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Dear Reader,

The growing demand for precise location information, in combination with the ongoing evolution of GNSS technology, means that today's GNSS market is bigger than ever. With an estimated 5 billion GNSS devices in use around the world – a number expected to grow to 8 billion by 2020 – GNSS has become a ubiquitous technology.

It is within this context that I am pleased to introduce the 5th edition of the GSA's *GNSS Market Report*. Providing in-depth information on today's GNSS market opportunities and a data-driven forecast of its evolution through 2025, this edition will be *the* go-to-resource for anyone looking to successfully navigate this exciting market.

The *GNSS Market Report* takes a comprehensive look at the global GNSS market providing a thorough analysis per market segment and application type. In addition to the information on shipments, revenues and installed receiver base that you have come to expect from the Report, this edition has some new features, including:

- An expanded section on such **macrotrends** as the Internet of Things (IoT), Smart Cities and Big Data, many of which encompass numerous traditional GNSS market segments.
- The unique added value that **European GNSS** (EGNOS and Galileo) brings to each segment and how, with the recent Declaration of Galileo Initial Services, Galileo is already enhancing the functioning of many applications.
- Segment-specific **user perspectives**, with an emphasis on the increasingly stringent demands of today's GNSS users.
- A **special feature** on the important role that GNSS plays in the growing market of **drones**.

By pairing this *GNSS Market Report* with its sister publication, the GSA's *GNSS User Technology Report*, you have an encyclopedia-worth of GNSS market information at your fingertips. I am confident that using these tools in your day-to-day planning and strategic decision-making will give your business the competitive edge it needs to succeed.

I look forward to your feedback and our continued work together.

Carlo des Dorides
Executive Director

The European GNSS Agency (GSA)
Prague, May 2017

Asia-Pacific will consolidate its position as the largest regional GNSS market

North America	2015		2025	
	Value	%	Value	%
Installed Base	683 mln	16.4	1.2 bln	13.3
Revenue (€)	24.3 bln	25.6	61.9 bln	23.1
Devices per capita	1.4		2.3	

European Union (EU28)	2015		2025	
	Value	%	Value	%
Installed Base	666 mln	16.0	1.2 bln	13.2
Revenue (€)	21.9 bln	23.1	59.4 bln	22.2
Devices per capita	1.3		2.4	

Russia and Non-EU 28 (Non-EU28 Europe)	2015		2025	
	Value	%	Value	%
Installed Base	264 mln	6.3	570 bln	6.2
Revenue (€)	6.3 bln	6.7	15.8 bln	5.9
Devices per capita	1.1		2.4	

Asia-Pacific	2015		2025	
	Value	%	Value	%
Installed Base	1.9 bln	46.1	4.3 bln	46.8
Revenue (€)	32.7 bln	34.5	96.8 bln	36.1
Devices per capita	0.5		1.0	

South America + Caribbean	2015		2025	
	Value	%	Value	%
Installed Base	312 mln	7.5	818 mln	8.8
Revenue (€)	5.8 bln	6.1	15.7 bln	5.8
Devices per capita	0.6		1.5	

Middle East + Africa	2015		2025	
	Value	%	Value	%
Installed Base	322 mln	7.7	1.1 bln	11.7
Revenue (€)	3.8 bln	4.0	18.5 bln	6.9
Devices per capita	0.2		0.6	

New and emerging GNSS trends by market segment

LBS	More and more smartphones integrate multi-constellation GNSS, boosting GNSS performance. Over 90% of context-aware apps now rely on GNSS.
Road	GNSS answers the need of Autonomous Driving (AD) for reliable and accurate positioning. OEMs and technology companies are leading the development of Autonomous Vehicle encouraged by governments.
Aviation	The aviation market continues to increasingly rely on GNSS, including rotocraft and unmanned vehicles. SAR beacons manufacturers are developing solutions for Aircraft Distress Tracking leveraging GNSS.
Rail	GNSS-enabled solutions can offer enhanced safety for lower cost, e.g. in railway signalling. GNSS is becoming a generic system widely used in non-safety relevant applications.
Maritime	GNSS has become the primary means of obtaining PNT information at sea. SAR beacon manufacturers are preparing for multi-constellation GNSS.
Agriculture	GNSS applications represent a key enabler for the integrated farm management concept. Drone uptake in agriculture is increasing, accounting for over half of the commercial market.
Surveying	Falling device prices drive the democratisation of mapping. GNSS remains the backbone technology in increasingly sophisticated applications.
Timing & Sync	GNSS timing is at the core of many critical infrastructures, including telecoms, energy, finance. Evolution of telecom networks makes GNSS increasingly essential, driving future shipments.

Bolstered by strengthening macroeconomic stability, increasing market maturity and the continuous evolution and diversification of services, the **global GNSS market** is **witnessing steady growth**. Despite gradual saturation across the markets of Europe and North America, the global **installed base** is forecasted **to increase** from 5.8 bln GNSS devices in use in 2017 **to almost 8 bln in 2020** – averaging an estimate of more than one device per person on the planet. In terms of GNSS diffusion, developing economies are gradually catching up with established markets.

"Smartphones account for almost 80% of the global installed base of GNSS devices."

Underpinned by an expanding mobile economy and growing purchasing power across key regions of the developing world, the **global installed base of GNSS devices** continues to be **greatly dominated by smartphones**, followed a distant second by **Road**, with 5.4 bln and 380 mln devices respectively in use in 2017.

Although the number of GNSS devices in use for professional applications is far lower than their mass-market counterparts, the **professional market is growing, with millions of people** globally **benefitting** from them on a day-to-day basis - whether by enjoying the produce of sustainable and cost-effective agriculture, by using efficiently coordinated transport networks, or by leveraging on GNSS-synchronised telecommunications networks.

In terms of **revenues**, the global **GNSS downstream market for devices and augmentation services** is forecasted **to grow by more than 6% annually** between 2015 and 2020 before gradually decelerating over the following years. This slowdown is primarily due to the **growing maturity** of the global GNSS market **leading to increasing competition** and higher pressures on prices.

"Added-value services will increasingly be the largest source of revenues."

These **downstream markets are** in turn **enabling added-value services**, which are set to witness skyrocketing growth of 20% annually between 2015 and 2020 before attenuating over the following five years. Added-value services comprise all services that create an added value to users by leveraging on GNSS technology, including fleet management applications for transport and many smartphone apps.

"GNSS enables innovation across major technology developments."

As the most cost-effective and performant source of positioning and timing information in outdoor environments, **GNSS has become an essential element of major contemporary technology developments** notably including the IoT, Big Data, Augmented Reality, Smart Cities and Multimodal Logistics.

In turn, the advent of 5G, Automated Driving, Smart Cities and the IoT is set to spawn a further proliferation and diversification of GNSS-enabled **added-value services**. Their annual **revenues will hit € 195 bln in 2025**, more than 2.5 times higher than the expected GNSS device and service revenues. These distinct macrotrends take place within, across and beyond conventional GNSS market segments. Whereas GNSS is a key enabler of many services encapsulated in these **macrotrends**, emerging technology paradigms such as the IoT or Smart Cities create linkages between established GNSS market segments, **creating** a window of **opportunity for** hybrid and **cross-cutting applications and generating new user needs** and requirements.

"The global GNSS industry is characterised by a few very large companies and a great number of SMEs."

Major players in the GNSS industry **engaged in** a number of **takeovers, driving consolidation** at the top. This is apparent in the concentration of turnover, with the top 5 companies accounting for almost 60% of turnover in 2015. This is almost twice as high as the share generated by the top 5 in 2012.

Home to leading component manufacturers, system integrators and service providers, the United States continues to lead the global GNSS market. Accounting for a quarter of global revenues, **Europe has claimed the second rank in 2015**. Driven by a few large companies and a plethora of innovative SMEs and start-ups, Europe performs particularly well in the development of applications and services. The European app economy is set to witness continued growth.

"Galileo officially moved from a testing phase to the provision of live services."

The Declaration of **Galileo Initial Services** reflects Europe's achievement to **satisfy evolving user needs and** to **enable** chipset and receiver manufacturers and application developers to start leveraging on **more performant GNSS signals**. Already today, leading GNSS companies representing more than 95% of the GNSS chipset market produce Galileo-ready chips.

Following widespread adoption in high-precision devices, a number of **Galileo-ready devices** has already **hit the mass market** (for up-to-date list see www.useGalileo.eu), including smartphones and in-vehicle navigation systems. Initial Services are the first step towards full operational capability, which will occur when the Galileo constellation is complete by 2020. Adopted in 2016 by the European Commission, the **Space Strategy for Europe** proposes a range of actions to allow Europeans to fully seize the benefits offered by space, create the right ecosystem for space start-ups to grow, promote Europe's leadership in space and increase its share on the world space markets. With Galileo and Copernicus becoming operational, the strategy **reflects a shift to concrete applications based on space data**.

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Introduction to the GNSS downstream 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).

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:** Percentage of time over a specified time interval that a sufficient number of satellites are transmitting a usable ranging signal within view of the user.
- **Accuracy:** The difference between true and computed position (absolute positioning).
- **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:** 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**.

GNSS downstream market

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

The GNSS downstream market presented in this report comprises device revenues, revenues derived from GNSS augmentation services and other necessary software solutions and content (including digital maps); and added-value services directly attributable to GNSS.

The scope of added-value service revenues includes 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 such smartphone apps, considering sales revenue, advertisements and in-app purchases.

For multi-function devices, such as smartphones, the revenue quantification includes 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.
- **Personal Navigation Devices (PNDs):** 100% of retail value as GNSS is the key enabler.
- **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.

On charts and Methodology

Data contained within the charts starting from the year 2016 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.
- **GNSS penetration:** Proportion of all possible users that avail of GNSS.

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

Smartphones account for almost 80% of the global installed base of GNSS devices

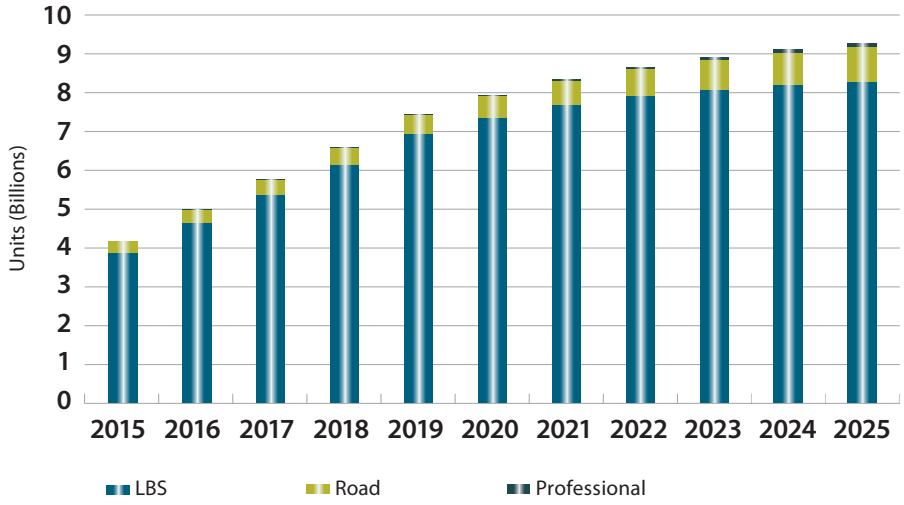
GNSS is widely used, with **5.8 bln GNSS devices in use in 2017**. By 2020, this number is forecasted to increase to almost 8 bln – an estimate of more than one device per person on the planet.

Underpinned by declining handheld device prices and growing purchasing power across key regions of the developing world, the global installed base of GNSS devices continues to be greatly dominated by **smartphones** (5.4 bln in 2017), which remain the most popular platform to support mobile Location-Based Services. The share of smartphones as a percentage of the global installed base is set to remain relatively constant well into the 2020s.

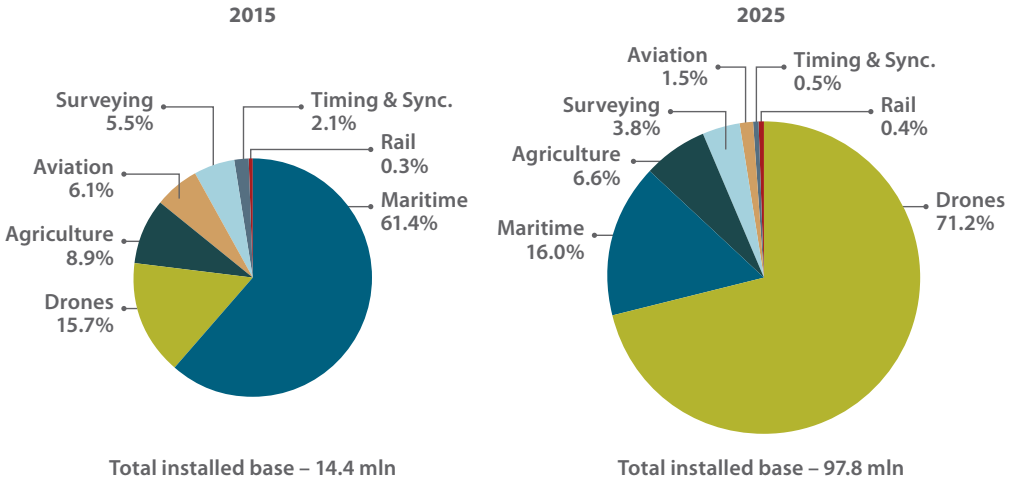
In terms of the number of units in use, **Road** follows LBS as distant second, with 380 mln devices in use in 2017. Boosted by the growth of the In-Vehicle System (IVS) market and by EU legislation on the eCall, the installed base of devices used for road applications is however set to grow substantially, with a CAGR of 11.4%.

Although the number of GNSS devices in use in the **professional market segments** is lower, billions of people globally benefit from them on a day-to-day basis – whether by enjoying the produce of sustainable and cost-effective **agriculture**, by using efficiently coordinated **transport** networks, or by leveraging on GNSS-synchronised **telecommunications** networks. Fostered by a maturing regulatory environment, the installed base of **drones** is expected to skyrocket over the upcoming years, set to account for over 70% of the installed base by 'Professional segments' in 2025.

Global installed base by segment



Installed base of 'Professional' segments



Added-value services will increasingly be the largest source of revenues

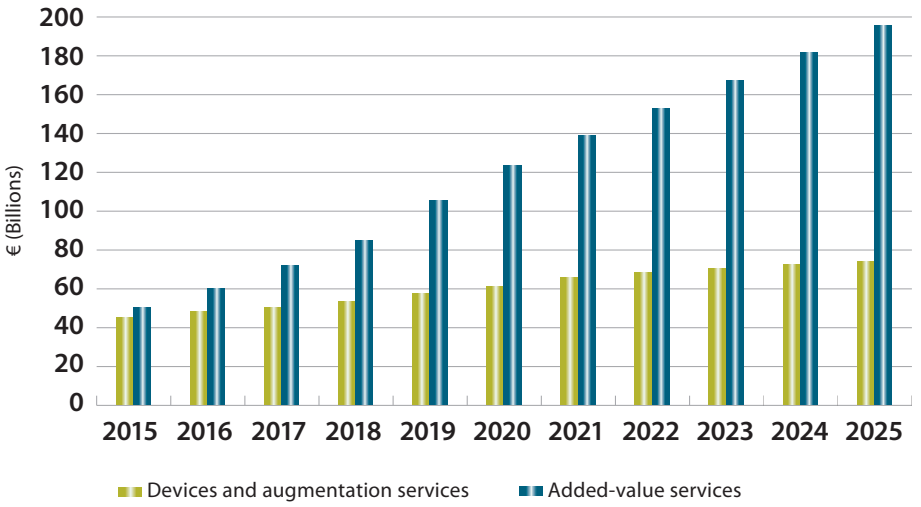
Global GNSS downstream market

The global **GNSS downstream market**, which comprises both **devices** (e.g. GNSS receivers) and **augmentation services**[1], is forecasted to grow by 6.4% annually between 2015 and 2020 before slightly decelerating to 3.8% towards 2025. This is primarily due to the growing maturity of the global GNSS market leading to increasing competition and higher pressure on prices.

