems, such as the **ERA-GLONASS** in Russia, send a message including location to emergency response centres in case of accident, accelerating assistance to drivers.
- **Dangerous goods tracking** can be done by transmitting GNSS-based positioning data on the vehicles carrying them, together with other information about the status of the cargo.

Liability applications can generate significant legal or economic consequences based on positioning data:

- In **Road User Charging (RUC)** GNSS-OBUs support toll operators in charging levies for the use of roads and for congestion control.
- **Insurance telematics** black boxes rely on GNSS data to increase the fairness of motor insurance for both insurers and subscribers.
- **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.

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What you can read in this chapter

- **Key trends:** Smarter vehicles become platforms for innovative services and applications.
- **User perspective:** Better GNSS performance required by more demanding applications.
- **Industry:** Road Transportation and Automotive Value Chain.
- **Recent developments:** While PND declined and IVS soared, new applications drove GNSS shipments.
- **Future market evolution:** The IVS is set to become the primary PNT source for a variety of applications.
- **Focus on European GNSS:** EGNOS and Galileo contribute to road safety and security.
- **Reference charts:** Yearly evolution of GNSS devices' installed base and revenues by application and region.

NEW **Bike-sharing** application has been added to the reference charts and overall statistics data.

Smarter vehicles become platforms for innovative services and applications

Key market trends

- Value creation in the automotive industry is shifting: from hardware to software, with vehicles becoming more intelligent automated; and from product to service, thanks to connected vehicles and the development of the Mobility-as-a-Service paradigm
- As the data generated by the vehicle is at the core of new business models, OEMs internalise the technologies generating this data, including positioning and GNSS
- The development of in-vehicle positioning engines offers the opportunity to both OEMs and solution providers to leverage a unique GNSS receiver to support added-value services
- As automation requires vehicles to rely on very stringent positioning performance, there is a push towards increased robustness and accuracy of satellite navigation solutions

GNSS feeds different Smart Truck applications

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Commercial vehicles are already benefitting from a range of connected and smart applications relying on GNSS signals for accurate positioning and navigation.

Fleet Management Systems, which rely on GNSS positioning and vehicle data to efficiently manage a fleet of trucks, is widespread amongst companies, from SMEs to large enterprises. In recent years, GNSS also found its way to commercial vehicles thanks to the GNSS-enabled OBUs used for **Road User Charging** purposes in several countries across Europe.

Besides these applications, commercial vehicles are also equipped with an **in-vehicle system (IVS) as a primary source for PNT information**. This IVS is now becoming increasingly important with several of the upcoming applications expected to directly connect with the central positioning engine for the provision of positioning and navigation information. Relying on this central GNSS engine will facilitate the usage and synchronisation of the various services and contribute to a smoother integration of all applications, old and new.

From June 2019 onwards, the **Smart tachograph** will be introduced as the successor to the digital tachograph. In the future, this device might be used to enforce cabotage and detect border crossings. The ongoing work towards the introduction of an **eCall system**, similar to that for passenger cars, as well as the further developments towards **truck platooning and automation** will likely also make further use of the GNSS receiver of the IVS.

Internet of Things enhance Connected and Automated Driving

Connected and Automated Driving is transforming not only the way people use their cars, but also the way the vehicles are operated and integrated in the **connected mobility ecosystem**. One of the technologies contributing to this connected ecosystem is the Internet of Things (IoT). Thanks to this new paradigm, other connected devices such as traffic lights, street cameras, smartphones of pedestrians, etc. can share information about the road situation with these vehicles. The **GNSS-enabled data is shared via cloud-based system to analyse and put into use the acquired information** in order to improve the vehicle behaviour or enhance its capabilities.

The European Commission is supporting this technological advancement by funding several projects related to Automotive IoT. The AUTOPILOT project is leveraging real-life condition pilots in Finland, France, the Netherlands and Italy to investigate the role of IoT in enabling autonomous driving cars. One of the pilot cases involves vulnerable road users such as cyclists. By combining the GNSS-enabled positioning and navigation data from these cyclists with the information from the automated vehicles, situational awareness for both road users can be improved.

© Autopilot

Better GNSS performance required by more demanding applications

Reliable and accurate digital maps supporting the deployment of fully automated and connected vehicles

Although high accuracy GNSS is considered a key component towards the **realisation of fully Connected and Automated Driving (CAD)**, the industry will heavily rely on pre-build high definition (HD) maps as an important requirement for the deployment of fully automated vehicles.

Several of the leading map developers and providers such as TomTom and HERE are heavily investing in the creation of these maps with the aim to offer **affordable HD maps** by the time Automated Driving really takes off. Several elements that contribute to the steep price of HD maps are, for example, the need for continuous updates and the requirement that these maps have their coverage extended across all territories. Besides the network coverage and update rate, the quality and integrity of the data behind these maps is paramount for the safety of the automated vehicles and their passengers. On top of these challenges, international technical procedures ensuring HD Maps reliability are currently lacking.

At the beginning of 2019, the European Commission and the GSA launched a public consultation to better understand the needs of HD maps for CAD. The need for minimum performance parameters to **ensure the integrity, accuracy and reliability of the data**, as well as the creation of governance processes regarding the redistribution of mapping data were two of the key conclusions of this consultation.

Overview of main user requirements in Road

The table below depicts, in alphabetical order, the key Road user requirements as presented in the recently published GSA's Report on User Needs and Requirements. The report, updated on a regular basis, contain detailed and quantified requirements. Only high priority requirements are shown in the table, i.e. other requirements might also be relevant for considered applications. Information on the parameters is provided in Annex 2.

Applications	Safety related automatic actions in V2X, Autonomous driving, eCall, Tracking & tracing of dangerous goods		Liability: RUC, Pay-as-you-drive, Taxi meter, Smart tachograph		Smart mobility: Road navigation, Automated parking, Dynamic ride sharing
Key GNSS requirements	Accuracy (decimetre-level) Authentication Availability (>99.5%)	Integrity Robustness TTFF	Accuracy (decimetre-level) Authentication Availability (-99.5%)	Integrity Robustness TTFF	Authentication Integrity
Other requirements	Connectivity (mainly short range) Interoperability		Connectivity (short range and long range)		Connectivity (long range)

Cybersecurity rules in Cooperative, Connected and Automated Mobility

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With the ongoing evolution towards connected vehicles using the internet and new communication channels, cybersecurity is becoming an increasing concern for the industry. The types of threats related to automotive attacks are numerous.

These include access to vehicle systems devoted to infotainment and communication, interference with the functioning of safety-critical elements such as the engine and brakes, up to the override of automated vehicle functions, allowing remote control of the vehicle.

To cope with this threat, industrial organisations, standardisation bodies, UNECE and EC experts' groups started to support the design of new proposals for harmonised cybersecurity rules internationally. At the end of 2018, UNECE published its **Guidelines on Cybersecurity and Data Protection**, stating at the same time the need of clear cybersecurity and data protection rules in connected and automated vehicles.

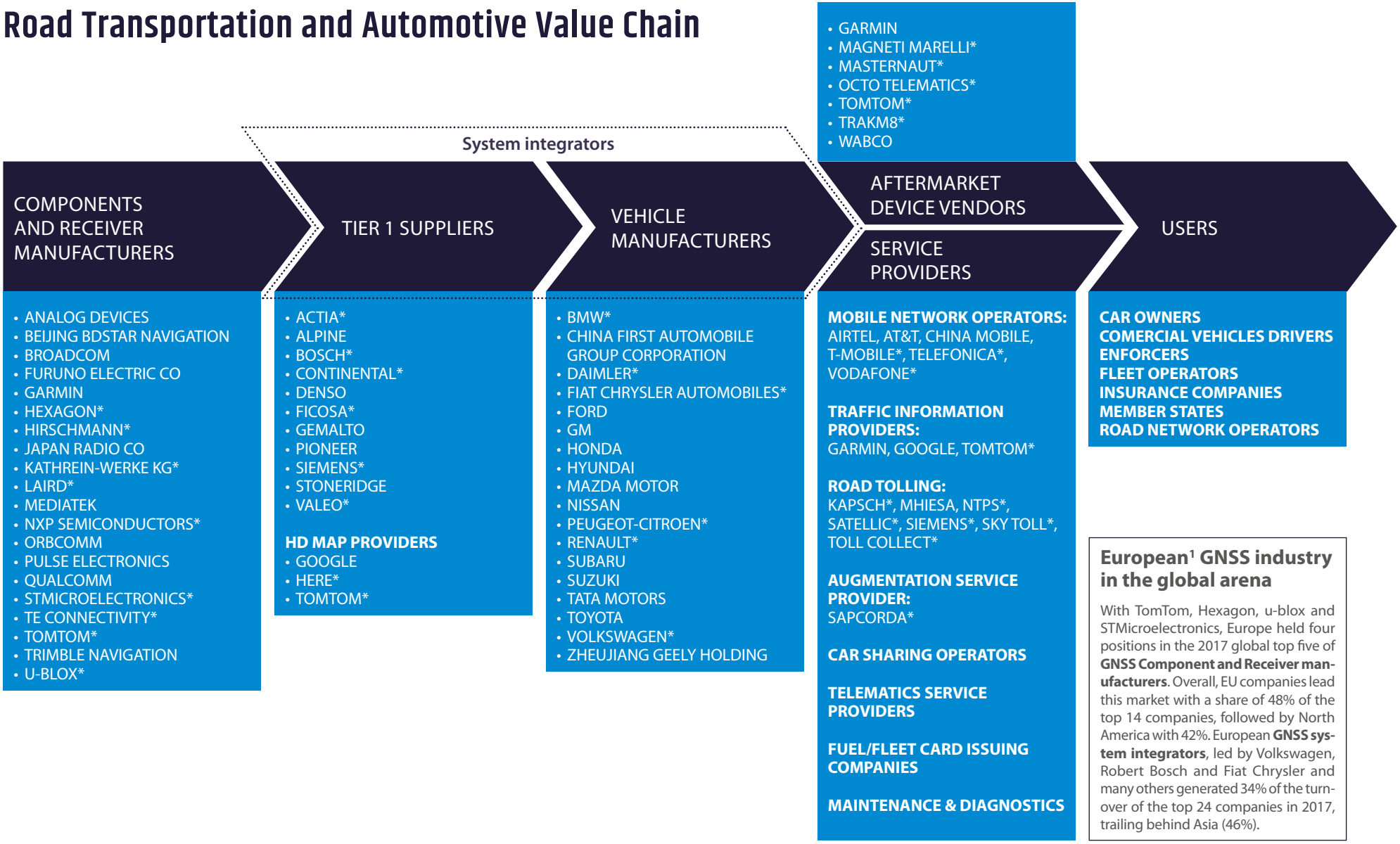
In these Guidelines, **GNSS-related threats** related to spoofing are clearly addressed and the verification of the **authenticity** of GNSS navigation messages is suggested as a mitigation action.

European public transport is ready for Galileo and EGNOS

Madrid City recently renovated its public buses to enhance positioning on-board units equipped with Galileo and EGNOS-enabled receivers. The communication of the exact position of buses enables commuters to plan their journeys and for public transport timetables to be more accurate. Empresa Municipal de Transportes (EMT) de Madrid improved positioning information on 2,050 of its buses, thus making it possible for **420 mln user journeys per year to benefit from Galileo and EGNOS.**

The Spanish capital is one of the first adopters of Intelligent Transport Systems (ITS) together with enhanced GNSS positioning services, in order to improve public transport services. In the near future, other European cities are expected to follow the example.

Road Transportation and Automotive Value Chain



European[1] GNSS industry in the global arena

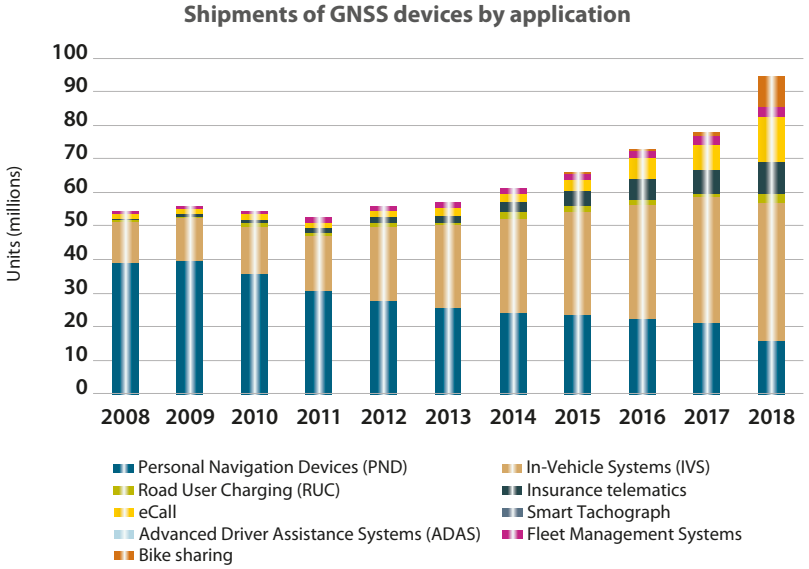
With TomTom, Hexagon, u-blox and STMicroelectronics, Europe held four positions in the 2017 global top five of **GNSS Component and Receiver manufacturers**. Overall, EU companies lead this market with a share of 48% of the top 14 companies, followed by North America with 42%. European **GNSS system integrators**, led by Volkswagen, Robert Bosch and Fiat Chrysler and many others generated 34% of the turnover of the top 24 companies in 2017, trailing behind Asia (46%).

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

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

[1] In the market share analysis, Europe is defined as EU28 plus Norway and Switzerland.

While PND declined and IVS soared, new applications drove GNSS shipments



Since 2011, in which the annual shipments reached slightly over 50 mln units, the road GNSS shipments grew by a CAGR of 6% leading to more than 94 mln shipments in 2018. Over the same period, the shipment of **In-Vehicle Systems (IVS)** has more than doubled from almost 17 mln units in 2011 to more than 40 mln in 2018. In contrast, **Personal Navigation Devices (PNDs)** has seen a rapid decline since 2009, driven both by the increased share of new vehicles being equipped with an IVS and the growing use of smartphones as a source of navigation.

An expanding collection of telematics devices and services into the automotive sector makes **insurance telematics** a very promising application, reaching almost 10 mln units in 2018.

Shipments of GNSS devices for **bike sharing** has contributed to explosive growth between 2017 and 2018 of the road GNSS device shipments in general and the dock-less bike sharing market in particular (see box below – right).

Finally, the growing number of **eCall system** shipments grew by a factor 5 over the past five years reaching more than 12 mln units in 2018. The doubling of shipments from 2017 to 2018 is greatly linked with the anticipation of the European market to the entry into force of the EU mandatory requirement (see box below – left).

Early adoption of the European eCall for the safety of all passengers

Following the entry into force of the EU mandatory requirement to fit all new car models with an eCall system, **the majority of car makers have launched eCall-enabled models**. With the emergency call devices, which automatically alert emergency services to the vehicle's crash location, the aim is to reduce the number of fatalities and the severity of injuries on European roads and beyond (e.g. ERA-GLONASS in Russia).

In 2019, 17.2% of newly registered vehicles in Europe, representing 3 mln units, are expected to be eCall-equipped. This share is expected to reach 100% by 2025, equalling 19 mln units.

With several projects ongoing, the introduction of eCall for commercial vehicles, buses and motorcycles is also foreseen in the near future.

Micro-mobility: a smart solution to urban congestion problems

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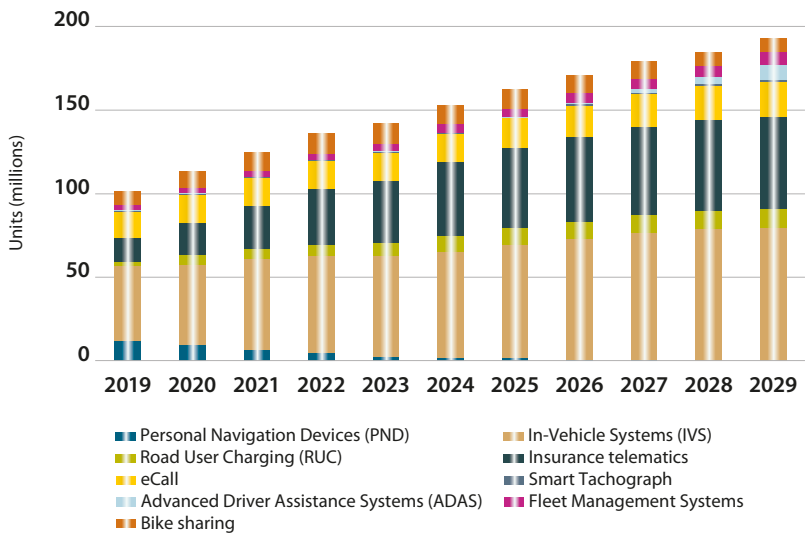
Micro-mobility is used as an **alternative to personal car usage** for urban transport and it is a booming element within the **shared mobility paradigm**. Providers of bike and scooter sharing services are relieving pressure on public transportation networks and making it easier for people to navigate around cities. **Business models** have also evolved: since 2017, service providers have launched dock-less and free-floating platforms, meaning the user can leave the bike or (kick)scooter where they want.

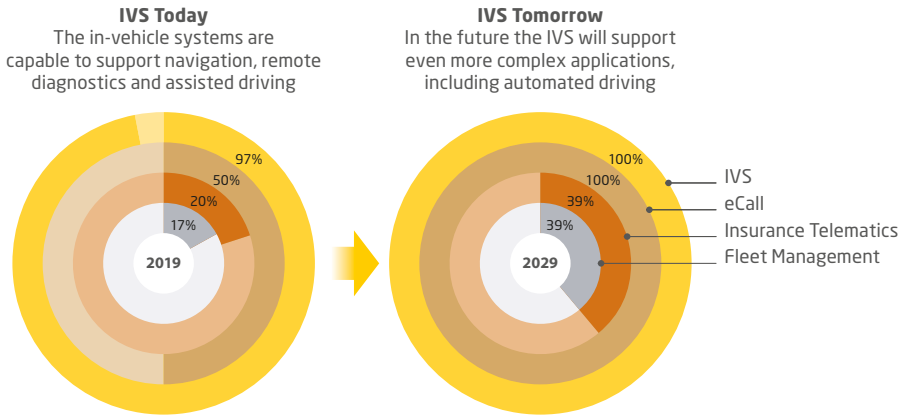
A **crucial role** in micro-mobility schemes, and especially these free-floating platforms, is **covered by GNSS**, allowing both users and service operators to easily locate and trace the bikes or (kick) scooters and across the city. Following the introduction of dock-less bikes, the number of bicycles available worldwide grew from around 1 mln units in 2015 to almost 21 mln bicycles in 2019. These numbers are forecasted to reach 45 mln by 2025. In addition, the annual GNSS-related revenues are expected to reach €66 mln in 2025, compared to less than €1 mln in 2015.

IVS is set to become the primary PNT source for a variety of applications

Shipments of GNSS devices by application



Whilst the GNSS hardware market is maturing, the functionalities of the IVS are expanding, pushing the uptake of GNSS applications across new vehicle shipments



Uptake of GNSS applications across new vehicles shipments
(both passenger cars and light commercial vehicles)

Growing with a CAGR of 6% over the next decade, the dominant role of the IVS will continue, leading to annual shipments of 80 mln units in 2029. In 2025, the shipments of **ADAS, which will allow cars and their passengers to enjoy autonomous driving features** (SAE level 4 and 5)[1], are estimated to reach 252,000 units in 2025. By 2029, this application is forecasted to surge to almost 10 mln units, accelerating the deployment of autonomous vehicles.

Nowadays, almost 97% of new vehicles are equipped with a GNSS-enabled IVS, which is evolving into the leading source of PNT data for a wide range of in-vehicle applications. As evident from the figures above, the **penetration of GNSS-enabled applications is expected to grow substantially over the next 10 years**.

Europe introduces new vehicle technology to prevent accidents

Following a provisional political agreement on the **revised EU General Safety Regulation**, new safety technologies will become mandatory in European vehicles to protect passengers, pedestrians and cyclists. These new technologies are set to become mandatory for new models of cars, vans, trucks and buses from 2022 onwards.

The **advanced safety systems enhanced by GNSS** to be fitted in all new vehicles are: event data recorder, intelligence speed assistance, lane keeping assist (only in cars and vans) and vulnerable road user detection and warning on front and side of the vehicle (only in trucks and buses). This is another step closer to the EU's long-term **Vision Zero** goal aiming to move to zero fatalities and serious injuries by 2050.

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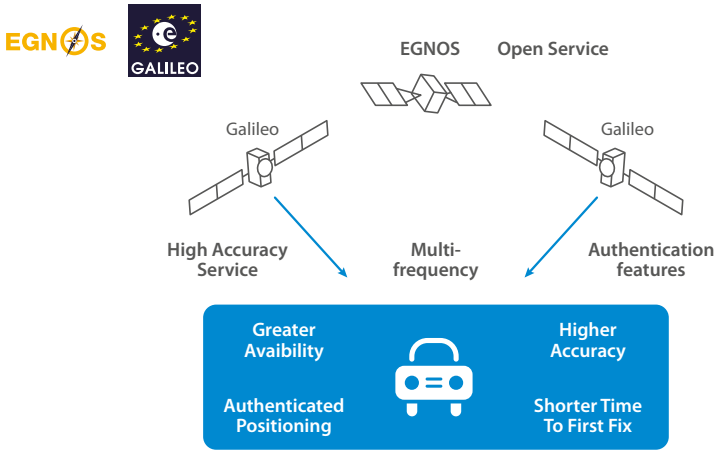
CAD is around the corner and GNSS is an essential element

The **automotive industry and a plethora of tech companies** are racing to introduce progressively automated models in the market. Although the Vienna Convention on Road Traffic and national road codes worldwide limit the possibilities of testing fully automated vehicles on public roads, specific government permits are available to the industry. With legislative progress being made every day, **the number of testing operations are growing**, thus accelerating the process of CAD adoption.

GNSS is at the **centre of the CAD technology** as it is the key source for absolute positioning information and is used in combination with other technologies such as LiDAR, HD maps, sensors and cameras. Automated vehicle are equipped with GNSS antennas, a high precision GNSS receiver and will likely rely on high accuracy GNSS augmentation services. This is why industry players such as Sapcorda, Swift Navigation and Trimble are developing innovative augmentation solutions.

[1] The In-Vehicle System is the leading GNSS unit to support applications under SAE level 3 whilst ADAS would be required for SAE levels 4 and 5.

EGNOS and Galileo contribute to road safety and security



Current usage of Galileo and EGNOS

Present in all European GNSS tolling schemes and new vehicle types equipped with eCall, Galileo is already contributing to **efficient road user charging** and **improved safety** on European roads.

EGNOS improves GPS accuracy and provides information on the reliability of the positioning information. The successful use of EGNOS in the tracking and tracing of hazardous goods transport across Europe contributes to a more efficient and effective response in case of an emergency scenario.

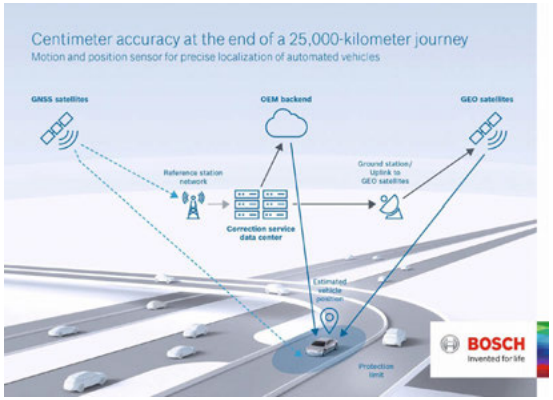
Galileo services and features to be explored

Galileo will provide significant added value to the connected and automated vehicles of the future, thanks to its **dual-frequency, high accuracy and Galileo's unique authentication feature**.

Galileo's High Accuracy Service fits perfectly in the evolution towards higher accuracy for demanding applications such as automated vehicles.

Multi-frequency GNSS system for precise positioning of automated vehicles

Bosch's new **vehicle motion and positioning sensor** (VMPS) is one of the first GNSS inertial positioning systems using correction data for highly automated driving. This solution is expected to be available on the road in 2020. The VMPS will provide safe position, velocity, attitude and time information, using a multi-frequency (Galileo E1 and E5), multi-constellation GNSS system and sophisticated integrity algorithms.



© Bosch

The system will use wheel speed sensors as well as automotive-grade, safe inertial sensors to bridge potential GNSS outages. The automotive supplier will use a correction service consisting of a **dense network** of **reference stations** spaced about 250 kilometres apart. The data will be transmitted via **geostationary satellites** as well as over **cloud connection** to the vehicle, so it can be leveraged by the VMPS to calculate the output signals and the integrity information.

More information on: https://www.bosch.de/en/

TransSec

HORIZON 2020

TransSec: on-road and off-road positioning and navigation to prevent use of trucks as a means for terrorist attacks

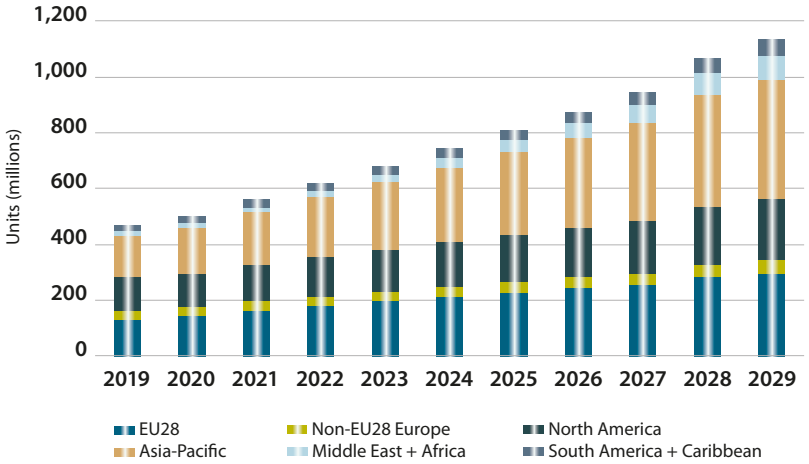
The TransSec project led by Daimler AG aims to introduce automated systems to **detect and prevent** vehicle-based terror attacks from occurring. **Precise positioning** is critical in the operation of the automated system, and a key role is foreseen for Galileo. The project uses **Galileo-enabled receivers** and **antennas** to ensure positioning quality and reliable decimetre-level vehicle position.

The project also focuses on the detection of road lane position, road lane departure and off-road positions and movement monitoring with critical area alarm. One of the key conclusions of the project is that Galileo and its dedicated services will be a clear differentiator when it comes to the provision of reliable and accurate positioning.

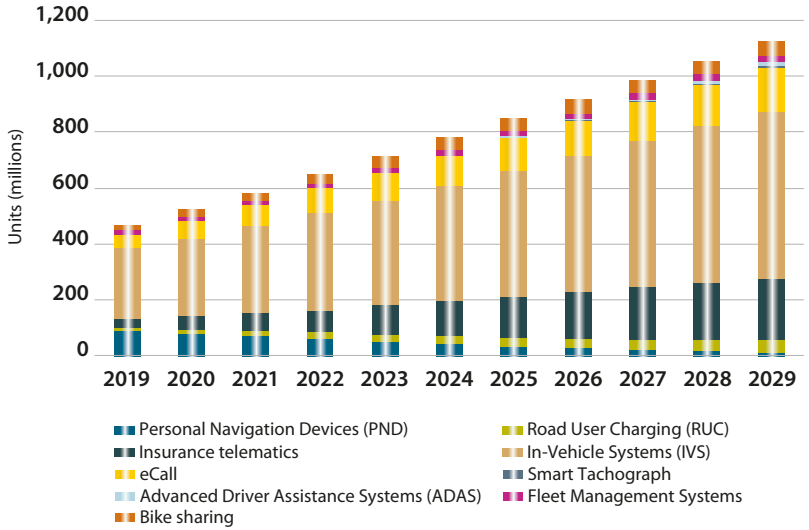
More information on:
http://www.transsec.eu/

© Transsec

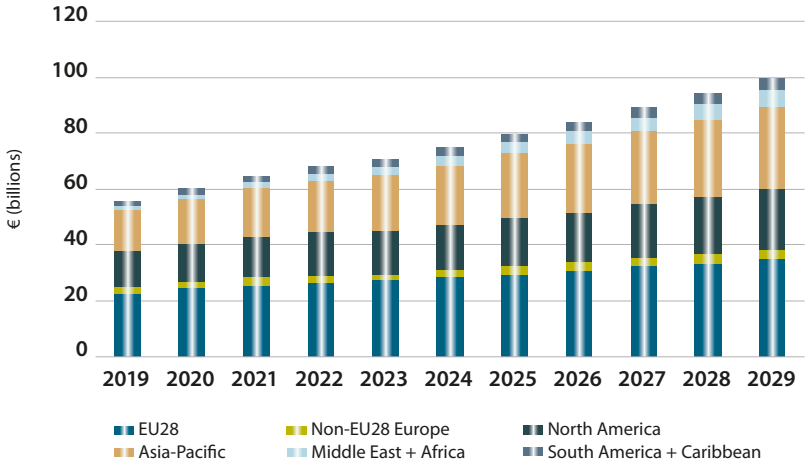
Installed base of GNSS devices by region



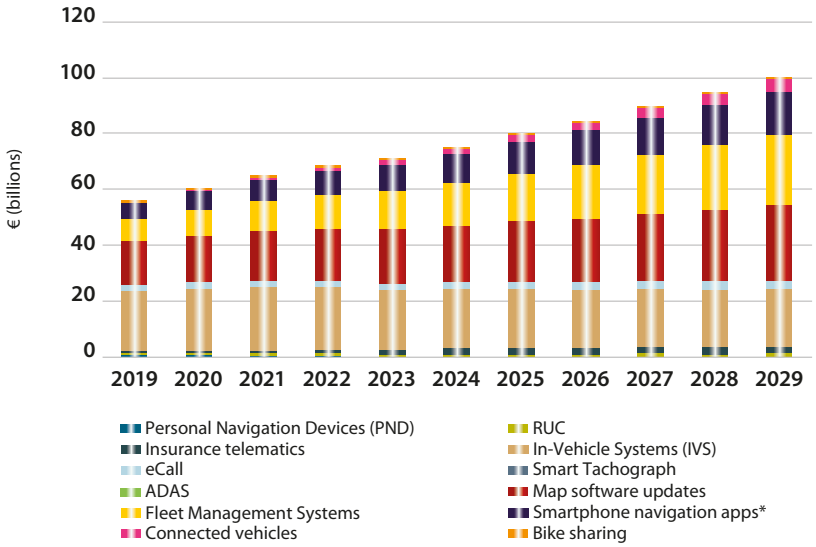
Installed base of GNSS devices by application



Revenue from GNSS devices sales and services by region



Revenue from GNSS devices sales and services by application



* Pay-to-download, In-app-purchases and ad revenue from navigation apps.

MANNED AVIATION

GNSS applications

Regulated applications in Aviation use certified equipment to achieve safe and efficient operations:

- **Performance Based Navigation (PBN)**, whereby an aircraft follows a specific procedure or route within a prescribed error margin. These procedures are available in all phases of flight.
- Applications combining **Enhanced Vision Systems (EVS) / Synthetic Vision Systems (SVS)** with GNSS have been developed and are being deployed enabling precision approach procedures for Business Aviation.
- In Surveillance, aircraft can automatically report their position to air traffic controllers on the ground and other aircraft equipped with receivers using **Automatic Depended Surveillance – Broadcast (ADS-B)**. ADS-B equipage mandates and proposal are put in place around the globe. **Advanced-Surface Movement Guidance and Control System (A-SMGCS)** provides surveillance for airport ground operations increasing conflict detection between vehicles and aircraft around the airport.
- In the evolution of **4D trajectory operations**, increasing interconnectivity between ground systems and with the global trend for data and information sharing, time synchronization plays a key role in ensuring all stakeholders have the same view of the timeline of operations. GNSS has the capability to be the single time reference needed to support all air transport operations.
- Knowing the aircraft position with precision is crucial for **Search and Rescue (SAR)** missions. It decreases time to locate the wreckage and increases the probability of saving lives or retrieving information.

In the unregulated market, many recreational pilots using Visual Flight Rules (VFR) make use of GNSS applications on devices to supplement their visual navigation techniques:

- **Moving maps** showing the aircraft position against the surrounding airspace and terrain and help pilots to monitor progress against flight plans.
- **Infringement alarms** help airspace users avoid restricted airspace.
- Increased use of **low-powered ADS-B transponders** improves the situational awareness for VFR operations by plotting adjacent aircraft on a moving map.

The European Aviation Safety Agency (EASA) is working to provide easier access for General Aviation pilots to Instrument Flight Rules operations. At the beginning of April 2019, EASA published an opinion laying down requirements for IFR flying qualification and addressing the objectives of the General Aviation (GA) Roadmap.

What you can read in this chapter

- **Key trends:** Aviation services move towards space-based assets.
- **User perspective:** Aviation actors are getting ready for a GNSS based environment.
- **Industry:** Manned Aviation Value Chain.
- **Recent developments:** GNSS uptake enabled by the development of new solutions.
- **Future market evolution:** Aviation world is growing while new concepts are being trialled.
- **Focus on European GNSS:** EGNOS enables improved efficiency in ATM operations.
- **Reference charts:** Yearly evolution of GNSS devices' installed base and revenues by application and region.

NEW **Search and Rescue (SAR) applications** are now covered in the dedicated Emergency Response segment of the Market Report issue 6 (see page 66).

© Getty Images

Aviation services move towards space-based assets

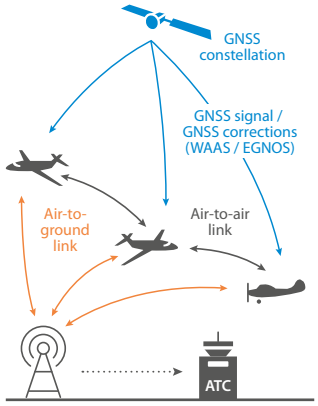
Key market trends

- Unified European regulation results in better cooperation between stakeholders and facilitates the adoption of technologies and techniques such as ADS-B or PBN
- The increased position accuracy and reliability provided by Galileo and EGNOS will allow GNSS to be used in new applications and improve aviation safety and efficiency
- EGNOSS and Galileo spread aviation services to areas where ground infrastructure is not physically or economically viable

Regulatory convergence stimulates adoption

ICAO's Global Air Navigation Plan (GANP) provides a roadmap for the deployment of new operational concepts and technologies with the aim to improve the efficiency of Air Traffic Management that is being adopted globally. Two of the key concepts in achieving a harmonised global Air Navigation system, Automatic Dependence Surveillance-Broadcast (ADS-B) and Performance Based Navigation (PBN), are now being mandated at a global level. Deploying these new concepts in a synchronised way is essential for a positive business case.

The ATM stakeholders are working on strategies for deploying integrated CNS infrastructure which will enable them to achieve economic and operational benefits as early as possible. This aligns perfectly with the convergence of the regulations leading to better collaboration between all actors.



ADS-B Deployment

In Europe, the SES mandate on **Surveillance Performance and Interoperability requirements (SPI)** Implementing Rule (IR) together with **the Aircraft Identification (ACID)** IR provides the regulatory framework for the deployment and operational use of ADS-B for both ground and airborne segments. The SESAR Deployment Manager (SDM), at the European Commission's request, developed an implementation plan at end of 2018 to synchronise deployment of ADS-B air and ground segments. The total equipage of mandated aircraft is predicted to reach 74% by the 2020 deadline reaching an equipage of 96.7% by December 2025.

In the US, the FAA mandate requiring airspace users to equip with ADS-B Out by 2020 is progressing with equipage levels reaching 70,000 aircraft. Users are recommended to equip with an SBAS capable ADS-B because it meets more stringent requirements. Mandates are also in place with Australia, Canada, China, Singapore, Taiwan, UAE, US and a few others. When Galileo is also integrated as a source for ADS-B equipment, the robustness of the position reported will increase further.

The space-based ADS-B tracking services continue to evolve supporting new operations all around the globe. As a result of this, new players are coming into the market – e.g. Aireon, Aerial & Maritime, AirNav RadarBox, etc.

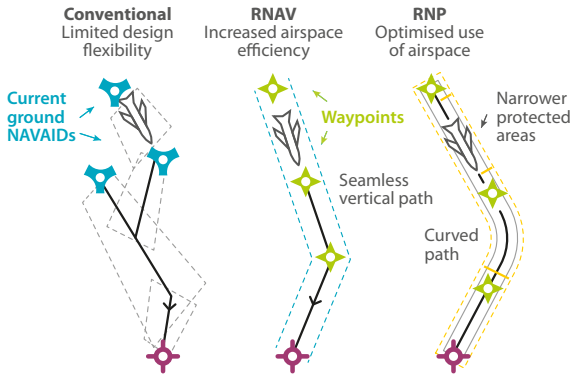
PBN Deployment in earnest

The EU commission IR EU 2018/1048 calls for the full deployment of LPV approach procedures utilising EGNOS from 2024. By 2030, PBN approach procedures are to be the primary means of navigation. The deployment schedule required is outlined in the table below.

03rd Dec 2020	• LPV approach procedures to All Instrument Runway Ends (IREs) without precision approaches • All routes above FL150 (i.e. 15,000 ft) to be Area Navigation (RNAV) 5 capable
25th Feb 2024	• LPV approach procedures to all IREs • At least one RNAV 1 (or RNP1) STAR and SID to be implemented • All routes below FL150 to be RNAV5 capable
06th Jun 2030	• All STARs and SIDs RNAV1 capable, or RNP1 where necessary • PBN procedures will be primary navigation means

The benefits of PBN and LPV are being extended beyond the traditional aerodromes and users to non-instrument runways. **The GSA is working closely with EASA** to define the elements and necessary safety promotion material to facilitate such implementation. Rotorcraft operations are increasingly benefiting from EGNOS deployment through the use of Low Level Routes and Point-in-Space (PinS) procedures to hospitals and more advanced applications such as Simultaneous Non-Interfering (SNI) operations into mainstream airports.

Evolution to Performance-Based Navigation



Aviation actors are getting ready for a GNSS based environment

User needs driving the evolution of avionics

The **European ATM Masterplan and International ICAO GANP roadmap** for the future ATM system **both promote and support GNSS as a key enabler of the ATM functions going forward**. The recent developments on DFMC provide evidence of GNSS applications supporting the Airspace Users and ANSPs needs for more efficient and environmentally friendly operations.

The development of **Advanced Receiver Autonomous Integrity Monitoring** (ARAIM) concept, which is one of the enablers of the PBN environment, is being done by the ICAO Navigation Systems Panel and by the Working Group C - ARAIM Technical Subgroup put together by the EU-U.S. Cooperation on Satellite Navigation. The final report published in 2017 provides a roadmap that sees an incremental implementation of ARAIM's horizontal and vertical services relying on the industry's experience with SBAS and on its infrastructure for a more rapid deployment. The roadmap proposed by the WG-C includes a series of prototyping activities for both airborne equipment and offline monitoring functions with the aim of delivering commercial avionics by 2030. This prototyping should aid in the development of detailed, validated standards supporting a global deployment.

The table on the right summarises the key user requirements across the Aviation applications. For more details, please consult the Report on User Needs and Requirements.

Airspace Users' view on GNSS based CNS

From the Airspace Users perspective, it makes more sense to couple the various avionics upgrades required for compliance with difference regulations (ADS-B and PBN). Past projects showed that a **synchronised deployment of the avionics for PBN and ADS-B capabilities brings significant improvement** to both business cases leading to positive results for both instances.

PBN and ADS-B together enable Airspace Users to fly more fuel efficient routes reducing the environmental footprint and enabling noise reduction and improvements of air quality around airports through steeper approach segments.

PBN implementation is increasing globally and Europe is moving forward to full PBN operations by 2030. Implementation of these operations will allow conventional navigation aids to be rationalised.

Overall, the main driver for GNSS uptake within the Airspace Users' community are integrated avionics which allow the reduction of deployment and maintenance costs.

Applications	Non-safety navigation (relevant for General Aviation VFR)	Performance based navigation (relevant for all IFR)	Surveillance (including ADS-B)
Key GNSS requirements	Availability	Accuracy (16m horizontally, 4m vertically for 95% of the time)[1], Availability (99-99,999%), Continuity, Integrity Robustness	Accuracy[2] , Availability, Integrity, Robustness
Other requirements	N.A.	Interoperability, Resiliency	Connectivity (communication link)

1 For demanding PBN manoeuvres, accuracy is an important factor, as a drop below the required level necessitates the procedure to be abandoned. Accuracy nonetheless remains secondary to integrity, availability and continuity.

2 Accuracy is relevant for certain ground-based ADS-B applications (i.e. airport surveillance); In both cases, accuracy demands are only moderate compared to other market segments.

GNSS frees traffic from traditional infrastructure constraints

Recently launched **space-based ADS-B services provide uniform surveillance performance globally**. They allow the 'leap-frogging' of expensive infrastructure investments in less developed areas, and may even offer airport ground surveillance services thanks to their unobstructed line of sight. Even without space-based solutions, ADS-B is a **very low cost surveillance option**, often built in to other surveillance solutions such as multilateration and even Mode-S radar.

When DFMC (Galileo + GPS) is supported by EGNOS, together with ARAIM, ADS-B will provide a highly accurate and robust surveillance layer.

The use of **ADS-B within ATC is an enabler of traffic growth** as it supports the development of operations where the coverage of conventional surveillance solutions is limited or not available at all. The main candidates are low level airspace, where other surveillance solutions are not economically justified (due to line of sight constraints), and oceanic airspace, where the traffic is going beyond the coverage of Secondary Surveillance Radars (SSR).

GNSS will be a key enabler for new and current airspace users. Future entrants will also need a resilient and highly performant navigation system as they will be either flying around our buildings within the city (Urban Air Mobility, Air Taxis, drones for Personal Transport) or will be give us the opportunity to see our home planet from above (High Altitude Flights and Suborbital Flights).

Aviation Value Chain

DEVICE MANUFACTURERS

- AVIDYNE CORP
- COBHAM
- COLLINS AEROSPACE
- ESTERLINE TECH CORP
- GARMIN
- HONEYWELL
- KANNAD
- MCMURDO
- THALES AVIONICS*
- TRIG AVIONICS*
- UNIVERSAL AVIONICS

AIRCRAFT MANUFACTURERS

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

BUSINESS, ROTORCRAFT AND GENERAL AVIATION MANUFACTURES
- LEONARDO-AW (AGUSTAWESTLAND)*
- CESSNA
- CIRRUS
- DAHER*
- DASSAULT*
- DIAMOND AIRCRAFT*
- GULFSTREAM
- PILATUS*
- PIPER
- PIPISTREL*
- TECNAM*

URBAN AIR MOBILITY
- UBER, LILIUM

AIRLINES / AIRCRAFT OWNERS

MAIN AIRLINES ALLIANCES
- ONEWORLD
- SKYTEAM
- STAR ALLIANCE

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

AIR NAVIGATION SERVICE PROVIDERS

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

AERODROMES

INTERNATIONAL AIRPORTS
PRIVATE AIRPORTS
REGIONAL AIRPORTS

ASSOCIATIONS
- AIRPORTS COUNCIL INTERNATIONAL (ACI)

European[1] GNSS industry in the global arena

Within the aviation segment, EU and North American organisations continue to dominate manufacturing of GNSS receivers for aviation (>90% of the market) in 2017. Original Equipment Manufacturers (OEMs) have now started to deliver new aircraft models with SBAS capabilities as part of the standard configuration for both navigation (LPV) and surveillance (ADS-B).

GNSS receivers for DFMC will be developed as a result of ICAO publishing the Standards and Recommended Practices (SARPs) for Multi-Constellation. Adoption of DFMC receivers is expected to start in the mid 2020s. Currently North American receiver suppliers have an 85% market share and European ones most of the rest (14%).

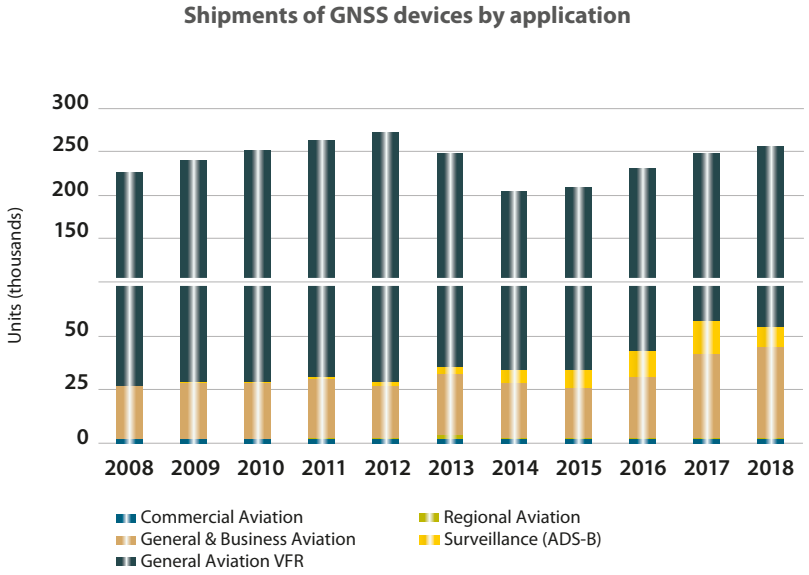
The publishing of the DFMC SARPs has prompted ICAO to provide a set of recommendations at the 13th ICAO Air Navigation Conference for the adoption of DFMC. ICAO has recommended the states to take advantage of the improved robustness and performance offered by DFMC encouraging the uptake of all core constellations that are SARPs compliant. European manufacturers are well placed to capitalise on this development.

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

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

[1] In the market share analysis, Europe is defined as EU28 plus Norway and Switzerland.

GNSS uptake enabled by the development of new solutions



GA VFR devices are used for navigation, but some users might have stand alone surveillance (ADS-B) devices with integrated GNSS receivers. Other user`s navigation devices provide the GNSS position information for any onboard ADS-B devices.

General Aviation demand drives GNSS device shipments

The continued demand for GNSS devices by General Aviation continues unabated. The chart opposite shows that **GNSS devices sold for GA purposes far exceed that of the IFR community** driven by a higher fleet size, the interests of recreational fliers and a wish by GA pilots to benefit from traffic awareness (ADS-B surveillance) and increased use of PBN procedures.

General Aviation pilots' recognition of the benefits for situational awareness is having a marked impact on the growing use of ADS-B and other surveillance technologies increasing the number of GNSS devices being sold. These are bundled on occasion with hand-held moving map displays and low-cost ADS-B devices resulting in **several GNSS devices being present on the same aircraft with different functions** – surveillance and navigation – especially for VFR operations.

For instrument operations, the availability of SBAS (such as EGNOS) and the increasing availability of GNSS based instrument approach procedures is leading to increased uptake of avionics capable of supporting these applications. These types of applications benefit aerodromes identified within the European PBN Implementing Regulation 2018/1048, and the potential roll out of PBN to non-instrument runway ends, which is now beginning. Uptake of PBN procedures will help mitigate the risks of controlled flight into terrain for the GA community. Of interest to GA and Rotorcraft encouraging uptake, are approach applications enabled through EGNOS leading to increased precision down to RNP 0.3 and decision heights of 200ft and facilitating low-level en-route operations.

Galileo is now also finding its way into the aviation VFR community through products such as the Garmin Pilot Watch providing alternative position information to pilots and supporting flight plan tracking and 'direct-to' functionality to find the bearing to the nearest airport.

GNSS improving established solutions (EVS/SVS)

Additional funding will be allocated at European and international level for further development of Enhance Vision Systems (EVS)/Synthetic Vision Systems (SVS) based solutions for precision approach procedures (i.e. LPV). The combination of any CAT I approach (LPV 200, ILS CAT I) with an EVS or SVS solution can deliver a similar service to CAT II i.e. approaches going down to 200 feet.

FAA intends to implement approaches below 100 ft, but in Europe approaches below that have to be visual. Currently, both FAA and EASA have approved combined vision systems for operational use for approaches down to 200 feet above ground level. These systems are produced by multiple manufacturers on both continents Including Dassault, BAE, Thales, Rockwell Collins, Honeywell, etc. The image on the right side shows a Dassault Falcon 8X FalconEye combined vision system while in operation at one of the US airports. EVS/SVS in combination with GNSS-based approaches can vastly facilitate operations at difficult or unfamiliar airports.

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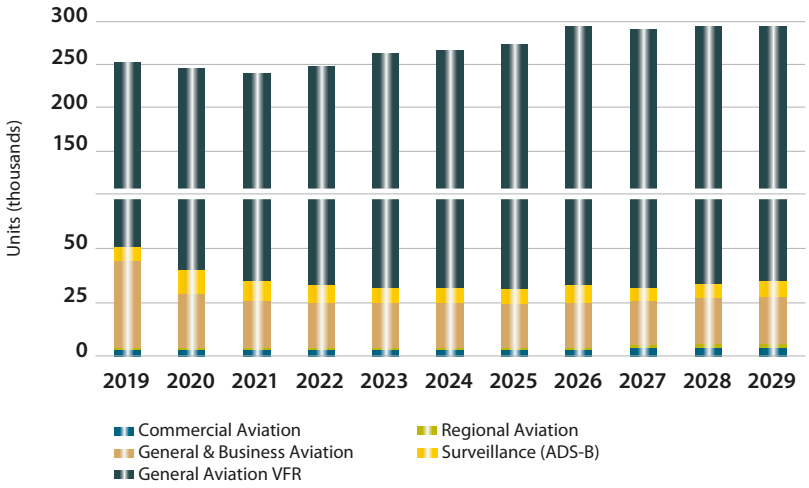
The aviation world is growing while new concepts are being trialled

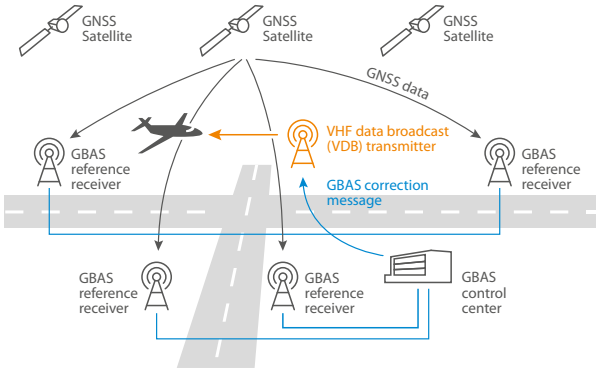
Shipments of GNSS devices by application



GBAS development advances towards CAT II/III operations

SESAR solution PJ.14-03-01 – GBAS aims at finalising the development of GBAS CAT III L1 (i.e. GBAS Approach Service Type (GAST) – D/F). **The deployment of this solution will maximise the benefits of GBAS technology** enabling CAT II/III operations. GAST – F on the other hand is planned for enabling DFMC (GPS + Galileo) CAT III performance level.

The **EU Air Navigation Strategy** was presented by the EC in the 63rd Single Sky Committee meeting during December 2016 outlining the approach for PBN implementation. The European Strategy see the **implementation of SBAS for CAT I operations as a first step and then the deployment of GBAS for operations beyond CAT I, as a second step**. This would support both short term and long term goals for the PBN environment.



General aviation demand will continue to drive GNSS device shipments

The chart on the left indicates that the **majority of future shipments of GNSS devices will continue to be driven by General and Business Aviation for their use for Surveillance and Navigation purposes**. However, an increase in GNSS devices to be used for Commercial Aviation and Surveillance only (ADS-B) is expected. This change is driven among other by the transition from traditional navigation and positioning techniques to use of GNSS-based technologies for these purposes. **Overall GNSS devices shipment levels will be stable in the next decade** with their total number reaching approximately 300 thousand per year.

New transportation concepts start to shape

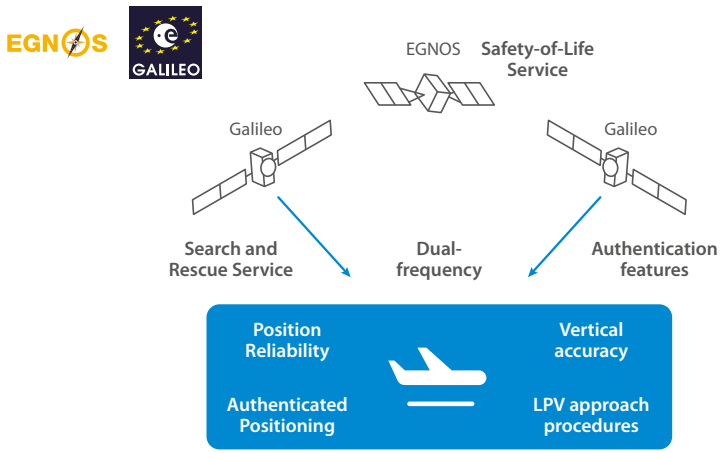
The concept of **door-to-door seamless transportation** (i.e. using the same "vehicle" for the transportation on the ground and in the air) is starting to pick up interest not only in the aviation world but also in the ground transportation sector. The philosophy around this initiative is that users will be able to book the end-to-end travel while in the background the system is booking all the individual components: taxi/air taxi, parking, airport shuttle, trains, flight, etc.

Urban Air Mobility is an initiative that is looking to enable more efficient and faster travel within the urban environment. The concept lays down the grounds for and proves the concept of personal transportation using air taxis be it by drones, helicopters or new hybrid vehicles combining ground based and airborne technology. Currently, there are 64 towns and cities worldwide that are involved in the Urban Air Mobility initiative and their number is growing:

- **Iceland** is considered the leader with several delivery services already being put in place using 13 pre-defined routes.
- **Middle East region** is also one of the leaders and first adopters of the Urban Air Mobility. UAE demonstration missions have already successfully taken place during 2018.

Big industry players are also involved and keen to contribute to the development of new transportation concepts. For example, Airbus developed a platform called Voom that allows its users to book a helicopter transport on the spot, similar to Uber operating concept.

EGNOS enables improved efficiency in ATM operations



How EGNOS is being used now

The first deadline of the EU's PBN Mandate (3rd December 2020) is requiring ANSPs and Airspace Users to deploy PBN routes and procedures. EGNOS is one of the key enablers of this technology.

Demand for LPV procedures has increased and as a result at the beginning of 2019, ESSP's LPV tool registered 605 EGNOS enabled procedures, including 5 for helicopter operations, servicing a total of 320 airports around Europe.

As awareness of LPV benefits has spread, **EGNOS dependent procedures are being developed for non-instrument runway ends**. This is delivering increased safety to airspace users who previously could not benefit. The GSA funded project "GAGA", is one of the first deploying such procedures.

The role of EGNOS and Galileo in the future

EGNOS V3 is planned to be operational in 2025 and will provide an increase in performance through Dual Frequency Multi Constellation (DFMC) operations using GPS and Galileo running on L1 and L5 bands. EUROCAE has published in February 2019 the SBAS MOPS for DFMC in ED-259.

In the future Advanced Receiver Autonomous Integrity Monitoring (ARAIM) will similarly utilise Galileo for DFMC. ARAIM is planned to first provide a horizontal service only, H-ARAIM, where validation trials have shown Dual Frequency (L1-L5) provides the highest level of performance. The target operational performance level for the vertical service (V-ARAIM) is LPV-200 globally.

BLUEGNSS HORIZON 2020

BlueGNSS enabling EGNSS adoption in the Mediterranean area

BLUEGNSS is one of the H2020 projects funded by GSA in 2016 with the objective of harmonising the implementation of PBN procedures by using EGNOS in the BLUE MED Functional Airspace Block (FAB) States: Italy, Republic of Cyprus, Malta and Greece.

The project's success comes from achieving for the first time a synchronised deployment of PBN at FAB level and, for the first time in the world, for setting up a regional, multi source GNSS Monitoring Network. The GNSS Monitoring Network has the capability of performing interference assessment and reporting as well as GNSS data recording on top of the standard GNSS performance assessment.

The project started in January 2016 and successfully achieved its objectives on June 2018.

More information on: BlueGNSS website

GSA Aviation Grants continue to support the evolution of ATM/Aviation

© GSA

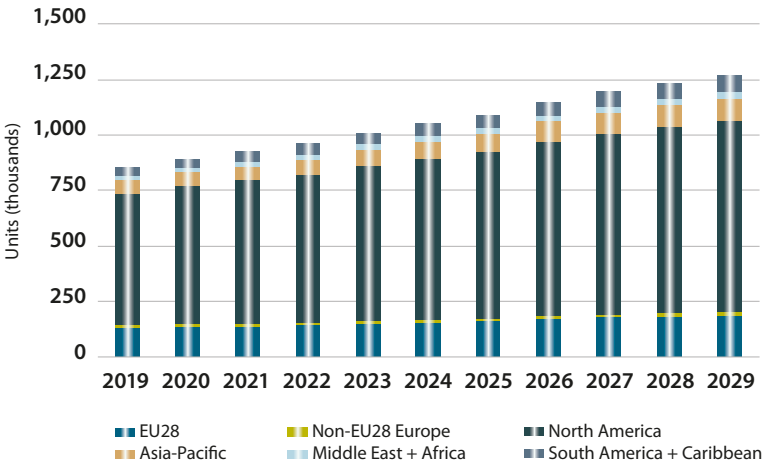
GSA has established the Aviation Grants Programme in 2014 in order to promote EGNOS operational implementation in aviation. Its objective is to **foster EGNOS adoption** by enabling the stakeholder of the Aviation world to make best use of EGNOS enabled routes and procedures. It supports Airspace Users, Air Navigation Service Providers as well as airports and heliports.

Up to June 2019 GSA have launched 3 Calls for proposals of a total investment **22 mln euro**. Overall GSA has funded **42 projects** covering all aviation market segments including commercial, regional, business, general and rotorcraft. These projects not only extend the EGNOS enabled network, but also help fill the gaps of where EGNOS procedures are available in Europe, allowing more operators to benefit from it.

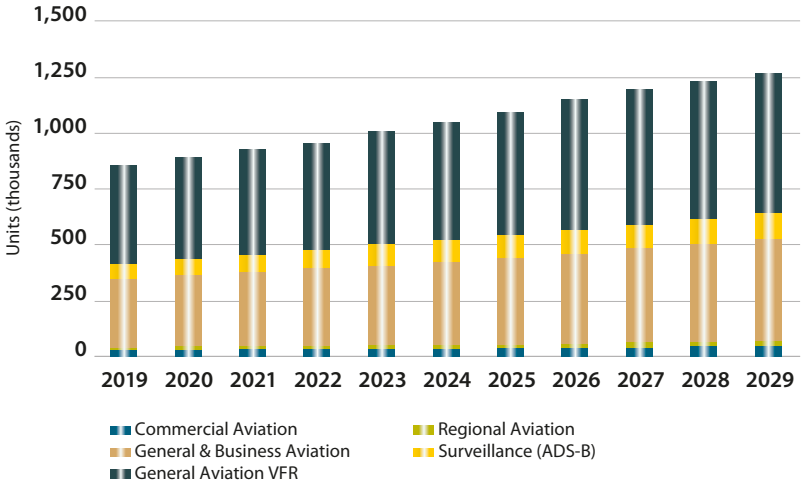
Among the success stories we would like to mention:

- **IMPROWE project** designed and implemented seven EGNOS LPV/LPV 200 approach procedures at five European airports of Austria and Slovakia. The project introduced precision approach procedures in challenging environments i.e. mountainous terrains of Innsbruck and Poprad-Tatry airport.
- **LPV Implementation for FSTDs project**: This project implemented LPV capabilities in three different ALSIM flight simulator models: AL250, ALX and AL42. These capabilities enable safer and cost-effective training for LPV approaches as the PBN/LPV training is mandatory by 2020 for all instrument rating trainings.
- **E-GEN project succeeded in retrofitting the whole aircraft turboprop fleet of Air Baltic** with EGNOS-enabled avionics which further stimulated the interest of other Baltic operators in implementing EGNOS approach procedures in the Baltic region. Up today Air Baltic has logged over 400 successful EGNOS LPV approaches already.

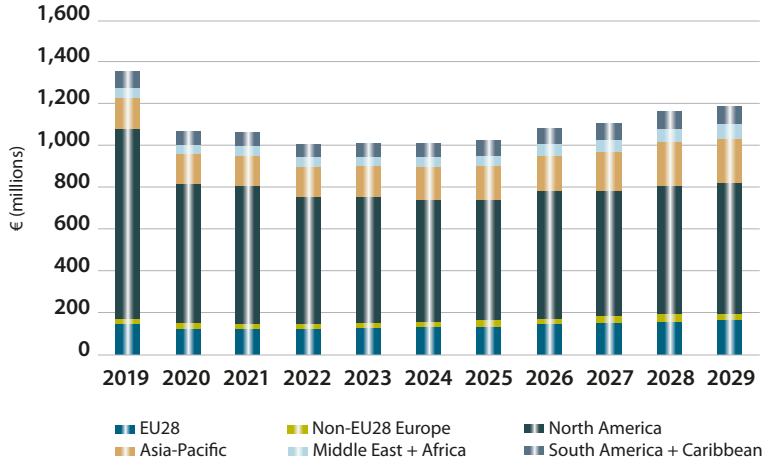
Installed base of GNSS devices by region



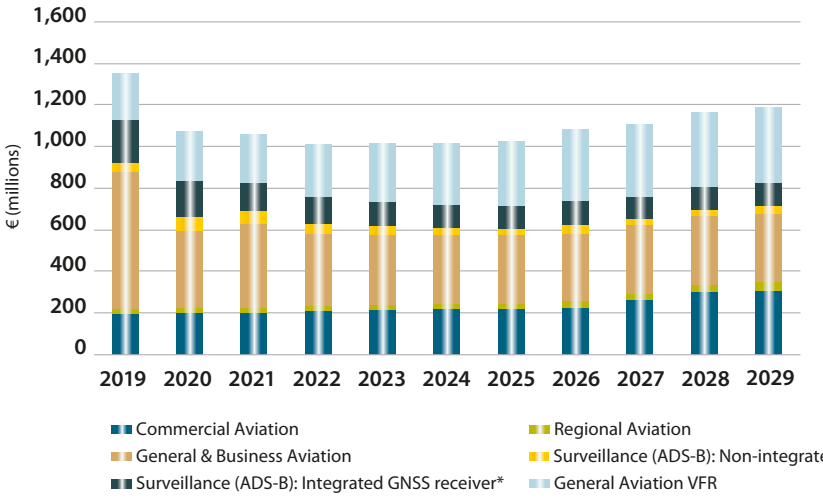
Installed base of GNSS devices by application



Revenue from GNSS devices sales by region



Revenue from GNSS devices sales by application



* The category Surveillance (ADS-B): Integrated GNSS receiver refers to revenues that are fully enabled by GNSS but for which PNT information is derived from the aircraft's integrated GNSS receiver. This is opposed to revenues derived from ADS-B devices that have their own GNSS receiver.

DRONES

What you can read in this chapter

- **Key trends:** GNSS powers drone sector growth.
- **User perspective:** Galileo and other secure and accurate GNSS solutions empower drone users.
- **Industry:** Drones Value Chain.
- **Recent developments:** Recent developments show that GNSS is key to unlocking the drone market.
- **Future market evolution:** GNSS positioning information will enable safe and harmonious drone market growth.
- **European GNSS:** Drones are starting to use EGNSS to meet the demand for high accuracy.
- **Reference charts:** Yearly evolution of GNSS devices' installed base and revenues by application and region.

GNSS applications

Depending on their specific payload, drones can support or facilitate the delivery of a vast array of applications and services. Whilst the list of drone use cases is almost endless, many of them can be categorised along the following classes of applications:

- **Agriculture:** Precision agriculture, crop/field/soil monitoring, variable rate applications, livestock tracking, insurance, forest monitoring & management, etc.
- **Border security:** Border monitoring, enhanced surveillance for border control.
- **Communications:** Local coverage broadcasting (e.g. Google/Facebook drone plans for internet access in remote areas).
- **Insurance:** Monitoring of assets for insurance purposes and their inspection to assess damages in the claims process.
- **Leisure:** Toys, aero-modelling, self-tracking/filming drones (first person view), drone racing, etc.
- **Maritime surveillance:** Provision of a situational awareness in maritime areas through long-endurance drones.
- **Media:** Film, photography, TV/other broadcasting (e.g. sport events), etc.
- **Military:** Use as platform for observations or delivering defensive and offensive capabilities.
- **Surveying:** Infrastructure and environmental monitoring (energy distribution, railways, solar panels,…), cadastral surveying, mining, marine surveying, GIS, photogrammetry, etc.
- **Other applications:** Calibration of aviation nav-aids, asset management, advertisement, marketing, entertainment, etc.
- **Package delivery & eCommerce:** Initiatives of developed by companies such as Amazon to exploit drones in package delivery or 7-Eleven and Domino's for food delivery.
- **Public security & safety:** SAR operations, firefighting, urgent medicine/medical equipment delivery, other natural disaster monitoring (e.g. floods, earthquakes), police applications, crowd observation, border (including maritime) patrol, security, etc.
- **Scientific:** Meteorological monitoring, atmospheric measurements, swarm techniques, general R&D, etc.
- **Urban air mobility:** Personal transportation services in urban areas which are being developed by companies such as UBER and LILIUM.

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GNSS powers drone sector growth

Key market trends

- EASA drone regulation paves the way for harmonised regulation within Europe
- Use of GNSS and increasing automation is key for both consumer and commercial drone use
- Specialised use of drone acquired-data is leading to vertical integration within the supply chain

Legislative work is entering an intense development period

To ensure that drones can be used widely in a variety of roles, **harmonised, and ideally *standardised*, drone legislation is required**. Regulation is important as without it in place it will be considerably more difficult to use drones easily in a wide variety of contexts and in a number of roles consistently across Europe. The European Union Aviation Safety Agency (EASA) has already published implementing and delegated regulation for drones that have been adopted by EC in summer 2019 as **Implementing regulation 2019/947 and Delegated regulation 2019/945**.

The regulation classifies drone operations into categories such as 'open', 'specific' and 'certified' **based on the risks that their operations present**. Specific operational constraints apply to each category. The regulation also prescribes the procedures to be used to verify that a drone can execute particular mission types. As there were no objections to the draft, EASA published these as regulations in mid-June 2019 ((EU) 2019/945 & (EU) 2019/947). EASA will also provide additional guidance material to help drone operators comply with these rules.

Further advances are being made by the Joint Authorities for Rulemaking on Unmanned Systems and EUROCAE, which are developing accordingly rules on how to identify the level of risk posed by various drone operations and standards to ensure drones can be operated safely including how the use of multi-frequency GNSS can support such operations,

GNSS underpins both consumer and commercial drone operations

Whether used for guiding drones automatically back to the operator, building inspection or just maintaining geo-awareness to avoid obstacles or no fly zones, GNSS has become a 'must have' for drone operators. Compared to GPS-only solutions, the improved integrity and accuracy provided by EGNOS, together with the added availability from using Galileo, increases the utility of drones and helps enable a number of features below:

- GNSS enables **usability** features such as In-app tracking, geofencing, or 'return home' functionality making drone operations safe.

- Thanks to GNSS-enabled **augmented reality** application's vital information can be overlaid on a drone feed, improving situational awareness. For uses such as emergency response this can be critical, providing significant societal benefits.

- In applications such as survey or inspection, the GNSS-driven ability to freely position a sensor **predictably**, **accurately** and ultimately **efficiently**, is what generates value. For example, in agriculture crop health can be monitored through photographic survey by drones. With further post-processing and merged with GNSS data, the amount of fertiliser to be used at each section of the field can be calculated and a map layer produced to direct farm machinery.

A service which will benefit both consumer and commercial users is **automated drone traffic management**. With it the operator will no longer have to keep their drone in line of sight, worry about encroaching on restricted airspace, interfering with manned aviation or even flying the drone. The user will only have to plot the flight route or assign a destination and the flight will be automatically executed.

Drone traffic management requires systems to track the location of drones in flight, and GNSS will be a pillar of any such service. Drone traffic management, currently in demonstration phases by companies in Europe such as Altitude Angel, AIRMAP or Unifly, will help enable a host of futuristic applications such as automated parcel delivery, linear infrastructure (e.g. railways and powerlines) inspection and surveys. By automating these processes industries can both reduce cost and increase inspection and survey frequency.

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Galileo and other secure and accurate GNSS solutions empower drone users

GNSS is enhancing drone functionality

Automated drone functions are becoming accessible to an ever-increasing user group. Previously specialised functions such as 'return to home' or flight planning are now available in even budget models that may be a leisure user's first experience of drones, meaning GNSS is simply an expected feature.

Automation is helping to vastly simplify the operation of the drones themselves. Todays drones can often be operated using a point and click interface. Thanks to increasing miniaturisation, drone control software have increased computational power. This enables the **merging of GNSS data with that from other sensors such as cameras and combined with artificial intelligence allows advanced functions such as 'follow me'**.

These trends have allowed a larger group of businesses to use drones with shorter training periods, meaning users can focus on maximising the benefit of their drones, rather than learning how to fly them.

© Event 38

GNSS, and in particular Galileo, help **expand geo-awareness features**. Virtual geofences can be plotted, helping ensure that users of GNSS-equipped drones do not accidently violate any airspace access restrictions and negatively impact public order. This can also save users from facing hefty fines or legal issues and some systems even apply temporary restrictions (e.g. during large public gatherings). If the position of potential obstacles such as powerlines is known, and the drone knows where it is within the terrain, it can keep well away from hazards.

The **improved integrity and high accuracy of GNSS positioning information provided by solutions such as Galileo will help ensure that drones follow their assigned routes closely**, ensuring that surveys or inspections can be carried out using the most efficient flight route – decreasing flight time and avoiding the need for repeat flights to cover any missed regions. Compared to traditional operations, accurate, predictable and regular drone flights bring significant savings to operators by reducing the need for resource-intensive operations and allow issues to be identified earlier.

GNSS brings increased freedom of airspace access

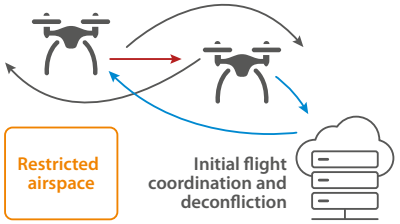
It is probable that in the near future most drones will be registered before being allowed to fly, as it is with road vehicles today. **Although not always obligatory, as of 2019 drone registration is already required, or will be required imminently, in a number of countries including the UK, Spain, Poland and the US**.

Once registration is in place, the accurate position information obtained by GNSS will allow individual drones to be tracked. In turn, this **will help implement functions such as 'detect and avoid' and drone traffic management**. Already a number of commercial solutions that facilitate flight planning and airspace booking are available in certain countries, these include 'Drone Assist' in the UK, 'Drone Radar' in Poland, and the AMC Portal in Croatia.

Flight planning software will interact with drone traffic management systems once they are available. Once the drone is airborne, a data connection will update the drone with changes in the air situation and the drone will respond appropriately based on its position acquired via GNSS. In addition, Collaborative Detect and Avoid (DAA) systems will depend upon sharing position information from GNSS.

Organisations such as EUROCAE have dedicated teams (WG-105, SG-11, SG-12, SG-13) working on solving issues related to DAA. Traffic management and DAA interactions are shown in the chart to the right. A summary of requirements of drone users based on the 'European Space Week GSA drone survey' is provided below.