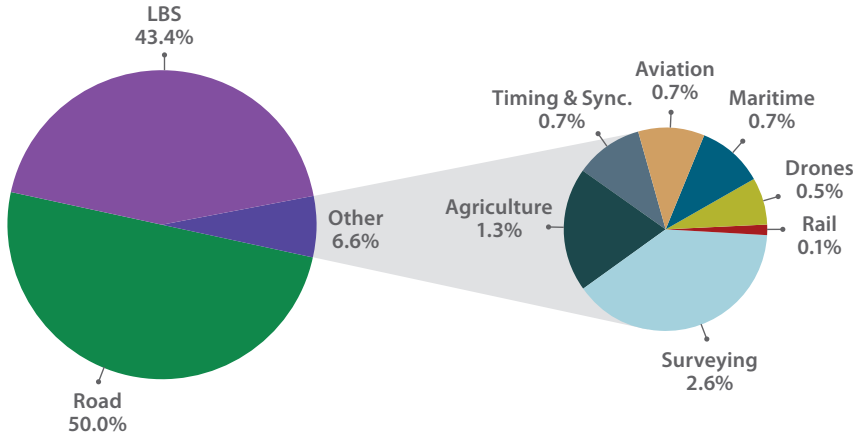
These downstream markets enable the development of **added-value services**, which are set to witness skyrocketing growth between 2015 and 2020 at 20% annually, gradually slowing to an average annual growth of 9.6% through 2025. These comprise all services that create an added value to users by leveraging on GNSS technology, including navigation services, fleet management applications and many location-aware smartphone apps. In 2015, the added-value market size for the first time exceeded the combined size of GNSS devices and augmentation services.

The advent of 5G, Automated Driving, Smart Cities and the IoT is set to spawn a rapid **proliferation and diversification** of these added-value services. Their **annual revenues** will hit € 195 bln in 2025, which is more than 2.5 times higher than the expected GNSS device and service revenues that same year.

Global revenue by type



Cumulative Revenue 2015-2025 by segment



Road and LBS dominate the total revenues

Applications in the **Road** and **LBS** segments **dominate** all other market segments in terms of cumulative **revenue**, with a combined total of more than 93% for the forecasting period 2015-2025.

Technological evolutions in the **Connected Vehicles** and **Automated Driving** domains are expected to be a major **driver of growth** of GNSS-enabled road applications and services over the upcoming years. GNSS information empowers automotive services ranging from precise navigation to location-based information services including the localisation of speed cameras or available parking sports, dynamic weather updates and traffic alerts.

The ubiquitous uptake of **GNSS in smartphones** enables a rapidly **diversifying portfolio** of smartphone apps to provide a wealth of services ranging from outdoor Augmented Reality apps to navigation apps for the visually impaired. With **multi-constellation** penetrating the handset market, newer smartphone models are becoming capable of **supplementing professional applications** – in addition to navigation applications or dedicated mapping applications.

[1] The report distinguishes between "augmentation services", which relates to all services directly supporting the GNSS system (e.g. augmentation and correction) and "added-value services" which are enabled by the GNSS technology (navigation services, location-aware apps, etc.).

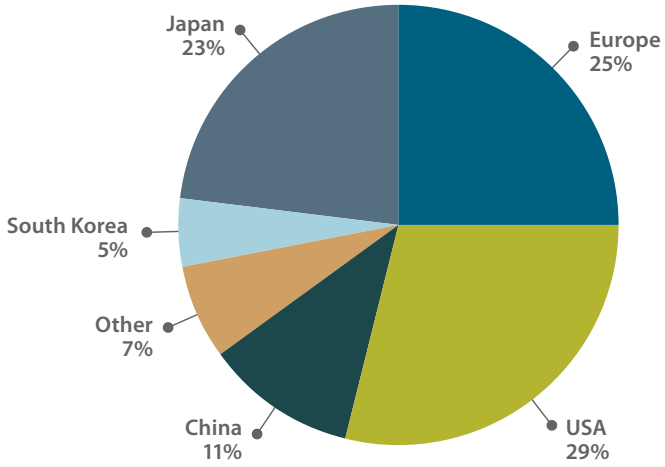
Mergers and Acquisitions drive further consolidation in the GNSS downstream industry

Chinese GNSS industry saw rapid growth between 2012 and 2015

The GNSS industry is characterised by a few very large companies and a great number of SMEs. Major players in the GNSS industry continue to engage in high-profile take-overs, driving consolidation at the top. This consolidation is well-reflected in the concentration of turnover among components and receiver manufacturers, with the top 5 companies accounting for almost 60% of turnover in 2015. This is almost twice as high as the share generated by the top 5 in 2012. In 2015, the largest company had one-third of the global market, compared to 12% in 2012.

The pie chart below shows the comparison of the size of GNSS industry by region and country, with a special focus on countries with a relatively large market share.

Revenue generation in the GNSS industry by key countries
(% split of revenues 2015)



Home to leading component manufacturers, system integrators and added-value service providers, the **United States** continue to lead the global GNSS market. Accounting for a quarter of global revenues, **Europe[1] has claimed the second place** in terms of 2015 revenues. China's GNSS industry is growing rapidly, accounting for 11% of global revenues in 2015, up 4% from 2012. China's growing GNSS industry is difficult to comprehensively assess due to data limitations.

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

Market of component manufacturers is being consolidated

As the core GNSS downstream industry, the market of **component manufacturers** is becoming increasingly consolidated. Underpinned by a number of recent Mergers and Acquisitions, the industry's two leading companies – Qualcomm and Broadcom (now owned by Avago to form Broadcom Limited) – together account for over 40% of revenues.

Top 10 companies across the value chain based on 2015 revenues

Component manufacturers		System integrators		Added-value service providers		GNSS applications users
Qualcomm	USA	Toyota	JP	Google	USA	Mass Market Users, Professional Users, Users With Special Needs, Retailers
Broadcom	USA	General Motors	USA	Here Global ●	DE	
Mediatek ●	CN	Garmin	USA	Pioneer	JP	
Trimble Navigation	USA	Ford	USA	Denso	JP	
Hexagon	SE	China First	CN	Microsoft	USA	
u-blox ●	CH	Volkswagen	DE	Boeing ●	USA	
STM ●	CH	Samsung Elec.	KR	Ericsson ●	SE	
Cobham	UK	Apple	USA	Garmin ●	USA	
Furuno Electric	JP	Nissan	JP	Clarion	JP	
Topcon ●	JP	Honda	JP	Tomtom	NL	

● New Entrants in the Top 10

System integrators primarily comprise car manufacturers and smartphone vendors, for which GNSS represents only a small part of their product offering. With no new entrants amongst the Top 10, this is the most stable of the three downstream industries.

Whereas GNSS historically constituted only minor part of the product offering of **added-value service providers**, GNSS currently offers an increasingly large potential for app development. Revenues of context aware apps will hit €30.6 bln by 2019, a market size three times larger than in 2015.

European GNSS industry accounts for a quarter of global GNSS revenues

EU28 shipments and revenue

Shipments of GNSS devices in EU28 are expected to **surge** in the upcoming years, rising from **210 mln units in 2015** to almost **290 mln in 2020**. Increasing saturation of the European market will cause attenuating growth during the first half of the next decade. **Revenues** follow a similar trajectory, increasing strongly from **22 bln in 2015 to almost 43 bln in 2020** before slightly slowing down towards 2025.

European industry

European companies accounted for 25% of the global GNSS market in 2015, with significant variation across the value chain and market segments. In **components manufacturing**, European companies continue to perform strongly in **Road**, **Surveying** and **Maritime**. European companies lead **systems integration** in **Surveying** and **Agriculture**, and have a strong position in **Maritime**, **Rail** and **Road.** European **systems integrators** comprise both large OEMs primarily engaged in Road, as well as cross-cutting players that are active across multiple segments. Driven by a few large companies and a plethora of innovative SMEs and start-ups, Europe performs strongly in the development of **added-value applications**.

Differences in Europe's performance between years is driven by: relative **revenue growth** of European firms, **mergers and acquisitions, new market entrants and exchange rate fluctuations**.

European Space Strategy set to drive growth in the European GNSS industry

In October 2016, the European Commission adopted the **Space Strategy for Europe**. The strategy sets out an ambitious vision for the future of space activities in Europe with its underlining message that 'Space matters for Europe'. Funding of EGNSS innovation, through R&D support instruments, is an integral part of the strategy.

The Commission strategy proposes a range of actions to allow Europeans to fully seize the benefits offered by space, create the right ecosystem for space start-ups to grow, promote Europe's leadership in space and increase its share at the world space markets. The strategy aims at fostering a **competitive and innovative European space sector** and maintain Europe's **strategic autonomy** while strengthening its global role in space. With **Galileo** and **Copernicus** becoming **operational**, the strategy reflects a shift to concrete applications based on space data.

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

European[1] market share

The table below shows the regional market shares for component manufacturers and system integrators in 2015 for each market segment. The market shares of companies in other regions are not shown in the table.

	Component manufacturers (Europe: 20%)			System integrators (Europe: 27%)		
	Europe*	North America	Asia+Russia	Europe*	North America	Asia+Russia
	6%	61%	33%	4%	36%	60%
	51%	23%	27%	30%	21%	48%
	25%	65%	10%	23%	76%	1%
	31%	46%	23%	33%	14%	53%
	43%	9%	47%	**37%**	37%	26%
	6%	63%	31%	**42%**	39%	19%
	36%	40%	24%	**37%**	34%	29%

Added-value service providers cannot be linked directly to market segments. Aggregate values amount to: **Europe: 26%; North America: 50%; Asia+Russia: 24%**

Fundamental Elements

HORIZON 2020

European Global Navigation Satellite Systems Agency

Fundamental Elements and Horizon 2020 – ensuring R&D funding across the GNSS value chain

Horizon 2020 is the EU Research and Innovation programme with nearly €80 bln of funding available for the 2014-2020 period. The **European GNSS (EGNSS) applications** are part of the Space Theme, having synergies with topics on societal challenges. Three calls have been opened so far, with an overall budget of **€96 mln**.

Fundamental Elements is a new EU **R&D funding mechanism** supporting the development of EGNSS-enabled **chipsets**, **receivers and antennas**. Key objectives are to facilitate the adoption of EGNSS systems, to improve the competitiveness of EU industry, to address user needs and to maximise benefits to European citizens. The total **budget is €111.5 mln** between 2015 and 2020.

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

EGNSS evolves to match user needs and create new business opportunities

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, Commercial Service, Search and Rescue and Public Regulated Service) will offer various levels of accuracy, robustness, authentication and security. The next page provides an introduction to Galileo Initial Services, which were declared in late 2016.

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 such safety critical applications as flying aircraft or navigating ships through narrow channels.

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	LBS, Road, VFR General Aviation, Maritime (e.g. leisure boats navigation), and Rail (e.g. passenger info)	LBS, Road, Rail and Agriculture (including farm and livestock mgmt)	Road (e.g tolling operators, insurance telematics), LBS (e.g. mobile payments) and Maritime (e.g. fisheries, marine park management)	Aviation and drones, Road, LBS (emergency caller location) Rail and Maritime	Agriculture, Surveying and Maritime	Timing & Synchronisation
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 standards	Absolute and pass to pass Accuracy	Improved quality of synchronisation

[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

Interaction with user communities is essential for the success of the European Union Satellite Navigation Programmes. Continuous **user** feedback is indispensable to ensure that their **needs are met**, to **improve the services** that the EGNOS and Galileo system deliver (level of performance, new services, and timelines) and to **enhance existing applications**.

In order to facilitate a continuous dialogue with key user communities, the European Commission and the GSA have decided to establish a formal **User Consultation Platform (UCP)**. Providing a forum for the dynamic exchange of information, the UCP aims to facilitate the sharing of information on the EU GNSS user communities' **trends, needs and requirements**.

The outputs of **regular UCP meetings** will be further used in various processes of European satellite programmes, such as planning of evolutions and next generations of EGNSS. The forum will also provide a platform to deliver official questions, issues, requests and suggestions to the EGNSS programme management. Four sub-forums are foreseen: mass market, professional market, transport and research & development. The European GNSS Service Centre (GSC) **www.gsc-europa.eu** and the User Consultation Platform will be the two main interfaces with the growing user community of Galileo and EGNOS.

Galileo Open and Commercial Services will create new business opportunities

The forthcoming **Galileo Open Service** (OS) engenders a significant innovation when compared to the Open Services of GPS, Glonass and other global GNSS systems. The free-of charge Galileo OS will be the first to broadcast authentication data through its **Navigation Message Authentication (OS NMA)**. Providing users with information about the received signal's authenticity and impeding the spoofing of the GNSS signal, this feature will benefit all those GNSS-enabled applications in which a **liability risk** would arise following a falsification of the signal, including Road User Charging, the Smart Tachograph, Vessel Monitoring Systems for fishing vessels and many other applications.

The **Galileo Commercial Service** will complement the OS and provide a **higher positioning accuracy and improved signal robustness** due to authentication. This service will provide a significant added value to the GNSS downstream market and is likely to pave the way for new business models for service providers.

Galileo goes live to deliver concrete benefits to users!

With the Declaration of **Galileo Initial Services**, Galileo officially moves from a testing phase to the provision of live services. Users around the world can now be guided using the positioning, navigation and timing information provided by Galileo's global satellite constellation.

Already in the Initial Services phase, Galileo will benefit GNSS users worldwide by providing more **accurate** and **reliable** positioning, delivering an unprecedented **timing** accuracy and contributing to reducing response time to **emergencies** through Galileo's Search and Rescue service. The additional resiliency provided by Galileo is expected to enable a range of new applications and services that will benefit from increased positioning reliability, thus driving economic growth in Europe and beyond.

The advent of Galileo Initial Services enables chipset and receiver manufacturers and application developers to start leveraging on Galileo signals. Following widespread adoption in high-precision devices, a number of Galileo-ready devices has already hit the mass market, including **smartphones** and **in-vehicle navigation systems**. Initial Services is the first step toward full operational capability, which will occur when the Galileo constellation is complete by 2020.

New GSA website documents strong growth of Galileo-enabled devices

To keep users up-to-date with detailed information on all available Galileo-compatible products, the GSA launched **www.useGalileo.eu**. From this dedicated website, users can easily browse the regularly updated list of currently available **Galileo products and devices** and search for devices by market segment.

Currently, the majority of Galileo-enabled chipsets and receivers can be found in the automotive, mass-market, agriculture and surveying domains. In the **road** segment, Galileo contributes to vehicle navigation and fleet management. In the **high-precision** market, all leading receiver developers have already integrated Galileo into their products.

In the **LBS** mass-market, Galileo improves the positioning information users receive from their smartphones – particularly in urban environments where narrow streets and tall buildings often block satellite signals. Due to the additional LBS performance provided by Galileo, a steadily growing number of manufacturers is expected to provide Galileo support for their multi-constellation smartphones.

Galileo and Copernicus synergies enable more powerful applications

The added value of combining GNSS and Earth Observation information

GNSS, together with Earth Observation (EO) data create a powerful layer of information for multiple applications in various segments. There is a high potential for synergies between navigation and remote sensing systems at different levels of the value chain:

- At the **EO data processing, reselling and distribution** level where GNSS techniques can be used to calibrate and validate EO data, by geo- and time-referencing the maps;
- **Application domains** (downstream), which benefit a lot from the combination of the two systems. Selected examples include:
  - **Maritime search & rescue:** GNSS is used for the navigation of vessels and for locating SAR beacon signals. EO used for situational awareness.
  - **Infrastructure & environmental monitoring:** EO data and imagery is used to monitor buildings, bridges, also natural phenomena. GNSS sensors are installed on infrastructures to detect and analyse any kind of movement.
  - **Crop insurance:** GNSS and EO are used to collect data from crops through imagery or in-field observations. The data helps insurance companies to improve their insurance products sold to farmers to protect loss of their crops.

Through the various applications, GNSS and EO synergies generate benefits for society as a whole by enabling inter alia higher agricultural productivity, improved safety, improved urban planning solutions and more effective traffic flow management.

HORIZON 2020

GEO-VISION

Satellite data as a key enabler of improved disaster response management

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

The core of the project is the mission-critical visual communication wherein the end users upload imagery of disaster-struck areas to disaster response and emergency management operators. GNSS can fuse geo- and time-stamped visual imagery and earth observation imagery. GNSS is also used to navigate micro drones for live observations or mapping. Copernicus and the Sentinels are helpful in collecting large amount of data to assist in the disaster response management.

The project already resulted in the creation of three smartphone apps available for iOS and Android, with the end user group encompassing the United Nations, EU, World Bank and insurance companies. More information on: **http://www.geo-vision.space/index.php**

Synergies between GNSS and EO already benefit end users

One of the applications with the highest potential for synergies between GNSS and EO is **Integrated Farm Management**. The Copernicus programme and its Sentinel missions collect spatial information on the soil and the development of crops to create soil and crops maps. Consequently, GNSS is used for autonomous driving and automated steering of agricultural equipment like tractors and harvesters.