Drone traffic management and DAA



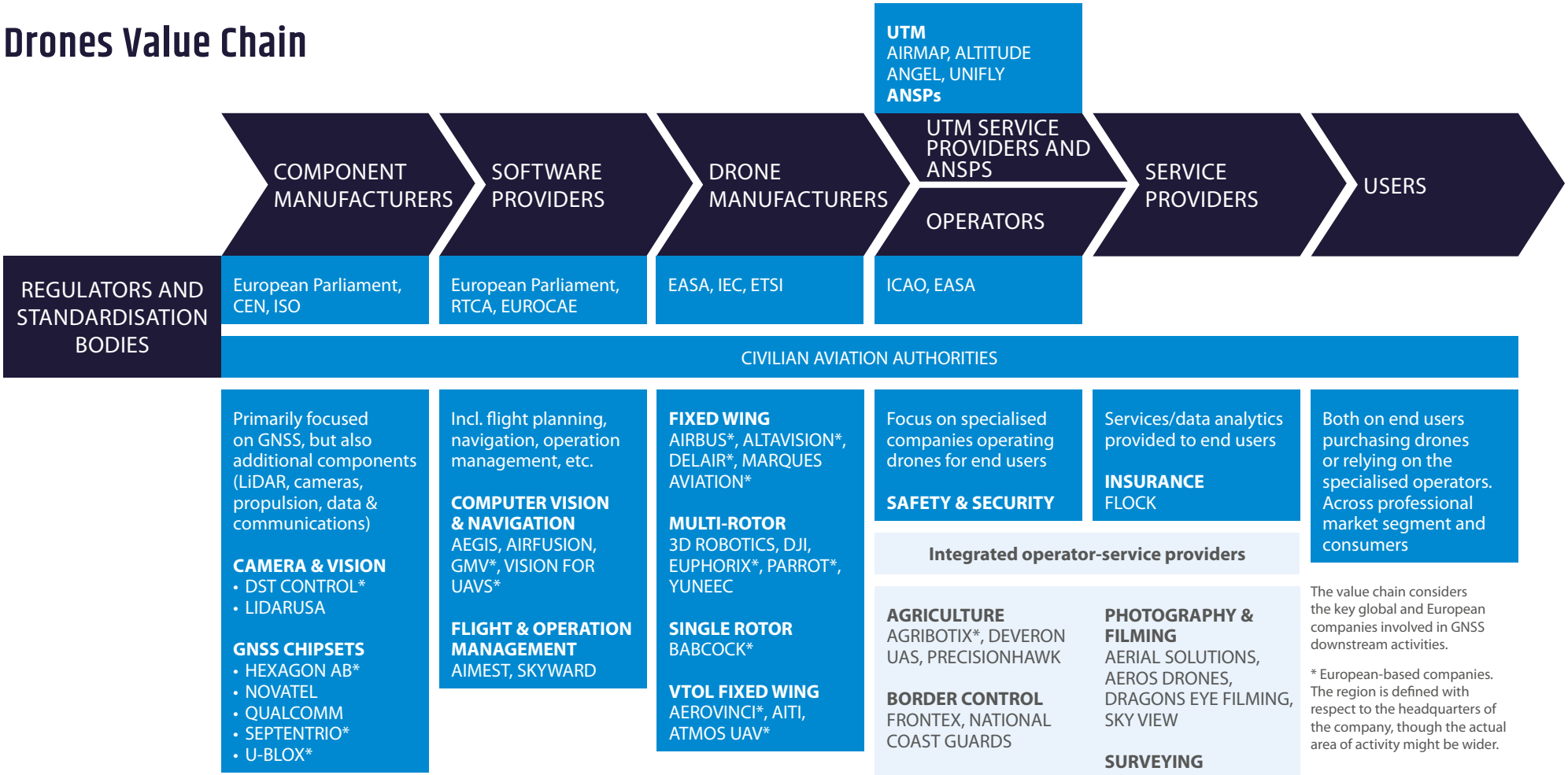
Type of requirement	Drone user requirements (based on GSA's Drone Survey)
Key GNSS requirements	Accuracy (sub-metre level, depending on applications), Availability, Continuity, Integrity, Robustness
Other requirements	Connectivity (communication link), Power consumption

Further details are available in the GSA Aviation User Needs and Requirements report.

Importance of dealing with public concerns

As drone traffic management is introduced, and drone position associated with registration data is increasingly tracked, safeguards will be needed on the handling of this data. Users must know what information is collected, what it is used for, where and for how long is it stored. Detect and avoid functionalities will also decrease the chance of drones causing harm to the public. Accurate GNSS acquired position information could be broadcast via ADS-B to other drones and airspace users to ensure early detection and collision avoidance.

Drones Value Chain



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

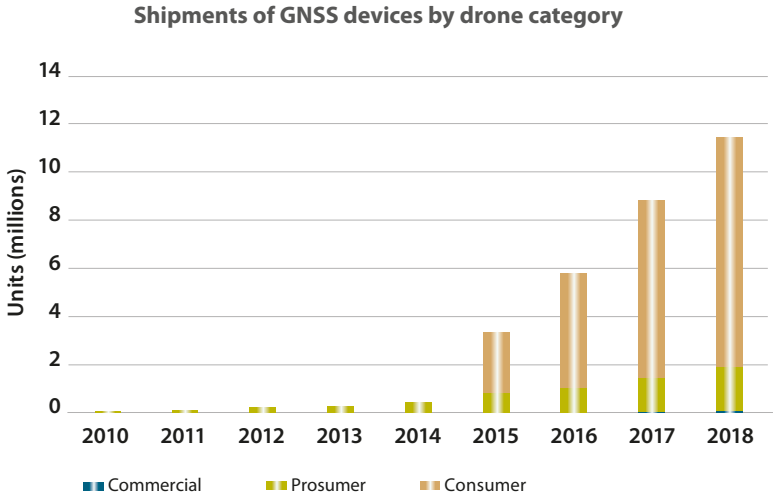
* European-based companies. The region is defined with respect to the headquarters of the company, though the actual area of activity might be wider.

European[1] GNSS industry in the global arena

In 2017, 88% of receivers for drones are provided by North American and Asian suppliers with European companies providing the remaining 12%. Within the drone segment most system integrators (i.e. drone manufacturers) are based in Asia (86%), although European companies such as Parrot remain important players (14% of the market). European companies lead the provision of drone related services (Flock, Sensefly) and drone traffic management (Altitude Angel, Airmap and Unifly). European programmes such as the GSA's R&D programme for the development of drone services leveraging GNSS as well as SESAR are providing a good environment for the further development of these types of services. Integration between operators and service providers is increasingly common as domain and drone knowledge are both needed to derive full value from drones.

[1] In the market share analysis, Europe is defined as EU28 plus Norway and Switzerland.

Recent developments show that GNSS is key to unlocking the drone market



Drone GNSS device shipments have greatly increased in recent years

Drones can be divided into 3 key categories based on their price. **Mass market drones** for consumers costing up to €750; Drones with advanced functions for **commercial user** (over €2,000), and '**Prosumer**' drones less advanced than commercial but with more advanced functions than typical consumer drones (€750 – €2,000).

The number of GNSS devices shipped on these drones has greatly increased in recent years, especially starting in 2015 when prices had decreased sufficiently for consumer drones to become more widely available.

Regulatory advances in airspace and drone uses

The Joint Authorities for Rulemaking on Unmanned Systems' Specific Operations Risk Assessment (SORA) documents provide a complete methodology of determining how to establish the level of risk presented by drones (in the 'Specific' category as defined by EASA proposed regulation) and reduce it to acceptable levels. As a result of following this process, it is possible to specify how a drone has to be equipped to ensure that it can conduct a particular type of operation.

The methodology outlined in the SORA has already been endorsed by regulators in early adopting countries (e.g. Spain). **Accurate tracking solutions enabled by GNSS are critical for reducing operational risks and complying with SORA**.

For instance within EUROCAE a dedicated Work Group (WG-105 subgroup 62) is providing 'Guidelines on the use of multi-GNSS in UAVs' in order to comply with SORA.

In Europe, the **concept of U-SPACE**, which refers to services and procedures that will support a safe, efficient and secure access to airspace by a large number of drones, is being pioneered. A blueprint has been defined and a number of **European Network of U-space Demonstrators** focused on showing the coordination required between multiple stakeholders to enable automated drone flights have been held already. Initial U-SPACE services are expected to be offered in 2019.

Today operators are working hard to start beyond line of sight operations

Even without drone traffic management drones might be flown out of line of sight in certain circumstances such as during police and security operations or search and rescue missions. GNSS provided position information is relied upon to maintain situational awareness during these operations. In this context, accurate position information is especially relevant as in certain types of terrain even a few metres of inaccuracy could make it difficult to later spot and rescue a person.

European companies have been developing drones with beyond visual line of sight capabilities, for example: Airbus, which is developing surveillance orientated drones (such as the KZO, ATLANTE, European Male RPAS); and the French company Delair-Tech. The high reliability, robustness and accuracy provided by Galileo will be essential in ensuring that accurate position information on the drone is available and that beyond line of sight operations can be conducted safely.

Galileo will support air delivery

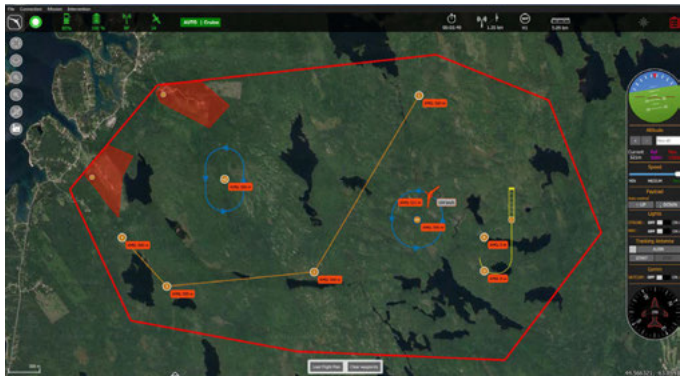
Drones have the potential to expedite and reduce the costs of package delivery. In urban settings, where high potential for interference exists, it is critical that drones follow designed routes precisely to avoid damaging buildings or causing injury. High accuracy GNSS services enabled by the anticipated **Galileo high accuracy service (HAS)**, Galileo multi-frequency receivers, and **OS-NMA**, will help drones predictably and precisely follow their routes in urban settings. Accurate GNSS sensor data will also be essential during high risk operations and in urban settings. The use of **EGNOS** will further increase integrity and support robust navigation resulting in improved delivery speed and decreased costs.

GNSS positioning information will enable safe and harmonious drone market growth

Automation and improved position tracking will drive the drone market

Drones and user interaction with them will become increasingly automated and seamless as drones, support services, flight operations, infrastructure and messenger solutions become interconnected. This will greatly simplify use of drones for inspections or transport of goods as it might become as simple as summoning a car using a telephone application today.

Flight planning is expected to be handled automatically by companies specialised in determining the best flight path for a particular type of drone or mission type. These companies will interface with automated drone traffic management systems, secure the relevant flight permissions, and ultimately might be able to further automate interaction with the drones from the user perspective by informing the user of any operational constraints, the flights progress, expected delays or other possible issues that the drone might encounter.

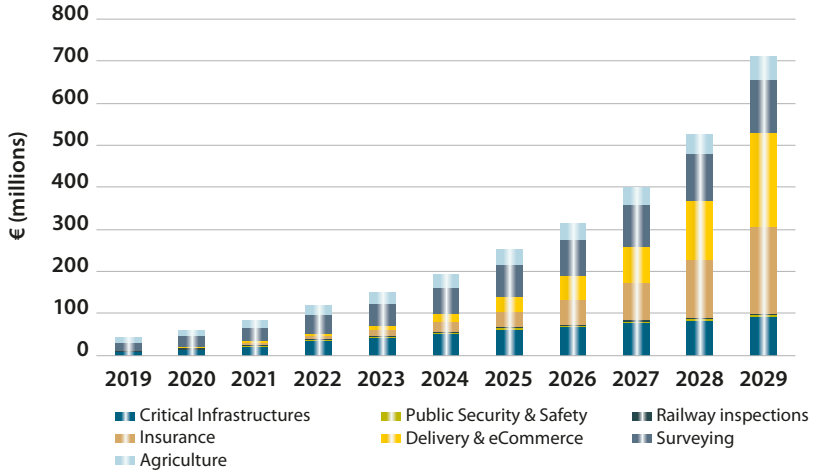


The **H2020 project – SKYOPENER**, has led the way in developing flight planning mobile apps, that would act as a middleman between drone traffic and ATM. Subsequently, more companies are developing their own flight planning apps – Altitude Angel, AIRMAP or Unifly to name a few. The aim is to provide **a platform that interconnects all actors in the airspace**. GNSS is critical for the functioning of such apps as it enables drone tracking and precise drone localisation enabling safe and efficient traffic control.

Flight planning software will also help ensure that drones create as little as possible distraction to users on the ground by planning the routes flown by drones depending on the time of day, weather or other factors such as public events.

Mobile apps in the drone market are not limited just to flight planning. As an example, GNSS equipment is an enabler for predictive risk analytics to provide additional equipment insurance.

EU28 dependent service revenue by service area



Dedicated drone services are expected to soar across a wide range of markets

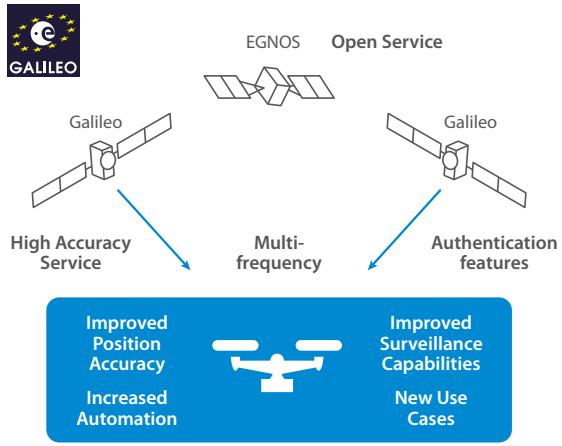
The service component of the drone market is growing. Today dedicated drone services are being offered by a number of specialised companies. European drone service revenues are expected to nearly double from €32 mln in 2018 to approximately €60 mln by 2020 and are eventually forecast to reach €150 mln by 2023.

Currently, the highest revenue incomes and the largest number of specialised drone operators are present in **surveillance and agriculture applications**. These services are primarily being deployed outside of densely populated areas. Applications such as crop or remote infrastructure monitoring are in high demand as in these contexts drones can often replace less efficient or more costly equipment.

It is forecasted that **from 2021 onwards, services will increasingly be offered in the urban environment**. Services such as drone package delivery will see initial services kicking off, paving the way towards more mass-market adoption of drone services.

Due to the universal benefits of drones, the number of drones is expected to grow at a similar pace across all geographic regions. The high pace of growth in the next few years will plateau by the mid-2020s when market saturation is reached. Drones typically have an operational life of only a few years, and thus although the level of shipments is expected to remain substantial, the total number in operation will reach saturation.

Drones are starting to use EGNSS to meet the demand for high accuracy



EGNOS enhances drone functionality

An **increasing number of drone applications require accurate positional information**. In fact based on a recent survey conducted by the GSA almost 50% of drone users expect a horizontal accuracy of below 10 cm and 38% a vertical accuracy of below 10cm.

Similarly, 40% of users indicate that the maximum tolerable horizontal error should not be more than 1 metre, with a 35% holding a similar conviction about the vertical error level. This type of accuracy is not achievable without any GNSS signal augmentation. **The EGNOS open service can augment GPS signal to a minimum accuracy of 3 metres in the horizontal and 4 metres in the vertical planes** compared to 17 and 37 metres for non-augmented GPS. This increased performance is critical for multiple drone applications.

Galileo receivers are increasingly being used in drones

Although Galileo was only enabled at the end of 2016, its use will become increasingly common as mass market drone manufacturers such as DJI (estimated to have a market share of more than 70% in their segment) have started including Galileo capable receivers on all their drones. Multi-constellation receivers are especially helpful in environments close to the ground or where drones operate.

Galileo helps ensure trust in position data

With increasing drone automation cybersecurity is becoming increasingly important. It must be ensured that drones can not be hijacked or otherwise diverted through means such as GNSS signal spoofing (as demonstrated at the DEF CON hacker competition) to be diverted from their approved courses. **Galileo OS-NMA** which helps ensure resistance to spoofing attacks, is designed with increased security in mind.

EasyPv

HORIZON 2020

EasyPv stands for EGNSS High Accuracy System improving PhotoVoltaic plants maintenance. The aim of EasyPV project allows for **cost-effective, automated drone inspection of PV** plants by detecting faulty modules using drone-mounted thermal cameras. EasyPV decreases plant operating costs and helps enhance the energy production. Due to PV plants being spread over large areas, **high accuracy EGNSS is an important enabler for this solution**.

The project was developed by Italian company SISTEMATICA SPA and supported by European Union's Horizon 2020 research and innovation programme. EasyPV started generating revenues within one year of its market introduction and is currently being marketed worldwide.

More information on: http://www.easy-pv.eu/

GAUSS

HORIZON 2020

GAUSS stands for **Galileo-EGNOS as an Asset for UTM Safety and Security**. The GAUSS project is focused on ensuring that the technological advantages of EGNSS can be applied to the best effect to drones flying in U-Space. GAUSS chairs the EUROCAE WG 105 SG 62 developing guidelines on the use of Multi-GNSS for UAVs. **The outputs of the project will apply to all EASA categories of drone operations**. As part of Gauss data from a number of organisations is used to produce technical, regulatory and performance requirements to enable drone operations and contribute to regulation development and unification. Some of GAUSS objectives are to improve drones' positioning, speed and guidance capabilities; ensure drone security and mitigate their vulnerability to cyber-attacks; these improvements are implemented in drone traffic procedures.

More information on: https://www.projectgauss.eu/

GEOVISION

HORIZON 2020

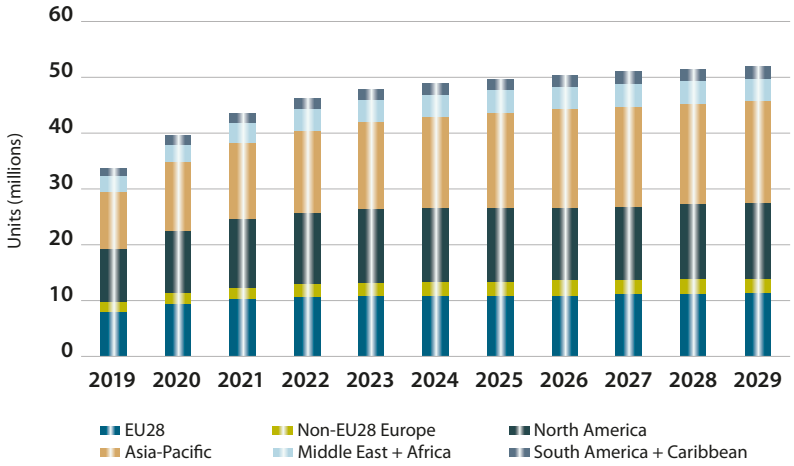
GEO-VISION stands for **GNSS-driven Earth Observation and Verifiable Image and Sensor Integration for mission-critical Operational Networks**. The goal of this project was to develop a solution to obtain situational awareness in the physical environment of disaster sites by combining visual content and GNSS information. This is especially useful to emergency services. GEO-VISION incorporated the RAIDO and AGILE solutions which are described below.

RAIDO was developed to improve crisis management and improve crisis response efficiency but can be used for various applications where situational awareness is vital. It is a tool for communicating visual content. The AGILE tool provides the ability to detect GNSS spoofing and jamming attacks (SAD and JAD) by checking the GNSS signal integrity. Both RADIO and AGILE solutions can be used for other application that require precise location information.

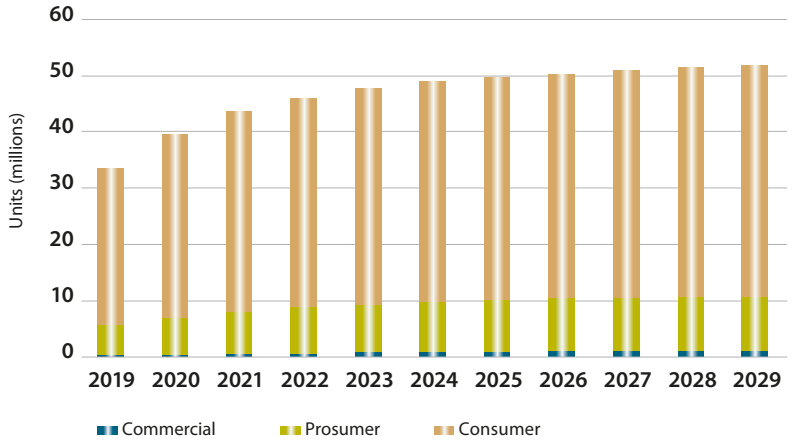
The project developed by the United Nations is now finished. It has been commercialised for wider use and relevant software is available in Android and Apple app stores.

More information on: https://cordis.europa.eu/project/rcn/193815/fact-sheet/en

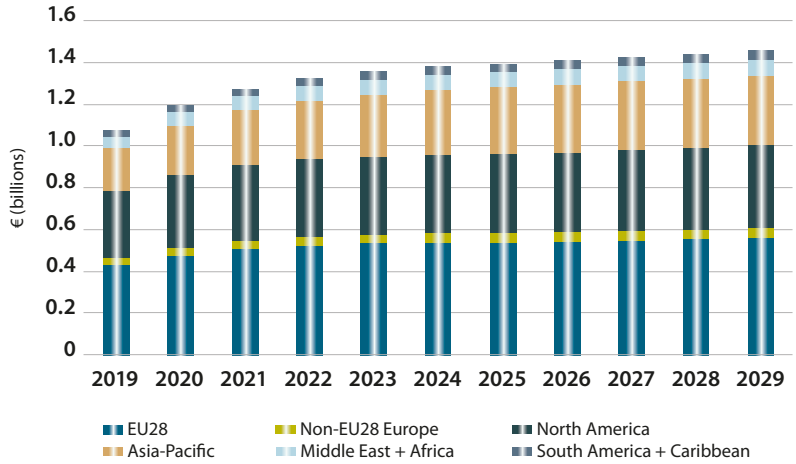
Installed base of GNSS devices by region



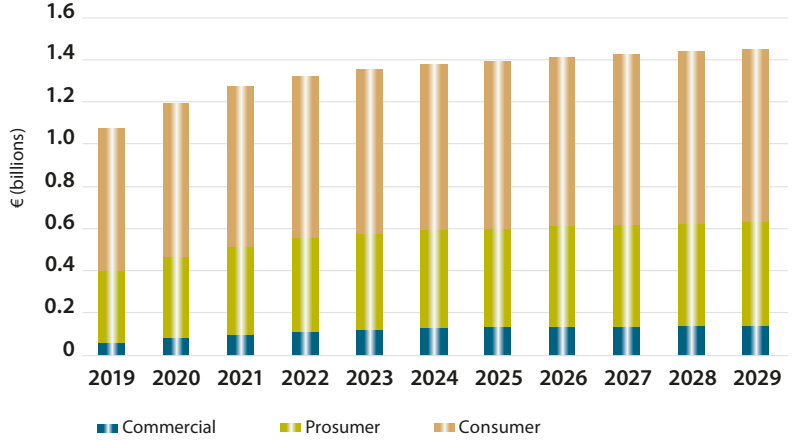
Installed base of GNSS devices by drone category



Revenue of GNSS device sales by region



Revenue of GNSS device sales by drone category



MARITIME

GNSS applications

According to the distinction provided by IMO Resolution A.915(22), **GNSS applications** can be split into navigation and positioning:

Navigation

- **Sea:** GNSS is the primary source of positioning information in sea navigation. Vessels are divided in two categories:
  - **Safety of Life at Sea (SOLAS) vessels:** All passenger ships, cargo ships larger than 500 gross tonnage or larger than 300 tons if engaged on international voyages are regulated and rely heavily on GNSS to support navigation activities. At least 3 devices are typically fitted on vessels for redundancy reasons.
  - **Non-SOLAS vessels:** 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.
- **Inland Waterways (IWW):** GNSS is also used to ensure safe navigation in inland waterways (rivers, canals, lakes and estuaries).

Positioning

- **Collision Avoidance and Surveillance:** These activities are supported by GNSS-based systems including **Automatic Identification System (AIS)** and **Long-Range Identification and Tracking (LRIT)** both in sea and inland waters.
- **Search and Rescue** is the search for and provision of aid to people in distress or danger. Different types of devices can make use of GNSS positioning:
  - In the frame of the COSPAS-SARSAT programme, 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 satellite communication.
  - When activated, **AIS Search and Rescue Transponders (AIS-SART)** and **AIS Man Overboard (AIS-MOB)** devices continuously transmit an alert message including ID number and GNSS-based location, which triggers an alarm on all AIS equipped vessels within Very High Frequency (VHF) range.
- **Fishing vessel control:** GNSS positioning enables Vessel Monitoring Systems to check the position of fishing vessels, as well as the time spent in international and foreign waters, protected marine areas, etc.
- **Port operations:** Transit progress, docking and loading-unloading operations are monitored through GNSS-based technologies.
- **Marine engineering:** GNSS is used to support marine construction activities (e.g. cable and pipeline laying).

What you can read in this chapter

- **Key trends:** GNSS supports cost-effective maritime operations and enhanced safety at sea.
- **User perspective:** Efficiency, safety and security gains push for greater GNSS performance and resilience.
- **Industry:** Maritime Value Chain.
- **Recent developments:** Continued stable growth of GNSS application shipments over the last ten years.
- **Future market evolution:** Sustainable growth of GNSS application market expected, opening up the market for more innovative applications.
- **Focus on European GNSS:** EGNSS set to be a key differentiator in the maritime domain.
- **Reference charts:** Yearly evolution of GNSS devices' installed base and revenues by application and region.

NEW **Search and Rescue (SAR)** applications are now covered in the dedicated Emergency Response segment of the Market Report issue 6 (see page 66).

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GNSS supports cost-effective maritime operations and enhanced safety at sea

Key market trends

- The widespread use of satellite-based augmentation systems is cementing their place as the primary source of integrity and higher accuracy across the maritime and inland waterway domains
- VHF Data Exchange System (VDES) gains support for e-navigation communications and it is well positioned as the successor of the Automatic Identification System (AIS)
- The integration of Galileo SAR into the COSPAS-SARSAT system is enhancing the effectiveness of search and rescue operations (more SAR-related trends are presented in the Emergency Response chapter)

Galileo receiver testing by the Joint Research Centre (JRC)

Receiver manufacturers are participating in tests for the implementation of Galileo in maritime shipborne receivers in order to enhance their reliability and resilience. These tests aim to assess the correct implementation of Galileo in the receivers with a GNSS simulator and/or live GNSS signals, and the consistency of the performance requirements set for Galileo in the maritime domain. The tests are usually taking 4 months per model. At the end of the test, manufacturers receive a confidential comparative analysis.

The test campaign is **executed by the Joint Research Centre (JRC)**, the European Commission's science and knowledge service, i**n collaboration with the GSA**, that is leading the activity and liaise with industry. The tests, which are free of charge and can be customised to the manufacturers' needs, were launched in 2018 and will continue in 2019. Interested shipborne receiver manufacturers and AIS Class A manufacturers are invited to take part in the testing campaign.

VDES satellite component provides very large area coverage cost effectively

In 2004, the IMO made it mandatory for all passenger vessels and merchant vessels above 300 GT on an international voyage to be equipped with an **Automatic Identification System** (AIS) receiver. Since the introduction of AIS, the automatic sharing of vessel information with other vessels and coastal authorities, **has contributed to a great extent to vessel collision avoidance as well as to a close monitoring of all AIS-equipped vessels**.

With the ongoing digitalisation in the maritime sector and the growing amount of data being transmitted, evolution continues towards a more optimised use of the spectrum needed for the transmission of this data. Over the past years, work towards the development of a **VHF Data Exchange System (VDES)** has been started by IALA to leverage on the capabilities of AIS, but allowing for a greater amount of data to be transmitted.

Following the IALA roadmap on VDES, it is **expected that from 2021 onwards, the full operational capability of VDES can be achieved**. Several testbeds are currently ongoing, looking to different uses of VDES including the retransmission of SBAS corrections as well as investigating the feasibility to transmit authenticated positioning information to all users.

SBAS is becoming the main source of augmented GNSS data

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Maritime users rely on a network of Differential GPS (DGPS) stations across the world **for the provision of GNSS correction data** ensuring more accurate vessel positioning information, as well as the use of the integrity service at system level. The system has been in place since the late 1980s.

With **multi-constellation GNSS becoming the norm in GNSS receivers** and the availability of satellite-based augmentation systems (SBAS) such as the American WAAS and the European EGNOS, the question as to whether DGPS stations still have a role in the future of the maritime sector has been waging for several years.

Despite the fact that there is no mandate to carry an SBAS-enabled receiver on-board vessels, **around 80% of the GNSS receivers currently in use and available on the market are SBAS-enabled**. These receivers can be used to support a wide range of maritime applications by providing greater accuracy as well as integrity information.

Recently, the US Coast Guard (USCG) announced that they will continue the discontinuance of its DGPS sites, a move which is expected to be completed at the end of 2020. This follows the affirmation that the positioning information received by SBAS-augmented GNSS is sufficient for the requirements laid out by the USCG for mission and navigation requirements such as coastal navigation. Whilst other countries are still deciding on the future of their DGPS network, the GSA proposes as a first step prior to the complete discontinuance, that Maritime Authorities use some DGPS stations for the retransmission of SBAS corrections. In this regard, IALA published their Guidelines G-1129 on the Retransmission of SBAS corrections using MF-Radiobeacon and AIS.

However, technical work alongside regulatory and standardisation initiatives on shipborne receivers is still ongoing as well as the development of a dedicated maritime safety service leveraging EGNOS SiS. One of the key features of this service would be the delivery of integrity information, complemented with RAIM, contributing even greater to the safety of navigation.

Efficiency, safety and security gains push for greater GNSS performance and resilience

Maritime pilots contributing to safe port navigation

The shipping industry is operating with more and bigger ships, which create traffic intensive routes and involve heavy and risky traffic port operations. **To ensure safety, security and port efficiency, the highly skilled maritime pilots are taking the navigational control of the world's largest vessels**. The angle rate of turn and the speed detection are two critical parameters for the maritime pilots, when executing harbour transit or manoeuvring. The high impact speed of the vessel can cause serious damage to the fendering and to the port infrastructure. Therefore, the speed should be at around 0.1 m/s, which requires the speed to be measured at centimetre-level accuracy. To this end, **maritime pilots in the largest ports are using portable pilot units (PPU) equipped with GNSS receivers relying on port-based RTK networks**.

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Innovative IWW applications push for greater performances

Europe's inland waterways (IWW) vessel market size will grow by a 9% CAGR from 2017 to 2024, resulting in €102 bln market by 2024. **In Europe, thousands of cities and industrial areas are connected by over 37,000 km of inland waterways**. The incorporation of the latest technology into the ships and ports enhances their performance and safety significantly. The **advanced navigation systems enable efficient and fast travel of ships**. There are different innovative applications based on specific cases of river ship navigation such as: navigation guidance for river ship manoeuvres; bridge collision warning; automatic mooring for ports; bottleneck area guidance; and assistance for lock procedures.

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Another example is in the case of an accident, where it can be crucial to prove that positioning data of the vessels involved were accurate and reliable. To this end, accident/event investigation replay application could be of great use. All these applications require stringent horizontal & vertical accuracy, high availability, integrity and continuity.

A resilient PNT is crucial

Being more automated and connected, both vessels and ports are becoming vulnerable to cyber attacks. Some examples include accessing and manipulating a vessel's AIS, where hackers could prevent ships from providing movement information, thus making AIS users to detect vessels in false locations. Another possibility involves the hacking of the port's digital container tracking system so as to locate specific containers.

Given the fact that GNSS is a primary means for PNT information at sea, it is critical to ensure resilience and resistance to unintentional and intentional interference. Therefore, the usage of multi-constellation GNSS receivers rather than a single constellation GNSS receiver is encouraged. To address the broader challenge of cybersecurity, the IMO has issued 'Guidelines on maritime cyber risk management', which provide high level recommendations on maritime cyber risk management to protect shipping from current and emerging cyber threats and vulnerabilities. In addition, the Maritime Safety Committee, adopted 'Maritime Cyber Risk Management in Safety Management Systems' to encourage administrations to ensure that cyber risks are appropriately addressed in existing safety management systems.

Overview of main user requirements in Maritime

The table depicts, in alphabetical order, the key Maritime user requirements as presented in the Report on User Needs and Requirements. The report, updated on regular basis, contain detailed and quantified requirements. Only high priority requirements are shown in the table, i.e. other requirements might also be relevant for considered applications. Information on the parameters definitions is provided in Annex 2.

Applications	Navigation[1]	Ship Operations	Traffic Management & Tracking	Search & Rescue	Port Operations	Engineering & Offshore
Key GNSS requirements	Accuracy (from metre to 10 metres) Availability Integrity	Accuracy (from sub-metre to 10 metres) Availability Integrity	Availability Continuity	Accuracy (final approach 5 metres) Availability	Accuracy (sub-metre) Availability Integrity	Accuracy (sub-metre) Availability Integrity TTFF
Other requirements	Interoperability	Interoperability	Connectivity	Connectivity (incl. return link) Power consumption Resiliency	Inter-operability	Inter-operability

[1] The GNSS requirements for general navigation vary with the given maritime environment.

Maritime Value Chain

MARITIME ORGANISATIONS

- **CIRM** is an international association for marine electronics companies
- **EFCA** European Fisheries Control Agency
- **EMSA** EU agency charged with reducing risks of maritime accidents, marine pollution and loss of human lives at sea
- **IALA** is an international technical association harmonising aids to navigation
- **IAPH** and **ESPO** port & harbour associations
- **ICS** and **BIMCO** shipping associations
- **IMO** sets the standards for safety, security of shipping and pollution prevention
- **IMPA** and **EMPA** maritime pilots associations

COMPONENTS AND RECEIVER MANUFACTURERS

- BEIJER ELECTRONICS*
- BEIJING BDSTAR NAVIGATION
- BEIJING UNISTRONG
- COBHAM*
- COBRA ELECTRONICS
- FURUNO
- GARMIN
- GMT CO
- JAPAN RADIO CO
- JOHNSON OUTDOORS
- KONGSBERG MARITIME*
- NAVICO*
- OROLIA*
- SAMYUNG ENC

SYSTEM INTEGRATORS

- AB VOLVO*
- HYUNDAI HEAVY INDUSTRIES
- INMARSAT*
- KAWASAKI HEAVY INDUSTRIES
- MITSUBISHI HEAVY INDUSTRIES
- PRONAV
- ST ELECTRONICS
- SUNGDONG SHIPBUILDING & MARINE ENGINEERING YANMAR

USERS

SHIP OWNERS/OPERATORS

- APL
- CMA CGM GROUP*
- EVERGREEN LINE
- HAPAG-LLOYD*
- MAERSK LINE*
- MSC*

FISHING BOAT OPERATORS
OFF-SHORE OPERATORS
RECREATIONAL BOATERS
SOLE MARINERS

USERS OF POSITIONING INFORMATION

PORT AUTHORITIES

SURVEILLANCE AUTHORITIES

DATA-ANALYTICS COMPANIES

- MARINETRAFFIC
- MYSHIPTRACKING
- VESSELTRACKER

The SAR beacon value chain has been moved to the dedicated Emergency Response segment

Rolls-Royce Commercial Marine acquired by Kongsberg Gruppen
Designated as a move to make Kongsberg a more complete supplier of the maritime industry, the acquisition of Rolls-Royce Commercial Marine is expected to create a strong world leader when it comes to the development of the first autonomous vessels.

European[1] GNSS industry in the global arena

In 2017, European companies, generated 33% of the global GNSS revenues of the **receiver suppliers** industry, dominated by Kongsberg Maritime accounting for 25%. This placed Europe in second place behind North America, which had 45% of the global market.

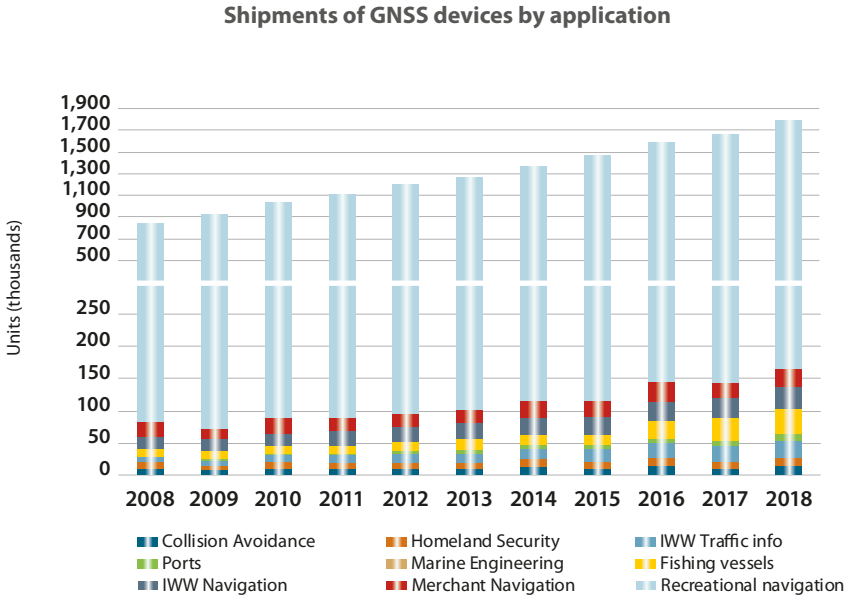
Global revenues generated by **system integrators** are dominated by Asian companies, with 60% of the global market. European companies (including AB Volvo, Inmarsat and Partner Plast) collectively accounted for 23% of global revenues, putting the Europe second in terms of market share ahead of North America.

[1] In the market share analysis, Europe is defined as EU28 plus Norway and Switzerland.

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

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

Continued stable growth of GNSS application shipments over the last ten years



In 2018, the global size of the GNSS application shipments topped the 1.7 mln units mark for all applications used for positioning and navigation across the different type of maritime vessels and infrastructures (e.g. port-based augmentation infrastructures). Over the last decade, maritime GNSS shipments have witnessed a 7.8% CAGR, from 830,000 units in 2008.

Although the world economy is driven by the maritime sector and the total gross tonnage witnessed a CAGR of 4.6% over the same period, the world merchant fleet has only grown by a CAGR of 1.9% as ships are becoming bigger and bigger. Looking at merchant vessel applications such as navigation, receivers and collision avoidance through AIS, a similar CAGR around 2% has been achieved over the last ten years.

Recreational navigation remains the largest market, totalling close to 1.6 mln units shipped in 2018, up from 745,000 units in 2008. The category of Port applications which includes port-based infrastructure applications as well as Portable Pilot Units, saw the largest growth with a CAGR of 32.2% over this timeframe.

Automation of port operations on the rise

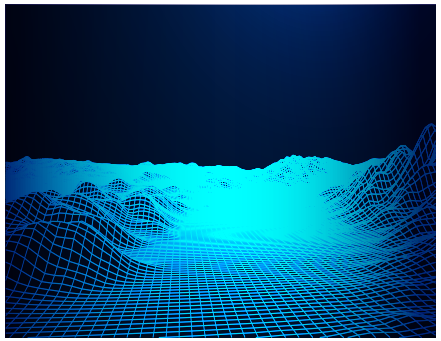
© Getty Images

With ships becoming increasingly automated and connected, ports need to follow so are embracing the latest technological inputs. Many ports and terminals are now focusing on automated port operations (e.g. container terminal automation). Reflecting this trend, **GNSS has become a critical part as these port operations and ports need high accuracy, integrity and authentication information** in order to allow safe operations of various applications.

GNSS not only plays a critical role for pilotage operations, but it is also crucial for the positioning of gantry cranes and straddle carriers. With automation being introduced at high speed within the fleet of container handling equipment, the demand for high-performance GNSS is on the rise, with **several worldwide ports already taking advantage of EGNSS-enabled innovative port applications** in combination with additional sensors such as LiDAR.

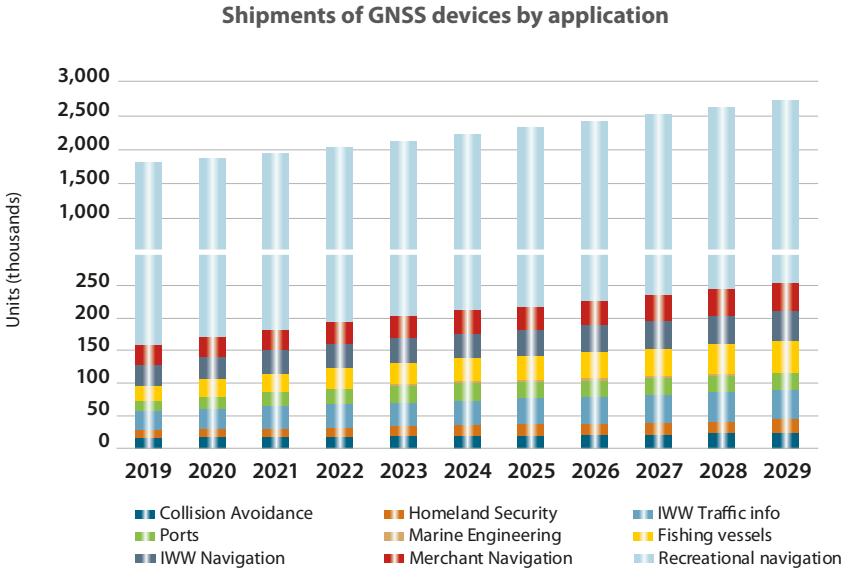
Unmanned vessels supporting surveying activities

Unmanned Autonomous Vessels are used for numerous surveying applications such as water quality sampling and monitoring, flow measurement, hydrographic survey, oceanographic research and security patrol. **To perform these applications, autonomous vessels are equipped with modern sonar technology and GNSS receivers enabling centimetre-level accuracy**.


© Getty Images

When it comes to the hydrographic survey, unmanned vessels are especially useful for enclosed, shallow, coastal or inland waters, requiring recurring updates. Maritime cartography is also of extreme utility in oceans, where less then 10% of the seafloor has been mapped in detail and less then 20% of the world's ocean bottom has not been surveyed at all.

Sustainable growth of the GNSS application market expected, opening up opportunities for more innovative applications



By 2029, it is forecasted that the number of **annual shipments** of GNSS applications will reach 2.7 mln units, **sustaining a moderate annual growth of 4.1% over the next ten years**. Throughout this forecasting period, it is expected that the share of recreational navigation will remain stable at around 90% of overall maritime shipments.

Considering these annual shipments, it is expected that the **overall installed base** of maritime applications **will reach more than 16 mln units by 2029**, which is an 66% increase compared to the current installed base of less than 11 mln units.

By 2026, it is expected that the Asia-Pacific region will overtake the North American market as the biggest market in terms of shipments. Europe will remain the third market far ahead of the rest of the world.

Global revenues (see Reference Charts) are expected to amount to €1.1 bln in 2019 and forecasted to reach over €1.6 bln by 2029 (a CAGR of 3.9%), with both capital-intensive GNSS-enabled port applications (€206 mln) and recreational navigation (€960 mln) leading the pack by 2029.

The future of maritime is autonomous

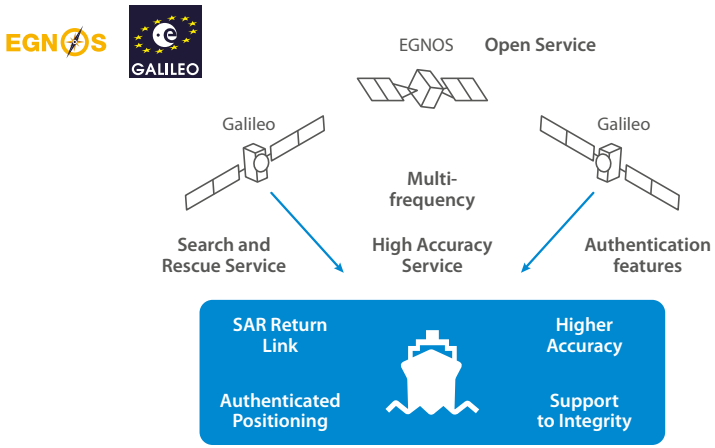
Just as automated vehicles and trucks will bring huge changes to the automotive industry, **autonomous ships are becoming the next major transportation innovation**. Well-established companies and new players are pushing 'full-speed ahead' towards unmanned vessels. Back in 2017, Rolls-Royce demonstrated the world's first remotely operated commercial vessel. Since Kongsberg acquired the company, a contract has been signed with leading Japanese shipping companies (e.g. Mitsui OSK Lines, Nippon Yusen and others) to contribute to Japan's aim of achieving practical use of autonomous vessels by 2025.

On the other hand, Kongsberg, through its partnership with YARA, is developing the YARA Birkeland which will be the first fully electric and autonomous container vessel. In 2019, testing of autonomous capability will be carried out to pave the transition from manned operations to fully autonomous operations over the 2020-2022 timeframe. All of the above examples rely on satellite communication, as one of the critical elements to enable remotely operated or autonomous operations.

© Kongsberg

Fully autonomous ships aren't yet allowed in international waters, but the International Maritime Organisation (IMO), which regulates shipping, started discussions that could allow unmanned ships to operate across oceans. IMO already defined Maritime Autonomous Surface Ships (MASS) and the different degrees of autonomy and will continue to consider integration of new and advancing technologies in the regulatory framework. Not waiting for progress at IMO-level, several Scandinavian countries such as Denmark, Finland and Norway have already established autonomous operating zones within their own national waters allowing the live trial and testing of autonomous systems.

EGNSS set to be a key differentiator in the maritime domain



Current usage of Galileo and EGNOS

Since the recognition of Galileo as part of the World-Wide Radionavigation System (WWRNS), around 15% of receiver models are Galileo-enabled.

Galileo and the innovative Return Link contribute to the COSPAS-SARSAT program, improving SaR missions worldwide. **More details are presented in the dedicated Emergency Response segment of this report**.

EGNOS penetration in receiver models reached 82%, whilst work is ongoing to harmonise its implementation using integrity information.

Galileo and EGNOS services and features to be explored

The authentication service by Galileo will contribute a real added-value and improve the robustness and resilience of maritime receivers.

The future of EGNOS in maritime follows a two-step approach. The first step focuses on the **retransmission of EGNOS corrections through AIS/VDES and IALA beacons**, whilst the second step focuses on the **use in the shipborne receiver of the Signal-in-Space to add a dedicated maritime service provision layer** and integrity information, complemented with RAIM.

HULL TO HULL

HORIZON 2020

Use of EGNOS and Galileo to support autonomous maritime operations

By utilising multiple GNSS constellations, including Galileo, and dual-frequency in combination with sensors, communications and data processing, **the H2H project aims to provide high accuracy and relative positioning measurements to mariners** in the form of a digital twin of the vessel's hull so to improve the navigational safety alongside stationary and moving objects.

© Hull to Hull

Throughout the project, three demonstrators will take place to showcase the solution in different operational use cases, being simultaneous operations (Norway), auto-mooring (Netherlands) and inland waterway operations (Belgium).

The **overall aim of the project is to address the need of the maritime community to safely navigate in close proximity of other vessels and objects**, thus supporting them in making correct navigation decisions, which is also a fundamental requirement for the development of autonomous vessels.

More information on: https://www.sintef.no/projectweb/hull-to-hull

LOGIMATIC

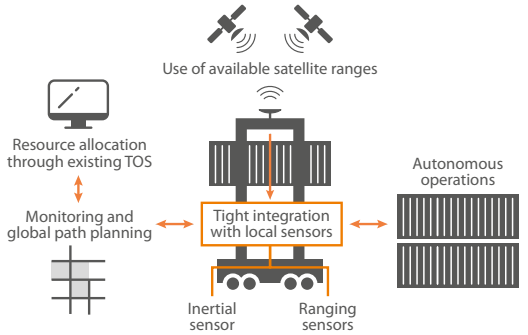
HORIZON 2020

EGNSS as a contributor to port vehicle automation

The LOGIMATIC project focuses on the **development and demonstration of an innovative location and navigation solution for the automation of the operations of straddle carriers in container terminals**. By relying on GNSS and leveraging on the differentiators of Galileo, the project is developing an advanced automated navigation solution based on the integration of GNSS and sensors onboard the straddle carriers.

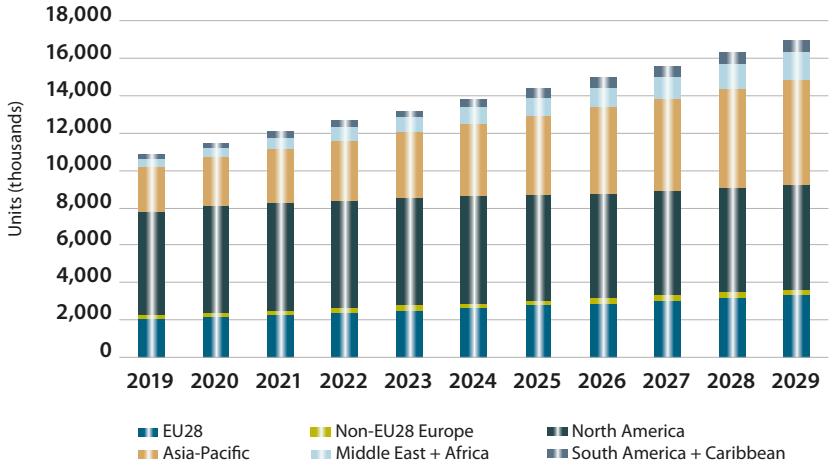
LOGIMATIC implements a GIS-based control module compatible with existing Terminal Operating Systems (TOS) for optimised global (yard level) route planning and fleet management. The project is also defining a security mechanism in order to detect and avoid spoofing and/or jamming attacks. The solution is tested in real port yards in Greece, Spain and Italy, where the aim is to replace old equipment.

More information on: https://www.logimatic-project.eu

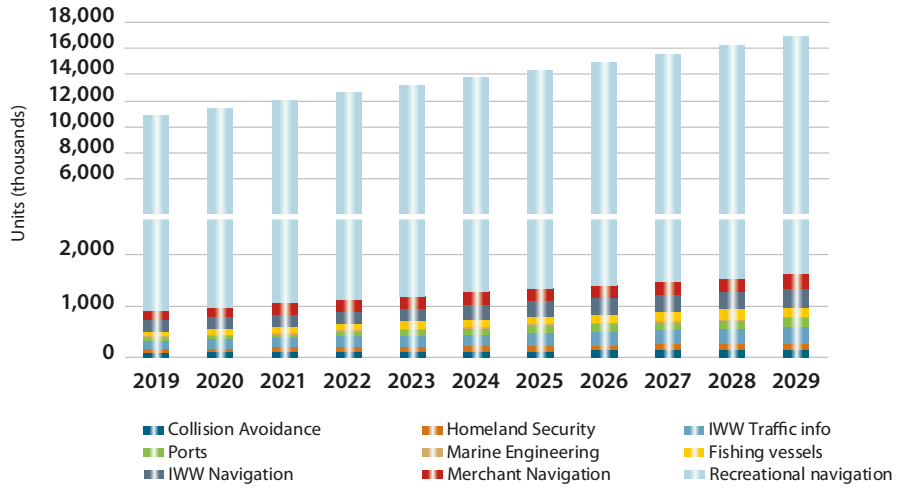


© Logimatic

Installed base of GNSS devices by region

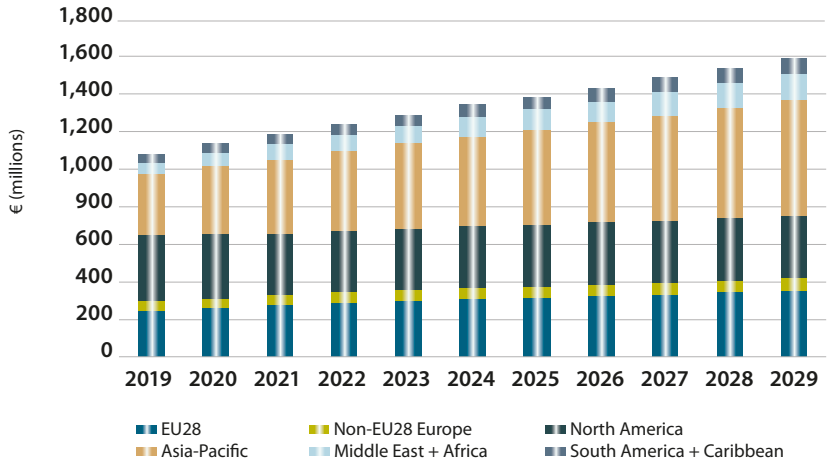


Installed base of GNSS devices by application

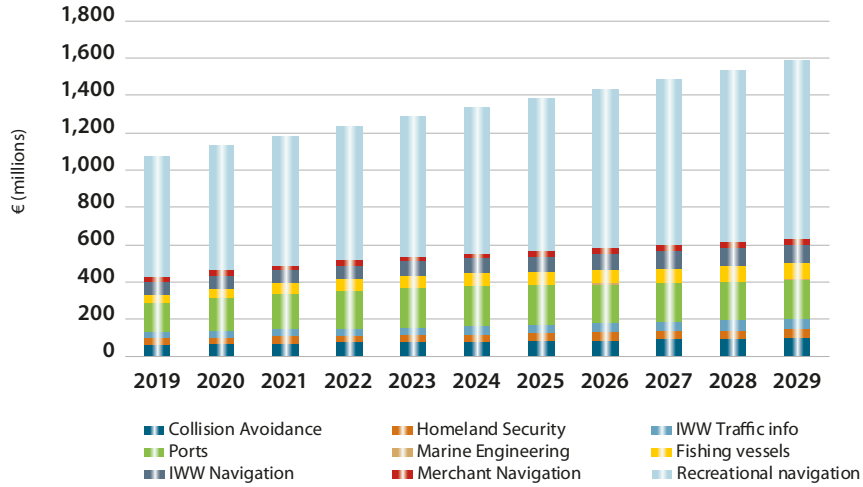


Merchant navigation, traffic management, search and rescue and marine engineering show SOLAS and NON-SOLAS vessels combined.

Revenue from GNSS devices sales by region

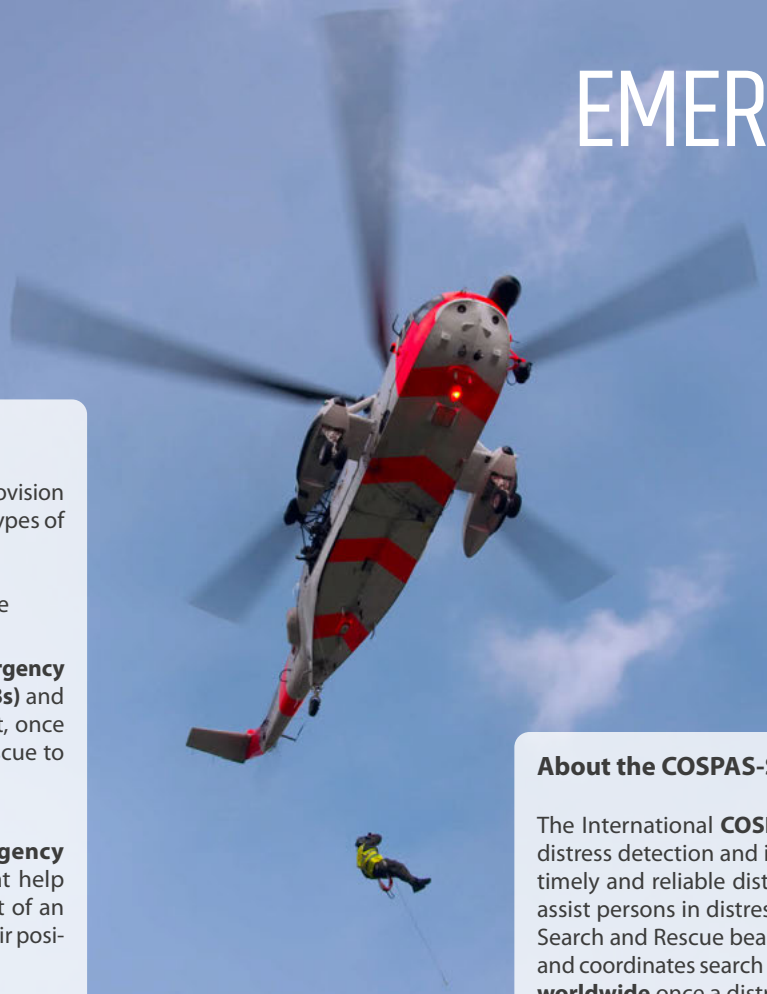


Revenue from GNSS devices sales by application



Merchant navigation, traffic management, search and rescue and marine engineering show SOLAS and NON-SOLAS vessels combined.

EMERGENCY RESPONSE



What you can read in this chapter

- **Key trends:** GNSS and international cooperation as key pillars for global Search and Rescue.
- **Global market:** Growing market of GNSS-enabled SAR beacons contribute to saving lives on land, in the air and at sea.
- **European GNSS:** Galileo as a key contributor and differentiator to global Search and Rescue.

GNSS applications

Search and Rescue (SAR) is the search for, and provision of aid, to people in distress or danger. Different types of devices can make use of GNSS positioning.

- In the frame of the COSPAS-SARSAT programme
  - MARITIME
    Ship and person-registered beacons, i.e. **Emergency Position Indicating Radio Beacons (EPIRBs)** and **Personal Locator Beacons (PLBs)** transmit, once activated, the necessary information for rescue to authorities via satellite communication.
  - AVIATION
    Aircraft should be equipped with **Emergency Locator Transmitters (ELTs)** or a **PLB** that help Search and Rescue operations in the event of an incident. Many ELTs utilise GNSS to report their position when triggered.
  - LAND
    Climbers and hikers are advised to equip themselves with a **PLB** in case they find themselves in distress.
- Outside the COSPAS-SARSAT programme
  - When activated, **AIS Search and Rescue Transponders (AIS-SART)** and **AIS Man Overboard (AIS-MOB)** devices continuously transmit an alert message including ID number and GNSS-based location, which triggers an alarm on all AIS equipped vessels within Very High Frequency (VHF) range.

About the COSPAS-SARSAT Programme

The International **COSPAS-SARSAT programme** is a **satellite-based Search and Rescue** distress detection and information distribution system with the mission to provide accurate, timely and reliable distress alert and location data to help search and rescue authorities to assist persons in distress whether they are **on land or at sea**. The programme recognises all Search and Rescue beacons that transmit a signal on the **406MHz distress frequency band** and coordinates search and rescue operations through a **network of Mission Control Centres worldwide** once a distress call is identified.

The programme is currently in the process of upgrading its satellite system to **complement the existing GEOSAR and LEOSAR systems with the MEOSAR system**. MEOSAR is bringing both the benefits of GEOSAR (i.e. global coverage) and LEOSAR (i.e. works without GNSS) together and overcomes their limitations by providing transmission of the distress message, and independent location of the beacon – on top of the one provided by GNSS if the beacon is GNSS-enabled – with near real-time worldwide coverage. MEOSAR will also **facilitate other enhancements such as a return link transmission** to confirm to the users that their distress signal has been received.

On top of this, COSPAS-SARSAT also maintains a **database of all registered 406MHz beacons** to facilitate SAR missions. It has to be noted that although not all produced beacons are GNSS-enabled, there is an **increasing trend towards GNSS uptake** amongst SAR beacons.

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GNSS and international cooperation as key pillars for global Search and Rescue

Key market trends

- International COSPAS-SARSAT is aiming for near-real-time beacon detection and localisation and overcoming of existing LEOSAR and GEOSAR systems by completing the transition towards MEOSAR by 2020
- Multi-constellation receivers for Search and Rescue beacons are the recognised way forward by all major beacon manufacturers
- Innovative features such as Return Link and Remote Activation expected to contribute to even greater success rates of global Search and Rescue efforts

Crucial role for GNSS in Search and Rescue

Thanks to the **COSPAS-SARSAT programme**, Rescue Coordination Centres (RCCs) and coast guards around the world have been able to improve their search and rescue activities every time a search and rescue beacon is activated by somebody in distress. Although the programme only detects and locates the distress beacons operating at the 406MHz distress frequency band, through coordination with the RCCs, the call to the rescue of a man overboard and vessels in distress is facilitated.

Since the introduction of Location-Protocol-enabled 406MHz beacons in 1997, it is possible to also transmit the encoded position data of the beacon by relying on GNSS. **Thanks to the availability of GNSS, additional accuracy improvements, and the SAR beacon registry, success rates of search and rescue missions have been improved which led to the saving of tens of thousands of human lives over the past decades**.

However, as the latest results of the annual Beacon Manufacturers Survey points out, not all 406MHz beacons produced are equipped with a Location Protocol. In 2017, around 142,000 beacons out of 218,000 (or 65%) were GNSS-enabled beacons.

European and global installed base of SAR beacons (2018)[1]

Beacon type	PLBs	EPIRBs	AIS-MOBs	ELTs	AIS-MOBs
Price	€ 290	€ 570	€ 240	€ 920	€ 500
EU28 installed base	116,000	84,000	108,000	11,000	8,000
Global installed base	595,000	266,000	176,000	80,000	26,000

Note: Prices presented are market averages based on a set of samples for each beacon type.

[1] Market analysis performed by the GSA

MEOSAR system to achieve full operational capability in 2020

© Cospas Sarsat

Currently operational, the Medium-altitude Earth Orbiting Satellite System for Search and Rescue (MEOSAR) is expected to receive its declaration of full operation capability by 2020, heralding the end of the transition to MEOSAR and complementing the LEOSAR and GEOSAR systems.

The MEOSAR system provides global coverage and near-real-time beacon detection and independent location, improving both the efficiency and effectiveness of global search and rescue operations. As the LEOSAR system only has a view over a small part of the planet at any given time, and the GEOSAR cannot locate a beacon unless the location is encoded in the beacon's message through an embedded GNSS receiver, MEOSAR offers the advantages of both systems and a solution to these limitations.

Galileo remote activation: the case of the ELT-DT

Since the still-unresolved disappearance of Malaysia Airlines MH370, **the International Civil Aviation Organization's (ICAO) has amended its aircraft tracking standards**. These standards are the first of two phases of international airworthiness recommendations that aim to turn ICAO's Global Aeronautical Distress and Safety System (GADSS) into a reality.

Under the current aircraft tracking standards and recommended practices (SARPs) aircraft under normal flight conditions needs to be tracked every 15 minutes. The latest update of ICAO Annex 6 requires autonomous position reporting every minute when the aircraft is in distress.

With **Galileo's foreseen Return Link Service present in aviation ELT-DT** (Distress Tracking ELT) distress beacons, **remote activation from the ground** would allow to geolocate unresponsive aircraft, greatly improving the chances to locate and find aeroplanes once normal communications is lost in case of a crash or other unforeseen events.

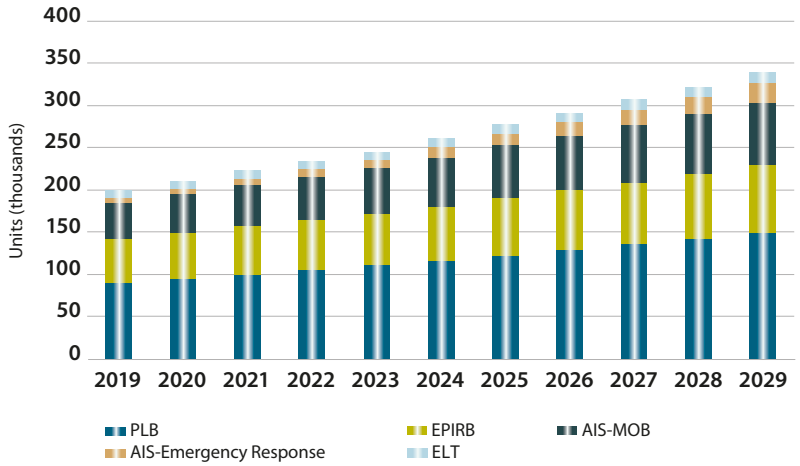
Growing market of GNSS-enabled SAR beacons contribute to saving lives on land, in the air and at sea

RECEIVER MANUFACTURERS	SAR BEACON MANUFACTURERS	USERS	USERS OF POSITIONING INFORMATION
• QUECTEL • STMICROELECTRONICS* • U-BLOX AG*	**EPIRB & PLB** ACR ELECTRONICS, JOTRON AS*, MOBIT TELECOM, OCEAN SIGNAL*, OROLIA* **AIS-SART & AIS-MOB** ACR ELECTRONICS, JOTRON AS*, OCEAN SIGNAL*, OROLIA* **ELT** • ACR ELECTRONICS, ASTRONICS CORPORATION, • OROLIA*, SAMYUNG ENC, • ELTA, ECA GROUP	**AIRPLANES and HELICOPTERS PILOTS** **FISHING BOAT OPERATORS** **HIKERS** **MOUNTAINEERS** **OFF-SHORE OPERATORS** **RECREATIONAL BOATERS** **SHIP OPERATORS** **SOLE MARINERS**	**SAR RESPONSE** • COAST GUARDS • COSPAS-SARSAT • DISASTER MANAGEMENT TEAMS • JOINT COORDINATION CENTRES

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

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

GNSS devices shipment by application



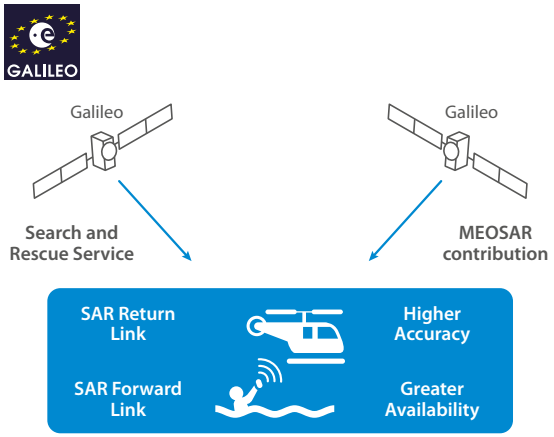
GNSS market share of PLBs boosted by growing uptake of Location-Protocol beacons

With close to 95,000 units in 2019, increasing to an expected 150,000 units by 2029 the category of **Personal Locator Beacons (PLBs) is by far the largest group of GNSS-enabled search and rescue beacons** being sold each year. The leading market for PLBs remains North America whilst the European Union is leading the market in both AIS-SARTs and AIS-MOBs.

Currently, the overall installed base of SAR beacons is roughly 1.3 mln beacons and this is expected to double by 2029. PLBs contribute to around 50% of this global installed base and despite both **AIS-SARTs and AIS-MOBs forecasted to increase their installed base by a 14% CAGR** over the next year (as opposed to only 2% for PLBs), PLBs are expected to continue dominating the global installed base in absolute numbers. One reason for this is the growing share of GNSS uptake across PLBs (i.e. 89% of produced units in 2017) compared to other SAR beacons such as EPIRBs (i.e. only 49%) and ELTs (i.e. only 41%).

Over the period 1982 to 2017, a total of 46,553 persons have been rescued over a total of 13,627 search and rescue events. Deep-diving into the statistics for 2017, 963 distress alerts were detected by the COSPAS-SASAT programme which led to the rescue of almost 2,750 lives. Whereas the majority of the events took place on land (404 events), it is in the maritime environment where most people get rescued (1,765 rescued persons).

Galileo as a key contributor and differentiator to global Search and Rescue



Current usage of Galileo

Since the launch of Galileo's Initial Services, the **Search and Rescue service** is contributing to the overall improvement of global search and rescue activities.

Galileo's **Forward Link** is already in use, relaying the distress call from the beacon to the satellites and from then onwards to the Mission Control Centre (MCC) and Rescue Coordination Centre (RCC). Key beacon manufactures already introduced **Galileo-enabled SAR beacon**s such as the Kannad SafeLink Solo PLB, SafePro AIS EPIRB and the GADSS ELT-DT on the one hand and the McMurdo FastFind 220 PLB and the SmartFind G8 AIS EPIRB.

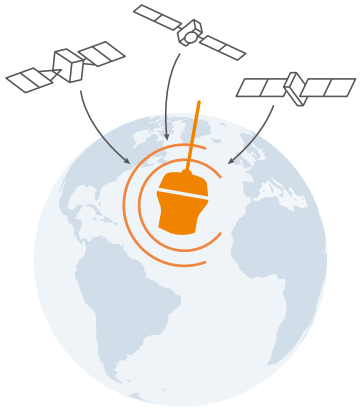
Galileo services and features to be explored

In the future, Galileo will become an even greater differentiator when it comes to search and rescue with the introduction of the **Return Link Service (RLS)**. This service would **provide an acknowledgement capability to the distress beacon confirming that the alert has been detected and located** by the system, ensuring the person(s) in distress that the distress alarm has been well received. The RLS will rely on Galileo's L1 navigation signal and will be available worldwide for RLS-enabled beacons.

By 2023, **Galileo's Early Warning System** will be fully operational. This service will be global in its scope and deployable in response to all types of hazards, from earthquakes, tsunamis, floods to forest fires or terrorist attacks. In the case of such events, a warning message with instructions would be broadcasted to smartphones in the affected zone.

Helios HORIZON 2020

Helios: Developing new generation SaR beacons leveraging Galileo's differentiators



The Orolia-led Helios project is **developing the next generation of distress beacons by leveraging multi-constellation GNSS**, including the Galileo Search and Rescue Service, as well as the MEOSAR system of COSPAS-SARSAT.

In the scope of the project, the Consortium is aiming to commercialise ELTs, EPIRBs and PLBs to **improve the search and rescue activities in the air, at sea and on land**. An objective that has already been realised following the launch of an upgrade to the McMurdo FastFind 220 and Kannad SafeLink Solo PLBs.

For the Aviation sector, the upgraded GADSS ELT-DT is the first ELT implementing the international airworthiness recommendations as set out in ICAO's Global Aeronautical Distress and Safety System (GADSS).

More information on: http://helios-gsa-project.eu/

HORIZON 2020

SINSIN: Improving SAR 'slow-moving beacon' localisation accuracy by a factor of 10 by leveraging EGNSS and MEOLUT

© TRIMIS

The ongoing (2017-2020) SINSIN project, which builds upon the results of the SAT406M project aims to develop an enhanced Personal Locator Beacon (PLB) with an embedded EGNSS receiver and leveraging the latest Medium-Earth Orbit Local User Terminal (MEOLUT). This **wrist-watch PLB, complying with the COSPAS-SARSAT standards** would significantly reduce the localisation of anyone in a distress situation by a factor of 10.

By relying on the enhanced MEOLUT, the localisation of the PLB should be possible with only 1 or 2 satellites in view, increasing the success rate of a SAR mission even if the SAR beacon was activated with restricted sky visibility such as in canyons, forests and mountains.

Besides contributing to further development and improvements in the field of SAR beacon technology, **the project also aims to set a new European standard for the Search and Rescue systems and services**.

More information on: TRIMIS website

RAIL

GNSS applications

- **Main Line Command & Control Systems** assist train command and control on lines with high traffic density, referring primarily to the European Train Control System (ETCS) in Europe and across the world, as well as Positive Train Control (PTC) in North America. GNSS can also be a source of additional input, e.g. for enhanced odometry in ETCS or to support PTC.
- **Low-Density Line Command & Control Systems** provide full signalling capabilities supported by GNSS on lines with low to medium traffic. These lines are usually located in rural areas, where cost savings can be vital to ensure the viability of a service.
- **Asset Management** includes functions such as fleet management, need-based maintenance, infrastructure charges and inter-modal transfers. GNSS is increasingly seen as a standard source of positioning and timing the information in these systems.
- **Passenger Information Systems** on-board trains show the real-time location of a train along its route. Increasingly, the GNSS location of a train is also supporting platform and online passenger information services.
- **Driver Advisory Systems (DAS)** use real-time geo-location to help train drivers operate their trains (driver assistance). The goal of a DAS is to enable optimised operation of train traffic.
- **Predictive Maintenance** relies on continuous location and monitoring performance, as well as damage and condition data to develop predictive maintenance models and ensure the efficiency of the network.
- **Trackside Personnel Protection** relies on positioning information in order to alert workers of an approaching train. GNSS is used as a supplementary tool to deploy equipment alongside the train tracks.

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What you can read in this chapter

- **Key trends:** Digitalisation is becoming the new driver of railway technology and innovation.
- **User perspective:** GNSS is progressively finding a role in safety and non safety-critical applications.
- **Industry:** Rail Value Chain.
- **Recent developments:** New services developed for an increased competitiveness of the railway system.
- **Future market evolution:** GNSS penetration is mainly driven by non safety-critical applications such as asset or traffic management.
- **Focus on European GNSS:** EGNSS is already present within non safety-critical applications and is on the way to be introduced within safety-critical applications, such as signalling.
- **Reference charts:** Yearly evolution of GNSS devices' installed base and revenues by application and region.

NEW **Trackside Personnel Protection** application has been added to the reference charts and overall statistics data.

Digitalisation is becoming the new driver of railway technology and innovation

Key market trends

- Railways are in the process of digitalisation and GNSS is part of the game
- The current market of GNSS in rail concerns non-safety relevant applications such as fleet or asset management and predictive maintenance
- GNSS based solutions for signalling applications will help reduce costs and enhance performance within the European Train Control System (ETCS)

Railways in the process of digitalisation

Digitalisation is one of the top priorities for the rail sector and its future. The objective of the rail sector is to offer highly efficient and attractive transport options to their customers as well as making the most of the opportunities offered by digital transformation.