The availability of informative maps allows farmers to improve decision making. It also supports prompt intervention and chemicals optimisation. This has a positive impact on farm management, with cost reductions between 6% and 10%, and on the surrounding environment.

A second high potential use case arises in the **Air traffic management** and navigation domain, where the integration of EO, namely the Copernicus Atmosphere Monitoring Service, and GNSS data are improving the safety and efficiency of air traffic operations. For example, the consequences of the 2010 eruption of the Icelandic volcano Eyjafjallajökull, whose ash plume grounded about 100,000 flights and millions of passengers, could have been limited if air traffic managers had such enhanced Air traffic management and navigation systems at their disposal.

Evolving user technologies are driving the future of positioning

The **2016 GNSS User Technology Report** is the go-to source for comprehensive knowledge and information on the dynamic, global GNSS user technology industry and the latest trends.

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.

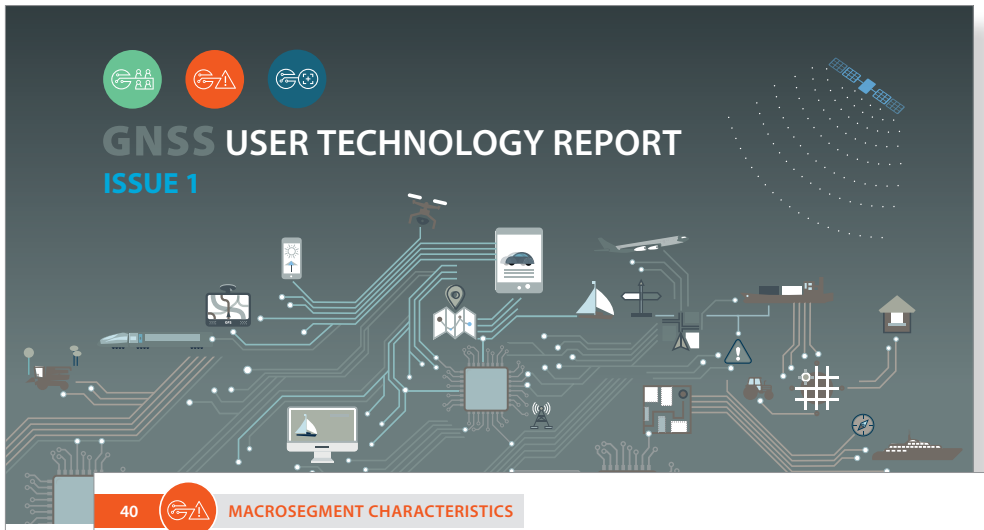
The First issue of the GNSS User Technology Report begins with a comprehensive overview of **GNSS user technology**. This is followed by a macrosegment analysis that focuses on **receiver** design, innovative **signal processing** techniques, changes that have an impact on **antennas**, and GNSS **vulnerabilities** – and how to mitigate them.

The report also investigates how changes in user needs, GNSS systems, and the underlying technologies all **impact receiver design**. Specific developments and typical solutions for a given application area are presented. These applications are grouped within three macrosegments:

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

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/2016-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.



40 MACROSEGMENT CHARACTERISTICS

High levels of confidence and resilience are required for transport safety and liability-critical solutions

Characterisation of the transport liability and safety-critical segment

This segment covers receivers and technologies used to cope with the stringent requirements of safety or liability-critical applications found in aviation, maritime, rail and road transport applications. However, it has to be noted that:

- Not all transport applications are liability or safety-critical. For instance, aftermarket in-vehicle navigation (PNDs) is dealt with in the "Mass Market" macrosegment, and fleet management in the "High precision, Timing and Asset Management" one.
- Some critical applications may arise in domains other than transport, although currently not considered in this report. The only exception is timing and synchronisation of critical infrastructures, which is dealt with in the next group within the "High precision, timing and asset management solutions" macrosegment.

There is a clear trend towards using GNSS as a position sensor in such liability-critical applications as road charging and even in safety-critical applications such as autonomous cars. Following this trend, road devices are gradually developing similarities with aviation, rail and maritime devices, and are therefore discussed together. Therefore, in-vehicle navigation, factory-fit GNSS receivers are included in this segment, despite their (current) predominant use in vehicle infotainment systems.

Applications considered in this segment range from relatively simple "positioning" to the most complex "control" of such things as autonomous vehicles, with an increasing level of criticality. Because of this criticality, these applications are often regulated or, for the emerging ones, likely to become regulated or subject to standardised design/performance requirements.

Key performance parameters*

Within this segment, all applications require a high level of confidence and resilience, which translates into the following performance parameters:

- **Integrity:** a failure in integrity could lead to catastrophic events for safety-critical applications, such as mid-air collision or controlled flight into terrain in aviation. It can also lead to erroneous charges/fines and undermine the entire application for liability-critical ones.
- **Continuity:** in combination with integrity, it is vital that safety-critical application systems function for the duration of the procedure. This is also highly important for liability-critical applications, as discontinuity may render certain applications inert (such as road tolling or insurance).
- **Robustness:** susceptibility to jamming or the inability to detect spoofing could lead to accidents or render the application useless.
- **Availability:** since the applications supported can be operated 24 hours a day, 365 days a year, it is important that the positioning technology supports it.
- **Accuracy:** some applications may require a high level of accuracy in order to function.

To summarise, with the exception of personal car navigation, all these applications share the following key parameters: **Integrity, Robustness, Availability** and **Continuity**. In addition, **Accuracy** may be required for some specific applications/operations.

***Signal Authentication** is an important feature and, in some cases, a fundamental enabler of **Robustness**. However, here it is considered a "Signal Property" rather than a user's "Key Performance Parameter".*

Key Performance Parameter*	Safety & Liability Critical
Availability	●
Accuracy	●
Continuity	●
Integrity	●
Robustness	●
Indoor penetration	●
Time To First Fix (TTFF)	●
Latency	●
Power consumption	●

● Low priority ● High priority

* The Key Performance Parameters are defined in Annex I

MACROTRENDS IMPACTING GNSS ACROSS MARKET SEGMENTS

GNSS supports innovation across major technology developments

GNSS features across key technology trends of this decade

As a cost-effective and globally available source of location and timing information, **GNSS** contributes to a **rapidly diversifying range** of **technologies** and **applications**, which in turn enable a plethora of use cases. Bolstered by incremental performance enhancements and growing user awareness of its potential, GNSS has become an essential element of major contemporary technology developments, notably including the **Internet of Things, Big Data, mHealth, Augmented Reality, Smart Cities,** and **Multimodal Logistics**.

This chapter covers the following **macrotrends**:

Internet of Things (IoT)		A major development in the role of the internet, the IoT allows physical devices, vehicles, buildings and other objects to be **interconnected** and **controlled remotely** across network infrastructures. IoT is relying on a wide range of **different sensors** and technologies, one of them being **GNSS** which provides **localisation** and **timing information**.
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 processing**. 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.
mHealth		**Mobile Health (mHealth)** is a sub-segment of eHealth and covers medical and public health practice supported by mobile devices. Key mHealth application categories include **disability assistance, preventive medicine** and **emergency**, and leverage fusion of big data with GNSS.
Augmented Reality (AR)		**AR** integrates **digital information** with the user's **environment**. Unlike virtual reality, which creates a totally artificial environment, AR uses the existing environment and overlays new information on top. **GNSS** provides a globally available source of georeferenced information that **brings augmented reality into the open**. GNSS allows the creation of a direct link between the surrounding reality and digital objects.
Smart Cities		**Smart Cities** feature an integrated system for collecting, measuring, collating and broadcasting city data and for making it easily **accessible** to citizens, municipalities and city planners. GNSS is one of the key technologies used within **infrastructure design** and **mobility** of smart cities, offering numerous opportunities to **citizens, local governments** and **city planners** alike.
Multimodal Logistics		Multimodal logistics refers to the transport of goods by at least two different modes of transport in the framework of a single multimodal transport contract. Logistics service providers draw on GNSS for **efficiency, security** and **safety.** GNSS contributes to the monitoring of **cargo** along the entire supply chain and enables pivotal **asset management** applications.

The Internet of Things relies on GNSS for location and timing information

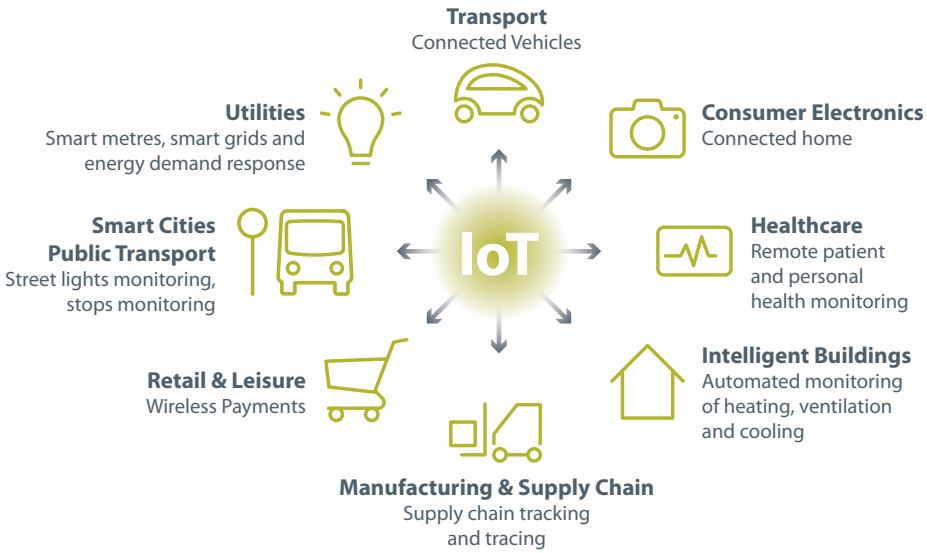
What is the Internet-of-Things?

The **Internet-of-Things (IoT)** comprises the networked connection of physical objects with a unique IP address. A major development in the role of the internet, the IoT allows physical devices, vehicles, buildings and other objects to be interconnected and/or controlled remotely across existing network infrastructures.

Estimates on the future growth potential of the global IoT market continue to differ tremendously. Embracing a narrower definition of IoT and using conservative estimates, the overall market for IoT is expected to generate **€1 tn** in revenues in 2020. Using a more comprehensive definition yields a forecast of up to **€7** tn in revenues for the same year.

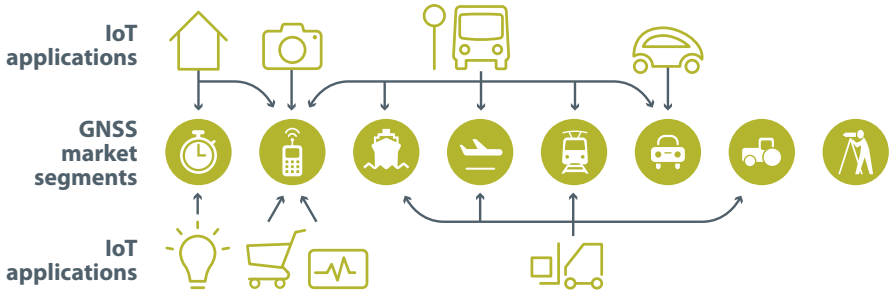
Irrespective of the definition used, the majority of current forecasts converge in their assessment that the domains **"Manufacturing and Supply Chain"** and **"Smart cities"** will constitute the most sizeable markets in terms of revenues, projected to account for approximately €2.5 tn and €1.3 tn in 2020 respectively. Whilst likely to yield much lower compound revenues by 2020, contemporary research forecasts the IoT Healthcare market to witness the highest growth rate, with a CAGR of 38%.

What can be connected



IoT infrastructure connects many GNSS segments

Across many market segments, GNSS provides **real-time geolocation and timing information** to countless applications. Amongst the market segments that harness major benefits from integrating GNSS in future IoT infrastructures are Logistics, LBS and Agriculture.



The spread of IoT in **logistics** (road, maritime, rail, aviation) will significantly change how the supply chain operates, connecting people, processes, data, and things via devices and sensors. The key advantage relates to in-transit visibility, namely the provision of identity, location, and other tracking information all the way from the manufacturer to the retailer. Combining real-time sensor data with environmental data allows efficient decision-making that drives overall productivity and moves the supply chain from a reactive mode to a proactive one. Additional benefits include improved warehouse and fleet management and fuel savings.

Nowadays, the **agricultural industry** is facing increasing water shortages, limited availability of lands, difficulties to manage costs, while it still must cope with the increasing consumption needs of the global population. Farmers can leverage IoT to remotely monitor sensors that can detect soil moisture, crop growth and livestock feed levels, remotely manage and control their smart connected harvesters and irrigation equipment, and utilise artificial intelligence based analytics to analyse operational data, yielding new insights and improving decision making.

A fundamental enabler of **LBS**, GNSS will underpin future IoT infrastructures by providing geolocation and timing data from a plethora of LBS devices, ranging from smart healthcare solutions, to connected bikes and lawnmowers for IoT-embedded smart cities and smart homes. By connecting devices, vehicles and infrastructure everywhere in a city, governments and their partners can reduce energy and water consumption, keeping people moving efficiently while improving safety and quality of life.

GNSS is becoming an essential data source for Big Data processing

What is this hype all about?

Every single day, about 2.5 quintillion bytes of data are created globally and 90% of the data in the world today has been created in the last two years alone. As traditional data processing is not able to deal with these volumes of data, complex systems are currently being created to allow for big data processing.

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The big data market comprises three major segments:

- **Infrastructure:** Computing, networking, storage infrastructure, and other datacentre infrastructure (including security).
- **Software:** Information management, discovery, analytics, and apps software.
- **Services:** Professional and support services for infrastructure and software.

Data grow by 60% annually, bringing both challenges and opportunities

Big Data processing is characterised by the '4 V's':

- **Volume:** Increasing volumes of data and new types of information require capacious storage capabilities and high-performance analysis solutions.
- **Variety:** New data sources are generated every moment, ranging from wearables and smartphones to weather sensors, purchase transaction records and health records.
- **Velocity:** Velocity relates to the necessity of matching the speed of data production with the speed of data processing to meet the growing demand for real-time analytics.
- **Veracity:** Data often originates from unverified sources, making it necessary to establish and flag the quality of data before it is included in larger datasets.

Last but not least, the **value** of data is of key importance. Traditionally, businesses conducted simple analyses through data processing. Nowadays, large businesses increasingly position data analytics at the centre of operations, on the basis of which corporate strategies can be devised and fine-tuned.


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GNSS provides valuable location and timing information for Big Data business

GNSS constitutes a major data source providing location and timing information to the world of Big Data processing. With GNSS devices proliferating, a skyrocketing amount of location and timing data are becoming available for businesses interested in obtaining consumer insights and seeking to adapt their corporate strategies accordingly. At the same time, end users benefit from personalised and crowd-sourced services building on GNSS-embedded Big Data.

The GNSS segments in which Big Data processing has the biggest value are:

- **LBS:** With ubiquitous positioning becoming a reality, GNSS-enabled location data generates exorbitant volumes of georeferenced data from portable devices worldwide.
- **Road:** GNSS-integrated connected vehicles will upload approximately 25 GB of data to the cloud every hour, necessitating a highly reliable and performant processing infrastructure.
- **Timing & Synchronisation:** From financial transactions to future smart electricity grids, GNSS serves as an indispensable source of timing information across widely dispersed areas that require high-performance real-time data processing technologies.


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Big Data processing raises privacy and security issues

GNSS-enabled location and timing data can be delicate in terms of **safety** both for private individuals and for business assets. With often convoluted privacy terms, many GNSS users are uncertain about the use of their private data for commercial purposes. Some types of location-based information, particularly those related to health concerns (e.g. frequency of doctor visits, activity levels, etc.) are highly sensitive and could be unduly exploited by commercial firms.

The European Union provides a **legal framework for data protection** that tackles personal data usage in electronic communication as well as data retention. However, there are persistent shortcomings with regards to how these legal provisions are applied to various services and applications. Nevertheless, the large majority of users is sharing their personal information in exchange for the tangible benefits that GNSS applications bring.

From better well-being to better treatments, mHealth's growth trend also relies on location information

How mobile devices are changing healthcare?