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Transport of goods and passengers will become more user-centred. **Mobility-As-a-Service (MAAS) needs a connection for each mobility model** in order to provide access to real-time journey information, plan onward journeys, make reservations and purchase tickets. **One single platform shall allow passengers to book their door to door trips using intermodal solutions**. Passengers can connect to each other, access real-time travel information, entertainment or even e-commerce websites to pick-up their orders on arrival at the station.

With digitalisation, GNSS will become a standardised component of new trains and benefit every rail user, owing to services such as commuting mobile apps, real-time passenger information, tracking & tracing applications (for freight and passengers).

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Future maintenance will be connected

The use of **digital data processing is revolutionising infrastructure maintenance and rolling stock**. Trains and assets are equipped with sensors including GNSS that allow the localisation and monitoring of performance damage, as well as conditioning data on a continuous basis.

Advanced Traffic Management and Control Systems

The Shift2Rail program intends to take advantage of new technologies and practices to offer increased functionalities and become more competitive on the transport market. GNSS is one of the key technologies identified. The development of a fail-safe GNSS-based localisation unit for ERTMS (European Railway Traffic Management System) is a long process but is at the core of most ongoing projects dedicated to rail (ERSAT GGC, X2Rail2, ASTRAIL to name a few).

The architecture definition for the location unit needs a strong collaboration between infrastructure managers and railway undertakings on one side, and industry on the other side.

The solution facilitating interoperability with ETCS will rely on a hybridised architecture ensuring accuracy, availability and continuity, with a robust algorithm for fault detection and mitigation. Once available, this core function could also provide positioning for other additional applications as it will offer a robust and reliable positioning service already used for signalling.

Automation as the next step of innovation

Automation will increase the track capacity, the reliability of services, improve safety and energy efficiency, as well as reducing noise and vibration. Automatic Train Operation (ATO) is a promising solution to fully operate automated trains on mainline services in the future. The key advantages when the European Train Control System (ETCS) is combined with ATO are, above all, improved energy efficiency and greater line capacity.

Deploying GNSS within signalling, will reduce the number of balises installed on the track. This reduction of balises will help reduce costs, while maintaining safe train localisation.

The role of GNSS for signalling systems highlighted at the "Space for Innovation in Rail" conference

In the words of Josef Doppelbauer of ERA, **"Satellite-based technology can contribute to massive saving for rail signalling systems**, GNSS can remove the need for trackside infrastructure, while delivering massive data redundancy, which will influence the safety case. GNSS has the potential to revolutionise the European Railway Traffic Management System (ERTMS)."

As a first step, the inclusion of the virtual balise concept in ETCS as a non-intrusive solution to facilitate interoperability is foreseen. This step will then be followed by a more advanced multi-sensor positioning platform that should be further developed to potentially gain greater benefits from GNSS.

GNSS is progressively finding a role in safety and non safety-critical applications

The need to foster the rail sector attractiveness and competitiveness

Railways operate in a competitive environment and therefore commit to innovation. A large program of innovation and digitalisation has begun, in which larger deployment of GNSS (for non-safety applications) will benefit various users.

The Roadmap for digital railways from CER identifies the following key actions regarding connectivity, customer experience, capacity, or competitiveness:

1. **Enhancing customer experience** by offering added value with real-time location-based information for passenger guidance in stations or on platforms and information about cargo delays. They will benefit from improved accuracy and availability of positioning as well as smooth multimodal transport by connecting the different possible modes.

2. **Increasing capacity** by enhancing the reliability, efficiency and performance of railways. With the use of the IoT and new sensors, monitoring of the railway assets will improve efficiency and reduce the costs via preventive actions or fast interventions.

3. **Tracing cargo** allows the monitoring of dangerous goods as well as their CO2 impact. Cargo monitoring will improve the supply chain visibility information and boost the attractiveness of freight transport instead of other transport modes.

Reduction of maintenance costs

Monitoring the health status of the railway's most demanding assets (wheel, rail, pantograph and catenary) will help reduce 15% of railway maintenance costs, 25% of maintenance unscheduled events and 15% of derailments associated to the rail-wheel interface.

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Location data will enable:
- Less manual inspection of assets;
- Enhanced safety due to efficient maintenance, asset health monitoring and diagnosing tools;
- Planned maintenance before a defect occurs as opposed to emergency intervention, thus reducing congestion which increases efficiency and capacity.

Overview of the main user requirements in Rail

The table below depicts the key user requirements as assessed through the GSA's continuous monitoring with the user community (in particular during the User Consultation Platforms). The refinement of these requirements is in progress, in the framework of several projects or working groups. They are translated into the Rail User Needs and Requirements Report that consolidates the values for some agreed applications; the others are qualitative at the moment.

In rail applications, some requirements are defined from a functional point of view, as GNSS will be used in combination with other technologies.

Only high priority requirements are shown in the table, i.e. other requirements might also be relevant for considered applications.

	Non safety-critical applications			Safety-critical applications
Applications	**Asset management**	**Passenger Information**	**Trackside personnel protection**	**Signalling and train control applications**
Key GNSS requirements	Accuracy (10 metres) Availability (High)	Accuracy (5 to 100 metres) Availability (95%)	Accuracy (1 to 10 metres and track discrimination) Availability (95%)	Accuracy (1 to 20 metres) Availability (High) Integrity Robustness
Other requirements	Connectivity Power Consumption	Connectivity (communication link)	Connectivity (communication link)	Interoperability

Galileo is already on-board!

SNCF is implementing European GNSS in already 250 TGV High speed trains, to provide Customer information and On board location based services. This represents more than 50% of the TGV fleet. By 2021, 90% of the TGV will be equipped, allowing more than 70 mln passengers per year to benefit from this improvement. Furthermore, SNCF will also install GNSS receivers using Galileo on many regional trains, freight trains or 'yellow fleet' (more than 2000 locomotives) by the end of 2020 to support customer information and fleet management services.

Rail Value Chain

COMPONENTS AND RECEIVER MANUFACTURERS

- ANALOG DEVICES INC
- BEIJING BDSTAR NAVIGATION
- BROADCOM
- COMNAV TECHNOLOGY LIMITED
- CORE CORPORATION
- GARMIN
- GENERAL ELECTRIC
- GMV*
- HITACHI
- LANNER ELECTRONICS INC.
- NOTTINGHAM SCIENTIFIC LIMITED*
- OHB SE*
- SATEL OY*
- SEPTENTRIO*
- THALES*
- TRIMBLE NAVIGATION
- U-BLOX*

SYSTEM INTEGRATORS

- ALSTOM TRANSPORT*
- AZD PRAHA*
- BOMBARDIER
- CAF
- CATERPILLAR INC.
- CRRC CORPORATION LIMITED
- GENERAL ELECTRIC
- GMV*
- HITACHI
- KAWASAKI
- KINTETSU RAILCAR ENGINEERING
- MITSUBISHI
- SIEMENS*
- ST ELECTRONICS
- STADLER RAIL AG
- THALES SA

TRAIN MANUFACTURERS

- ALSTOM*
- BOMBARDIER
- CHINA SOUTH LOCOMOTIVE AND ROLLING STOCK
- HITACHI
- SIEMENS*

TRAIN OWNERS / OPERATORS

TRAIN AND FREIGHT OPERATING COMPANIES:

- ARRIVA*
- COLAS*
- DEUTSCHE BAHN*
- RENFE*
- SBB
- SNCF*
- STAGECOACH*
- TRENITALIA*
- Urban transport operators

ROLLING STOCK OPERATING COMPANIES:

- Consortia
- Investment banks
- National companies

INFRASTRUCTURE MANAGERS

- ADIF*
- DEUTSCHE BAHN*
- INFRAESTRUTURAS DE PORTUGAL
- NETWORK RAIL*
- RFI*
- SBB
- SNCF*
- Urban transport operators

European[1] GNSS industry in the global arena (2017)

The rail industry is spread within Europe, Asia/Russia and North America, considering components and receivers as well as system integrators.

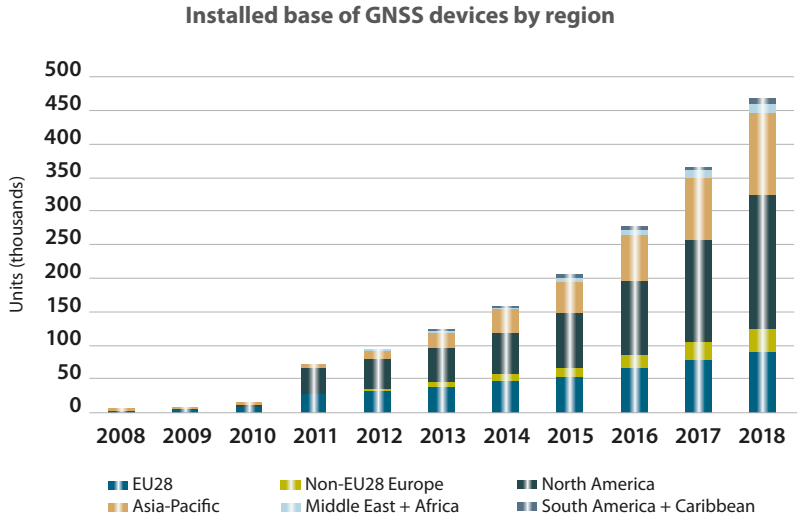
Following the acquisition of Ansaldo STS by Hitachi, European companies now have a **market share** of 10% among components and receivers manufacturers, whilst the market is largely being dominated by North Asian companies – like Hitachi. European companies are strong among system integrators, **controlling 51% of the market**. Alstom, Siemens and Thales are listed within the global Top 5 companies.

[1] In the market share analysis, Europe is defined as EU28 plus Norway and Switzerland.

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

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

New services developed for an increased competitiveness of the railway system



A growing market all over the world

Market penetration of GNSS devices is growing in all regions. The way GNSS is used for railway applications can differ from one region to another, but the families of applications are comparable. For example, the development of Train Control Solutions or modernisation programmes have similarities with the Positive Train Control implementation in the US, the KLUB-U in Russia and the Chinese programmes.

Freight tracking: A huge need to drive shippers back to rail freight

To increase its attractiveness, rail freight has to become more efficient, reliable and ensure better connectivity. **Real-time data can contribute to the move towards tracking freight**, which in turn will allow customers to follow their shipment. Together with other sensors, **GNSS-based solutions inform the client about the location of the wagons, weight of the load, contents, or inform about potential delays**. Furthermore, real-time information on the wagons status will help to enhance scheduling and predictive maintenance activities.

HORIZON 2020

STARS Project: GNSS performance prediction for ERTMS

© STARS

The STARS project was closed in November 2018. Its main achievements, deliverables and conclusions are available on STARS website (see link below), where information can be found on:

- The first universal approach to perform GNSS measurements in the railway environment and its application to an extensive measurement campaign performed during the project
- Correlation illustrations between the local environment and its impact on GNSS performance 32.2% over this timeframe.
- Demonstration that GNSS will benefit from hybridised sensors to counterbalance the local effects on GNSS signals and EGNOS received via GEO satellites, and thus meet all the rail requirements
- First recommendation to investigate a solution to design a dedicated distribution mechanism of the EGNOS messages based on a Euroradio-like protocol to ensure a secure data exchange.

More information on: www.stars-rail.eu

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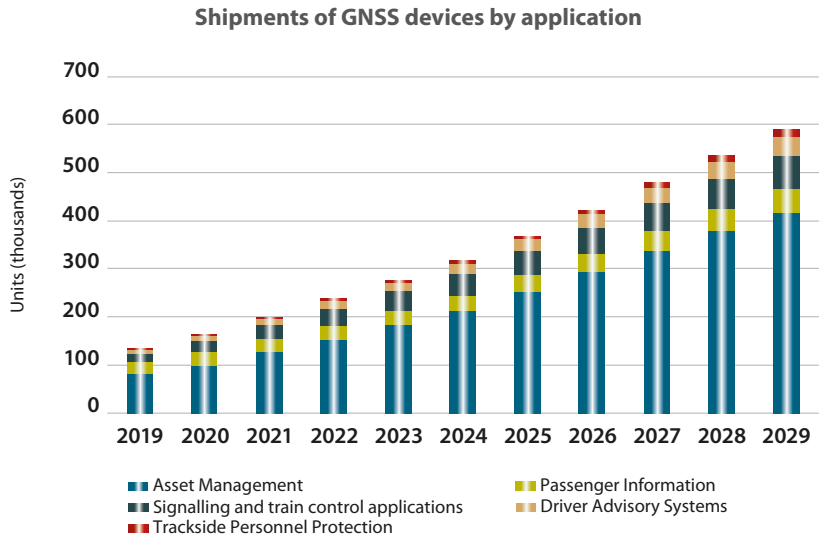
GNSS will improve trackside personnel protection

GNSS chips will improve workers' safety on the track. Trackside personnel protection systems today rely on human-based procedures and alert equipment. However, part of the new generation of equipment embeds GNSS receivers as a supplementary source of information for the staff concerned. Locating the equipment allows the guarantee of the minimum safe distance between them.

In the future, when trains will be able to continuously provide their current position, speed, driving direction and information on the track used, it will be possible to explore more innovative solutions, such as warning track workers of an approaching train through a smartphone app.

GNSS penetration is mainly driven by non safety-critical applications such as asset or traffic management



Most of the deployed devices contribute to non safety-related solutions

The GNSS market in rail moves slowly. A recent and growing trend of process digitalisation will, however, boost the market for non safety-critical applications, owing to the large-scale deployment of sensors for **asset management and passenger information**. These GNSS devices represent about two-thirds of the installed base of receivers.

EU Certification will help establish the long term safety-critical applications market

Recent projects have demonstrated the feasibility of using GNSS for signalling applications. Since the Memorandum of Understanding was signed between the European Commission, decision makers and rail stakeholders in 2016, **GNSS has been recognised as a 'game-changer' in the development of ERTMS**, alongside Galileo being identified as enabling efficiency and reliability improvements in rail transport.

The deployment of GNSS-based Positive Train Control systems within the coming years in the United States has driven initial shipments within North America. In Europe, GNSS will soon be used as part of any ERTMS/ETCS onboard system, replacing physical balises with virtual ones. A GNSS-based Virtual Balise Reader will have to be integrated within all vehicles. With the new safety certification regime that applies as of 16 June 2019, the ERA will be the authority in charge of authorising the launch of any new vehicle on the market following a certification assessment process, including GNSS-based subsystems. The market relating to Signalling and train control applications is therefore expected to grow following the introduction of the framework for GNSS-based solutions associated with safety-relevant applications.

Beyond ERTMS and Virtual Balise is Automation

The next step for increasing traffic capacity and safety without requiring new infrastructure will be the development of suitable automation paradigms. Incremental development of Automatic Train Operations (ATO) will enable the realisation of safe driverless operations such as acceleration and braking under control of Automatic Train Protection (ATP), and the utilisation of information from Traffic Management Systems and train location. Localisation capabilities required for automation will benefit from previous work performed in the X2R2 project that will provide a GNSS-centred fail-safe positioning solution for signalling applications.

SIA HORIZON 2020

SIA Project: System for vehicle/infrastructure interaction and assets health status monitoring

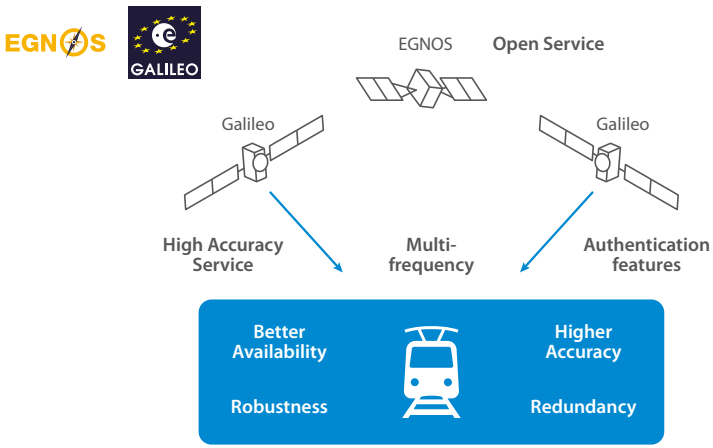
The objective of SIA is the development of four new ready-to-use services that will provide prognostic information on the health status of the railway's most demanding assets in terms of maintenance costs (wheel, rail, pantograph and catenary). It will include the development of low-cost sensor nodes, a data hub, predictive component degradation models and a visualisation platform.

More information on: https://siaproject.eu/

SIA INNOVATION

- **Development of new end-to-end EGNSS based services to address end-user needs.**
- **Combination of cutting-edge technologies to provide added value to end users.**
- **Innovation in busibness model.**

EGNSS is already present within non safety-critical applications and is on the way to be introduced in safety-critical applications, such as signalling



Current usage of Galileo

Positioning goods and assets via GNSS allows the train companies and infrastructure managers to deliver a better service and a more efficient use of the infrastructure.

This benefits a wide range of end-users including passengers and freight clients. Galileo contributes to increasing position availability and accuracy. Recent devices already embed a Galileo enabled receiver or are fully "Galileo-ready". These devices are deployed for non safety-critical applications such as asset or traffic management and Driver Advisory Systems (DAS).

Galileo services and features to be explored

Galileo's High Accuracy Service will provide added value for rail-related surveying, and for safety-critical applications requiring track identification.

Multi-constellation capabilities provided with Galileo will bring robustness to the location unit.

The capacity of multi-constellation with independent, redundant, and spectral diversity will be explored as well as the ARAIM or other RAIM algorithms.

ERSAT GGC: certification process of the satellite assets

ERSAT GGC

HORIZON 2020

The ERSAT GGC (Galileo Game Changer) innovation project will contribute to the roadmap of ERTMS for the adoption of the EGNSS. Particular focus is given to the certification process of the satellite assets, to allow the ERTMS to operate seamlessly with Virtual Balises and thus ensuring the end-to-end compatibility within ERTMS.

The Project's high-level objectives are the following:

- Validation of EGNSS assets and relevant certification process compatible with the ERTMS Standards;
- Definition and certification of a STANDARD Process, Methodology and the related Toolset for Classifying Track Areas as "Suitable" or "Not Suitable" for locating Virtual Balises;
- Consolidation and certification of the Enhancement of the Functional ERTMS Architecture integrated with satellite based Location Determination System (LDS);
- Contribution to the standardization process & dissemination of results on the satellite and rail stake-holders.

More information on: http://www.ersat-ggc.eu

X2RAIL 2

Shift2Rail

X2Rail2-WP3: development of a fail-safe positioning architecture

The objective of X2Rail2-WP3 is to achieve a significant reduction of the use of traditional train detection systems in ERTMS/ETCS by the means of attaining an absolute and safe train positioning system based on a multi-sensor concept, where GNSS is the preferred technology.

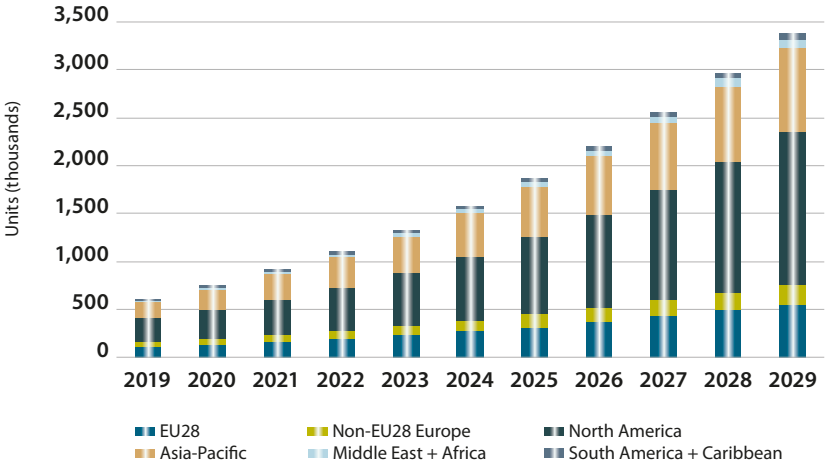
More specifically, X2R2 focuses on the:

- Definition of the System Requirement Specification and the System Architecture in the context of the ERTMS evolutions;
- Identification of the different possible technological solutions, develop proof of concepts based also on modelling and simulators;
- Provision of a Business Model for GNSS application in Railway.

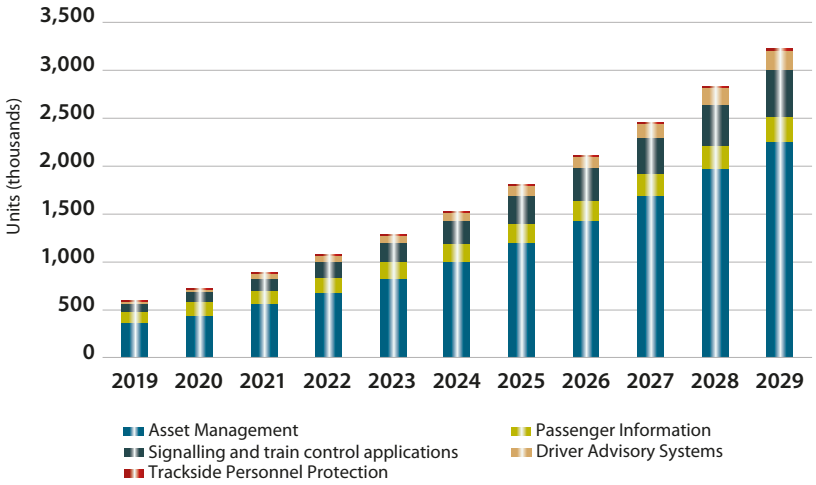
The project is planned to end in August 2020.

More information on: https://projects.shift2rail.org/s2r_ip2_n.aspx?p=X2RAIL-2

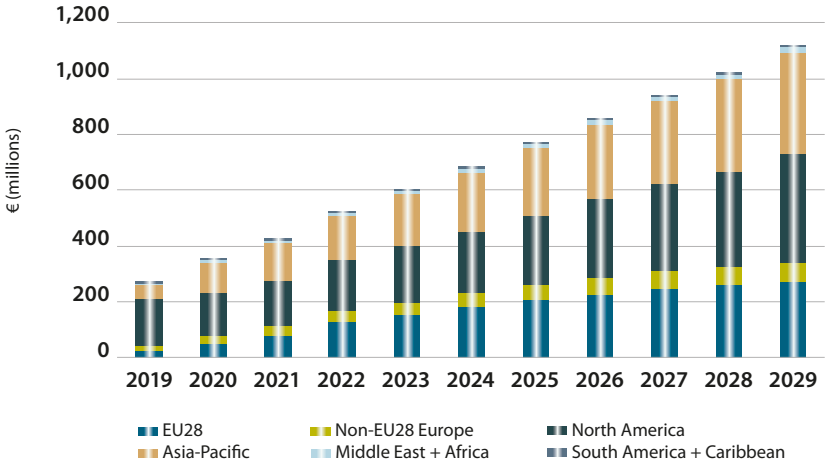
Installed base of GNSS devices by region



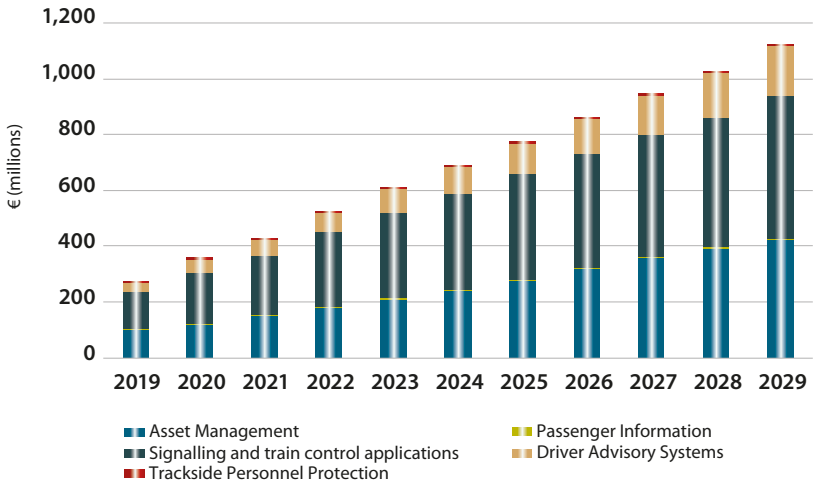
Installed base of GNSS devices by application



Revenue of GNSS device sales by region



Revenue of GNSS device sales by application



AGRICULTURE

What you can read in this chapter

- **Key trends:** 'More with less', the mantra of Agriculture 4.0 enabled by GNSS.
- **User perspective:** Harvesting a wealth of data drives agricultural users.
- **Industry:** Agriculture Value Chain.
- **Recent developments:** GNSS an integral part of growth for many solutions in the digital agriculture era.
- **Future market evolution:** GNSS is key to untapping the full potential of future evolution in agriculture.
- **Focus on European GNSS:** The added value of European GNSS is driving its adoption in farming solutions.
- **Reference charts:** Yearly evolution of GNSS devices' installed base and revenues by application and region.

GNSS applications

Precision agriculture is the application of different technologies and solutions to manage the variability of agricultural production, in order to improve crop yield and reduce environmental impact. Key GNSS enabled applications include:

- **Farm machinery guidance** uses GNSS positioning to assist drivers in following the optimal path thanks to a digital display, thus minimising risks of overlaps.
- **Automatic steering** completely takes over steering of the farm equipment from the driver allowing the operator to engage in core agricultural tasks.
- **Variable rate application** combines GNSS positioning with information from other sensors and digital maps to distribute the right amount of agrichemicals.
- **Yield monitoring** enables site-specific monitoring of harvest, combining the output of a yield sensor with GNSS positioning of the harvester.
- **Biomass monitoring** enables site-specific monitoring of biomass in an agricultural field, providing up-to-date information on crop development.
- **Soil condition monitoring** enables updates of soil moisture levels, fertility or diseases to optimise their management. GNSS positioning and software applications identify the exact position of the soil samples sent to laboratories. Data from soil sampling is used in VRT application maps.
- **Livestock tracking and virtual fencing** use a GNSS-enabled portable equipment to track animals behaviour, leveraging tracking and virtual fencing.
- **Precision Viticulture** relies on GNSS for the geo-location of sensors or machinery within vineyards.
- **Precision Forestry** involves the use of GNSS for site-specific forest management activities and operations to improve wood product quality and utilisation.

Agri-logistic applications help farmers to increase efficiency and to comply with number of regulations and new standards:

- **Farm machinery monitoring and asset management** use real-time GNSS information for monitoring the location and mechanical status of equipment and to manage work flows efficiently.
- **Geo-traceability** enhances the effectiveness of food, animal and product traceability by using transponders on animals and vehicle GNSS trackers, as well as by geo-referencing location and size of land parcels.
- **Field definition** is the activity of measuring precisely the boundaries and the size of agricultural fields. In the EU, GNSS-based operations using EGNOS and Galileo support a system of area-based subsidies for farmers within the Common Agricultural Policy (CAP).
- **Geo-tagged photos** – enabled by GNSS – will be used under the CAP in support of subsidies control (validation process) and updates on the Land Parcel Identification System (LPIS).

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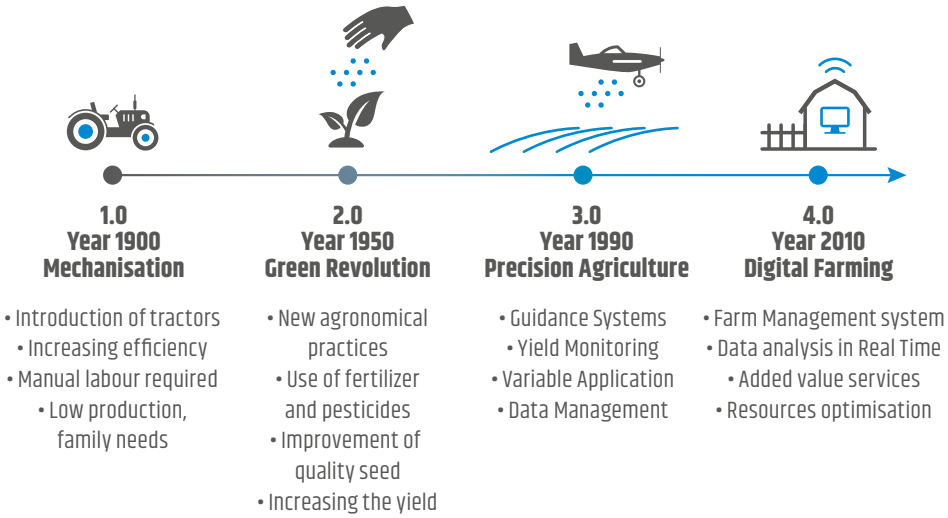
‘More with less’, the mantra of Agriculture 4.0 supported by GNSS

Key market trends

- Increased connectivity (IoT), advanced sensing capabilities (e.g. via satellites and drones) and big data analytics are shaping the reality for farmers in the Digital Agriculture era
- GNSS has become an integral part of smart, connected and integrated farm management solutions and a key driver for precision farming across the whole crop cycle
- The demand in the Precision Farming market, which is growing at a CAGR of 14%, is driven by increased adoption of GNSS-enabled telematics solutions

Agriculture 4.0: a world of opportunities, a world of challenges

The agricultural sector today is characterised by a **stark contrast**: On one hand lies the simplicity of its mission, namely to produce enough food for a continuously growing population. On the other hand, lies the complexity of achieving this mission within an overall context that places significant strains in the execution of agricultural practices. These strains are associated with decreasing farm income, limited resources, rising costs of inputs, climate-change effects and environmental regulation. Thus, the farmers of the 21st century are called to carry out strenuous efforts towards enhanced, efficient and sustainable agricultural productivity, whilst at the same time reducing the environmental impact of their activities. **Knowing exactly what to do, where, and when in order to achieve more with less has become the mantra of modern agriculture**. To answer this call, farmers find themselves in the Agriculture 4.0 era, operating in a fully-connected, fully-digitised paradigm, whereby a multitude of data is collected via advanced proximal or remote sensing (EO satellites and drones), processed with advanced analytical techniques, and translated into site-specific actions thanks to GNSS-enabled localisation and guidance.



The rise of autonomous tractors and robots

Whilst the rest of the world is hyped about self-driving cars and their everyday life implications, the world of agriculture is pushing ahead to realise the full set of advantages provided by autonomous tractors and robots. This is reflected in the current growth of the market at CAGR 24%. Thanks to **GNSS-enabled high-precision positioning, autonomous tractors are emerging as an invaluable tool for advanced precision farming applications**, helping to cut down costs (labour, fuel, maintenance) and increase efficiency. Autonomous tractors are also acting as a mobile hotspot for the collection of data from sensors located throughout the field. Fully autonomous, self-driving tractors are being developed in support of multiple agricultural activities from precise planting, to spraying and harvesting. Alongside autonomous tractors, **swarms of robots are progressively exiting the realm of R&D and entering the daily reality of farmers**. Such robots are performing different activities from planting, to pest scouting, and from green pruning in vineyards, to harvesting and spraying. The wider uptake of both autonomous tractors and robots is currently hindered by safety concerns, but as sensing technologies and regulatory frameworks advance, so will the use of such disruptive solutions.

5G: a key to unlock the benefits of digital farming

Rural areas across the world suffer from the lack of reliable and high-bandwidth connectivity. This is an important constraint for the full realisation of benefits associated with digital agriculture, whereby different streams of data are communicated between various IoT components. The advent of 5G will enable farm equipment to communicate with other machines on the field by streaming data from vehicle to cloud and back down to machine operators in the shortest time possible. Thanks to this ‘real-time connectivity’, farmers across the globe will be able to experience the full set of benefits associated with smart, connected and integrated farm management solutions.

Harvesting a wealth of accurately localised and timely collected data drives agricultural users

Overview of the main user requirements in Agriculture

The table below presents the key GNSS requirements for the different application groups in agriculture. It has been compiled following extensive interaction with user groups, providers and experts in a continuous process culminating at the User Consultation Platforms.

The most important requirement for the execution of GNSS-enabled applications in agriculture is accuracy. Other key requirements include availability and continuity. All requirements are documented in detail and updated regularly within the Report on Agriculture user needs and requirements.

	Operations		Monitoring	Other applications
Applications	**Farm Machinery Guidance**	**Automatic Steering, Variable Rate Application**	**Harvest/Yield Monitoring, Biomass Monitoring, Soil Sampling**	**Livestock Tracking, Virtual Fencing, Geo-traceability, Machinery Monitoring, Field Boundary Measurements**
Key GNSS requirements[1]	Accuracy (decimetre-level) Availibility Continuity	Accuracy (centimetre-level) Availibility Continuity	Accuracy (centimetre-level) Availibility	Accuracy (centimetre-level) Availibility Authentication
Other requirements	Connectivity	Connectivity Interoperability	Connectivity Interoperability	Connectivity Interoperability Traceability

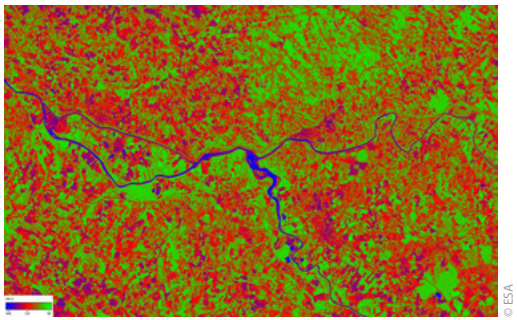
[1] Please note that:
- for 'operations' horizontal, pass-to-pass accuracy is stated. However, certain in-field operations that involve coming back to exact locations at different times require in addition high-repeatability;
- for 'monitoring' and 'other applications' horizontal, absolute accuracy is stated.

Translating the multitude of data into well-informed actions

The key to reaping the full benefits of digital farming lies in the ability to effectively **translate the different kinds of data into actionable information**. However, farmers in Europe and the US have been continuously reporting that they find it moderately or very difficult to compile and analyse field operations data from different sources. In that regard, **interoperability has been a formidable obstacle** for the widespread adoption of digital farming solutions. To overcome this hurdle, multiple initiatives are focussed on enabling interoperability between software and hardware applications. For instance, AgGateway, a non-profit organisation with the mission to promote and enable the industry's transition to digital agriculture, has been collaborating with multiple manufacturers, integrators and the Agricultural Industry Electronics Foundation (AEF) to develop ADAPT. This is an open-source project that provides the tools and the framework for the simplified communication between farmers, their machines and their partners. In Europe, this effort is spearheaded by IOF2020, a flagship Horizon2020 project, that strives to make 'Agriculture 4.0' a success.