Mobile Health (mHealth) is a sub-segment of eHealth and **covers medical and public health practice supported by mobile devices**. It especially includes the use of mobile communication devices for health and well-being services and information purposes as well as mobile health applications. Mobile health applications are expected to play a major role for the management of personal health in the future.

mHealth covers a wide range of purposes including health promotion, illness prevention and healthcare delivery. There are five prominent use cases for generating value through the use of mobile devices in healthcare:

- **Asset & process optimisation:** Connect and collect data from all levels of medical workflows to identify efficiencies, generate savings and new workflows.
- **Remote medicine:** Remote monitoring, diagnosis, and treatment by linking smart, connected devices to centralised treatment facilities.
- **Clinical Innovation:** Discover new ways to improve patient care and train practitioners using smart, connected devices.
- **Consumer wearables:** Wearables & sensing devices to measure individual health indicators, focused on wellness and monitoring.
- **Personalised medicine:** Tailor medical solutions for individual patients using IoT devices (e.g. pill cameras, genomic sensors).

Human Enhancement Technologies are not science fiction

One of the frontiers of mHealth regards the use of technologies for human enhancement. **Human Enhancement Technologies (HET)** are techniques that can be used not simply for **treating illness and disability**, but also for **enhancing human characteristics and capacities**. Among the main drivers responsible for the developments in this field is the specialisation of wearable devices able to perform more and more complex functions. Already in the market, it is possible to find devices exploiting light reflection, facial expressions, skin conductance and even brain waves to interact with the body. The use of such devices offer various types of performance improvements from night vision enhancement and isolation of sounds in crowded settings to improved body coordination and even telepathic communication to control objects remotely.

Main mHealth application categories leverage fusion of big data with GNSS

Disability assistance: Today, over a billion people have some form of disability. mHealth products/services represent an increasing opportunity to improve life for most of them by providing solutions aimed at reducing the barriers that limit the access to public and private services/infrastructures. GNSS-based products in this category are mainly designed to address issues related to vision (e.g., navigation solutions for the blind) and cognition (e.g. tracking solutions aimed at geo-fencing and/or locating patients with Alzheimer's disease). Other GNSS-based navigators (e.g. European project INCLUSION) are specially tailored to provide support to upper and lower body-impaired individuals.

Well-being: The increasing penetration of wearable devices for both leisure and professional purposes, is part of a general trend towards pre-emptive healthcare and maintaining personal well-being. The measurement of effort, distance and speed of movement provided by GNSS enabled devices are used in targeted sport applications (rowing, golf, athletics, soccer training, skiing, etc.) allowing identification of specific sport aptitudes and improvements. Moreover, new available platforms allow the synchronisation of data to a personal health record eventually providing medical professionals with real-time vision into the lives of their patients, replacing or integrating annual medical check-ups with constant monitoring.

Emergency: By integrating accurate GNSS position information into distress beacon signals, GNSS is also revolutionising search and rescue (SAR) operations. By 2020, all Cospas-Sarsat Emergency Personal Location Beacons (registered personal devices that can be used in any remote location or situation where people may require rescue) are expected to be using precise GNSS positioning, helping to reduce response times and save lives. In Galileo-enabled beacons, the Galileo return link service will reassure the navigator that the signal has been received and that help is on its way. GNSS data are also used within specialised smartphone applications for disaster management integrating crowdsourcing data from users and from other systems such as Earth Observation (e.g. Copernicus) and/or weather stations allowing civil protection services and policymakers to effectively prevent and/or react during natural disasters (e.g. European projects iReact and Floodis).

GNSS set to play an enriching and supporting role in Augmented Reality

Augmented Reality: adding a digital layer to the real world

Augmented reality (AR) is the **integration of digital information** with the **user's environment** in real time. Unlike virtual reality, which creates a totally artificial environment, augmented reality uses the existing environment and overlays new information on top of it. There are three fundamental categories of Augmented Reality tools:

- **Augmented Reality 3D viewers**, which allow users to place life-size 3D models in the surrounding environment with or without the use of trackers. Trackers are simple images to which 3D models can be attached to in Augmented Reality.
- **Augmented Reality browsers** enrich a camera display with contextual information. For example, pointing a smartphone at a building it can display its history or estimated value.
- **Immersive gaming experiences** that utilise the actual surroundings. The biggest use of Augmented Reality gaming to-date is Pokémon Go, allowing users to catch virtual Pokémon who are placed on a virtual layer on top of the real world.

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The evolution of the Augmented Reality market

The **global augmented reality market** is expected to reach **€108 bln** by 2022, driven by a CAGR of 75% between 2016 and 2022. Currently, the mobile augmented reality market covering applications on smartphones, tablets, PDAs, smart glasses and wearables is the strongest driver of this growth and forecasted to reach €75 bln, or 69% of the total augmented reality market value.

GNSS is a key enabler for future ubiquitous Augmented Reality

Current augmented reality technology combines internal sensors such as gyrometers, accelerometers and 3D-cameras with indoor solutions such as Bluetooth, indoor beacons and ZigBee. Thanks to GNSS, it is possible to create a direct link between the surrounding reality and the digital objects projected through augmented reality. This provides users with outdoor navigation and the possibility to geo-reference specific objects or areas relevant for the AR application.

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The next step in the evolution of AR is likely to see the emergence of hybrid AR, in which the user can leverage on a single device using hybrid positioning technology providing a seamless transition in user experience between indoor and outdoor augmented reality.

The hybridisation of augmented reality will provide additional benefits to a wide range of applications currently available or under development. In the field of **Location-Based Services**, AR will play a role in a range of recreational applications, such as the discovery of cultural heritage. For **Surveying applications**, AR is expected to play a more prominent role in construction and maintenance, to utilities infrastructure management such as visualizing pipelines and wires, up to territorial planning.

Finally, the first use cases of augmented reality in **Road** are providing navigation assistance directly on the windscreen as a more natural means of displaying navigation information compared with the additional screen of an IVS or PND.

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GNSS makes our cities smarter and more sustainable

Rapid urbanisation drives need for more efficient and sustainable cities

More than 50% of the global population already lives in cities and it is forecast to grow up to 66% by 2050 (compared to 30% in 1950). People are looking for better quality of living, access to information, education and jobs, as well as connectivity in urban settlements.

Cities are implementing policies and strategies to improve operational urban efficiency, protect environmental sustainability and provide services tailored to citizens' needs.

Smart Cities have an integrated system for collecting, measuring, collating and broadcasting city data and for making it easily accessible to citizens and visitors.

This results in new services accessible on the individual user level, but also in a centralised, integrated way as part of the cities infrastructure, which is also called Infrastructure 3.0 and provides real-time optimisation and incident management.

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GNSS lies in the centre of the Smart City concept

GNSS is one of the key technologies used in Smart Cities infrastructure design, fulfilling the needs of different services and stakeholders.

For city planners and citizens alike, GNSS offers numerous opportunities to:

- **plan new infrastructure** and improve existing one based on measuring traffic flows – e.g. longitudinal traffic flow data informing future infrastructure investment decision,
- **decrease CO_2 emissions** coming from the transportation vehicles – e.g. smart bus stops and efficient phasing of traffic lights,
- **ensure safety** based on citizens' reports from certain locations – e.g. combining citizens' emergency reports with CCTV data,
- **improve infrastructure monitoring**, optimise maintenance intervals and reduce the costs for upkeep – e.g. combining data on the use of bridges and sensor-provided status of various elements.

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European municipalities are among global leaders of Smart Cities

Data and ICT infrastructure are key technological backbones of the Smart City concept and its smart grids. The urban invisible networks include high-performance wireless and wired broadband infrastructure, LTE, RFID, NFC, WLAN and a wide range of communication hardware, actuators and sensors. It is hard to imagine Smart Cities without GNSS nowadays:

- The **City of London** was one of the pioneers to launch an operating control system that can monitor and manage more than 8,000 buses by satellites. That resulted in a 20% traffic decrease in one of the busiest cities of the world.
- **Barcelona** was named as the World Smartest City in 2015. One of the GNSS-based solutions that the city inhabitants enjoy is G-MOTIT system – an electric scooter sharing service for sustainable urban mobility based on GNSS, which is now enhanced by EGNOS and Galileo.
- **Reykjavik** implemented a prioritisation system of green lights for public transport and emergency vehicles based on GNSS, thanks to which buses are more punctual, traffic safer and there are significant energy and pollution savings.
- In its Smart City Strategy, **Berlin** recognises Galileo as one of the key enabling technologies to realise its goals as a city of the future.

HORIZON 2020

GHOST

Galileo is already enabling intelligent city services

One of the initiatives supported by GSA that develops intelligent solutions for Smart City needs is the **GHOST** project *(Galileo Enhancement as Booster of Smart Cities)*, which aimed at monitoring city infrastructure and assets. It relies on an intelligent system for public transport vehicle fleets enabling the automatic geo-referencing of snapshots of Point of Interests (POIs) thanks to the accurate positioning provided by a Galileo receiver.

The POI snapshots are gathered and processed in a centralised database that can be integrated with the existing IT system of the city operation centre.

These **Galileo geo-tagged pictures** can be a key enabler for the creation of many services, such as:

- Reporting of street lighting or road deteriorations;
- Monitoring of public garbage completion levels;
- Detection of double parking or unauthorised occupation of parking spaces reserved for handicapped drivers.

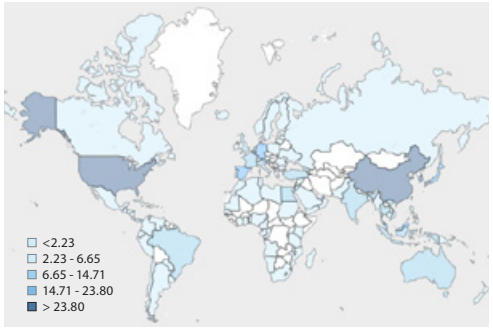
More information is available on: **www.ghost-project.eu**

GNSS can improve efficiency, security and safety in multimodal logistics

Market drivers and added value

Multimodal logistics refers to the carriage of goods by at least two different modes of transport on the basis of a single multimodal transport contract through road, rail, sea and air. Multimodal transport serves the needs of a globalised world and was developed by the introduction of containers. The key stakeholders in multimodal logistics are:

- **Logistics Service Providers**, who are planning, executing and marketing the transport service (e.g. carriers, freight forwarders, container lessors, multimodal hubs).
- **Transportation Network Managers** extracting available information about infrastructures, planning and execution of transport etc. and making these data available to Clients and Service providers (e.g. railway infrastructure managers).
- **Transport Regulators** that verify compliance with regulations.
- **Customs** and **Port Authorities** that act as Transport Regulators by monitoring the flow of goods, containers and vehicles.



Container port traffic in 2014 (million TEU)
Source: The World Bank (http://data.worldbank.org/indicator/IS.SHP.GOOD.TU?page=6)

In search of optimised and greener transport

A shift from road freight to greener transport modes are sensitive issues for the European Union, as logistics is recognised to play a critical role for sustainable and competitive mobility, safety, security and a reduced environmental impact at the European level. The European Commission committed to improving and innovating logistics and developing Intelligent Transport Systems (ITS) by launching the **Freight Logistics Action Plan** in 2007.

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GNSS improves efficiency in multimodal logistics

The multimodal logistics industry has a strong need for reliability, flexibility and cost effectiveness. One of the key advantages provided by GNSS is the possibility to achieve a significant **improvement in efficiency, security and safety** as a consequence of:

- Better monitoring of the cargo along the whole supply chain, from the consignee to the consignor. This implies lowering costs and increasing transport safety (e.g. in case of dangerous good transportation).
- The possibility to adjust supply chain operations based on information received enroute.
- GNSS PNT information from containers, vessels and trucks improves asset management, and allows for the optimisation of the use of different assets along the supply chain.
- Risk reduction of theft and attacks during transport.

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In order to equip the container fleet with GNSS devices, Logistics Service Providers either purchase them or sign leasing or rent contracts with service providers. As an example, recently, Orbcomm struck a deal with CIMC to equip their containers with GNSS telematics.

GNSS adoption for container tracking is growing, but barriers still exist

Despite the benefits available to multimodal logistics players thanks to GNSS monitoring of containers, adoption is still limited. Key reasons include:

- **Operational costs** – still high average prices for GNSS devices as compared with alternative technologies used to store and transmit information.
- **Power consumption** when monitoring unpowered assets.
- **Durability issues** of the devices subject to harsh environment during the carriage, as they may get damaged by shocks, precipitation or extreme temperatures.
- **Signal availability** when containers are stored in lower decks of vessels or in warehouses.

Once these challenges are solved, the industry foresees a steady growth of the GNSS adoption, assisted also by decreases in equipment costs via economies of scale.

Location Based Services (LBS)

GNSS applications

- **Navigation:** Route planning and turn-by-turn instructions based on GNSS support for both pedestrian and road navigation.
- **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/Augmented reality:** GNSS enables a wide range of location-based games on smartphones and tablets. In augmented reality games, positioning and virtual information are combined to entertain the user.
- **mHealth:** 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 help keeping in touch and sharing travel information.

LBS devices

GNSS-enabled Location-based services comprise a multitude of applications tailor-made to satisfy different usage conditions and needs. These applications are supported by several categories of devices: mainly smartphones and tablets, but also specific equipment such as personal tracking devices, wearables, digital cameras and portable computers.

What you can read in this chapter

- **Key trends:** Ubiquity of GNSS in smartphones is enabling a thriving context-aware apps market.
- **User perspective:** Emerging LBS applications are more demanding in terms of user requirements.
- **Industry:** List of main players by value chain segments.
- **Recent developments:** Asia-Pacific accounted for over 50% of global LBS shipments in 2016.
- **Future market evolution:** Smartphones shipments mature, shifting revenue streams towards added-value services.
- **Focus on European GNSS:** Galileo paves the way for the development of enhanced LBS applications.
- **Reference charts:** Annual evolution of GNSS devices' installed base and revenues by device type and region.

NEW **GNSS enabled app revenues** quantified in this edition of the GNSS Market Report.

Ubiquity of GNSS in smartphones is enabling a thriving context-aware apps market

Key Market Trends

- Over 90% of context-aware smartphone apps now rely on GNSS and first Galileo smartphones hit the market.
- A growing number of premium smartphones is going beyond dual-constellation by integrating multi-constellation GNSS chipsets, thus further increasing accuracy, availability and time to fix.
- Location-based services in mHealth are driving the diversification and sophistication of wearables and smartphone apps for healthcare.
- Availability of GNSS raw measurements on smartphones opens new possibilities for app developers.

The rise of context-aware apps

Context-aware apps extrapolate information about the user's **context** from the devices' **positioning technologies** and **sensors**. Context-awareness supports navigation, social networking, tracking, search and many other smartphone app categories including location-centric augmented reality games and utility apps that require absolute positioning. While hybrid context-aware smartphone apps for indoor positioning integrate Wi-Fi, Bluetooth and cell-ID location, hybrid and outdoor positioning continue to rely on GNSS as a source of efficient positioning.

Revenues of context-aware smartphone apps will hit €30.6 bln by 2019, up from €11.7 bln in 2015. GNSS penetration in context-aware apps is steadily increasing and reached a weighted penetration of over 90% in 2016, with GNSS-attributable app revenues reaching € 5 bln[1].

App store market becoming less concentrated

The increasing number of app stores and the growing **APAC** market have had a **disruptive** effect on the long-standing global duopoly of Android's Google Play and iOS' Apple App Store. Already in 2016, almost 60% of Chinese Android users downloaded apps from third-party app stores. This trend is likely to continue.

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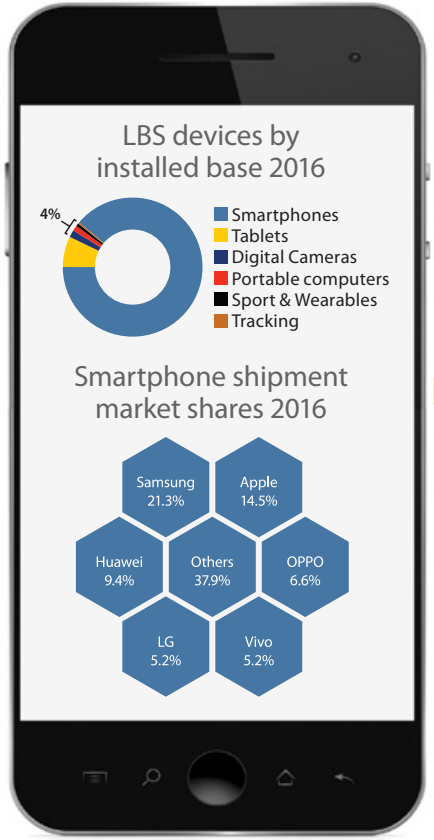
With €28 bln, the Asia-Pacific app market accounted for 56% of global app revenues in 2016 and is forecasted to grow to €57 bln by 2020 (CAGR of 19.4%).

In 2016, **Android** consolidated its leadership in terms of annual global app **downloads**, with over two downloads from Google Play for each **iOS App** Store download. Inversely, the iOS App Store generated twice the revenue of Google play in 2016.