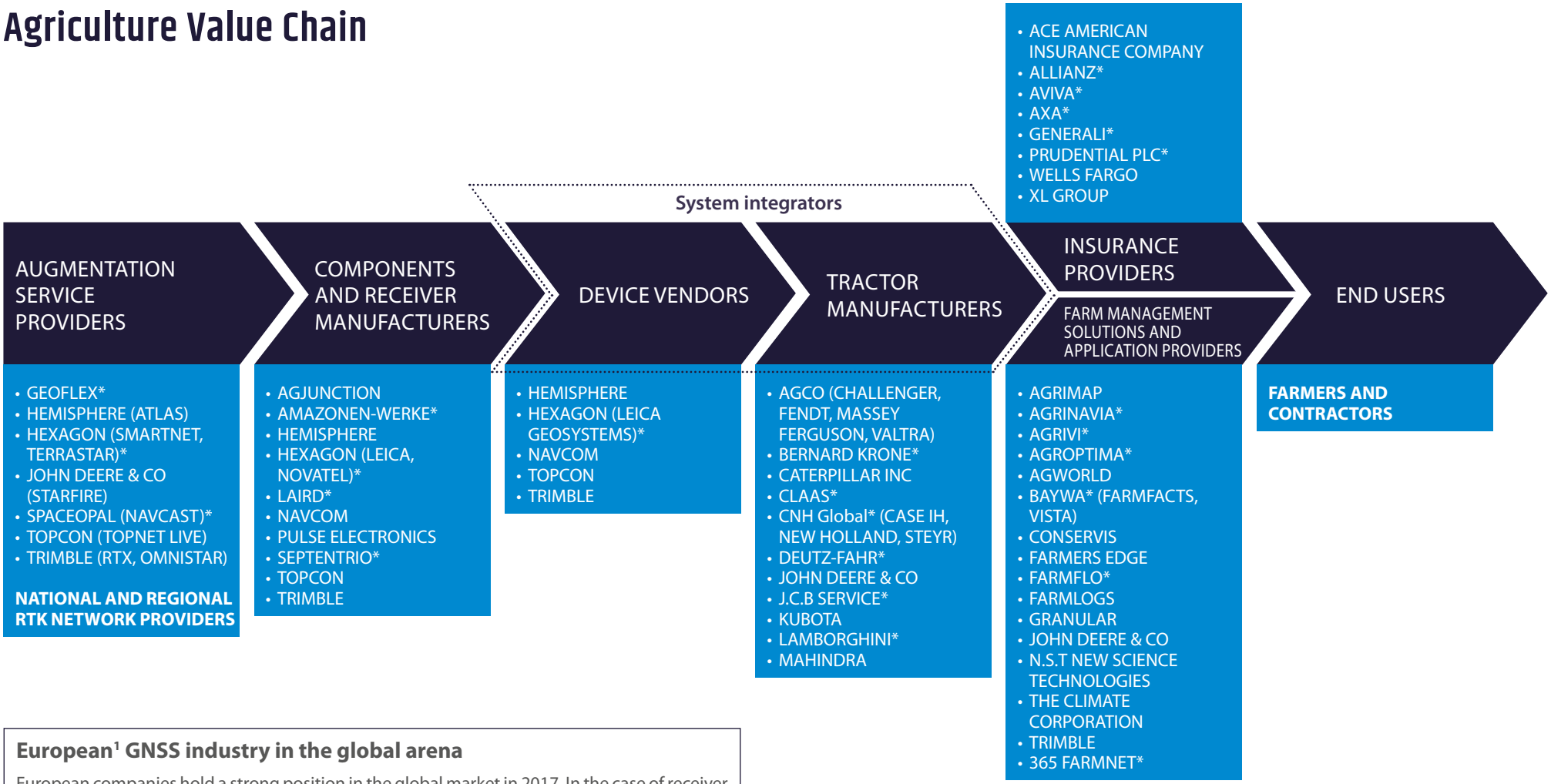
More 'eyes' and the key to be precise

The availability of 'Big Data from Space' – driven by the Copernicus free, full and open data **policy** – is providing farmers with an unprecedented amount of reliable and timely-captured information of what is happening in their fields the whole year through. For example, Sentinel 2 provides a 10-metre resolution that can be relevant even to individual land parcels, whilst its revisit time stands at 5 days making it highly relevant for crop dynamics monitoring. By measuring the energy reflected in visible and infra-red bands, Sentinel 2 enables the calculation of the normalised difference vegetation index (NDVI).



This information is **complemented by additional 'eyes' on the ground or on drones and robots**, making use of cameras and sensors of increasing sophistication. Using advanced big data analytics, machine learning processes and IoT connectivity, integrated farm management tools are combining this information to support farmers' decisions on what needs to be done when and where. In this emerging digital farming paradigm, **GNSS plays a central role, as it enables accurate localisation of this data and the precise positioning of farm machinery** during the execution of site-specific practices throughout the whole crop cycle.

Agriculture Value Chain



European[1] GNSS industry in the global arena

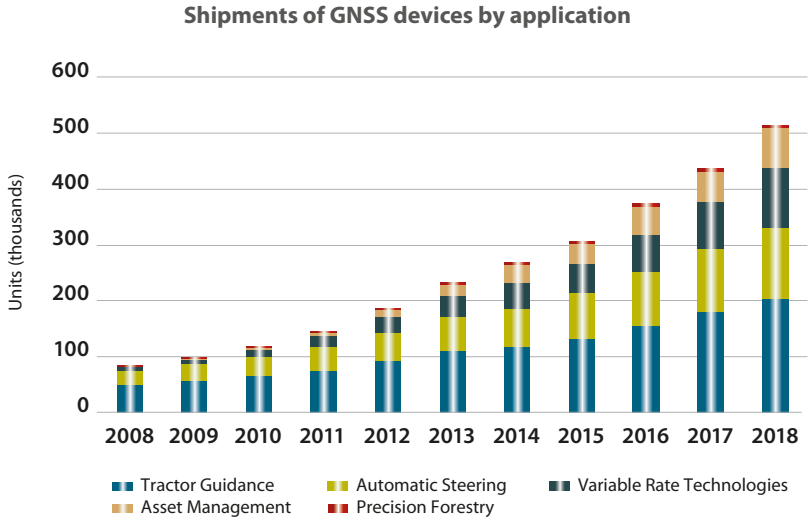
European companies hold a strong position in the global market in 2017. In the case of receiver suppliers, this amounts to a 27% global market share primarily thanks to Hexagon's prominent presence (i.e. around one quarter of the market). Looking at system integrators in agriculture, Europe holds the largest market share, with European companies combining for 43%. In this domain many European companies are active with CNH Industrial having the largest share (15%).

[1] In the market share analysis, Europe is defined as EU28 plus Norway and Switzerland.

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

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

GNSS is an integral part of growth for many solutions in the new digital agriculture era



The desire for increased accuracy drives GNSS adoption

Whereas up until the early 2010s, **tractor guidance** was the major driver of GNSS adoption, accounting for more than 50% of total shipments worldwide; in the past year, more advanced systems foreseeing **automating steerin**g have gained traction and, together with the growth of **variable rate application** systems and **asset management** solutions contributed to the sustained growth of the market.

In 2018, **entry-level tractor guidance** remained the most popular application, with 200,000 units shipped worldwide and an installed base close to 1 mln devices. In the same year, automatic steering shipments accounted for 130,000 units. The increasing popularity of automatic steering confirms the trend of **accuracy being addictive** for farmers since it is directly related to increased productivity and savings of agricultural inputs.

In the same year, variable rate technologies complementing guidance systems accounted for around 100,000 devices, and asset management solutions for additional 70,000 units.

Galileo and EGNOS are key tools for the simplification and modernisation of checks under the Common Agricultural Policy

Since 1962, and throughout a series of reforms, the CAP has not only supported farmers in their efforts to supply EU citizens with high quality and safe food; it has also been guiding the implementation of sustainable agriculture across the EU. The recent amendment to the regulation introduced in May 2018, attempts to modernise the implementation of checks for area-based payments and for cross-compliance requirements. This **landmark change foresees that modern solutions such as geo-tagged photos, EGNSS-enabled receivers, drones and data from Copernicus Sentinel satellites are used to carry out checks**. This new 'monitoring approach' promises significant benefits for farmers and administrators alike. The realisation of these benefits will be facilitated by the improved accuracy and increased availability provided by Galileo and EGNOS. In addition, the Galileo Open Service Navigation Message Authentication (OS-NMA) will significantly facilitate the performance of robust checks.

The European Commission, in cooperation with GSA and JRC, is leading an effort to build an Android-based Open Source Application which will help to achieve better positioning accuracy and increased robustness for geo-tagging photo applications for post-2020 CAP.

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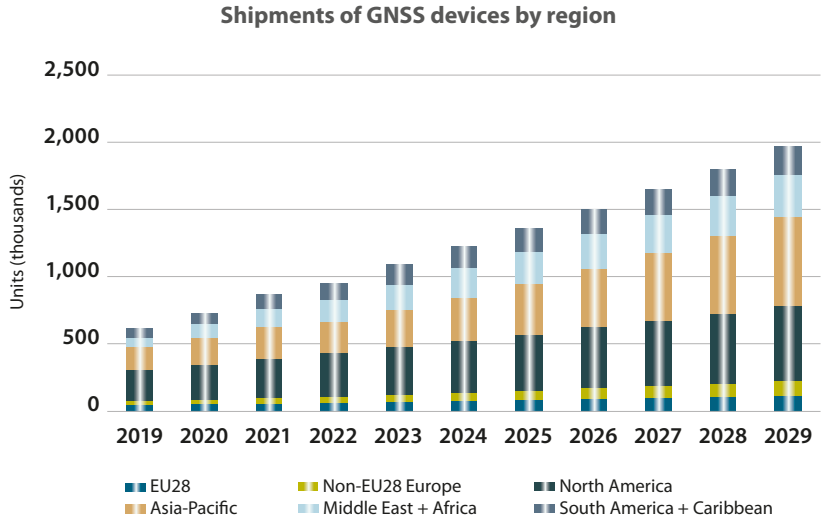
GNSS is key to exploiting the full potential of future evolution in agriculture



Growth in GNSS adoption is forecasted across the globe

In the coming years, the **transition** from tractor guidance to **more advanced steering solutions** will continue. After 2025, as the **overall market will account for 1.5 mln** units sold, automated steering shipments will outweigh sales of tractor guidance solutions. At the same time, variable rate technology will gain prominence to the point of becoming the single most sold application. The possible advantages from the optimisation of agricultural inputs will lead farmers to make their implements smarter, independently from the sophistication of the steering systems they adopt.

Moving to the regional level, demand for precision agriculture solutions in **Asia-Pacific** will be a major driver for market growth. Although the region includes very diverse countries in terms of agricultural holdings and agriculture digitalisation (such as Australia, China, India, Japan, South Korea and others), in many cases the investment and political support in agriculture by many governments will play a key role in the uptake of GNSS. **North America** will remain a large – as well as the most advanced – market for precision agriculture. Similarly, in **Europe**, GNSS market growth will be driven by the increasing number of smart applications in use, rather than by first-time adoption.

GREEN PATROL

HORIZON 2020

European GNSS is powering cutting edge solutions, from R&D to the market – the case of GreenPatrol

The H2020 GreenPatrol project makes direct use of the added-value provided by European GNSS to develop an innovative robotic solution for Integrated Pest Management in greenhouses. The GreenPatrol solution relies on the increased accuracy provided by Galileo, thanks to its signal strength inside the greenhouse and to the availability of multiple frequencies. Together with visual sensing and deep learning techniques, European GNSS enables the GreenPatrol robot to detect and control pests in greenhouses efficiently. This can significantly contribute to increased yields for the farmers.

More information on:
http://www.greenpatrol-robot.eu/

© Green Patrol

Precision Agriculture at your fingertips!

From data collection to crop scouting, and from hiring farm machinery to tracking its performance, **mobile apps are becoming increasingly important in precision agriculture**. The evolution of the market is driven by numerous start-ups who seek to break through to smallholder farmers, and by established market players who promote advanced farm management solutions among their existing clients. App developers are benefitting by the **emergence of dual frequency GNSS smartphones** in the market and by the **availability of GNSS raw measurements at the Operating System level** – for Android 7.0 (and higher). They can now access GNSS clocks, navigation messages and measurements, allowing them to develop more advanced smartphone-based solutions. Such efforts are supported by GSA through the recently launched GNSS Raw Measurements Task Force (more information in the section on User Perspectives within the Consumer Solutions segment).

In the developing world, mobile apps are often seen as a breakthrough allowing the realisation of precision-farming benefits for smallholder farmers. Meanwhile, in Europe, the uptake of mobile apps by farmers will be driven by regulatory provisions such as those related to geo-tagged photos in the post-2020 CAP.

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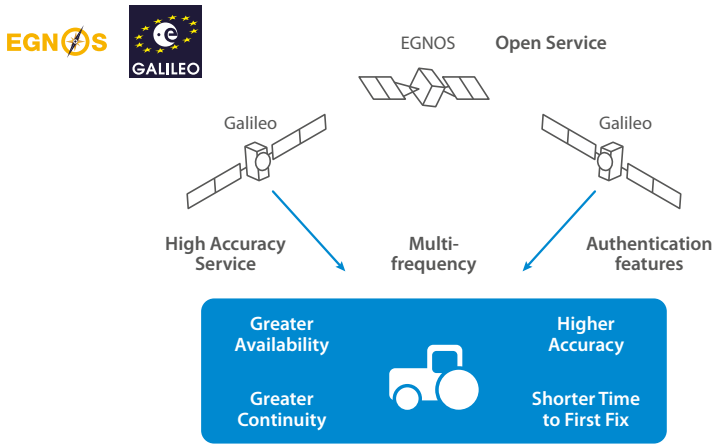
The added-value of European GNSS is driving its adoption in farming solutions



Cost-benefit tools at farm level are essential for increased adoption of precision farming solutions – the EASE Tool

© Getty Images

The lack of a clear understanding of the costs and benefits associated with precision agriculture solutions, is often a major barrier for their adoption by farmers. Recognising this need, **the EASE (Egnos sAvingS in agriculturE) tool intends to provide farmers with cost-benefit analyses on the introduction of EGNOS for machinery guidance in some of their typical agricultural practices**.

The tool uses a comprehensive model to calculate different types of savings (fuel, inputs, time/labour) considering the specific circumstances of a given farmer. The basis of these savings lies in the reduction of the pass-to-pass error provided by EGNOS with respect to the case of an unaided driver or using only GPS. The tool can perform scalable studies, including as many operation tasks as the farmer considers relevant. In the end, the user can print or export the results obtained. The EASE tool is mostly applicable for those types of crops that do not require very high precision solutions, i.e. extensive crops in dry areas, such as dryland cereals, legumes and sunflowers.

More information: EGNOS Support website

Current usage of Galileo

GNSS lies at the core of numerous applications helping farmers to increase their productivity and reduce their environmental impact. Galileo is not only contributing to the improved execution of multiple-precision farming practices; it also enables new applications thanks to its unique features (for instance authentication). Its continuously increasing adoption in agriculture is reflected in the proliferation of Galileo-enabled receivers for machine guidance applications. Moreover, all major agricultural machinery manufacturers are 'Galileo-ready', whilst most augmentation service providers and device vendors are incorporating Galileo in their offering too.

More information and up-to-date numbers can be found at https://usegalileo.eu/EN/

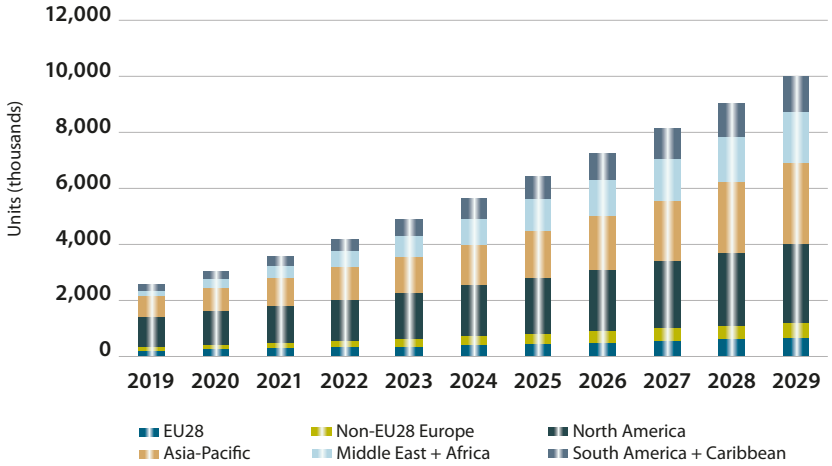
Galileo differentiators for agriculture

Farmers across the globe can strongly benefit from the added-value enabled by Galileo. This entails increased availability, continuity and reliability thanks to the multiple frequencies of Galileo Open Service. Moreover, this enables better resilience to multipath effects and improved convergence time when Galileo is integrated into PPP solutions. Galileo will also offer increased robustness to spoofing thanks to its Signal Authentication Service (SAS) and the Open Service Navigation Message Authentication (OS-NMA). As the use of robotics and autonomous vehicles is increasing in agriculture, so will the importance of this Galileo differentiator. Finally, Galileo's third frequency (E6) allows faster convergence times thus contributing to PPP and RTK solutions.

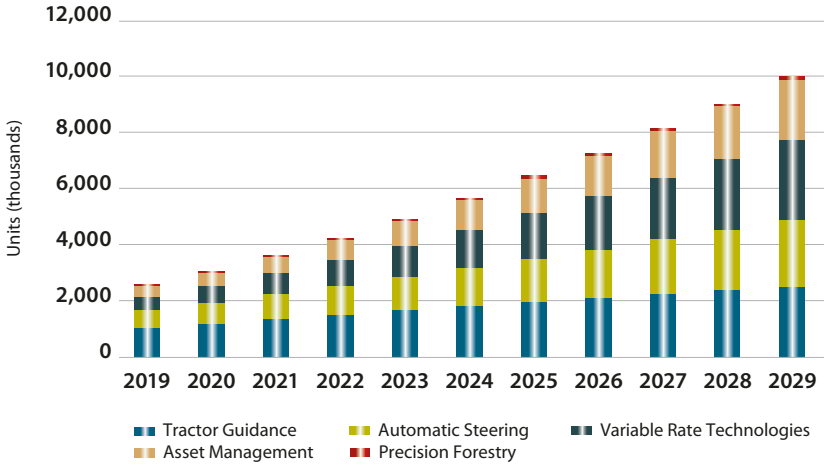
EGNOS: 'You don't know what you have until it's gone'

The true value of a solution is often fully realised only when it is not available. This is exactly the case with EGNOS and the recent PRN rollover that caused a brief, yet significant, disruption to farmers across Europe. On that occasion, several vendors of solutions utilising EGNOS were contacted by their clients about decreased performance (accuracy). This goes to show the importance of the continuous availability of European GNSS signals for the execution of precision farming activities. In the case of EGNOS, its strong value to farmers can be also better understood through the use of the EGNOS Agricultural Demonstrator available at: https://egnos-user-support.essp-sas.eu/new_egnos_ops/egnos-agricultural-demonstrator.

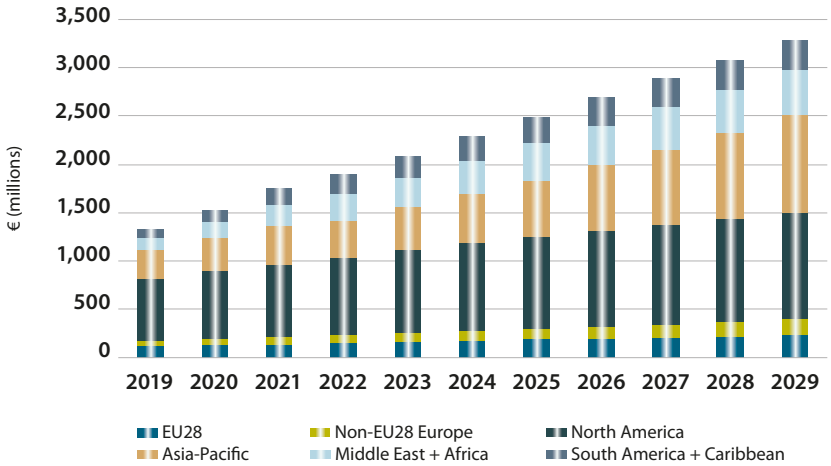
Installed base of GNSS devices by region



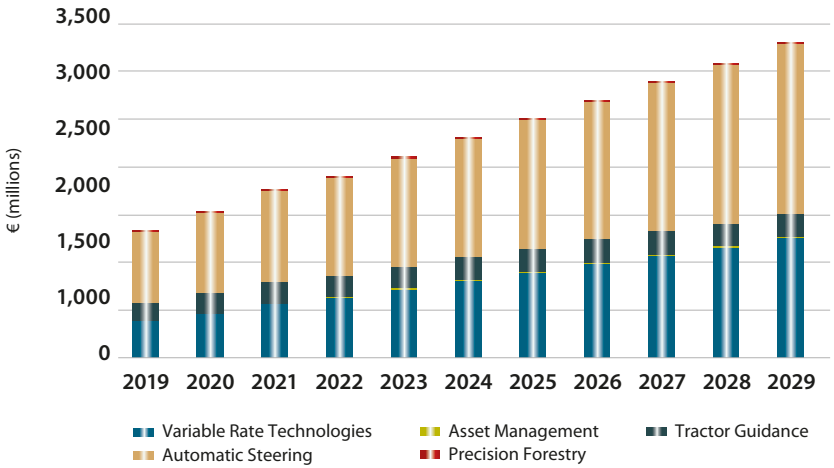
Installed base of GNSS devices by application



Revenue of GNSS device sales by region



Revenue of GNSS device sales by application



GEOMATICS

GNSS applications

Geomatics[1] utilise many geo-data collection services and tools: land surveying (including cadastral, construction, mapping and GIS, mining or infrastructure monitoring), photogrammetry and remote sensing, marine surveying and others. This chapter focuses on the major applications within geomatics, for which high-precision GNSS is either the paramount tool, or a key enabler.

- **Cadastral surveying** aims at establishing property boundaries. Fiscal policies such as land taxation rely widely on highly accurate and reliable GNSS measurements.
- **Construction surveying:** Person-based applications cover the different construction stages of a building or civil engineering work, whereas machine control applications automate construction activities thanks to GNSS that require human intervention.
- **Mine surveying** involves GNSS measurements and calculations at each phase of open-pit mine exploitation, including safety checks.
- **Mapping and GIS:** defines specific location points of interest for cartographic, environmental and urban planning purposes mainly via GNSS data collection.
- **Infrastructure Monitoring:** critical physical infrastructure and the natural environment is monitored via GNSS to prevent disasters and promptly intervene in case of emergency.
- **Marine surveying** encompasses a wide range of activities that rely on GNSS (seabed exploration, tide and current estimation, offshore surveying, etc.), and their outcomes are important for maritime navigation.

NEW

The **traditional surveying** portfolio of high-precision GNSS-enabled applications is now extended under the broader prism of Geomatics.

- **Photogrammetry:** terrestrial or airborne methods for terrain and object modelling rely strongly on real-time or post-processed GNSS for georeferencing purposes.
- **Laser scanning:** point clouds, collected via terrestrial laser scanning (static or mobile) and mobile mapping systems are georeferenced via high-precision GNSS.
- **Remote Sensing:** specific GNSS techniques for georeferencing of satellite-derived datasets can be used to complement Copernicus in applications such as soil moisture estimation or ground deformation monitoring.

What you can read in this chapter

- **Key trends:** The geomatics GNSS market faces the 4th Industrial Revolution.
- **User perspective:** Emerging applications call for updated standards and user requirements.
- **Industry:** Geomatics Value Chain.
- **Recent developments:** Innovative high-precision services provide cross-sectoral benefits to GNSS users.
- **Future market evolution:** A steadily growing GNSS market will reach stable levels in a decade.
- **European GNSS:** Galileo provides unique differentiators to the geomatics industry.
- **Reference charts:** Yearly evolution of installed base of GNSS devices and revenues by application and region.

[1] According to ISO/TR 19122:2004, geomatics comprises "the collection, distribution, storage, analysis, processing, presentation of geographic data or geographic information"

For more see: https://www.iso.org/standard/31088.html

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The geomatics GNSS market faces the 4th Industrial Revolution

Key market trends

- Digital transformation of the geomatics sector is driven by pay-per-use services and boosted by cloud computing
- The X-as-a-Service model provides better scalability and interconnectivity across geomatics applications
- Emerging applications in geomatics are driven by the 4th Industrial Revolution and advanced GNSS capacities

From the ground to the cloud: the digital transformation of surveying

The role of the traditional GNSS surveying is undergoing a rapid transformation thanks to the integration of emerging digital data collection techniques. Geomatics applications that rely on GNSS in combination with terrestrial or airborne sensors (optical, multispectral, RADAR or LiDAR) are focusing the implementation of solutions directly in the cloud. Intelligent processing of large GNSS-positioned datasets (e.g. cloud-based SLAM) provides fast and efficient transformation of Big Data to meaningful geo-data. This model ensures that the timeline between the GNSS-enabled measurements and the service delivery is shortened dramatically with reduced costs. On the other hand, software and added-value service providers continue to offer various pre-paid schemes to their customers (for access to RTK networks data, post-processing and analysis services, etc.), making **Subscription** one of the leading business models within geomatics.

Geomatics is an important cross-sector enabler

Geomatics is a highly demanding segment, which provides other business sectors (such as autonomous driving and drones) with precise GNSS data and versatile consultation services. This cross-sectoral integration is empowered by the implementation of emerging business models, such as **Capability-as-a-Service**. This approach, instead of focusing on separate sector-oriented products, provides complete consumer-centric solutions (including implementation, operation and maintenance) that combine GNSS with other geospatial technologies – SLAM, drones, crowdsourced mapping, AR and mobile mapping. Furthermore, the **Platform business model** and its related ecosystem of apps, marketplaces and services, is also being adopted. An increasing number and variety of mobile platforms are developing because of the dramatically increasing flexibility of data collection, as mass-market and high-precision GNSS capabilities are converging at a fast pace.

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The downstream GNSS market is empowered by the 4th Industrial Revolution

The 4th Industrial Revolution is a term that describes the profound economic impact from the radical growth of device interconnectivity and the incorporation of sensors, robots and powerful data analytics. Prime examples in Geomatics are the sophisticated products which fuse high-precision GNSS data with machines, inertial sensors, robotics and artificial intelligence (e.g. mobile mapping systems). The uptake of Building Information Modelling (BIM) and its integration with high-precision GNSS observations provide unprecedented levels of automation, interoperability and optimised decision making for the surveying and construction industry.

Emerging applications call for new standards and user requirements

Overview of the main user requirements in Geomatics

The following table incorporates all priority elements, specified in the Report on Surveying User Needs and Requirements and verified at two consecutive User Consultation Platforms. Accuracy is the only element that is quantified, as its magnitude is of paramount importance for the Geomatics users, while the rest of the requirements are qualitative and vary in terms of their application. All requirements are subject to constant refinement and amendment as new geomatics technologies arise.

Applications	Cadastral & Construction	Infrastructure monitoring	Mine surveying	Mapping and GIS	Marine surveying
Key GNSS requirements	Accuracy (down to mm), Availability, Continuity, Time To First accurate Fix (TTFaF)	Accuracy (down to mm), Availability, Continuity, TTFaF	Accuracy (down to cm), Availability, Continuity, TTFaF	Accuracy (down to cm) Availability Continuity	Accuracy (down to cm) Continuity Integrity
Other requirements		Connectivity Interoperability		Connectivity, Size, Weight	Interoperability Resilience

Growing user adoption of GNSS-based technologies in geomatics drives the need for new standards

As many new methods and tools arise, so does the need for well-defined requirements and standards, for instance, the **implementation of drone GNSS observations** for cost-effective, high-productive and accurate georeferencing of acquired data. Within mobile mapping systems, a set of standards would frame the **fusion of GNSS with LiDAR, optical cameras, inertial and distance measurement instruments**. Other key areas requiring stringent requirements and standards are seamless indoor-outdoor positioning and PPP-RTK. The recent advancement of augmented reality applications that rely on GNSS accuracy and availability would also benefit from the definition of certain standards.

GNSS provides high-precision data to integrated BIM/GIS solutions

Regarded as separate geomatics domains, BIM and GIS are now integrating into a single holistic environment. The process of accurate 3D modelling – common for both - is leveraged by high-precision GNSS location data. When stored and processed in the cloud, the GNSS, GIS and BIM information enable stakeholders in the whole construction industry to remotely manage data everywhere and produce better building/infrastructure designs with long-term savings. Moreover, the innovative concept of 5D BIM leverages 3D modelling with the addition of cost-related information and time.

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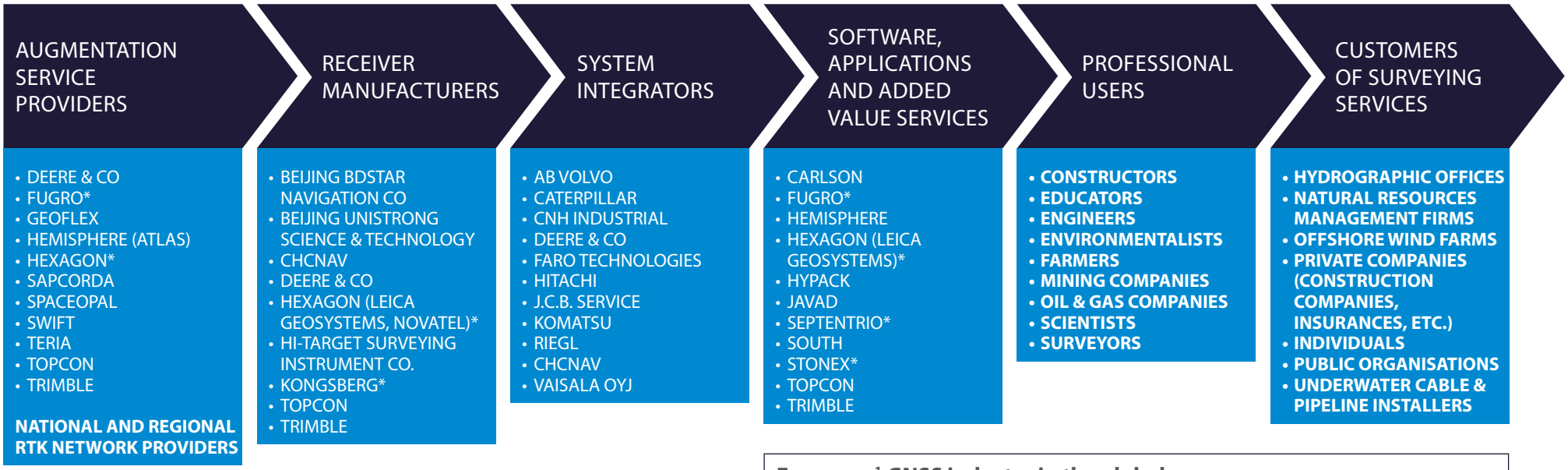
Geomatics Value Chain



European[1] GNSS industry in the global arena

Trimble, Hexagon and Topcon together cover just under 80% of the GNSS receivers production in 2017. Although the market continues to be dominated by the established players, emerging companies from China and Europe are starting to effect a slight market reshaping. European companies now hold almost half of the market (43%), with North American players accounting for 29%, followed closely by Asian firms with 28% of worldwide production.

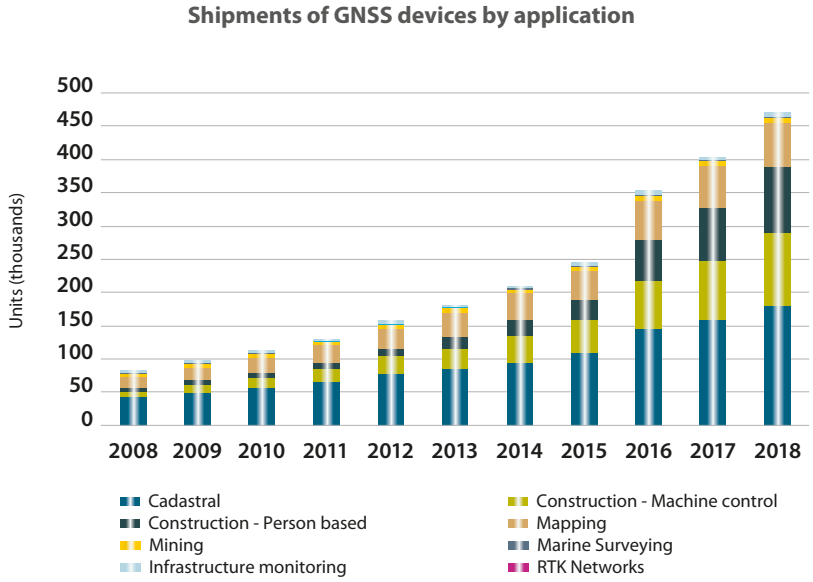
Concerning system integrators, different players are active according to the various applications (construction, mapping, marine surveying, etc.). The regional industry shares are distributed among North America (49%), Europe (14%) and Asia + Russia (37%). Within this segment J.C.B., RIEGL and CHN Industrial represent the top European companies.

[1] In the market share analysis, Europe is defined as EU28 plus Norway and Switzerland.

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

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

Innovative high-precision services provide cross-sector benefits to GNSS users



Shipments in the geomatics sector have experienced tremendous growth

In the geomatics segment Cadastral Surveying, Mapping, Person-based Construction and Machine Control account the vast majority of revenues.

It is therefore unsurprising that geomatics, a rather stable market during the global economic downturn, has experienced in the past years a staggering growth in terms of GNSS adoption, driven by both the sustained growth of the construction sector in emerging markets (almost +60% in the past decade) and the drop in prices caused by the entry of Asian suppliers in the competitive arena.

In line with the above, **Asia** has experienced a steep positive trend, with overall shipments of geomatics devices growing on average 33% per year between 2008 and 2018. The same holds for **Middle-East** and **Africa**. In the same period, **EU-28** and **North America**, which represent more mature markets and feature a more stable construction sector, have grown at a slower pace (8%).

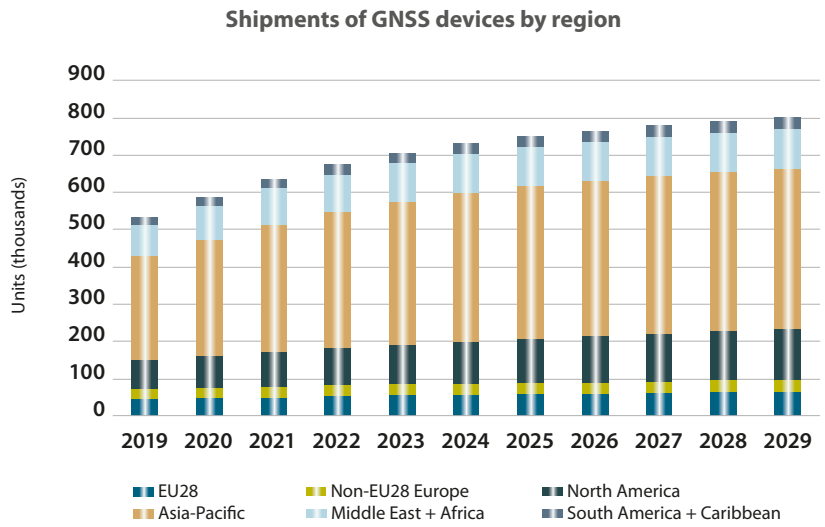
Drone market invests in new GNSS techniques for positioning

The global geomatics sector continues to be dominated by the dramatic rise of professional high-precision GNSS-enabled drones. This market provides solutions that have shadowed the role of the traditional GNSS surveyor. Consequently, R&D for optimised GNSS positioning of drones is yielding a return on investments. Dual-frequency RTK drones are becoming common in the industry. Apart from RTK, in the last few years, manufacturers of drones started to integrate Post Process Kinematic (PPK) capable GNSS functionality for accurate positioning of the flight trajectory. This approach leverages the global densification of CORS networks, thus providing easier data processing and cost-efficient results. Less investment for upfront hardware is needed, including for communication links, required by the RTK-positioned drones. Currently, drones are the ultimate tool in many geomatics applications, including small and medium site mapping, volumetric measurements and inspections, damage assessment and construction site monitoring.

Network PPP-RTK services now available for Geomatics

The growing geomatics GNSS market may now benefit from the uptake of PPP-RTK services. PPP-RTK is a modified variant of **PPP which provides single-receiver users with information that enables fast and reliable centimetre-level accuracy**. Fully operating PPP-RTK services are now available in several countries across the globe. PPP-RTK employs data from CORS networks (code and phase biases + ionospheric and tropospheric delays + clock and orbit corrections), albeit with lesser station density needed. It is expected that PPP-RTK will become an alternative to RTK and PPP in the near future. Not only it will ensure better high-precision continuity in areas with lack of internet coverage or RTK infrastructure, but will also trigger the correction services market to look for competitive pricing strategies.

A steadily growing GNSS market will reach stable levels in a decade



Shipments are gradually stabilising in the geomatics sector

In the long term, the growth of the GNSS market is forecasted to stabilise. After ten years of sustained growth, the construction sector is deemed to be close to reaching the peak of an economic cycle. **Asia-Pacific**, by far the largest market in terms of shipments already in 2019 (52%), will reach saturation in the coming years, following the same trend observed for western regions in the recent past.

In the long term, **shipments per year** (currently slightly above 500,000) are foreseen to stabilise at a value of around 800,000 units by 2029. At the same time, **pressure on prices** will continue, leading **global revenues** to peak in 2023 (€5.6 bln) and then drop at an average rate of 2% in the following years. However, this will be partially compensated by the increasing number of added-value services. Such a trend is not going to impact geomatic applications that are not closely related to **construction**, such as **mining**, **infrastructure monitoring**, **RTK networks** and **marine surveying**, which are forecast to enjoy a moderate yet sustained growth (+7% per year) in the coming years.