Total unique apps in store

Google Play 2.4 mln apps
Apple App Store 2.0 mln apps
Tencent MyApp ~2.0 mln apps
Windows Phone Store 669 k apps
Amazon Appstore 600 k apps



Users

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The global **installed base** of GNSS enabled handsets is expected to rise from 4.1 bln in 2016 to 6.1 bln in 2019 (many users have multiple devices). The strong growth in LBS revenue is primarily driven by the **growing** and **diversifying** usage of apps, rather than by the accruing installed base. Annual revenues of LBS GNSS device sales and services are expected to exceed €115 bln in 2025.

Over the last years, the worldwide **time users spent** in apps almost doubled, with Android users now spending 2 hours per day on average using smartphone apps.

With the rise of context-aware smartphone apps, more and more users are profiting from GNSS-supported LBS such as location-based **aggregation** services, geolocation social media **monitoring** and proximity-based **marketing** applications.

[1] Including €2.9bn revenues generated by smartphone apps for navigation, which are quantified in the Road segment

Emerging LBS applications are more demanding in terms of user requirements

New Augmented Reality apps require higher GNSS performances


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A growing number of smartphone apps is using **GNSS** to enable location-based **Augmented Reality** (AR) services. Allowing geo-referenced positioning globally, **GNSS** is an essential technology for AR apps in outdoor environments. The growing complexity of AR apps is driving the evolution of GNSS **user requirements**. Increasingly penetrating both the professional and the mass market, new location-based AR applications require a greater **accuracy** performance than most LBS smartphone apps.

Moreover, the rapidly diversifying portfolio of GNSS-enabled AR apps is driving the need for **authentication** of the position. A growing number of smartphone users is becoming aware of the risks of malicious interferences to GNSS signals thanks to the extensive media coverage on 'cheating' the Pokémon Go app through GNSS spoofing. Authentication can moreover contribute to protecting app developers' streams of revenue.

Driven by ever lower **device prices** and the rapid maturation and diversification of technology, the global AR market is expected to grow dramatically from €5 bln in 2016 to over €81 bln by 2020.

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A growing number of LBS applications require higher accuracy and authentication

The **user requirements** of many established **LBS** applications, such as turn-by-turn navigation, infotainment and social networking apps have remained relatively **constant** since their inception, and continue to be satisfied by levels of GNSS accuracy of 5 metres and more. Over recent years, a burgeoning group of new applications has emerged that does require far more **stringent** horizontal and vertical **accuracy** levels. These range from **augmented reality** applications to innovative safety-critical mHealth technologies such as guidance applications for visually impaired, which are among the most demanding types of smartphone apps.

Moreover, application categories such as **geo marketing and advertising**, fraud management and **location-based billing** require **authentication** of the position to protect app users from malicious signal interferences such as spoofing.

mHealth applications are driving innovation in hybrid positioning

Whilst **hybrid positioning** is relevant for many mass-market LBS applications, special user categories such as visually-impaired people or wheelchair users rely on a seamless navigation experience between outdoor and indoor environments to a much greater extent than most other user types. This has implications for **app developers** as pioneers in tackling the seamless positioning challenge.

Large healthcare providers such as hospitals are beginning to invest in hybrid navigation services and smartphone apps that enable staff, patients and visitors to navigate from their house door to a particular location in the facility using specific itineraries for different user categories, e.g. accessible routes for wheelchair users.


© Getty Images

LBS applications for healthcare are increasingly gaining ground, with a forecasted **CAGR** of approximately **32%** between 2016 and 2020.

Healthcare **needs** are driving the **diversification** of wearables. As an example, a GNSS-enabled haptic shoe allows visually impaired users to set a destination in the smartphone app. The soles guide the user to the destination by vibrating in the front, back, or sides.

Overview of the main user requirements in LBS

The table depicts, in alphabetical order, the key user requirements as assessed through the GSA's continuous monitoring with the user community. Only high priority requirements are shown, i.e. other requirements might also be relevant for considered applications, and the table is subject to updates. Information on the parameters is provided in Annex 2.

Applications	**Lower performance:** Navigation, Sports, Tracking, Social networking, Enterprise applications, Infotainment, Games	**Higher performance:** Augmented reality, mHealth, Geo marketing and advertising, Fraud mgmt and billing, Safety and emergency
Key GNSS requirements	Availability TTFF	Accuracy Authentication Availability TTFF
Other requirements	Connectivity (including short range) Interoperability Power consumption	Connectivity (including short range) Interoperability Power consumption

LBS Value Chain

COMPONENTS AND RECEIVER MANUFACTURERS

- BROADCOM
- INTEL
- MEDIATEK
- NIHON DEMPA KOGYO
- QUALCOMM
- SAMSUNG
- U-BLOX AG*

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, ZT

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

People Tracking: GARMIN, POCKET FINDER, SPOT, TELTONIKA

Original Design Manufacturers: 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 PHONESTORE

USERS

Mass Market Users, Professional Users, Users With Special Needs, Retailers

The European[1] GNSS industry in the global arena

The LBS segment is dominated by non-EU players. With a market share of over 60% in 2015, **North American** companies are leading in the components and receivers market, compared to a market share of less than 6% held by **European** companies such as u-blox. **Asian** companies were able to increase their share of **system integrators** revenues well beyond 50% of global revenues over recent years.

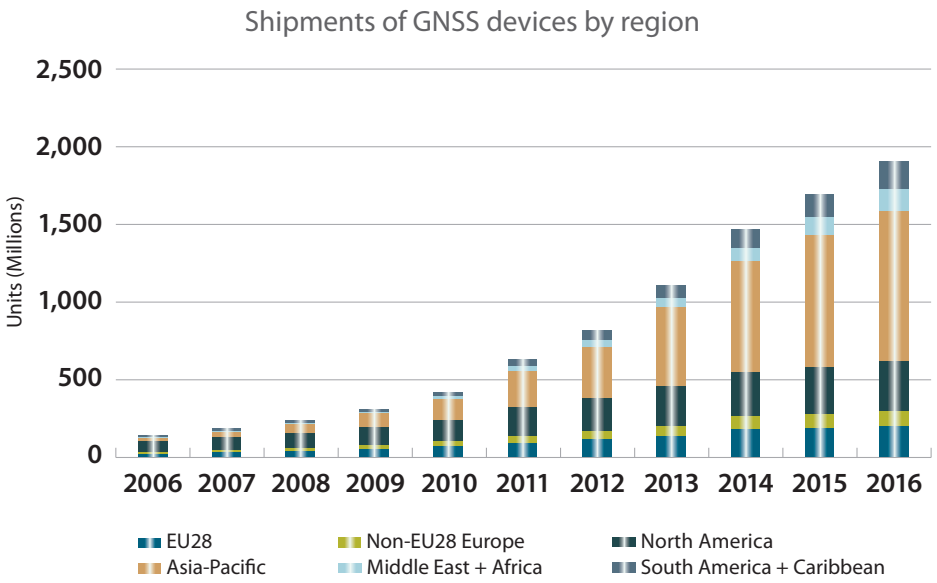
European players continue to perform strongly in **app development**. Of the 5.7 million app developers worldwide, over 22% work in the EU. By 2018, the European app economy is forecasted to contribute €63 billion to the EU economy and employ 4.8 million people.

A **technology-** and **innovation-friendly** environment for LBS in **Europe** has been bolstered by recent EU roaming rules, which oblige mobile telecommunications operators to apply the **domestic retail price** on any EU roaming customer for voice, SMS and data usage from mid-2017 onwards. Already in 2016, roaming in the EU was over 90% cheaper than in 2007. The further **reduction** in roaming charges is likely to boost the already growing usage of **location-based services** and **smartphone apps** beyond national borders.

The Value chain considers the key global and European companies involved in the GNSS downstream activities.
* European based companies. The world region is referred to the headquarter of the company, the actual area of activity might be wider.

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

Asia-Pacific accounted for over 50% of global LBS shipments in 2016



The largest regional LBS market since 2011, **Asia-Pacific** accounted for over 50% of global LBS shipments in 2016 with a total of almost 1 bln shipped devices. **North America** and the EU accounted for more than 320 mln and 200 mln respectively.

Smartphones greatly outnumber other LBS devices in terms of shipments. Due their large number of units, smartphones represent a great opportunity for application developers to effectively realise economies of scale. Driven by the growing context-aware smartphone app market, revenues attributable to GNSS grew from €150 mln in 2010 to €5 bln in 2016[1].

Due to the increasing saturation of the mature EU, North American and China markets and slackening global economic growth, the rise in global smartphone shipments has been gradually attenuating, with year-on-year growth in 2016 dropping to 12%, compared to 33% in 2014. The slowdown was underpinned by a rapidly **growing second-hand smartphone market**, which grew from 56 million smartphones traded globally in 2014 to over 100 million devices in 2016.

Other GNSS-enabled devices accounted for around 175 mln units in 2016. With 113 mln units shipped that year, **tablets** represented the second largest application. Their shipments saw a 250% increase between 2012 and 2016, with major regional markets consistently being **North America, Europe and Asia**. Driven by reducing device prices and growing consumer awareness, personal tracking devices witnessed the highest growth rate across all LBS categories, with a CAGR of 70% between 2012 and 2016.

Multi-constellation is broadening the possibilities of GNSS use on smartphones

A growing share of **premium** smartphones is integrating **multi-constellation** GNSS. Whilst many **low-end** smartphones continue to rely on single-constellation A-GPS, the vast majority of new premium smartphones integrate multi-constellation. GPS + GLONASS ranks as the most prominent combination of multi-constellation currently deployed in smartphones. Moreover, a growing number of high-end smartphones is additionally integrating BeiDou, thus further enhancing the benefits associated with multi-constellation devices. In mid-2016, the first Galileo-enabled smartphone entered the market.

With a growing number of premium smartphones using multi-constellation, more users are harnessing the associated benefits of higher **accuracy**, better **availability** in difficult environments and a lower **time to fix**.

As premium smartphones increasingly approximate the performance of low-end **professional-grade** receivers, the technological evolution of multi-constellation smartphones could in the future lead to the **democratisation of some professional activities**, such as rural cadastral surveying, and the "cannibalisation" of dedicated devices.

Different uses of GNSS create new market segments in wearables

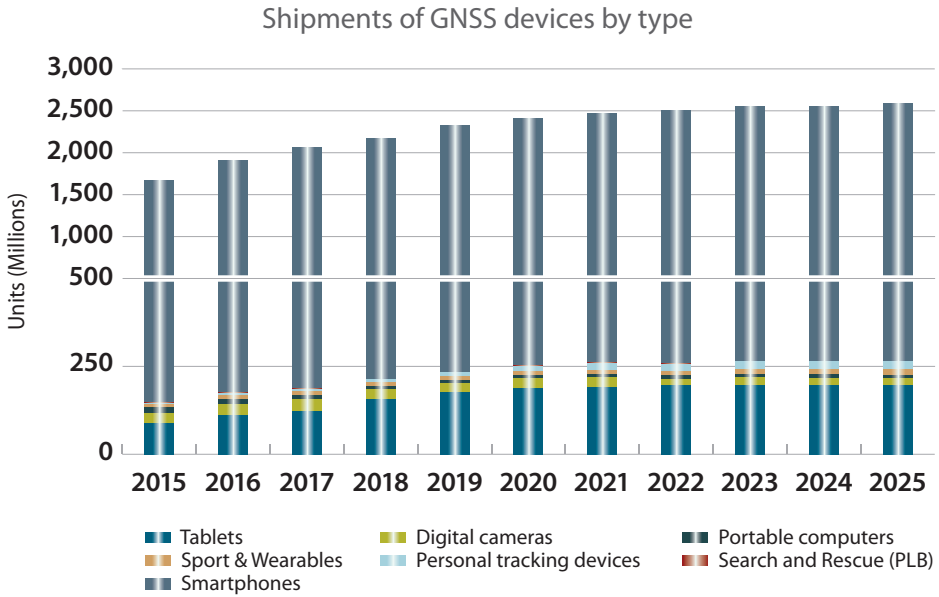
The incremental diversification of the GNSS wearables market has created differentiated markets with **distinct uses of GNSS**. GNSS supports diverse categories of wearables, including fitness wearables, smartwatches, healthcare wearables, smart clothes and smart eyewear.

For instance, GNSS Timing & Synchronisation entered the mass-market in 2016, with a growing number of watches drawing on **GNSS-referenced synchronisation**. High-end models integrate GPS-positioning that allows for automatic adjustment to correct time zones and have been available since 2012. Recently, Apple entered into competition with GNSS wearable market players Garmin and Polar by integrating GPS in its own range of smartwatches.

Growing **diversification** and **falling device prices** drove the **growth** of the wearables market over the recent years, with a CAGR of 15% between 2012 and 2016.

[1] Including €2.9bn revenues generated by smartphone apps for navigation, which are quantified in the Road segment

Smartphones shipments mature, shifting revenue streams towards added-value services



The growth of the global GNSS market in LBS will remain strong until 2020, followed by a period of attenuated growth due to increasing saturation in the **EU28, North American** and **Chinese** markets. Given the predominance of handhelds in the LBS segment, this slowdown will primarily be driven by the maturing **smartphone** market, which will grow by only 3.2 % annually between 2016 and 2025.

In 2017, more than 2 bln units of GNSS devices will be shipped, with annual shipments set to exceed 2.5 bln units in 2025. The **Asia-Pacific** region will continue to be the main motor of growth well into the post-2020 period. Underpinned by the growth and diversification of local search apps and augmented reality games, **app revenues** attributable to GNSS are expected to rise from €5 bln in 2016 to over €13.5 bln in 2020.

Tablets will remain the second most important application in terms of number of shipments, but annual growth rates will gradually decline due to the increasing maturity of the market. Future growth in this segment will be driven by the adoption of multi-constellation and the increasing computing power of tablets.

With a CAGR of 17.9% between 2016 and 2025, **personal tracking devices** will be the fastest growing market in LBS. With 14.1 mln units shipped in 2020, tracking devices are set to quickly overtake **wearables** in terms of number of units shipped.

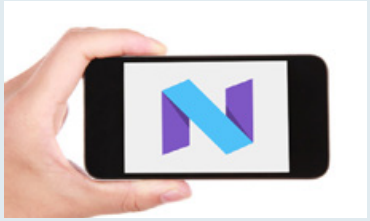
Hybrid positioning - closing the gap between outdoor and indoor LBS

The integration of outdoor and indoor LBS is ushering in the era of **hybrid positioning**, which comprises all services that leverage on both outdoor and indoor LBS technologies to enable a **seamless navigation experience** between outdoor and indoor environments. Hybrid positioning is particularly useful for spatially dispersed venues such as large urban universities or hospitals, whose facilities are often located at different locations in a city.

With indoor LBS increasingly **complementing** GNSS-based LBS for outdoor environments, seamless navigation solutions are forecasted to rapidly become more widespread. Currently, indoor LBS technologies such as Wi-fi, as well as Bluetooth low-energy and virtual beacons, are predominantly deployed by **large venue operators**, including shopping malls and conference centres as well as large public buildings such as airports, train stations, universities and hospitals.

Dubbed "the year of the beacon", 2016 saw a **skyrocketing** number of beacon manufacturers compete in an increasingly dynamic market. The global indoor LBS market is forecasted to grow at a CAGR of over 43% between 2016 and 2020, set to reach €7.7 bln in 2020.

Availability of pseudoranges could push the boundaries of GNSS performance



In May 2016, **Google** announced that it will make available raw GPS measurements, making **pseudoranges**, carrier phase and Doppler accessible from smartphones and tablets using the new Android operating system depending on how much the chipset layer will release. This will enable **device manufacturers** to enhance their real-life GPS performance testing and potentially enable the development of **more reliable and accurate** GNSS-based positioning using conventional hardware.

App developers are foreseen to be well-positioned to profit from this development in the future, as there is a number of benefits to be derived from **more performant smartphone apps** that draw on the newly released measurements. For app users, the expected benefits comprise higher accuracy and greater reliability, in turn enabling a **better positional performance.**

Galileo paves the way for the development of enhanced LBS applications

Mass market LBS applications require high availability, a fast Time To First Fix (TTFF) and moderate accuracy. Simultaneously, they need to preserve the battery life of the device and keep the cost of the receiver down.

In multi-constellation mass-market LBS devices, Galileo enhances core GNSS performances. By virtue of providing a higher number of available satellites, Galileo benefits users globally by **increasing accuracy, improving availability** in challenging environments such as urban canyons and light indoor environments and **lowering the TTFF**. Galileo improves location-based services and applications for users, ranging from enhanced ubiquitous positioning performances to the development of more sophisticated Augmented Reality applications in outdoor environments.

By furthermore providing signal-embedded authentication, Galileo could become a key enabler of future Location Based Billing services by facilitating the linking of user's location information to a payment for a given service.

EGNOS and Galileo might be employed for improving 112 caller location accuracy

EU funded HELP112 project is a pilot project on the design, implementation and execution of the transfer of **GNSS** data during an **e112 call** to a Public Safety Answering Point (PSAP). Caller location information is one of the **main challenges** that emergency services face nowadays. In practice there is a gap between **citizens' expectations** of location accuracy (5-10 m) and the current emergency location solutions available in EU Member States using mobile cell or sector ID (100m - 40 km).

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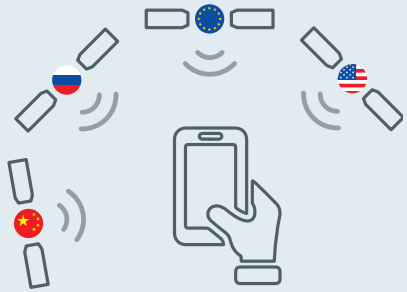
Accurate and **reliable** caller location leads to considerable gains in human, time and financial resources, and, above all, **lives saved**. The project tests and assesses the use of European GNSS solutions, notably Galileo and EGNOS, to define requirements and recommendations for technologies enhancing caller location information at the European level in a cost effective manner. Improved emergency caller location could save **800 lives** annually and up to **€100 billion** over the next decade, according to a study conducted within the project.

More information on: **www.help-112.eu**

The first Galileo-ready smartphones are hitting the market



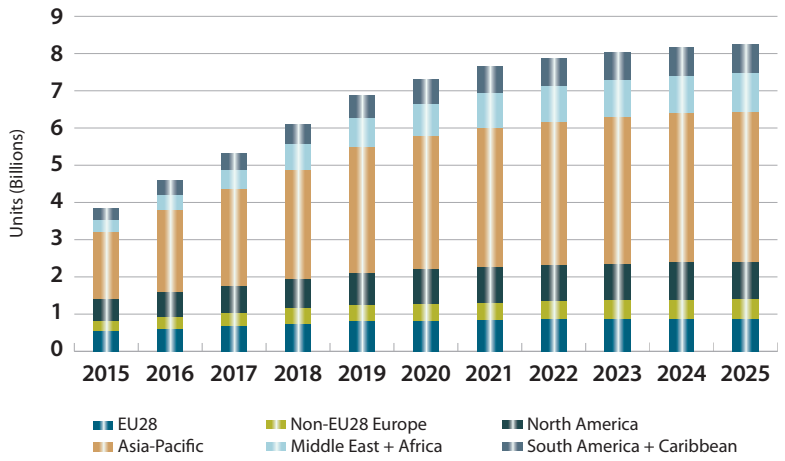
In mid-2016, the Spanish technology company BQ launched the **Aquaris X5 Plus**, the first European Galileo-ready smartphone. Integrating Qualcomm's Snapdragon 652 processor, the Aquaris X5 is a multi-constellation smartphone that is capable of receiving also GPS, GLONASS and BeiDou signals.

In early December 2016, Chinese manufacturer Huawei announced that its new premium models, the Huawei **Mate 9** and **Mate 9 pro**, will add Galileo support. Additional Galileo-ready smartphone models from Sony (**Xperia XZ Premium**), Huawei (**P10, P10 plus**) and Samsung (**S8**) have since hit the market (as of Mach 2017).

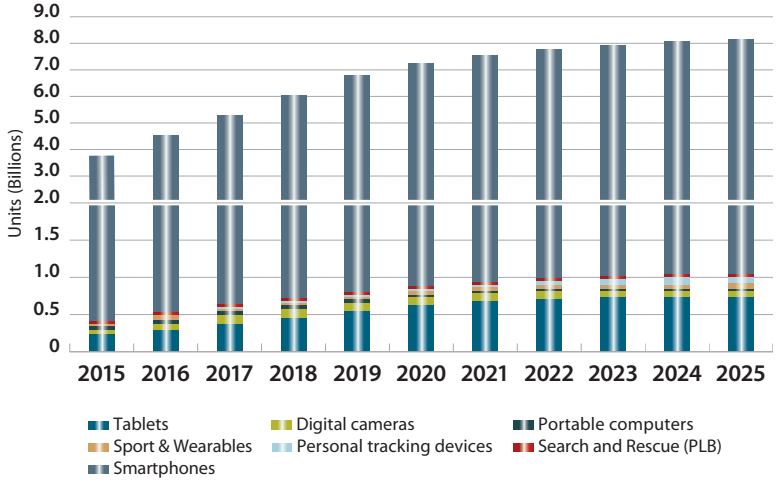
Due to the additional performance provided by an integration of Galileo, it is expected that a steadily growing number of smartphone manufacturers will provide Galileo support for their multi-constellation smartphones.

Users can refer to **www.usegalileo.eu** for the latest information on Galileo-enabled smartphones.

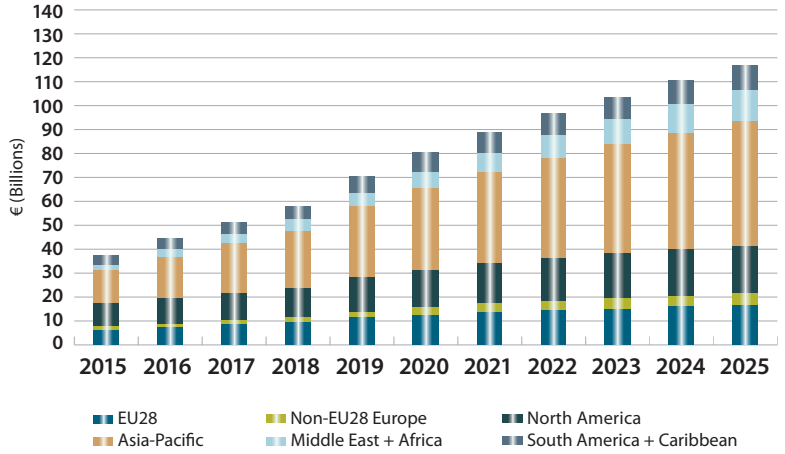
Installed base of GNSS devices by region



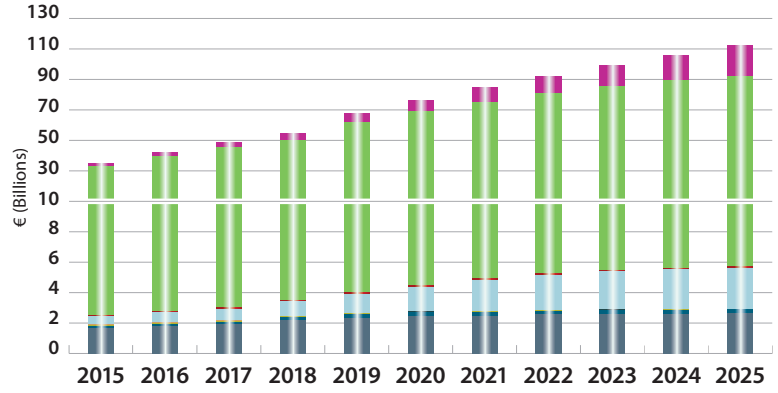
Installed base of GNSS devices by type



Revenue of GNSS device sales and services by region



Revenue of GNSS device sales and services by type



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

Road

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.

- **Safety-critical applications** leveraging on accurate and secure positioning to scenarios of potential harm to humans or damage to a system/environment:
  - In **Cooperative ITS**, GNSS positioning information feeds technologies allowing road vehicles to communicate with other vehicles, traffic signals, roadside infrastructure and other road users.
  - **Advanced Driver Assistance Systems (ADAS)** support the driver during the driving process and act as a first stepping stone towards **Autonomous Vehicles**.
  - **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-critical 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.

- **Regulated applications** apply the transport policies introduced by national or international legislations:
  - **eCall:** the pan-European GNSS-enabled in-vehicle systems (IVS) support system, such as the ERA-GLONASS in Russia, which sends an emergency call to 112 in case of accident, accelerating assistance to drivers.
  - **Smart tachographs** leverage on GNSS positioning to support road enforcers, by recording the position of the vehicle at different points during the working day.

In the Road domain, **connected vehicles**, enabled by the uptake of modern automotive connectivity solutions, represent the evolution of modern vehicles towards becoming integrated platforms capable of supporting, thanks to GNSS, smart mobility services and a range of safety applications.

What you can read in this chapter

- **Key trends:** GNSS will play an important role in the vehicles of the future.
- **User perspective:** GNSS user requirements vary significantly in different application categories.
- **Industry:** List of main players by value chain segments.
- **Recent developments:** In-vehicle systems consolidated their leading role as navigation platform.
- **Future market evolution:** A range of commercial and regulated applications will drive GNSS growth.
- **Focus on European GNSS:** EGNOS and Galileo contribute to road safety and security.
- **Reference charts:** Annual evolution of GNSS devices' installed base and revenues by application and region.

NEW **Fleet Management System**s and **Connected Vehicle service revenues** quantified in this edition of the GNSS Market Report

GNSS will play an important role in the vehicles of the future

Key Market Trends

- GNSS, together with other technologies, is a key answer to Autonomous Vehicles' need of accurate positioning combined with reliability of localisation.
- Whilst OEMs and technology companies are leading the development of Autonomous Vehicle, governments across the world encourage these efforts and allowing testing on public roads.
- Business models continue evolving, with OEMs pushing towards the ownership of GNSS data and aftermarket companies increasingly specialising in data collection and elaboration.

Autonomous Driving is high on the R&D agenda of many converging sectors

Worldwide, all major car groups are currently working on their own Autonomous Driving technology, which has caught the interest of both premium and volume manufacturers. The German automobile industry is defending its lead in terms of the state of development and availability of autonomous driving functions, whereas car manufacturers in countries such as the USA and China are benefitting from the availability of autonomous driving technologies in mass-produced vehicles. Looking to the current developments by the OEMs in the different regions it is clear that the technology is already finding its way to the market. Several OEMs and speciality-OEMs are offering semi-autonomous driving technology in their newest, high-end models.

In parallel with efforts by OEMs, tech giants such as Apple and Google have invested massively in autonomous vehicles, leveraging on their data combination and elaboration capabilities to step in the automotive world.


© BMW

To guarantee the necessary data availability to feed autonomous driving processes, in-vehicle sensors are of key importance. Together with other technologies such as LiDAR, radar sensors and cameras, **GNSS** is an **enabler** of the **autonomous driving concept**, although there are different technological trajectories on its final role once a dominant design will be established. At the present stage, GNSS is already in use, to assist the semi-autonomous vehicles during navigation using digital maps.

Further improvements in GNSS constellations will be further contributing to the path towards the fully autonomous vehicle, with Galileo features such as Open Service NMA and dual frequency playing a key role in providing an efficient, reliable, robust and low-cost defence against jamming or spoofing attacks.

The uptake of built-in GNSS could reshape the role of aftermarket players

More and more vehicle models are fitted with a GNSS-enabled IVS, which is set to become a platform to support both safety applications and infotainment services.

This trend will bring both challenges and opportunities to aftermarket suppliers. Currently, only the latest vehicle models are equipped with built in applications such as insurance telematics, eCall, ADAS and others. The current scenario is offering aftermarket solution providers the opportunity to offer **application-specific devices** to a large retro-fit market.

Integration is currently taking place in aftermarket solutions, which are moving towards **supporting multiple applications** through a single GNSS-enabled telematics platform. As a further step, in the future, ubiquity of IVS could make them the dominant platform for GNSS applications. Under this scenario, current aftermarket providers are expected to specialise in the **service provision element**, supported by IVS in a similar fashion to the smartphone-apps business paradigm in mobile devices.

EU and US policy makers joined by the industry take steps towards C-ITS

Near the end of 2016, both the EU and the US took key steps towards the implementation of Cooperative Intelligent Transport Systems (C-ITS). Following the Declaration of Amsterdam, the EU published its European Strategy on C-ITS, including the role of EGNSS, in December 2016. This strategy is seen as a first milestone towards cooperative, connected and autonomous driving which is expected to make the European road network a much safer environment. Prior to this, the US government had released a policy document on Autonomous Driving, providing a 15-point safety assessment on the manufacturing and sales of autonomous vehicles. Both policy efforts were supported by the industry, which stated its intention to start the full scale deployment of C-ITS enabled vehicles by 2019.

GNSS user requirements vary significantly in different application categories

The role of GNSS in autonomous vehicles

Although technical activities are ongoing and opinions on the use of GNSS for autonomous driving differ amongst the involved stakeholders, it is clear that **autonomous driving** technology requires **highly accurate position and navigation** in all scenarios.

This means 100% position availability at decimetre level or less, anywhere, anytime and under any condition, requirements that **no individual technology can provide on its own**. To overcome the shortcomings of these individual positioning technologies, sensor fusion is considered as the go-to-solution for the development of fully autonomous driving technology.

In this frame, GNSS is an element of a sensor fusion equation including also LiDARs/Radars, Inertial sensors and cameras. The **prominence** of the **GNSS role** is expected to **evolve through time**. In the long run, the availability of HD maps available on the cloud through the 5G network could enable LiDAR and cameras to be the main support for fully autonomous navigation, with GNSS representing the key element for positioning the vehicle within the maps.

Before all these pieces come into the puzzle, cost-effective **augmented GNSS** solutions, capable of supporting lane-level, high integrity positioning over wide areas, could be the first go-to choice for industry players racing to hit the road first with their autonomous vehicles.

Overview of the main user requirements in Road

The table depicts, in alphabetical order, the key user requirements as assessed through the GSA's continuous monitoring with the user community. Only high priority requirements are shown, i.e. other requirements might also be relevant for considered applications, and the table is subject to updates. Information on the parameters is provided in Annex 2.

Applications	**Safety critical:** Automatic actions in V2X, autonomous driving	**Payment critical:** RUC, pay-as-you-drive, taxi meter	**Regulated:** Smart tachograph, eCall, tracking and tracing	**Smart mobility:** Road navigation, automated parking, dynamic ride sharing
Key GNSS requirements	Accuracy Authentication Availability Integrity Robustness TTFF	Accuracy Authentication Integrity Robustness	Authentication Integrity Robustness TTFF	Authentication Integrity
Other requirements	Connectivity (mainly short range) Interoperability	Connectivity (short range and long range)	Connectivity (short range and long range)	Connectivity (long range)

How autonomous and legacy vehicles will start sharing the road

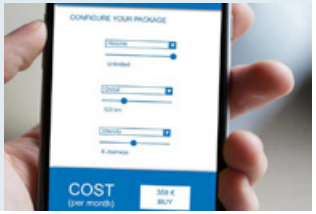
Policy makers, manufactures and citizens have to face a reality in which **man-driven** and **autonomous vehicles** will **share the same roads**. Connected vehicles might pave the way for AVs with V2V, V2I and V2X communication contributing to the fluent integration of human-driven and autonomous vehicles.

At the time being, drivers might feel uncomfortable with the idea of driving alongside an AV that will behave as a machine and not like any other human driver. Very likely a first step to address this point would be to only allow the active use of the autonomous driving mode on highways. Compared to dense urban areas, highways provide a less complex environment for AVs as behaviour of other vehicles on these roads is easier to predict. Linked to this first step, the criticality of the AVs will be to determine the optimal action in the presence of somewhat unpredictable human drivers. In turn, a possibility to initially overcome this issue could be to allow the use of semi- and fully autonomous vehicles only on designated road lanes.