AEC projects are driving the geomatics market forward

Architecture, engineering and construction (AEC) are one of the key consumers of GNSS technology within geomatics. Many major infrastructure projects – from highways to whole new cities - are ongoing in India, China and the Middle East. There is a huge interest in modelling of 3D construction data. This situation provides excellent opportunities for AEC companies, and it is a major driver for industry mergers and acquisitions.

According to the latest GeoBuiz report[1], it is expected that GNSS will continue to account for almost 60% of the total geomatics market, followed by GIS, EO and scanning.

The future market evolution in the geomatics segment will incorporate IoT, robotics/autonomous vehicles, apps/mobile devices, and artificial intelligence. This fusion will in all likelihood completely transform traditional surveying, both in terms of the equipment used and methods applied.

GNSS contributes towards autonomous real-time mobile mapping

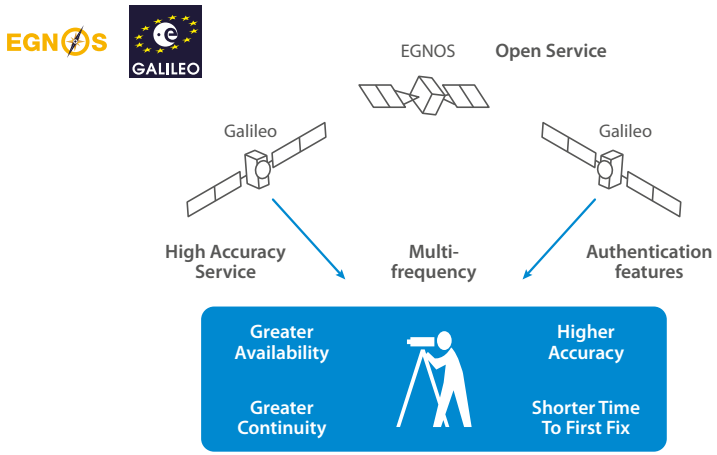
The eyes of the world are now focused on autonomous driving. GNSS provides several key contributions to that sector. First of all, high-precision GNSS is the source of reliable location data for all vehicle systems, ensuring safe lane-by-lane navigation and other positioning-related functionalities.

GNSS provides also optimal georeferencing of 3D point cloud and data acquired by scanners or cameras, to create or real-time update the high-definition maps (HD Maps) that are embedded in the vehicle software. The SLAM technique ensures real-time data processing and map creation, and the integration of INS empowers navigation in constrained environments.

The full fusion of these elements with GNSS will provide in the near future a completely autonomous machine that will collect and process geospatial data with unimaginable speed and cost savings.

[1] https://geobuiz.com/geobuiz-report-2019/

Galileo provides unique differentiators to the geomatics industry



Current usage of Galileo

Geomatics professionals already benefit from using EGNSS in a multi-constellation environment, providing higher availability, continuity, reliability and better results in harsh conditions. This is confirmed by a gradual penetration of Galileo in GNSS receivers for surveying and mapping: as of today, around 55% of the surveying GNSS receivers already support Galileo and around 90% are EGNOS-capable. In Europe, the majority of RTK providers have already upgraded or have started to upgrade to Galileo. This example is followed by major PPP and PPP-RTK providers that also support Galileo in their correction services.

Galileo services and features to be explored

Along with the Open Service Galileo will also offer a **free-of-charge High Accuracy Service (HAS) that will deliver PPP corrections across the globe** directly via Galileo satellites on the E6 frequency. This service is targeted at decimetre-level applications, such as GIS and mapping but will also entail a technological breakthrough for mass-market applications requiring high accuracy positioning.

Additionally, users will also benefit from authentication services through the Open Service Navigation Message Authentication (OS-NMA) and the Signal Authentication Service (SAS) to assure that the positioning is based on authentic measurements and data transmitted by Galileo satellites, to prevent spoofing. The surveying community has also started to exploit the benefits of using Galileo multi-frequency capability (E1, E5a, E5b, E5 AltBOC, E6) for advanced positioning techniques such as three (or four) carrier ambiguity resolution for faster TTFF.

Gims

HORIZON 2020

Project GIMS (Geodetic Integrated Monitoring System) leverages synergy with EO and sensor fusion

The main objective of the GIMS project is to **build and commercialise an advanced low-cost system based on EGNSS, Copernicus SAR and other in-situ sensors**, like inertial measurement units, for the purpose of monitoring ground deformations with a focus on landslides and subsidence. The system will recover deformations with millimetre-level accuracies and daily acquisition rate. Moreover the integration of in-situ accelerometers will give real-time alerts in case of sudden movements. Finally the low-cost infrastructure deployed for the landslide monitoring can be used as a collector of environmental data for smart grids purposes.

© GIMs

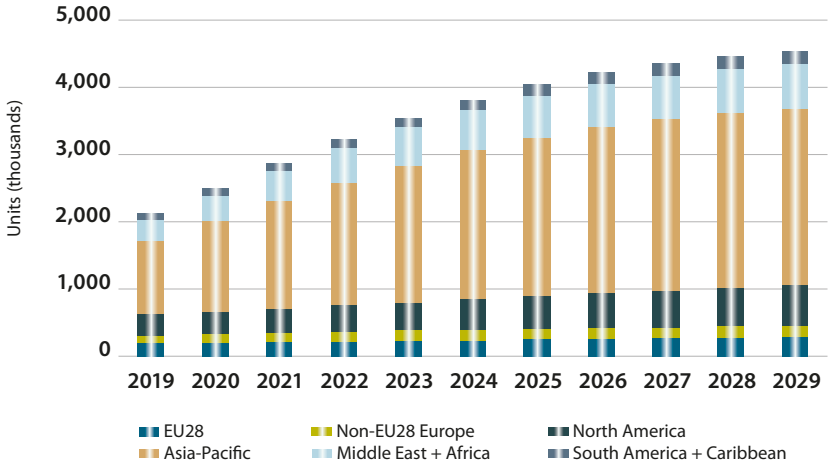
More information on: https://www.gims-project.eu/about/

CLGE Students' Contest

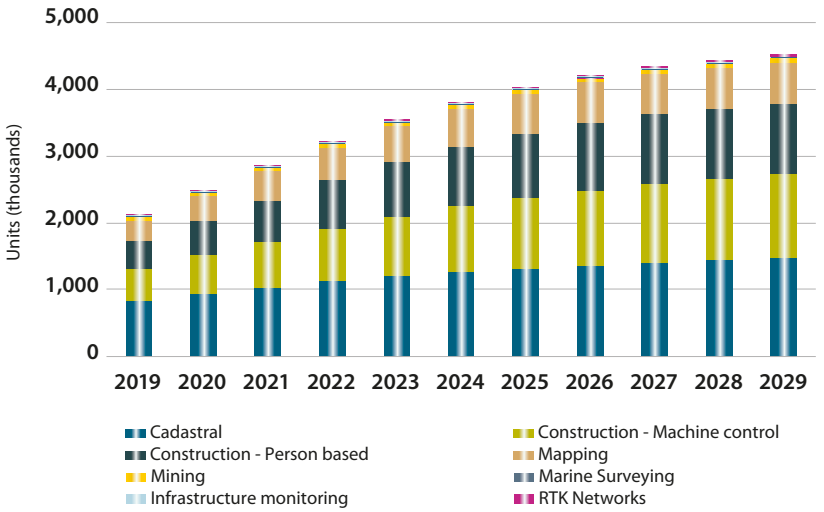
The GSA, in cooperation with the Council of European Geodetic Surveyors (CLGE), contributes to the organisation of the annual CLGE Students'Contest, promoting innovative ideas in different areas of Mapping and Surveying in order to increase the adoption of Galileo, EGNOS and Copernicus by the Surveying community. The winning team gets a €1,000 prize and is invited to participate at the yearly INTERGEO conference.

More information on: https://www.gsa.europa.eu/clge-student-contest

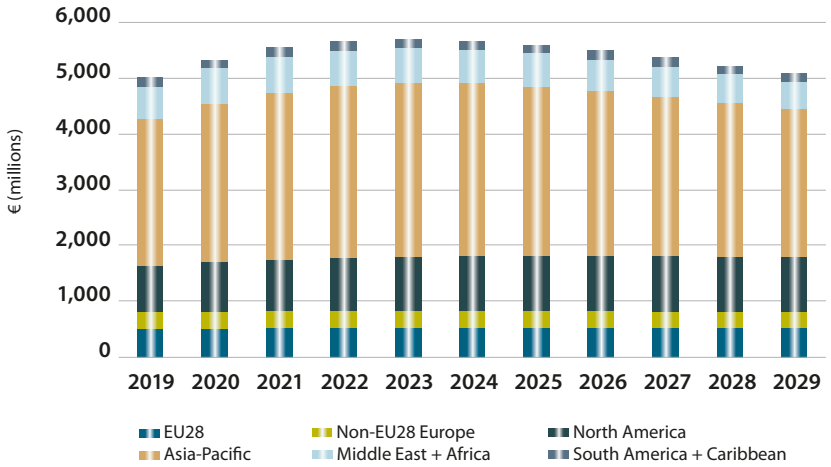
Installed base of GNSS devices by region



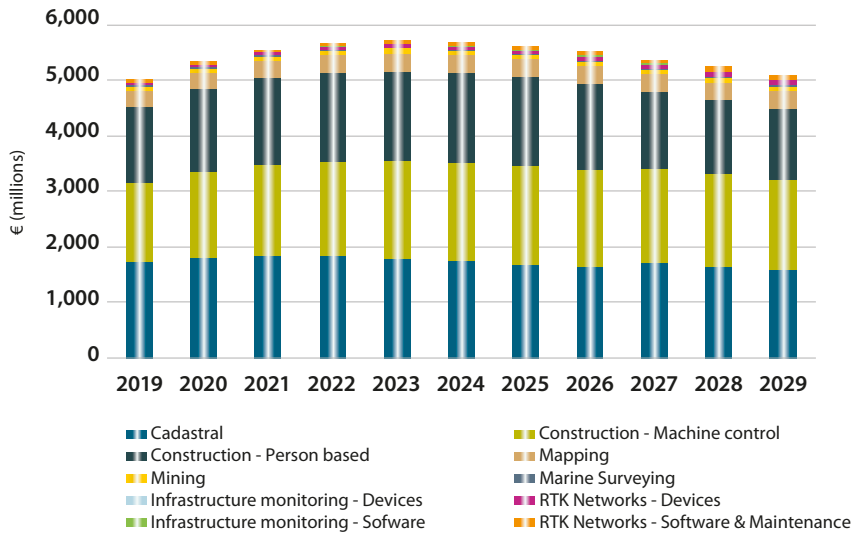
Installed base of GNSS devices by application



Revenue from GNSS devices sales and services by region



Revenue from GNSS devices sales and services by application



CRITICAL INFRASTRUCTURES

GNSS applications

- **Telecommunication applications:** Telecom operators require accurate time and a consistent frequency at distant points of their networks to meet increasingly demanding broadband requirements.
  - **Digital Cellular Network (DCN):** GNSS is used to provide consistent frequency and time alignment between all base stations within the network.
  - **Public Switched Telephone Network (PSTN):** GNSS is usually a back-up to atomic clocks to provide time slot management.
  - **Professional Mobile Radio (PMR):** GNSS is used for synchronisation of time slots and handovers between base stations.
  - **Satellite Communication (SATCOM):** GNSS is typically used in Satellite Control Stations and Telecommunications Gateways, mostly for frequency control.
  - **Small cells:** GNSS is used to provide frequency and phase alignment in small cell networks.
- **Energy applications:** Energy operators require an accurate time source to monitor the energy flow of their networks.
  - **Phasor Measurement Units (PMU):** GNSS is used to provide a precise timing marker at nodal points of the networks to ensure monitoring and protection against failure.
- **Finance applications:** Financial institutions are legally required to trace operations within a consistent and accurate time scale.
  - **Bank applications:** GNSS is used for time-stamping functions to log events in a chronological manner, and therefore be able to establish causal links.
  - **Stock Exchanges:** GNSS is used by Stock Exchange servers to apply time-stamps to the trades they execute and to the quotes they establish.

What you can read in this chapter

- **Key trends:** New paradigms are set to play an increasingly important role for Critical Infrastructures protection as resilience needs continue to grow.
- **User perspective:** GNSS uptake enabled by the development of high performance T&S devices.
- **Industry:** Critical Infrastructures Value Chain.
- **Recent developments:** Regulation and 5G to seize new market opportunities.
- **Future market evolution:** Sustainable growth of the GNSS T&S market expected despite competition from network-based technology.
- **Focus on European GNSS:** High Accuracy and Authentication are the two most desired EGNSS features.
- **Reference charts:** Yearly evolution of GNSS devices' installed base and revenues by application and region.

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New paradigms set to play an increasingly important role for Critical Infrastructure protection as resilience needs continue to grow

Key market trends

- GNSS Timing and Synchronisation (T&S), being a mature market, experiences a low growth rate; however, emerging paradigms (e.g. Time-as-a-Service) and innovative applications are expected to create new drivers of growth
- The greater need for resilience and improved accuracy, alongside regulation, is set to stimulate the GNSS T&S market
- Telecom applications are still driving the market with 5G expected to boost future GNSS deployment

Growing cyber threats and potential domino effect

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With its long heritage in providing timing and synchronisation to a wide range of sectors, GNSS has become an indispensable tool for Critical Infrastructure (CI) operations. Several cybersecurity experts predict that future attacks on CI will be more sophisticated and damaging.

Protecting CIs and their major components is therefore essential to maintain vital societal functions. As different CIs depend on others, it is necessary to be conscious of the potential **domino effect** that might ensue if one CI were to fail. Indeed, interactions between various critical infrastructures, as well as across countries are important considerations in respect of this domino effect. For instance, disruption of energy grids may impact Telecom and Finance networks at a regional, national or even cross-border level.

Resilience and robustness required for future market development

Deployment of IoT, 5G and automation (in particular autonomous cars) are expected to be significant drivers of growth for the GNSS timing market. However, development of these **new applications increases the number of potential victims of attack**. The resilience of the timing functionality is therefore paramount in order to ensure service continuity.

Time-as-a-Service to provide traceability and improved resilience

GNSS usage may be impeded by signal propagation and accessibility issues that can sometimes make GNSS difficult to deploy. Moreover network operators increasingly consider time as a commodity while requiring commitments on reliability, integrity, authentication and traceability whatever the time source. Several service provision schemes have emerged to respond to this demand. They rely on the use of stable oscillators tuned by GNSS signals as well as multiple timing sources including: multi-constellation, LEO communication constellation or network synchronisation propagation (e.g. SYNC-E, Precise Time Protocol). 'Time-as-a-Service' (TaaS) solutions, therefore, emerge as commercial solutions to improve robustness, resilience and provide service commitment.

FANTASTIC Fundamental Elements

FANTASTIC Anti-Spoofing Technology Protects Critical Infrastructure

FANTASTIC (Field Aware Navigation and Timing Authentication for Timing Infrastructure and Centimetre level positioning) is a **Fundamental Elements** project which aims at increasing availability, reliability and security of professional GNSS systems. One of the targets was to develop technology protecting critical infrastructure from spoofing attacks. Many installations rely on GNSS for timing, including telecom infrastructure, power grid and financial centres.

The static nature of these installations makes it rather easy to set-up a so-called carry-away spoofing attack. In such a case, the attacker sends simulated signals into the GNSS antenna, gradually overpowering authentic GNSS signals and altering their timing. This attack will eventually hijack the timing source of the installation, potentially leading to catastrophic events. This kind of spoofing attack can be generated with a low-cost software-defined radio connected to a mini-computer.

FANTASTIC leverages EGNSS to increase security and counter spoofing attacks. With OS-NMA, Galileo is the first satellite system to introduce an explicit anti-spoofing feature on a civil signal. OS-NMA allows to continuously evaluate the authenticity of the navigation message using similar technology as online banking security. In the framework of the FANTASTIC project, OS-NMA spoofing protection was prototyped and demonstrated on a Septentrio GNSS receiver.

More information on: http://gnss-fantastic.eu

GNSS uptake enabled by the development of high performance T&S devices

Growing interest from vertical markets

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GNSS Timing and Synchronisation needs are **transversal to many critical domains**. In addition to the Telecom, Energy and Finance applications a wealth of market opportunities emerge for highly performant GNSS.

A major opportunity is linked to the advent of **autonomous cars**. New generations of cars will be communicating nodes in a real-time cooperative network. Besides, cooperative data fusion requires that any sensor data within the vehicle is accurately time-stamped. Sharing information between cars – and between sensors in a given car – therefore requires accurate, robust and consistent timestamping. An extremely reliable timing system is needed with an accuracy of around 0.2 to 0.1 millisecond to UTC.

Moreover, the booming development of cloud computing and big data has confirmed the T&S needs of **data centres** (see box on the right). Distributed over the world, data centres can be of different sizes with customers operating worldwide. Hundreds up to thousands of data centres' sites can be operated by a cloud provider with typically billions of connected machines. The consistency of the data needs to be ensured locally and globally, with a millisecond-level of latency to recover the data and allow redundancy of data storage.

Many scientific applications require nanosecond level of precision, which can be provided by GNSS. These applications include, radio astronomy, particle physics experiments and time metrology.

Solving calibration issues to maximise GNSS penetration

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Network calibration and monitoring often provide a hurdle to network operators. Verifying and testing the level of timing accuracy in the field may even be more challenging than network synchronisation. Thus there is an increasing **demand for calibration** of hardware equipment for both scientific and industrial applications.

Strong growth of the data centre market is calling for highly accurate and reliable timing capability

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Greater use of the Internet and cloud computing by organisations and individuals has resulted in rapid and robust development of the data centre market.

The demand to provide computing power and data storage is not expected to slow down evidenced by the huge investments in Hyperscale Data Centres. The **data centre market has therefore exploded** and is expected to continue to develop at a rapid pace. According to Credit Suisse, the data centre colocation and interconnection market should reach €28 bln in 2021. GNSS is expected to benefit from this vivid market development as the only affordable means to an accurate global time reference (UTC).

Overview of the main user requirements for Critical Infrastructures

The following table incorporates all the prioritised requirements specified in the Report on Critical Infrastructures' User Needs and Requirements and verified at two consecutive User Consultation Platforms. The value of accuracy for Telecom is of importance for the Digital Cellular Networks operators and is, therefore, the only quantified value. The remaining requirements are qualitative and vary in terms of their application. All requirements are subject to continuous refinement and amendment.

	Telecom (PSTN, PMR, DCN, Satcom and Small Cells)	Energy (PMU)	Finance (Bank applications and Stock Exchanges)
Key GNSS requirements	Accuracy (up to 100 ns) Authentication Robustness	Authentication Robustness	Authentication Availability
Other requirements	Resilience Calibration	Resilience Calibration	Resiliency Traceability Calibration

Critical Infrastructures Value Chain

European[1] GNSS industry in the global arena

The timing receiver market continues to be dominated by established players, with market presence varying across segments (e.g. Telecom, Power and Finance). European companies hold a strong position in the global timing receiver market forming 44% of the overall market. Three of the world's top five GNSS timing device manufacturers are European-owned and based (Spectracom, OscilloQuartz, Meinberg), standing for around 28% of the overall market share in 2017.

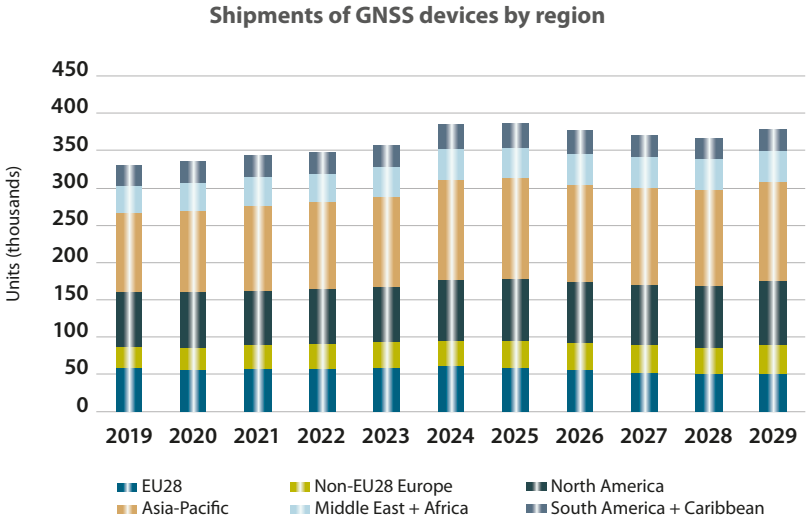
European timing system integrators also hold the largest market share, with European companies accounting for 62% of the market. The top three electricity network infrastructure vendors, ABB, Siemens and Alstom, are European-owned and based and comprise two of the top three mobile telecoms infrastructure vendors (Ericsson and Nokia Siemens Networks).

[1] In the market share analysis, Europe is defined as EU28 plus Norway and Switzerland.

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

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

Regulation and 5G to seize new market opportunities



Telecom still the most prominent market for GNSS

The GNSS T&S segment continues to be **dominated by the Telecom applications** which represent more than 90% of devices shipments. Asia-Pacific, EU28 and North America are the most active regions, driven by the deployment of 5G and small cells infrastructures. A peak of GNSS shipments is therefore expected in 2024/2025 as a consequence of the significant rollout of telecom infrastructures in these regions.

The shipments also increase because telecom network operators renew the T&S devices at an increasing frequency to benefit from new technological development and meet more stringent requirements, e.g. moving from frequency stability requirements to phase synchronisation. The average device lifetime of 8-years **is therefore decreasing** and could reach 5 years with the advent of 5G in 2020/2021. Meanwhile, **price erosion** might happen due to strong customer pressure and harsher competition from new actors, especially from the Asia-Pacific. However, revenues are not expected to be impacted owing to the inclusion of new features and improved performance for network resilience that insulates the industry from this price erosion.

Energy and Finance benefit from regulation implementation

The **Energy** PMU market is growing slower than expected in the absence of a strong push from the operators to change existing equipment. However, the strong growth of the global energy demand coupled with the need for sustainable and secure infrastructure is expected to revitalise the GNSS T&S market. With more than 2,500 PMU deployed in 2017, North America remains ahead in terms of PMU deployment followed by Asia Pacific. Regulations are expected to impose certification requirements which will limit device price erosion.

In the **Finance** segment, the MiFID II regulation positively impacted sales. Recent relocation of finance institutions and risk sharing issues led financial institutions to acquire new equipment resulting in a positive impact on the European GNSS market. Similarly to the Telecom segment, the average device lifetime has consequently decreased to about 5 years. The volume of funds at stake in the finance sector means users would want to benefit from the latest technology. Finance users would be willing to pay a premium in order to acquire state of the art T&S solutions, if the benefits outweigh the costs.

5G: a huge potential market for GNSS, bringing challenges and opportunities

5G will deliver high-speed, low-latency and high-capacity broadband connectivity that will open the door to a new generation of applications. Several mobile 5G commercial launches are expected over the next three years in North America, Asia-Pacific and Europe with 1.2 bln 5G connections expected in 2025 according to the GSM Association (GSMA). Deployment of 5G networks require significant investment from telecom operators. Some seek to limit the financial cost and therefore consider the possibility of reusing Timing and Synchronisation technologies developed for 4G.

However, the 5G T&S function may require more precision and more robustness than 4G, and will face more deployment challenges (e.g. a large number of sites in difficult locations).

The availability of accurate, cost effective and robust, dual frequency GNSS systems, in particular Galileo, will be critical in providing business opportunities within the 5G market.

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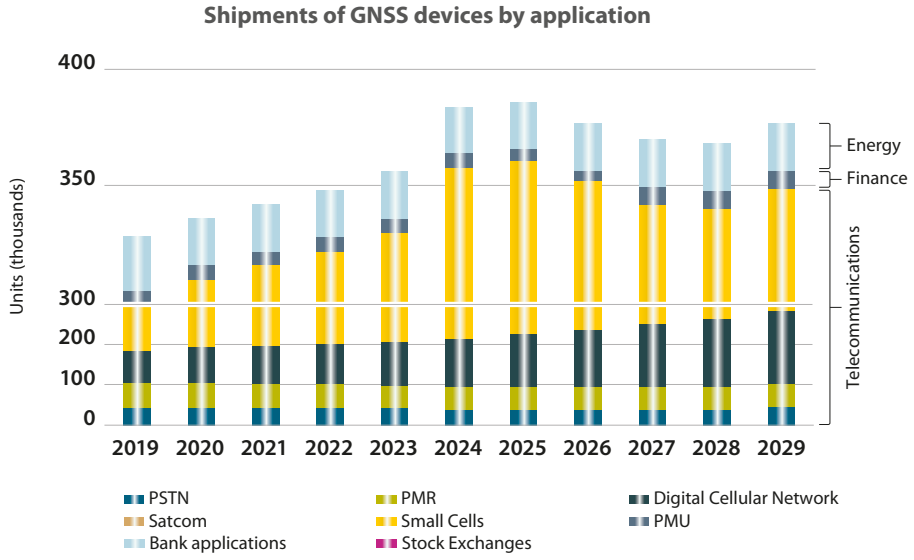
Sustainable growth of the GNSS T&S market expected despite competition from network-based technology

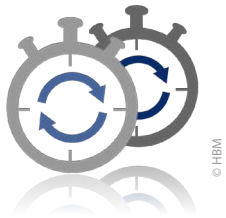


Precise Time Protocol (PTP) deployment might affect GNSS sales

GNSS is not the only source of precise and accurate T&S, and users increasingly consider alternative or complementary technologies to improve resiliency. PTP is one such technology that is already used by European telecom network operators. In North America and parts of Asia-Pacific, the network architecture is more GNSS dependent owing to historical conventions and rapid network development.

The deployment of PTP is likely to impact the future GNSS market. The technologies can be seen as **substitutes**, e.g. for small cells, where PTP offers an alternative source of time and therefore allows the operator to reduce the dependence on GNSS. Similar effects are already observed in PMUs, where devices are prepared to receive PTP inputs and in finance, where operators are starting to consider using PTP.

However, combining GNSS and PTP improves the resilience of T&S of critical infrastructures, GNSS T&S receivers will therefore always play an important role.



Overall, **GNSS T&S shipments are expected to grow at a CAGR of 1.4% over 2019 – 2029**. The Telecom market is expected to be the main contributor with a CAGR of 1.5% over this period while Energy (+3.1%) and Finance (-1,7%) will have a limited impact on GNSS shipment.

5G deployment should compensate small cells sales decrease from 2025

The telecom GNSS T&S market is expected to maintain continued growth over the following year, though the impact of alternative technologies may limit this growth. The outlook for GNSS sales in the Telecom segment remains bright with the upcoming 5G deployment. The subdued Telecom growth is mainly due to the GNSS small cells slowdown. The main reasons for this slowdown can be attributed to relaxed small cells deployment from 2025 and an increase in the use of other T&S technology for pico and microcells T&S (e.g. PTP).

However, the **Digital Cellular Network** applications will compensate this drop with a CAGR of 8.7% over 2019 – 2029 thanks to 5G roll-out. Shipments of the other Telecom applications should remain relatively stable.

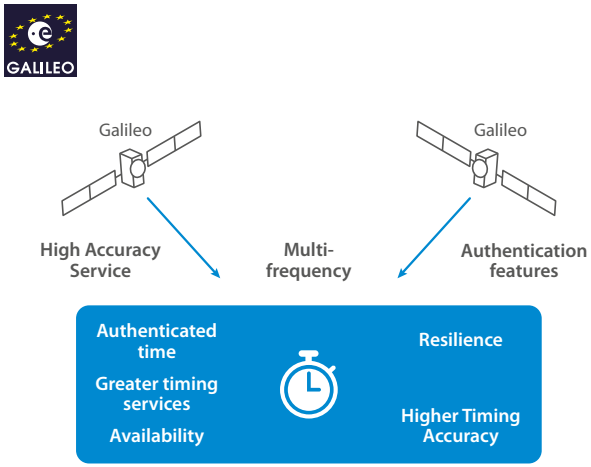
In **Satcom**, the role of GNSS might decrease as a result of the increased PTP importance and the availability of improved electronic steering multi-band antennas, resulting in a small decrease of GNSS shipment of -2.1%. Despite the increased appetite for secure communications, a lengthened life cycle of the legacy PMR device is expected. Moreover, 5G will offer security and special features which could, therefore, cannibalise applications currently covered by PMR. In the medium- long term, a shift from PMR to cell might be expected, though it is difficult to predict at this stage. The **PSTN** market is also not expected to grow significantly following network optimisation and cross-operator agreements.

Finance and Energy applications to be pushed by new opportunities

In the **Finance** market, GNSS shipments are expected to decrease slightly after 2020, as well as GNSS sales (-1.7%) due to the end of MiFID II. However, the potential of innovative products offering improved robustness and service continuity could limit this trend.

Frequent, synchronised, and accurate monitoring is a necessity for large-scale implementation of renewable energy, since all solar panels and most wind turbines rely on inverter technology which has no inertia. The need to accommodate these energy sources and stronger power demand, and security drives the acceleration of the Energy infrastructure modernisation. PMU applications are expected to positively contribute to GNSS sales, with a CAGR of 3.1% over 2019 – 2029.

High Accuracy and Authentication are the two most desired EGNSS features



Current usage of Galileo

Galileo is integrated into GNSS Timing & Synchronisation devices to improve the availability and robustness of the overall Timing solution. Implementing Galileo in multi-constellation products offers more reliability and accuracy of the Timing solution with quantified integrity, multiple source comparison and a versatile adaptive approach in mixing constellation and satellites. Galileo Open Service already provides UTC Time dissemination better than 30 ns [95%] and a frequency dissemination better than 3*10-13 [95%].

Similarly to most segments, T&S device manufacturers integrate GNSS chipset that is often Galileo-ready.

Galileo and EGNOS services and features to be explored

Galileo's Open Service Navigation Message Authentication will be particularly relevant to Critical Infrastructures' operators to improve trustability, resilience and ease of traceability.

In addition, Galileo's High Accuracy Service will provide network operators with a very high level of Timing accuracy, improving Timing stability. This could ease the deployment challenges and allow the development of new value-added services.

EGNOS contributes to improve time accuracy and stability. Trustability is also enhanced via the provision of an independent time source, the EGNOS Network Time, and built-in integrity that could be used to provide a certified Time service in the future.

Galileo Timing Application offering

Cognisant of the increased importance to reduce CI vulnerabilities and on the opportunity to leverage on EGNSS differentiators, the European GNSS Agency has designed the following bundle of Timing services.

- **Galileo Time Integrity** (dashboard): providing the validation and performance assessment of the timing information disseminated by the Galileo system.
- **Trusted Time Distribution and Remote Audit**: enabling the remote assessment of the client clock synchronisation and allowing the dissemination of UTC time and frequency over the Internet.
- **Certified Time Steering and Monitoring**: disseminating precise and accurate time using multi-GNSS Galileo-based Time transfer and providing real-time monitoring and certification of the time offset between the user terminal and the time reference facility.
- **Robust Accurate Time**: offering robustness against GNSS signals, system failures (incl. jamming and spoofing) and against failures or attack on the communication network.

Built-upon the achievements of the H2020 DEMETRA project, the GSA has already started to consider the implementation of these services.

HORIZON 2020

EGNOS and Galileo Timing Service Extension and Consolidation (EGALITE)

The importance of the timing capability offered by GNSS is substantial enough to give it the category of a proper Service in itself. For this reason, the European Commission has been considering the definition of a dedicated Timing Service (both for Galileo and EGNOS) that, once established, would serve to better respond to the needs of its users.

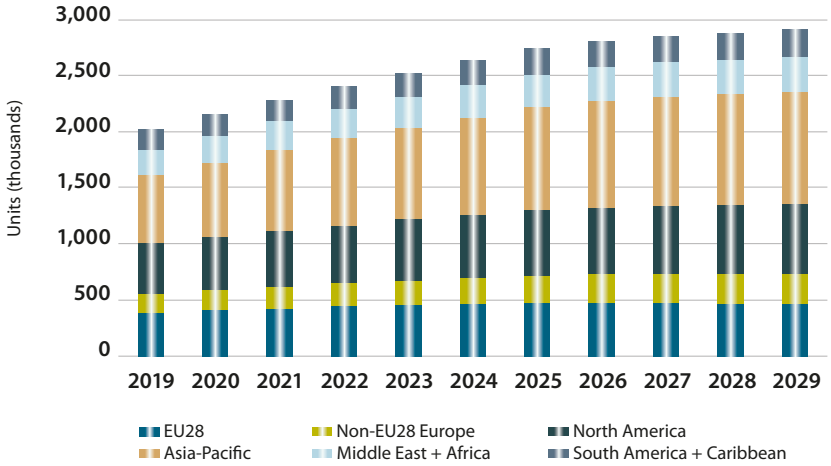
In this frame, the EGALITE project, funded by the European Commission as part of the Horizon 2020 Framework Programme, aims at studying the possibility of developing an EGNSS Timing Service based on Galileo and/or EGNOS, with committed end-to-end performances. The project's consortium is led by GMV with VVA, PTB and ORB as partners.

The main tasks performed within EGALITE project include:

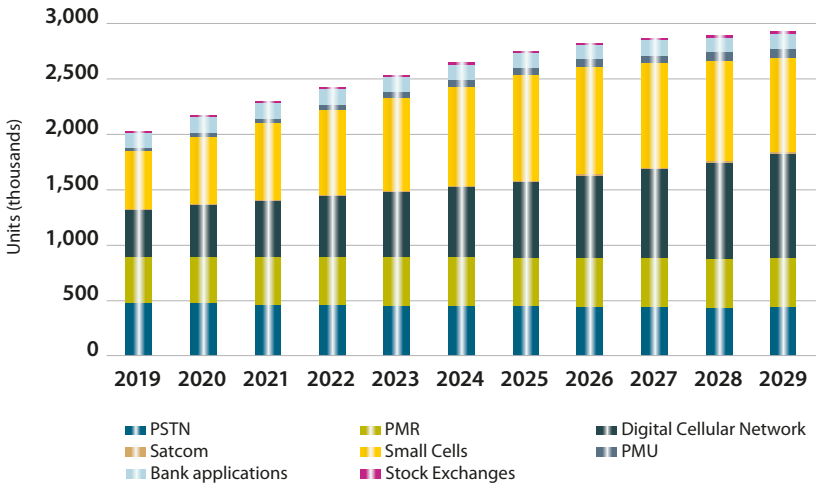
- Extension and consolidation of the European GNSS Timing Services predefined by the EC in previous activities;
- Analysis of GNSS use in Legal Time across Europe;
- Awareness and dissemination activities to interact with the T&S community.

Launched in September 2018, the project has an expected timeframe of 1 year.

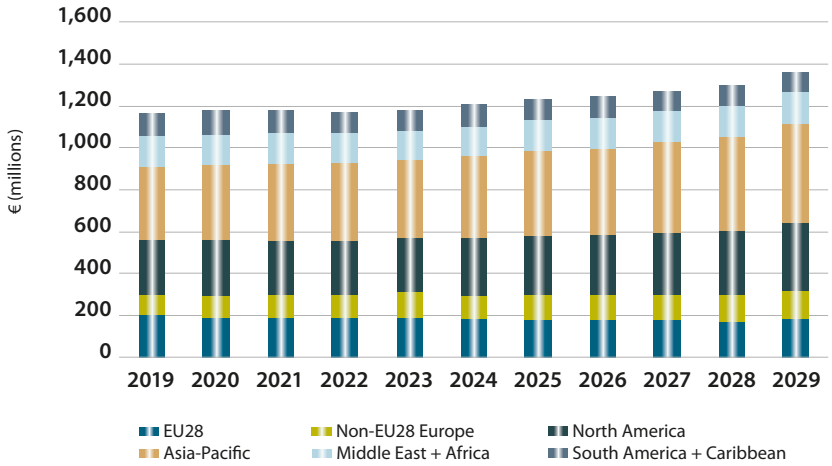
Installed base of GNSS devices by region



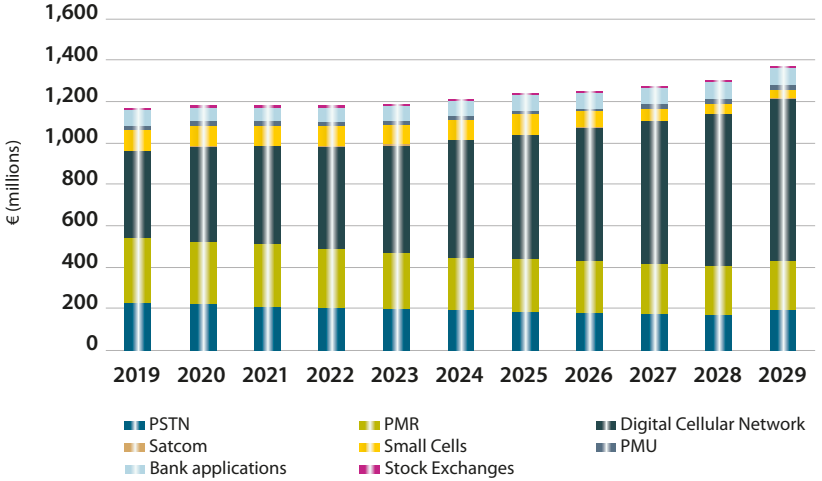
Installed base of GNSS devices by application



Revenue from GNSS devices sales by region



Revenue from GNSS devices sales by application



EDITOR'S SPECIAL: GNSS FOR NEWSPACE

GNSS applications

Though GNSS was originally designed to serve terrestrial users, it has also proven its worth as a valuable tool for in-space applications. From using real-time GNSS data for spacecraft navigation to deriving Earth observation measurements from it, the in-space applications are numerous. Formerly used mainly by governmental space entities, GNSS now serves an increasing number of commercial stakeholders within the 'NewSpace' paradigm.