Mobility as a Service: why accuracy and authentication matter

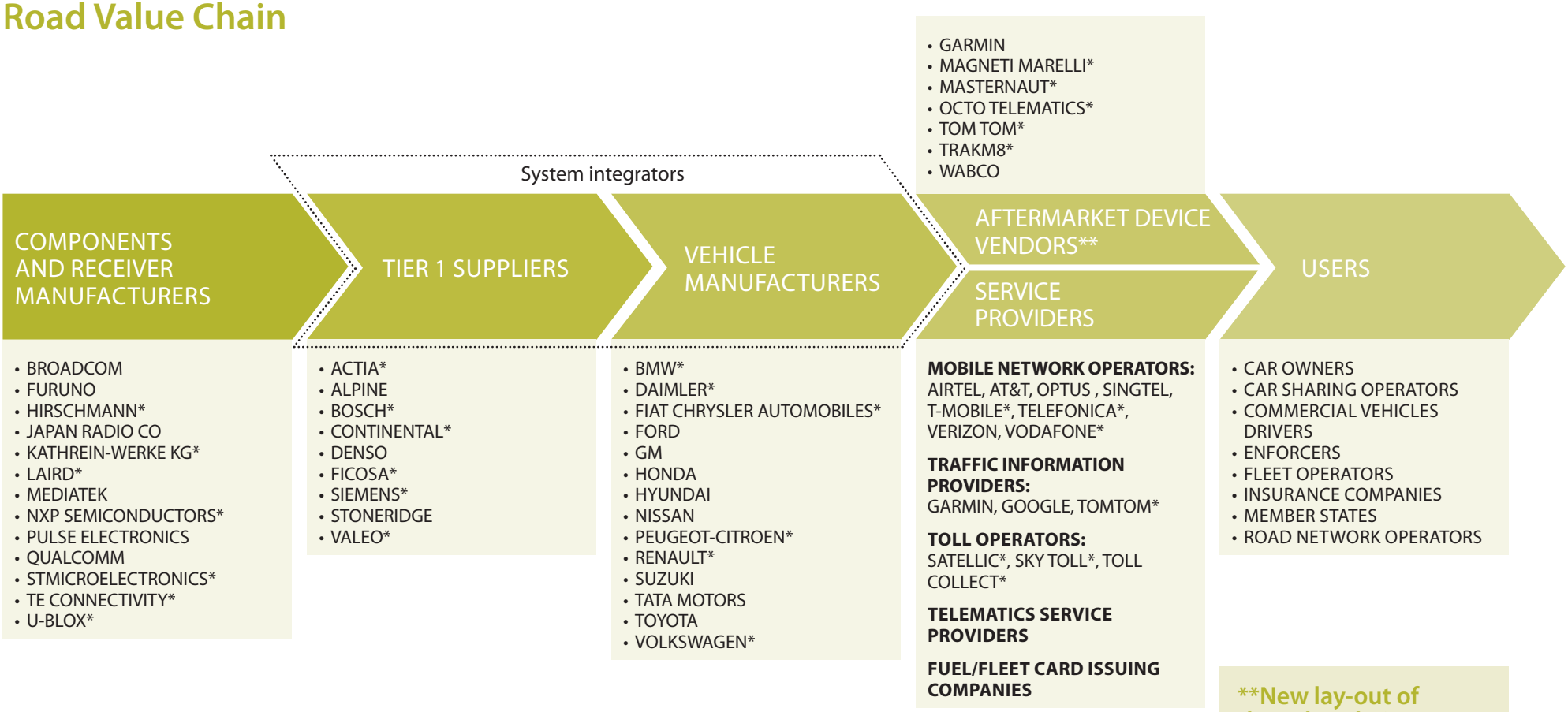
Mobility as a Service (MaaS) represents a **shift** as **compared to** the **private car ownership** paradigm. In MaaS, a **unique journey planning** and management service **identifies the best transport option** for users, through a smart combination of public transport and vehicle rental or sharing, based on the specific travel needs.

Within MaaS, **GNSS plays a key role**. On the one hand, it enables service providers to manage and optimise the use of the assets required to provide the different transport options. On the other hand, it enables the provision of smart mobility solutions to the users, including navigation, traffic information and journey planning directly.



In the frame of MaaS, **accuracy** and **availability** in urban areas, as well as the need of trustable transactions, represent **important requirements**, which **Galileo** is **well positioned** to satisfy thanks to its additional satellites and to Open Service Navigation Message Authentication (OS NMA).

Road Value Chain



The Value chain considers the key global and European companies involved in the GNSS downstream activities.
* European based companies. The world region is referred to the headquarter of the company, the actual area of activity might be wider.

The European[1] GNSS industry in the global arena

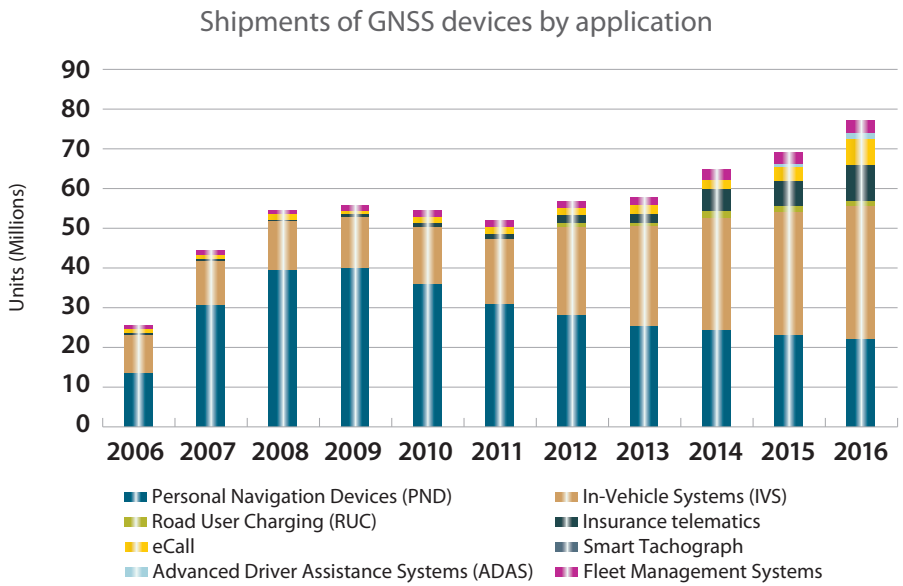
With u-blox, STMicroelectronics and TE Connectivity, Europe held three positions in the 2015 global top five of **GNSS component and receiver manufacturers**, reaching 32% of the global GNSS revenues. Overall, EU companies lead this market with a share of 51% followed by Asia and North America, with 27% and 22% of the market, respectively. European **GNSS system integrators**, led by Volkswagen and Robert Bosch amongst many others, on the other hand generated 30% of global turnover, trailing behind Asia (48%).

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

**New lay-out of the value chain

Tier 1 suppliers and aftermarket device vendors have been split in 2 different categories along the value chain. Additional Mobile Network Operators have been added to showcase their growing role in the Road segment brought by the Connected Vehicles.

In-vehicle systems consolidated their leading role as navigation platform



EU legislations expected to boost shipments of GNSS devices

Starting from April 2018, all new car and light duty vehicles models sold in EU have to be equipped with an eCall system. When a serious accident occurs, eCall will automatically dial the European 112 emergency and provide the emergency services with the necessary data related to the accident such as the exact position of the vehicle crash, allowing emergency response to react more efficiently and effectively. It is expected that around **10% of the new vehicles sold in Europe will correspond to new models equipped with eCall in 2018** and this penetration rate will sharply increase over the years. **By 2021**, around 90% of the newly sold European cars, **around 13 mln vehicles, could have an eCall system installed**.

Focusing on commercial vehicles, the **Smart Tachograph** will be introduced starting in June 2019. GNSS will support enforcement of legislation in Road transport, benefitting fair competition among road operators and road safety. The Smart Tachograph will be harder to tamper with and will allow remotely access some tachograph data. This will reduce the need for lengthy on-road stops, saving time for both the driver and the road enforcement authority. As the Smart Tachographs will **introduce GNSS**, it will offer a better enforcement to respect the driving and rest times of the drivers, by providing the start and final position of the vehicle as well as speed and direction to the road enforcers. **By 2025, it is estimated that around 1.4 mln vehicles will be equipped with a Smart Tachograph with an internal GNSS chipset**.

Since 2008, when road GNSS shipments surpassed the mark of 50 mln devices, the market has grown to 76 mln shipments in 2016. Over the same period, the shipment of **In-Vehicle Systems (IVS)** shipments has skyrocketed from 12 mln units in 2008 to 33 mln in 2016, keeping the total shipments of navigation applications stable as it is compensated for the rapid decline of **Personal Navigation Device (PND)**, 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.

Supported by an increasing popularity amongst insurers and users in markets such as Italy, UK and United States, **Insurance Telematics** witnessed a significant growth (CAGR of 54%) between 2012 and 2016, reaching 9 mln units in 2016.

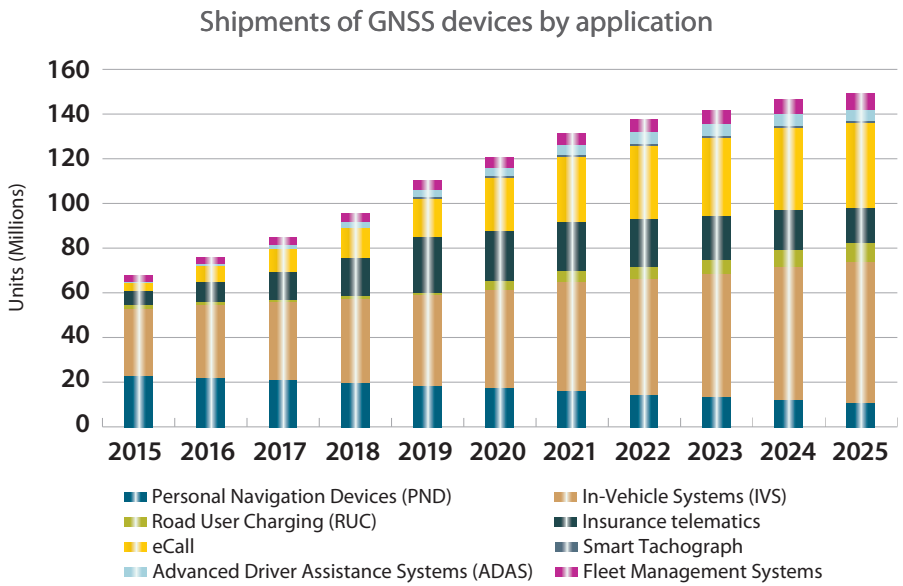
Shipments of On-Board Units (OBUs) for heavy truck **Road User Charging (RUC)** contributed to 1.5 mln units in 2016, with shipments stabilising after seven years of sustained growth. Due to the growing number of countries that use GNSS technology for road tolling (see box below), the estimated installed base of RUC OBUs reached 5.2 mln units in 2016.

More than 43,000km of GNSS-enabled road tolling in the EU

Across **Germany, Slovakia, Hungary and Belgium** more than 43,000km of roads in the EU are currently being charged by GNSS technology for the electronic tolling scheme of heavy goods vehicles. By 2019, **Bulgaria is set to join** this group of countries potentially adding 16,000km of roads to the total of EU roads tolled through GNSS. Outside the European Union, Switzerland and the Russian Federation are also using GNSS technologies in conjunction with other technologies for their tolling scheme. Singapore recently announced that it will have the first GNSS urban congestion charging system for all vehicles by 2020. Some EU Member States are also considering road tolling for passenger and light vehicle. In the case of Belgium, GNSS is likely to be the preferred technology.

More information in the **dedicated RUC report** downloadable via our website **https://www.gsa.europa.eu/system/files/documents/ruc-brochure.pdf**

A range of commercial and regulated applications will drive GNSS growth



Shipments of IVS are foreseen to continue growing, reaching 63 mln by 2025 and doubling the shipments of 2015. Through the IVS, OEMs will be able to offer a range of **Connected Vehicle** services, progressively adding additional revenue streams to their value proposition.

In the long run, IVS will increasingly become platforms for applications that are currently after-market. It is the case of **insurance telematics**, as key players are expected to leverage on embedded hardware and focus on service provision.

Boosted by the EU legislation requiring all new vehicle models sold in the EU from 2018 onwards to be equipped with an eCall system, **eCall** shipments are expected to reach 38 mln units by 2025. From 2018 onwards, the Russian eCall equivalent, ERA-GLONASS, is also expected to be introduced in other members of the Eurasian Economic Union, bringing GNSS-supported emergency call to countries such as Kazakhstan and Belarus.

Combined shipments of commercial vehicle related applications such as RUC OBUs, Smart Tachographs and commercial **Fleet Management Systems** will grow from 4.3 mln units in 2015 to 15.4 mln units by 2025 with Fleet Management Systems making up for almost 50% of the annual shipments. Several commercial vehicle OEMs already pre-fit their new models with the hardware and basic software to support Fleet Managements System services.

Autonomous Vehicles set to be a game changer for the automobile industry

Similar to how the Autonomous Vehicles will change our driving experience, they are also expected to bring a major change to the automobile industry. The traditional competitive landscape of the automobile industry has OEMs, Tier 1 and Tier 2 suppliers both cooperating and competing against each other. However, the idea of autonomous vehicles has attracted new players to this decade-old industry. New players such as mobility providers, tech giants and speciality OEMs are also trying to grab a share of the automobile market. The industry is relying more and more on data and software, of which GNSS is a core sensor; it is here that these new entrants have an edge on the classic OEMs.

Synergies between these different players are also on the rise. Recently, multiple partnerships between OEMs, map makers, mobility and technology providers have been forged. As an example, Ford and Geely (Volvo cars), both traditional OEMs and Uber, a mobility provider, are cooperating to offer autonomous driven car-sharing services. Across the entire automotive industry, acquisitions and partnerships between traditional players and new technology entrants (e.g. Google, Apple, Lyft, etc.) are taking place.

Deployment of autonomous vehicles foresees different scenarios

Scenarios	Conservative	Disruptive
2040s	Conditionally autonomous vehicles will account for 30-35% of new sales.	90% of new sales will be represented by fully autonomous vehicles.
2030s	18 mln sales of semi autonomous vehicles, first use cases of fully autonomous vehicles.	Fully autonomous vehicles sum up to 15% of new sales.
2020s	Large-scale testing of autonomous vehicles on public roads.	Fully autonomous vehicles launched on the market by tech giants and premium OEMs.
2016	Semi-autonomous vehicles tested on private and public roads supported by UNECE updating the 1968 Vienna Convention on Road Traffic.	

EGNOS and Galileo contribute to road safety and security

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

With these distinct features, (speciality-) OEMs, tech giants and software developers who are working on the cars of the future will be able to counter the threat of intentional and malicious GNSS interferences such as spoofing and jamming. In particular, Galileo's authentication feature, which will be available on both the Open and Commercial Service, will provide effective means to detect spoofing for applications such as autonomous vehicles, RUC, digital tachograph and insurance telematics.

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.

Due to the reliability and augmented accuracy of the positioning signal, EGNOS also plays a vital role in the Road User Charging schemes in several EU Member States (e.g. Slovakia and Belgium) and it contributes to the precise localisation of vehicles involved in a collision or accident within the scope of the pan-European eCall initiative.

InLane project to deliver lane-level information to in-vehicle navigation

© Getty Images

The consortium within the EU-funded **InLane** project is working on the fusion between computer vision and GNSS technologies in order to achieve the required level of positioning that allows the safe operation of autonomous vehicles.

The project is developing dynamic maps that receive real-time updates via the Cloud crowdsourcing techniques, with the aim to deliver up-to-date lane-level information to in-vehicle navigation. This will provide drivers the opportunity to chose not only the most optimal route to get to their destination, but also the most optimal lane. Especially in dense urban environments such as multi-lane roads and highways, these maps will contribute to the reduction of risk associated with last-minute manoeuvres associated with lane-changes.

More information on: **http://inlane.eu/**

TAXISAT project: results pave the way for successful commercialisation of WEpods self-driving shuttle components

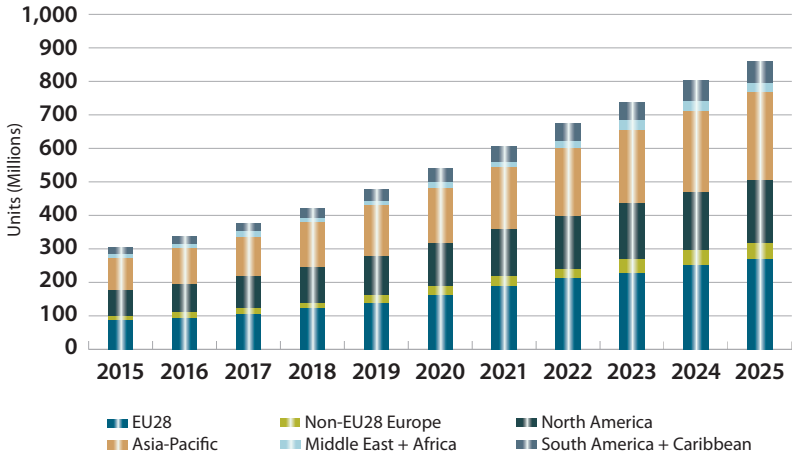
© WEpods

The WEpods come without driving wheel, brakes or accelerator pedals and are undergoing final tests on public roads in the provinces of Gelderland and the North Rhine-Westphalia, the Netherlands and Germany respectively – while similar driverless pods are already being used on dedicated lanes on Heathrow Airport and Rotterdam.