They are classified as follows:

- **Real-time On-Board Autonomous Navigation**
  It consists of the autonomous determination of the Position, Velocity and Time (PVT) of the space vehicle, allowing – if necessary – a correction to its orbital trajectory. It can also be used for relative navigation applications, with the objective to perform delicate operations such as autonomous Rendezvous and Docking between spacecraft, or formation flying (likely to increase with the NewSpace and the emergence of mega-constellations).
- **Attitude Determination**
  The attitude of a spacecraft (i.e. its orientation in space) can be determined from the relative positions of multiple GNSS antenna installed on the vehicle. Space missions' success often relies on the pointing accuracy and the stability of its payloads. Being accurately aware of the vehicle's orientation in space allows to apply – if needed – the necessary torques to obtain the desired attitude.
- **Earth Science**
  GNSS receivers can be used as Earth Observation (EO) payloads. Particularly, GNSS signals allow for the performing of Atmospheric Limb Sounding, Radio Occultation and Reflectometry. Some satellites dedicated to technology development or scientific studies also embed GNSS receivers, whether it is to test the receiver itself or new technologies in space.
- **Timing & Synchronisation**
  For some satellites, the synchronisation of the payload to GNSS time is important. The possibility to determine time with a high level of accuracy using GNSS receivers allows for less dependence on very expensive on-board clocks.

What you can read in this chapter

- **Key trends:** A growing need for GNSS in a rapidly changing space sector.
- **Strategic Market:** A rising market driven by the boom in LEO private services providers.
- **European GNSS:** Galileo's essential contribution to the Space Service Volume (SSV).

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A growing need of GNSS in a rapidly changing space sector

Key market trends

- The 'NewSpace' movement is transforming the space industry; with lower costs and new commercial actors, space has never been so accessible
- With the emergence of mega-constellations, particularly in the telecommunication domain, the number of small satellites in Low Earth Orbit is about to soar
- This market has a reduced size when it comes to shipments (compared to other markets) but it has high value due to the unitary prices

Different platforms for different needs

Depending on their mass, their designed lifespan and the orbit they are operating on, spacecraft are not equipped with the same kind of spaceborne GNSS receivers. Spacecraft can, therefore, be classified using the following categories, each of which has its own particularities.

Spacecraft operating in high Earth orbits (GEO, GSO, HEO)[1]: These satellites operate at very high altitudes (>35,000 km), located far above the existing GNSS constellations. In addition to a harsh operating environment, these spacecraft have to cope with significantly reduced GNSS signal availability and therefore need ultra-sensitive receivers, at the leading edge of technology.

Spacecraft operating in Medium Earth Orbits (MEO): Medium Earth orbits encompass a wide range of altitudes, most of which also have to deal with reduced GNSS signal availability – either located above GNSS constellations, or located closely below. As for high Earth orbits, receivers installed on MEO spacecraft have therefore to be ultra-sensitive and to cope with rough environmental constraints.

Spacecraft operating in Low Earth Orbits (LEO): Even though they require a minimum adaptation to the space environment and to the constraints of a rocket launch, GNSS receivers equipping spacecraft on LEO are also designed depending on the weight the lifespan of the vehicle. We can define the following three categories:

- **LEO Large & Medium (>250 kg)** – designed in most cases for an 8 to 12 years lifespan;
- **LEO Mini & Micro (>10 kg and <250 kg)** – often designed for a 2 to 5 years lifespan;
- **LEO Nano & Smaller (<10 kg)** – generally designed for a lifespan lower than 2 years.

In addition to these orbital and weight considerations, depending on its mission's specifics, a spacecraft may require the use of one or several GNSS receiver(s), with relatively low or relatively high accuracy needs.

Space debris: an issue and a driver

Space debris has become a proven threat for space activities: with an increasing number of space vehicles orbiting the Earth, the probability of catastrophic collisions is constantly growing. To tackle the problem, and to avoid its escalation, different mitigation measures are being considered, from the definition of post-mission disposal guidelines to the design of technical solutions.

Some of these measures, like spacecraft evasive actions as well as the development of cutting-edge space debris removal technologies (e.g. harpoon, giant net), require the use of accurate positioning systems, representing a real opportunity for the spaceborne GNSS market.

[1] Respectively the Geostationary Earth Orbit, the GeoSynchronous Orbit, and the Highly Elliptical Orbit.

NewSpace: the democratisation of space

For almost a decade, the space industry is experiencing structural changes and paradigm shifts, impacting both demand and supply sides. Characterised by the opening-up of the sector to non-governmental and more business-oriented actors, the '**NewSpace**' ecosystem is emerging.

Space activities are becoming increasingly commercial, making space data the basis of high value-added products, focused on the needs of its end users. The potential profitability of the space industry drives both its historical and emerging stakeholders to vie for competitive positions through faster, cheaper and easier access to space. Benefiting from major technological shifts such as artificial intelligence, digitalisation and miniaturisation, this dynamic results in a virtuous circle, characteristic of the so-called 'NewSpace'.

One of the direct consequences of the 'NewSpace' is the expected strong growth of the number of satellites orbiting the Earth. Coupled with a permanent quest for smaller, lighter and lower-cost solutions, the need for spaceborne GNSS receivers is, therefore, becoming increasingly important, particularly in the LEO region, due to the uptake of several mega-constellations.

The advent of LEO mega-constellations

One of the most significant changes to be witnessed in the space sector in the coming decade is certainly the advent of numerous mega-constellations in LEO. Driven by contemporary challenges (e.g. global broadband connectivity, Internet of Things, environmental monitoring), the space industry has begun to design unprecedented small satellites constellations (from hundreds to thousands of units) permitting to significantly cut implementation costs, reduce time-to-market and improve quality of service.

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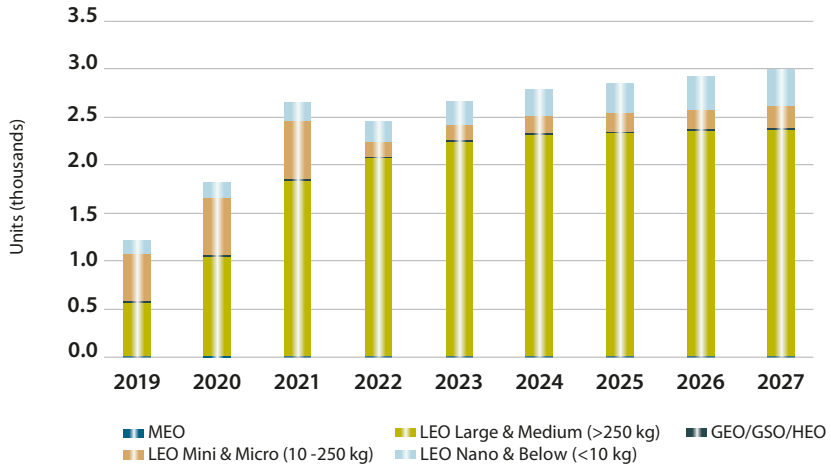
The two most important projects to date – in terms of constellation size – are by far ***OneWeb*** (OneWeb, 900 satellites) and ***Starlink*** (SpaceX, 12,000 satellites), whose launch started early 2019. Respectively expected to be operational by 2020 and 2024, these telecommunication projects will undoubtedly redefine the LEO landscape. Much smaller but already a success story, the ***Iridium NEXT*** constellation (Iridium, 75 satellites) is fully operational since early 2019. Using an innovative mesh of inter-linked small satellites, this constellation is paving the way for further innovations.

With a soaring number of satellites (particularly in LEO) and the proven utility of GNSS to serve many applications, the spaceborne GNSS receivers' market is expected to grow significantly.

A rising market driven by the boom in LEO private services providers

Shipments of GNSS devices by orbital sub-segment



A plethora of tangible benefits for spacecraft operators and end-users

Whatever their mission type (e.g. telecommunication, EO, space science, navigation), providing reliable real-time GNSS data to Earth-orbiting satellites can bring many financial, technical and societal benefits, interesting for both historical and emerging stakeholders.

Reducing the number of instruments required aboard (particularly expensive clocks) and reducing spacecraft's dependence on ground-based stations allows for **appreciable savings on mission costs**.

Spaceborne GNSS allows users to **benefit from improved navigation performances**. Better positioning information allows for perform faster and autonomous trajectory manoeuvres, ensuring mission continuity and increasing vehicles' lifetime. It also offers the possibility to perform formation flying and cluster flights, opening new missions' opportunities, as well as satellite servicing, allowing to significantly extend spacecraft's life, thanks to precise in-orbit operations (material upgrade, repair, refuelling and maintenance). Reducing the spacecraft's relative navigation errors would also allow for an increase in the density of satellites on the coveted and valuable GEO belt[1]. The result is that the use of GNSS has been gradually increasing with missions relying more and more on the technology for various types of operations.

The provision of a wealth of reliable GNSS-derived EO data may **bring societal benefits** (e.g. for smart farming, water management, renewable energy development, urban planning). Trustworthy EO data also substantially improve public-safety situational awareness of fast-moving natural events (storms, earthquakes, flash floods, forest fires, etc.) allowing to save lives and protect critical infrastructures.

[1] Developing a Robust, Interoperable GNSS Space Service Volume (SSV) for the Global Space User Community, F. H. Bauer & al., 2018.

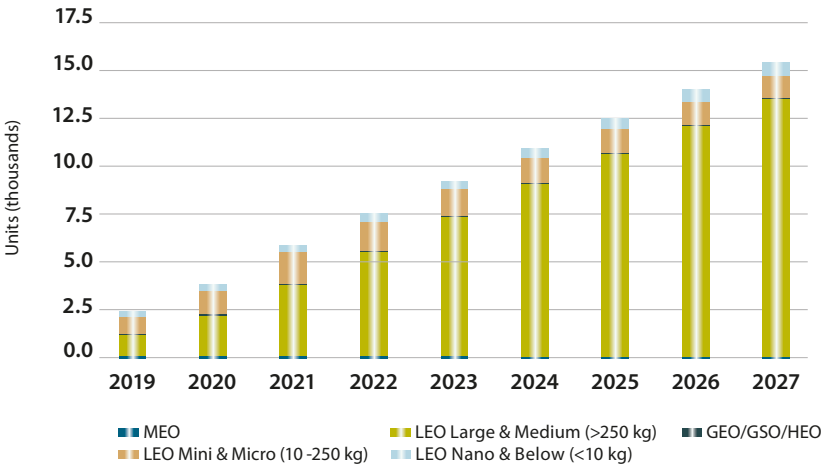
A market driven by LEO spacecraft

Due to the advent of NewSpace and mega-constellations, more than **90% of the satellites to be launched by 2027 will target LEO** – most of them with a need for GNSS receivers. With a shorter lifetime than those with higher earth orbits, and therefore a higher replacement rate, these satellites represent a key driver of the spaceborne receivers' market. The technical adaptations required to evolve in the space environment are moreover well-known and technically mastered in these low-altitude regions. The GNSS market for LEO satellites is therefore mature and several companies already propose off-the-shelf products (e.g. SSTL, GOMspace, Thales Alenia Space, etc.).

As an increasing number of spacecraft are expected to require the use of GNSS, **manufacturers can expect an unprecedented rise of orders, leading to downward price pressure**. Moreover, spaceborne GNSS receivers should, in the medium-term, be more often integrated into space vehicles' on-board computers, allowing to share electronic resources with other systems, which should contribute to price erosion.

With hundreds of satellites to be launched over the next few years, ***OneWeb*** and ***Starlink*** will drive most of GNSS devices shipments (see left chart) – belonging respectively to the 'LEO Mini & Micro' and the 'LEO Large & Medium' categories. The significant number of shipments expected in the latter category is linked to the strict schedule imposed to SpaceX by the Federal Communications Commission (FCC), as half of the constellation must be put into orbit by 2024 and all of it must have been launched by 2027. The 'LEO Nano & Smaller' category, which encompasses CubeSats, is also expected to represent a significant part of the shipments. As a symbol of an easier and cheaper access to space, they are widely used by both historical and emerging actors of the industry.

Installed base of GNSS devices by orbital sub-segment



Galileo's essential contribution to the Space Service Volume (SSV)

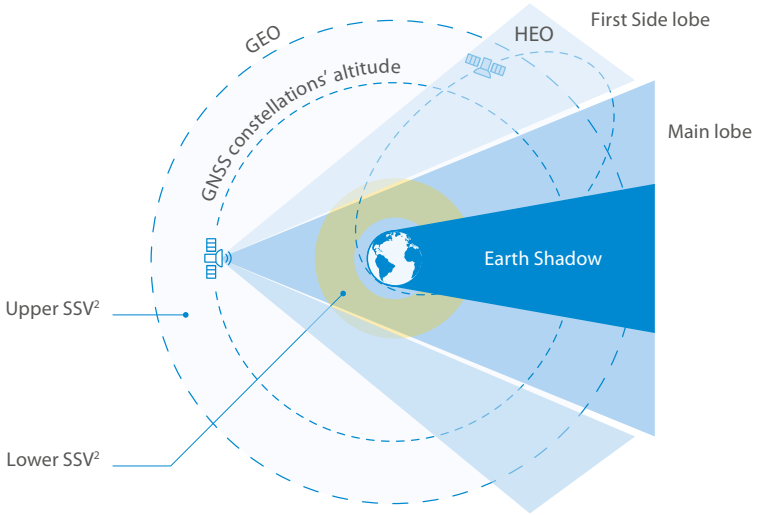
From the Earth to the Moon: the need for an extended interoperable SSV

As defined by the International Committee on Global Navigation Satellite Systems (ICG)[1], the **Space Service Volume (SSV)** is the region of space extending from 3,000 to 36,000 km, where terrestrial GNSS performances standards are not applicable.

It consists of two regions, characterised by different geometrical constraints and signal availability. In the region called the **Lower SSV**[2] (from 3,000 to 8,000 km altitude), GNSS receivers generally benefit from a good signal availability from any single constellation. High altitude applications are much more challenging as they often require the reception of GNSS signals travelling from the other side of the Earth (see figure): this region is named the **Upper SSV** (from 8,000 to 36,000 km altitude). There, spaceborne GNSS receivers generally have to cope with reduced signal power and visibility, potentially reduced pseudo-range accuracy, less optimal geometric diversity and highly dynamic motion – often requiring the ability to exploit GNSS signals first side lobes.

In order to cope with such constraints, the ICG has put a great deal of effort into creating a **well-documented interoperable multi-GNSS SSV** in which all existing global and regional navigation systems can be used together to provide improved capacities to the space users. This momentum seems essential to support the NewSpace paradigm and the arrival of many new stakeholders in the sector. The important work performed by the international space community in this regard reflects indeed an increasing demand for spaceborne GNSS receivers among the users, urging both the upstream and the downstream communities to design their products and services to support the simultaneous use of multiple GNSS constellations.

The characterisation of an interoperable multi-GNSS SSV is indeed an important enabler for new missions and a key driver for new technological developments. Its extension beyond the GEO (up to the Moon) is now even considered by the international space community. Simulations have indeed shown[3] that GNSS signals availability could be extended to lunar distances by augmenting navigation systems with a high-gain antenna as long as multi-constellation solutions are used. International cooperation is therefore key for this sort of applications.



Galileo is an essential component and a key enabler of the interoperable SSV, which already offers a very performant signal and will soon propose unique authentication functionalities to space users. Moreover a dedicated service is under consideration for future evolutions of the system.

GPS and Galileo Receiver for the ISS (GARISS)

In mid-2018, an experiment conducted jointly by the ESA and NASA achieved the first combined Galileo-GPS positioning fix in space, aboard the International Space Station.

Carried-out in the context of the **GARISS[4] mission** and based on the re-configurable NASA receiver called the **Space Communications and Navigation (SCaN) Testbed**, this result demonstrates the added-value of spaceborne dual-constellation receivers – a key milestone in the development of the SSV. The combined use of Galileo and other GNSS signals on an interoperable basis for positioning and precise orbit determination should indeed bring significant advantages for space users, providing a seamless navigation capability from low to high Earth orbits – and potentially beyond.

HORIZON 2020

The Future Concept of Space Navigation: ENSPACE

The ENSPACE (Enhanced Navigation in Space) project aims to develop an innovative software-defined radio GNSS Space Receiver based on System on Chip (SoC).

The ENSPACE technology is targeting the needs of robust positioning, navigation and timing of satellites with the flexibility of a software solution. Seeking to tap the full potential of Galileo services, the concept aims to guarantee improved availability, accurate positioning and robust navigation for different mission contexts (from LEO and GEO satellites to Interplanetary Missions such as spacecraft travelling to the Moon) and multiple GNSS-based applications (Navigation, Timing, Precise Orbit Determination, Attitude Determination, Security and Authentication).

More information on: https://www.gsa.europa.eu/enhanced-navigation-space

1 The Interoperable Global Navigation Satellite Systems Space Service Volume, United Nation for Outer Space Affairs, 2018.
2 The LEO region, located below 3,000 km of altitude, is not included in the Lower SSV.
3 Applications of GNSS Within and Beyond the Space Service Volume, B. W. Ashman & al., 2018.
4 Experimenting Galileo on Board the International Space Station, GRC-E-DAA-TN37642, 2016.

Annex 1: Methodology

Methodology

The present GNSS Market Report applies GSA's Market Monitoring and Forecasting Process.

The underlying market model utilises advanced forecasting techniques applied to a wide range of input data, assumptions and scenarios to forecast the size of the Global Navigation Satellite System (GNSS) market in terms of shipments, revenues and installed base of GNSS devices.

The forecast methodology is bespoke for 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. Key input assumptions are collected from regulation and studies to help inform the penetration of GNSS (e.g. a carriage mandate), the average lifetime of a device, device prices, and GNSS augmentation and added-value service revenues as well as GNSS dependent revenues per device. Input assumptions and outputs are validated 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.

NOTE: Quantitative data and forecasts throughout the Market Report is given for all applications listed in the charts of each market segment, carefully cross-checked in order to avoid the double-counting of devices. That is why it is possible that the front page of each market segment provides a long list of applications. As in many cases, a single GNSS device contributes to a variety of applications.

Sources

The model makes use of publicly available information and additional data and reports purchased from private publishers. Primary sources include:

ABI Research; Airbus; American Farm Bureau Federation; App Annie; appFigures; BCG; Berg Insight; BI Intelligence; Boeing; Bombardier; Broadcom; Cisco; Cubris; Deloitte; Digi-Capital; EU C-ITS Strategy; EGNOS Service Provider (ESSP); Embraer; Equasis; Eurocontrol; European GNSS Service Centre (GSC); Eurostat; European Commission; European Securities and Markets Authority; Farstad Shipping; Finnish VTT Research Centre; Food and Agriculture Organisation; FP7 and H2020 project websites; Federal Aviation Administration; Gartner; General Aviation Manufacturers Association (GAMA); General Aviation News; GE Transportation Signaling; Goodyear; Google; GPS World; Grand View Research; GSM Association; Gunter's Space Page; Harbor Research; Hitachi; IBM; IDC; Infomines; Infonetics; Informa Economics and Measure; Inside GNSS; International COSPAS-SARSAT Programme; International Council of Marine Industry Associations (ICOMIA); International Road Assessment Programme (IRAP); International Telecommunications Union (ITU); International Maritime Organization (IMO); International Convention for the Safety of Life at Sea (SOLAS); International Civil Aviation Organization (ICAO); Irish Health & Safety Authority; Juniper Research; Kapsch GPS World Receiver Survey; KPMG; London School of Economics; Lux Research; MarketsandMarkets; McKinsey; Ministère de l'Environnement, de l'Energie et de la Mer; Nanosats Database; NATS Jon King blog; Organisation Internationale des Constructeurs d'Automobiles (OICA); Pew Research Centre; Proxbook; Research and Markets; Rivers of the World Atlas; Rolls Royce; Royal Institute of Navigation; Sensors Magazine; SESAR Joint Undertaking; Siemens; Statista; Statistic Brain; Technavio; Thales Alenia Space; TTG Transportation Technology; Teal Group; The Verge; TrendForce; TNS/Google; UAVGlobal; UCS Satellite Database; UIC International Railway Statistics; United Nations Conference on Trade and Development (UNCTAD); United Nations public information; UseGalileo; US Bureau of Labor Statistics; US National Transportation Statistics; Vision Mobile; VTPI; World Bank; World Economic Forum; World Shipping Council; World Stock Exchange; Xinhua.

Disclaimer

The GNSS Market Report issue 6 was carried out by the European GNSS Agency in cooperation with the European Commission and with the support of VVA, Egis, Evenflow, FDC, IFFSTAR and LE Europe.

The information provided in the Report is based on the Agency's best estimates and forecasts at the time of publication. Although the Agency has taken utmost care in checking the reasonableness of assumptions and results, the Agency accepts no responsibility for the further use made of the content of the Report.

Any comments to improve the next issue are welcome and should be addressed to: **market@gsa.europe.eu**

Annex 2: Definition of key performance parameters

The definitions given below are to explain the key performance parameters as mentioned on the User Perspective page of each market segment. **Important notice: the definitions below are applicable to this report only, and are not meant to be used for any other purpose.**

Key GNSS requirements and performance parameters

Availability is the percentage of time the position, navigation or timing solution that can be computed by the user. Values vary greatly according to the specific application and services used but typically range from 95 to 99.9%. We can speak of two types of availability:

- System availability: is what GNSS Interface Control Documents (ICDs) refer to.
- Overall availability: takes into account the receiver performance and the user's environment. Values vary greatly according to the specific use cases and services used.

Accuracy is the difference between true and computed solution (position or time). This is expressed as the value within which a specified proportion –usually 95%- of samples would fall if measured. This report refers to positioning accuracy using the following convention: centimetre-level: 0-10cm; decimetre level: 10-100cm; metre-level: 1-10 metres.

Continuity 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 requirements and 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, GNamplSS 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; includes 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 system at the end will reach a failure state 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, LEOs, 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 can be illustrated by a traceable measurement is one that can be related 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 at the time-stamp.

Calibration is a term related to the calibration of a GNSS Timing Receiver. It is the process of measuring the different biases of the GNSS signals propagation through the antenna cable and equipment hardware in order to characterize them and take them into account when computing the timing solution.

Annex 3: List of acronyms

2D	Two Dimensional
3D	Three Dimensional
4D	Four Dimensional
ACI	Airports Council International
ACID	Aircraft Identification
AD	Autonomous Driving
ADAPT	Agricultural Data Application Programming Toolkit
ADS-B	Automatic Depended Surveillance – Broadcast
ADAS	Advanced Driver Assistance System
AEC	Architecture, engineering and construction
AEF	Agricultural Industry Electronics Foundation
AI	Artificial Intelligence
AIS	Automatic Identification System
AIS-MOB	AIS Man Overboard
AIS-SART	AIS Search and Rescue Transmitter
AML	Advanced Mobile Location
ANSP	Air Navigation Service Provider
AOPA	Aircraft Owners and Pilots Association
APAC	Asia-Pacific
AR	Augmented Reality
ARAIM	Advanced Receiver Autonomous Integrity Monitoring
ATM	Air Traffic Management
ATO	Automatic Train Operation
ATP	Automatic Train Protection
AU	Airspace User
A-SMGCS	Advanced-Surface Movement Guidance and Control System
A-PNT	Alternative Positioning, Navigation and Timing
BA	Business Aviation
BIM	Building Information Modeling
BIMCO	Baltic and International Maritime Council
CA	Commercial Aviation
CAD	Connected and Automated Driving
CAGR	Compounded Annual Growth Rate
CANSO	Civil Air Navigation Services Organisation
CAP	Common Agricultural Policy
CAT I, II, III	ILS Categories for precision instrument approach and landing
CBA	Cost Benefit Analysis
CCAM	Cooperative, Connected and Automated Mobility
CER	Community of European Railway and Infrastructure Companies
CI	Critical Infrastructure
CIRM	Comité International Radio-Maritime
CNS	Communication, Navigation and Surveillance
CORS	Continuously Operating Reference Stations
COSPAS-SARSAT	Cosmicheskaya Sistyema Poiska Avariynich Sudow - Search and Rescue Satellite-Aided Tracking
COST	European Cooperation in Science and Technology
CPR	Cardiopulmonary Resuscitation
CS	(Galileo) Commercial Service
DAS	Driver Advisory Systems
DCN	Digital Cellular Network
DFMC	Dual Frequency Multi Constellation
DGPS	Differential Global Positioning System
DME	Distance Masuring Equipment
DT	Digital Tachograph
EASA	European Aviation Safety Agency
EASE	Egnos sAvingS in agriculturE
EC	European Commission
EDAS	EGNOS Data Access Service
EBAA	European Business Aviation Association
EFCA	European Fisheries Control Agency
EGNOS	European Geostationary Navigation Overlay Service
EGNOSHA	EGNOS High Authority
EGNSS	European GNSS
EHA	European Helicopter Association
ELT	Emergency Locator Transmitter
EMPA	European Maritime Pilot Association
EMSA	European Maritime Safety Agency
EPIRB	Emergency Positioning Indication Radio Beacon
ERA	European Regions Airline Association
ERA GLONASS	Accident Emergency Response System of GLONASS
ERSAT GGC	ERSAT Galileo Game Changer
ERTMS	European Rail Traffic Management System
ESA	European Space Agency
ESPO	European Sea Ports Organisation
ESSP	European Satellite Provider
ETCS	European Train Control System
EU	European Union
EUROCAE	European Organization for Civil Aviation Equipment
EU28	European Union (28 Member States)
EVS	Enhance Vision System
FAA	Federal Aviation Administration
FAB	Functional Airspace Block
FAO	Food and Agriculture Organisation
FCC	Federal Communications Commission
FOC	Freight Operating Company
FP7	7th Framework Programme for Research and Technological Development
FSTD	Flight Simulation Training Devices
GA	General Aviation
GADSS	Global Aeronautical Distress Safety Systems
GAGAN	GPS Aided Geo Augmented Navigation
GAMA	General Aviation Manufacturers Association
GANP	Global Air Navigation Plan
GARISS	GPS and Galileo Receiver for the ISS
GAST	GBAS Approach Service Type
GAUSS	Galileo-EGNOS
GBAS	Ground Based Augmentation System
GEO	Geostationary Earth Orbit
GEOSAR	Geostationary Search and Rescue
GIS	Geographic Information System
GLONASS	Russian GLObalnaya NAvigatsionnaya Sputnikovaya Sistema (Global Navigation Satellite System)
GNSS	Global Navigation Satellite System
GPS	Global Positioning System
GSA	European GNSS Agency
GSC	European GNSS Service Centre
GSM	Global System for Mobile Communications
GSO	Geosynchronous Orbit
H2020	Horizon 2020
HAS	High Accuracy Service
HEMS	Helicopter Emergency Service
HEO	High Elliptical Orbit
HP	High Precision
IACA	International Air Carrier
IAPH	International Association of Ports and Harbours
IALA	International Association of Marine Aids to Navigation and Lighthouse Authorities
IATA	International Air Transport Association
ICAO	International Civil Aviation Organisation
ICG	International Committee on Global Navigation Satellite Systems
ICS	International Chamber of Shipping
IFR	Instrument Flight Rules
ILS	Instrument Landing System
IMO	International Maritime Organisation
IMPA	International Maritime Pilot Association
INS	Inertial Navigation System
IoT	Internet of Things
IOV	In-Orbit Validation
IPCC	Intergovernmental Panel on Climate Change
IR	Implementing Rule
IRAP	International Road Assessment Programme
IRE	Instrument Runway End

IRNSS	Indian Regional Navigation Satellite System
ITS	Intelligent Transport System
ITU	International Telecommunication Union
IVS	In-Vehicle System
IWW	Inland Waterways
JAD	Jamming Attack Detection
JRC	Joint Research Centre
JRCC	Joint Rescue Coordination Centres
LBS	Location Based Service
LDACS	L-band Digital Aeronautical Communications System
LEO	Low Earth Orbit
LEOSAR	Low-Earth Orbiting Search and Rescue
LiDAR	Light Detection and Ranging
LPIS	Land Parcel Identification System
LPV	Localizer Performance with Vertical guidance
LRIT	Long Range Identification and Tracking System
LTE	Long-Term Evolution, commonly known as 4G LTE
MAAS	Mobility As A Service
MASS	Maritime Autonomous Surface Ships
MEOLUT	Medium Earth Orbit Local User Terminal
MEOSAR	Medium Earth Orbit Search and Rescue satellites
MiFID	Markets in Financial Instruments Directive
MF	Medium Frequency
MON	Minimum Operational Network
MR	Mixed Reality
MSAS	Multi-functional Satellite Augmentation System
NA	North America
NDB	Non-Directional Beacon
NDVI	Normalized Difference Vegetation Index
NFC	Near-Field Communication
OBU	On-Board Unit
OEM	Original Equipment Manufacturer (as used in Automotive domain)
OS	(Galileo) Open Service
OS-NMA	Open Service Navigation Message Authentication
PBN	Performance Based Navigation
PinS	Point in Space
PLB	Personal Location Beacon
PMR	Professional Mobile Radio
PMU	Phasor Measurement Unit
PBN	Performance Based Navigation
PND	Portable Navigation Device
PNT	Position, Navigation, Timing
PPP	Precise Point Positioning
PPU	Portable Pilot Unit
PRN	Pseudorandom Noise
PRS	Public Regulated Service
PSAP	Public Safety Answering Points
PSTN	Public Switched Telephone Network
PTC	Positive Train Control
PMR	Professional Mobile Radio
PMU	Phasor Measurement Unit
PBN	Performance Based Navigation
PND	Portable Navigation Device
PNT	Position, Navigation, Timing
PPP	Precise Point Positioning
PPU	Portable Pilot Unit
PRN	Pseudorandom Noise
PRS	Public Regulated Service
PSAP	Public Safety Answering Points
PSTN	Public Switched Telephone Network
PTC	Positive Train Control
PTP	Precise Time Protocol
PVT	Position, Velocity, Timing
QZSS	Quasi-Zenith Satellite System
RLS	Return Link Service
RNAV	aRea NAVigation
RNP	Required Navigation Performance
ROSCO	Rolling Stock Operating Company
RPAS	Remotely Piloted Aircraft Systems (drones)
RTCM	Radio Technical Commission for Maritime Services
RTK	Real Time Kinematic
RUC	Road User Charging
R&D	Research and Development
SAD	Spoofing Attack Detection
SAR	Search and Rescue
SARP	Standards and Recommended Practices
SATCOM	Satellite Communications
SBAS	Space Based Augmentation System
SCaN	Space Communications and Navigation
SDCM	The System for Differential Corrections and Monitoring
SDG	Sustainable Development Goal
SDM	SESAR Deployment Manager
SIA	System for vehicle infrastructure Interaction Assets health status monitoring
SID	Standard Instrument Departure
SIS	Signal In Space
SLAM	Simultaneous Location And Mapping
SME	Small and Medium-sized Enterprises
SMS	Short Message Service
SNAS	Satellite Navigation Augmentation System
SNI	Simultaneous Non-Interfering
SoL	Safety of Life
SOLAS	International Convention for the Safety of Life at Sea
SORA	Specific Operations Risk Assessment
SPI	Surveillance Performance and Interoperability requirements
SSR	Secondary Surveillance Radars
SSV	Space Service Volume
STAR	Standard Terminal Arrival Route
STL	Satellite Time and Location
SVS	Synthetic Vision Systems
T&S	Timing and Synchronisation
TaaS	Time as a Service
TOC	Train Operating Company
TOS	Terminal Operating System
TTFF	Time To First Fix
UAV	Unmanned Aerial Vehicle
UCP	User Consultation Platform
UNCTAD	United Nations Conference on Trade and Development
UNOOSA	United Nations Office for Outer Space Affairs
USCG	United States Coast Guard
UTC	Coordinated Universal Time
UTM	Unmanned Aircraft Systems Traffic Management
VMPS	Vehicle Motions and Positioning Sensor
VMS	Vessel Monitoring System
VHF	Very High Frequency
VOR	VHF-Omnidirectional Range
VR	Virtual Reality
VRT	Variable Rate Technology
VTS	Vessel Traffic Services
WAAS	Wide Area Augmentation System
WI-FI	Wireless Fidelity. Wireless communication protocols
WWRNS	World-Wide Radio Navigation System
XR	Extended Reality

Annex 4: About the authors

The European Commission

The European Commission (EC) is responsible for the management of the European satellite navigation programmes, Galileo and EGNOS, including:

- Management of funds allocated to the programmes;
- Supervising the implementation of all activities related to the programmes;
- Ensuring clear division of responsibilities and tasks in particular between the European GNSS Agency and European Space Agency;
- Ensuring proper reporting on the programme to the Member States of the EU, to the European Parliament and to the Council of European Union.

The Galileo and EGNOS programmes are entirely financed by the European Union.

The European GNSS Agency (GSA)

The GSA's mission is to support European Union objectives and achieve the highest return on European GNSS investment, in terms of benefits to users and economic growth and competitiveness by:

- Designing and enabling services that fully respond to user needs, while continuously improving the European GNSS services and infrastructures;
- Managing the provision of quality services that ensure user satisfaction in the most cost-efficient manner;
- Engaging market stakeholders to develop innovative and effective applications, value-added services and user technology that promote the achievement of full European GNSS adoption;
- Ensuring that European GNSS services and operations are thoroughly secure, safe and accessible.

The authors would like to convey special thanks to the contributors to this report:
- VVA Group
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- Helios
- London Economics
- FDC
- IFSTTAR

Integrated Market Development at the GSA

The **GNSS Market Report** is a product of ongoing market development and technology monitoring activities that aim to:

- **Stay close to the user and the value chain:** involving GNSS users, downstream industry, experts and other stakeholders in key market segments by managing relationships with stakeholders, organising and participating in user and industry fora, identifying needs and assessing stakeholder satisfaction.

- **Monitor GNSS market and technology:** forecasting future developments by market segment, including regular collection, modelling and expert validation of current information, drivers and assumptions; analysis of the GNSS downstream industry market share; cost-benefit analyses of the European GNSS Programmes and future scenarios; monitoring trends in positioning technology; and tracking of EGNSS penetration.

- **Build and implement EGNSS market strategy with market players and institutional stakeholders:** fostering the use of EGNOS in aviation, agriculture, maritime, road, rail and surveying; preparing the market for the uptake of Galileo in all segments; promoting integration of EGNSS inside chipsets, receivers and devices; organising workshops and testing; and supporting EU industry business development and competitiveness.

- **Manage EU-funded R&D on GNSS applications and services within FP7 & H2020 programmes:** leveraging results for E-GNSS adoption and EU industry competitiveness, including 240 demonstrations of E-GNSS applications; 86 products, 206 prototypes, 23 patents/trademarks – with more results on the way.

- **Manage EU-funded R&D on GNSS chipsets, receivers and antennas:** gearing these end-products to end-users from all segments, aiming to support the EU industry with grants or tenders/procurements tailored to meet current and future user needs.

The European GNSS Agency: linking space to user needs.

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