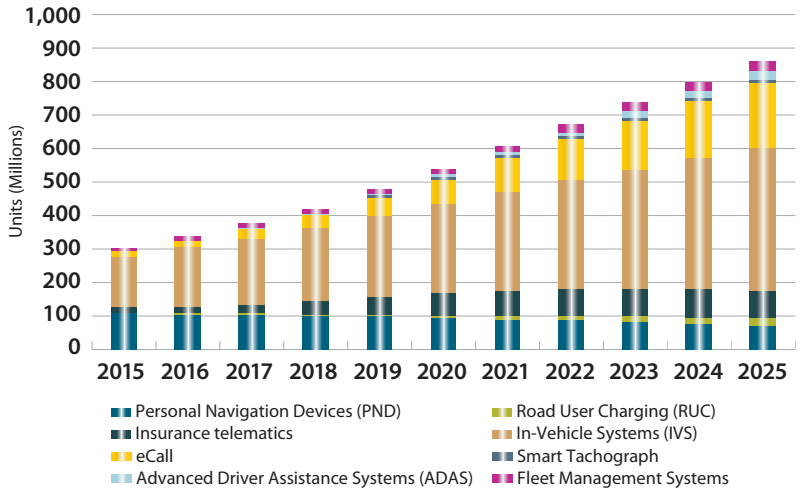
In 2014, the navigation module of these driverless "pods" was designed within the **TAXISAT** project, demonstrated during the Citymobil2 project and are finally being commercialised under the WEpods brand, after final tests in the beginning of 2017. Once they will run commercially, the passenger will be able to book a seat through an app and specify their starting points and their destinations.

More information on: **http://wepods.com/**

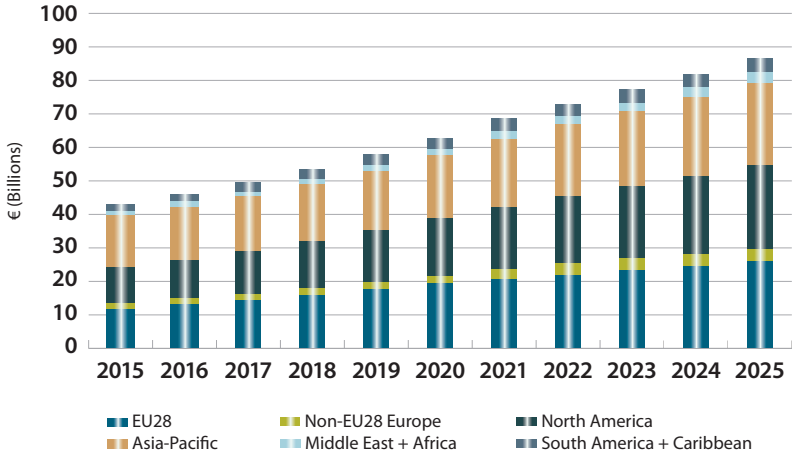
Installed base of GNSS devices by region



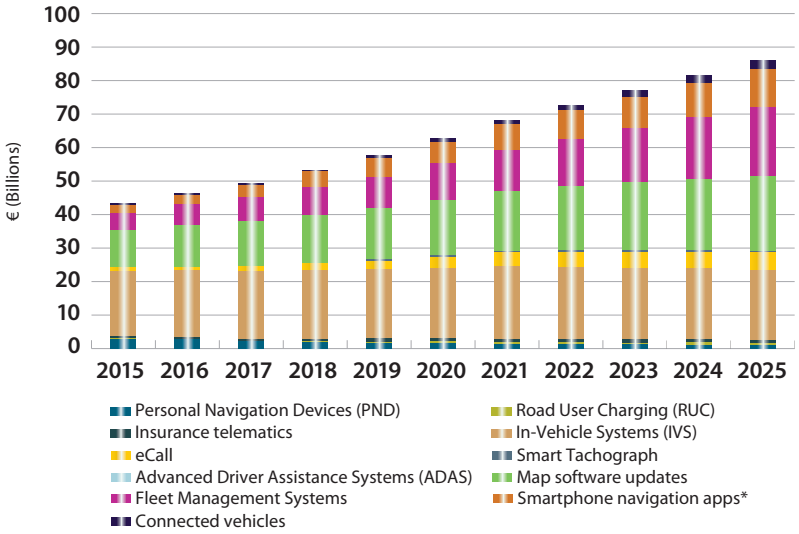
Installed base of GNSS devices by type



Total revenue of GNSS device sales and services by region



Total revenue of GNSS device sales and services by type



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

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.
- Aircraft should be equipped with **Emergency Locator Transmitters (ELTs)** that help Search and Rescue operations in the event of an incident. Many ELTs utilise GNSS to report their position when triggered.
- 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)**.

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:

- Pilots can use **moving maps** that show their current position on a map of surrounding airspace to help monitor progress against their flight plan.
- **Infringement alarms** can warn the pilot if they are getting too close to restricted airspace.
- New applications are being developed to improve **situational awareness** of other aircraft by receiving ADS-B transmissions and plotting them on the moving map.
- Pilots can carry **Personal Locator Beacons (PLBs)**, which are almost always equipped with GNSS, to help rescue services locate them in emergencies.

Drones incorporate GNSS for navigation and to avoid flying into restricted airspace. Regulation of drones is being debated, so they currently operate with basic safety restrictions in place. See Page 91 for detailed consideration of this high-growth, emerging market.

What you can read in this chapter

- **Key trends:** The adoption of GNSS in aviation is growing.
- **User perspective:** Aviation moves towards GNSS for Navigation and Surveillance.
- **Industry:** List of main players by value chain segments.
- **Recent developments:** Drones are challenging Aviation's regulators, while existing technologies are deployed.
- **Future market evolution:** US' declining GA vs Middle East and Asia's growing Commercial Aviation.
- **Focus on European GNSS:** R&D, expansion, and regulation support rise of European GNSS within aviation.
- **Reference charts:** Annual evolution of GNSS devices' installed base and revenues by application and region.

NEW **ADS-B** quantified in this edition of the GNSS Market Report

The adoption of GNSS in aviation is growing

Key Market Trends

- The aviation market continues to grow worldwide with reliance on GNSS increasing.
- Rotorcraft operations are currently rapidly expanding their use of SBAS.
- Regulators support expansion of PBN (particularly in Europe by 2020), resulting in significantly expanded role of GNSS in aviation – over 150 new runway ends enabled since the previous market report – and in the future using Multi-Constellation / Multi-Frequency (MC/MF).
- ELT ruling increases expected sales and further enhanced by Autonomous Distress Tracking (ADT) capabilities.

What is the Aviation Market?

Since 2014, there have been over 36,000 new civil aircraft registrations worldwide. IATA reported that industry-wide passenger traffic (measured by passenger kilometres flown) grew by 7% in September 2016, compared to 2015. Aviation comprises of more than just commercial passenger flights and in fact can be split into two broad categories:

- Flights operating under **Instrument Flight Rules (IFR)** include Commercial, General and Business (for example private jets), Regional (typically on smaller aircraft flying to smaller airports). These must comply with strict regulations that ensure safe and efficient operations and are controlled by air traffic controllers.
- Flights operating under **Visual Flight Rules (VFR)** are typically recreational (for example kit planes, micro lights, gliders and balloons).

Business and commercial operators tend to use GNSS receivers that are tightly integrated into their avionics. Regional operators predominantly also have tight integration, but like general aviation pilots, can use panel mounted displays that offer a cheaper and often more easily upgradeable solution.

Rotorcraft operations benefit from GNSS

The benefits of GNSS are beginning to have real impact on rotorcraft integration within the overall ATM system and low level operations which tend to be in terrain or infrastructure restricted environments. Deployment of low level RNAV routings and the use of simultaneous-non-interferring arrivals allow rotorcraft to benefit from arrival profiles better suited to their flight characteristics whilst keeping required separations.

In the previous market report, we raised the development of **Points in Space (PinS)**, which extend access to heliports in poor weather conditions. Since that report procedures have been published in Italy's Piedmont region, which has enabled Helicopter Emergency Services (HEMS) to utilise such procedures. Furthermore, PinS procedures are under development in Norway, the UK, Denmark, Austria and Switzerland for both HEMS and off-shore transport purposes.

© Getty Images

Performance Based Navigation: the future

Regulators support **Performance Based Navigation (PBN)** implementation:

- In October 2016, EASA published a technical opinion on the European PBN, recommending extended implementation beyond what is required by EU Regulation 716/2014. Furthermore it proposes that PBN approach procedures are implemented at all instrument runway ends *which are not already served by precision approach procedures* before 30 January 2020. Discussions are underway to extend PBN to all runway ends by 2024.
- In November 2016, the US FAA released its strategy to transition, by 2030, from predominately point-to-point navigation reliant on ground navigation aids to PBN-centric operations using GNSS.

Future evolution of GNSS applications: the near term push is for RNAV and RNP 1, while in the future there will be a desire to reach RNP0.3 for rotorcraft operations and RNP0.1 for curved approaches. With the GSA actively supporting PBN implementation, GNSS's role in aviation is set to expand significantly.

A high precision use of GNSS (in particular EGNOS LPV-200 Service level) within aviation is Localiser Performance with Vertical guidance (LPV) runway approaches. GNSS provides guidance to aircraft down to 200ft above the runway, which allows them to safely approach and land. Today, more than 460 EGNOS enabled approaches are operational in Europe. The figure will dramatically increase following the upcoming PBN regulation.

EASA ruling on ELT/PLB comes into force

EASA Air Operations Regulation (EU) 965/2012 applies to commercial and non-commercial flights within Europe and came fully into force in August 2016. Under the regulation all flights must carry an **ELT** or **PLB** if under 6 seats. This results in increased PLB sales in particular, as **VFR** pilots (who did not previously use a PLB) will now be required to carry one. In the longer term the International Civil Aviation Organisation (ICAO) Global Aeronautical Distress Safety System (GADSS) Standards and Recommended Practices (SARPs) - see page 46, allows for Autonomous Distress Tracking (ADT) systems to replace one of two required ELTs on aircraft. New ELTs already incorporate ADT. Galileo, as the first contributor to MEOSAR system leads the way in facilitating ADT.

Aviation moves towards GNSS for Navigation and Surveillance

The ARAIM milestone

In Feb 2016, the **Advanced Receiver Autonomous Integrity Monitoring (ARAIM)** milestone 3 report was released. In Nov 2016 the EU-US cooperation Working Group-C met to discuss it. ARAIM, is an evolution of RAIM, which expands support to include MC/MF, and therefore supports operations with more stringent integrity requirements such as vertical guidance, and allows for GNSS evolving capability. The capabilities are complementary to those provided by SBAS, and expect to coexist in the future.

Free Routing for more efficient flight

As the volume of air traffic increases, the way in which the airspace is designed and utilised also changes. Increasingly, aircraft are expected to be able to fly the most economical route directly between two points. This may not be coincident with the great circle distance. Consequently, there is reliance on GNSS to support the concept of **Free Route Airspace (FRA)** – one of the focus areas of the European Commission's PCP regulation, with implementation being managed by the SESAR Deployment Manager (SDM).

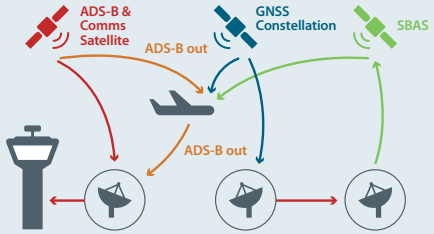
Adoption of GNSS and SBAS enabled operations

During 2016 the GSA selected 14 projects aimed at developing EGNOS use, on top of 13 projects already in progress. The on-going adoption of GNSS-enabled navigation[1], will allow rationalisation of existing ground-based navigation infrastructure. Examples include:

- UK plans to reduce 44 Very high frequency Omni Direction Radio Range (VOR) beacons to just 19 in 2020[1], a benefit for Air Navigation Service Providers (ANSPs), which will affect GA pilots as well as their commercial colleagues.
- France plans to deploy PBN approaches to more than 200 runway ends and reduce ground infrastructure costs.[2]

ADS-B Adoption

In the previous issue, we reported on the growth of **Automatic Dependent Surveillance Broadcast (ADS-B)** supplementing ground based surveillance.



The FAA mandate, as mentioned in the previous Market Report, requires airspace users to equip ADS-B out by 2020, and recommends users equip an SBAS capable ADS-B out system. The use of SBAS enables users to achieve performance equivalent to radar surveillance.

As a result the FAA reports rapid growth in the number of US aircraft which are equipped, from under 26,000 in November 2016, to over 33,000 in March 2017. EGNSS can benefit users, as EGNOS is able to support the same requirements and is interoperable with the US SBAS, WAAS.

Furthermore EGNSS will offer an additional constellation, which is being incorporated into standards (see also page 48). This will bring Multi-Constellation (MC) and ultimately Multi-Frequency (MF) to ADS-B PVT sources, further enhancing performance.

Overview of main user requirements in Aviation

The table depicts, in alphabetical order, the key user requirements as assessed through the GSA's continuous monitoring with the user community. Only high priority requirements are shown, i.e. other requirements might also be relevant for considered applications, and the table is subject to updates. Information on the parameters is provided in Annex 2.

Applications	**Non-safety navigation** (relevant for General Aviation VFR)	**Performance based navigation** (relevant for all IFR)	**Search and Rescue** (including ELT and PLB)	**Drones**	**Surveillance** (including ADS-B)
Key GNSS requirements	Availability	Accuracy[1] Availability, Continuity, Integrity Robustness	Availability	Accuracy, Availability, Continuity, Integrity, Robustness	Accuracy[2], Availability, Integrity, Robustness
Other requirements	N.a.	Interoperability Resiliency	Connectivity (incl. return link), Power consumption, Resiliency	Connectivity (communication link), Power consumption	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.

Aviation Value Chain

DEVICE MANUFACTURERS

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

AIRCRAFT MANUFACTURERS

- AIRBUS*
- ATR*
- AUGUSTAWESTLAND*
- BOEING
- BOMBARDIER
- CESSNA
- CIRRUS
- DIAMOND AIRCRAFT*
- EMBRAER
- PILATUS*
- PIPER

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)

AIR NAVIGATION SERVICE PROVIDERS

MAIN ORGANISATIONS

- Civil Air Navigation Services Organisation (CANSO)
- International Civil Aviation Organisation (ICAO)

AERODROMES

- International Airports
- Private Airports
- Regional Airports

The Value chain considers the key global and European companies involved in the GNSS downstream activities.
* European based companies. The world region is referred to the headquarter of the company, the actual area of activity might be wider.

The European[1] GNSS industry in the global arena

Within the aviation segment EU and North American organisations continue to dominate manufacturing of aircraft, as well as leading the way in research and development and regulatory improvement (for example through Europe's SESAR program, soon to transition to SESAR 2020). The role of EU companies is smaller when considering manufacturing of GNSS devices for use in aviation, where North American manufacturers have a much larger market share (with 65% of the market compared to Europe's 25%).

Whilst GPS is currently the constellation of choice for aviation (reflecting the dominance of North American manufacturers of GNSS avionics), the introduction of Galileo into aviation via **WG-62** (discussed in page 48 below), together with the expansion of SBAS to support Galileo, should provide a catalyst for growth within European GNSS device manufacturers in the near future.

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

Drones are challenging Aviation's regulators, while existing technologies are deployed


© Getty Images

Drones: special requirements in Aviation

Some concepts for drone usage involve the airframe operating Beyond Visual Line of Sight (BVLOS). In order for these to be viable it is vital that the user knows the location of the drone with a very high level of integrity. This requirement is further intensified by the nature of drones making them difficult for ground based surveillance technologies to detect and locate (they are too small for conventional primary radar, and do not have power to operate typical secondary radar transponders).

The positioning solution for drones therefore naturally involves GNSS. For the purposes of aviation, the integrity of this position must be extremely high. For example, drones flying into restricted airspace pose a safety risk; high integrity geofencing (which can be achieved through EGNOS) provides a solution. For the purposes of the end user application which the drone is supporting, the positioning solution may also have high accuracy requirements.

In this context the push for MC/MF and SBAS are obvious technical enablers, providing greater redundancy and resilience.

ICAO GADSS SARPs come into effect

In Mar 2016, ICAO's Standards and Recommended Practices (SARPs) for **Global Aeronautical Distress Safety System (GADSS)** came into effect and will apply from Nov 2018. These require the air operator to track their aircraft throughout their operations with 15 minute or better time intervals.

ICAO's SARPs for autonomous distress tracking came into effect in Jul 2016 and will apply from Jan 2021. These will require an aircraft to autonomously transmit information from which a location can be calculated once per minute.

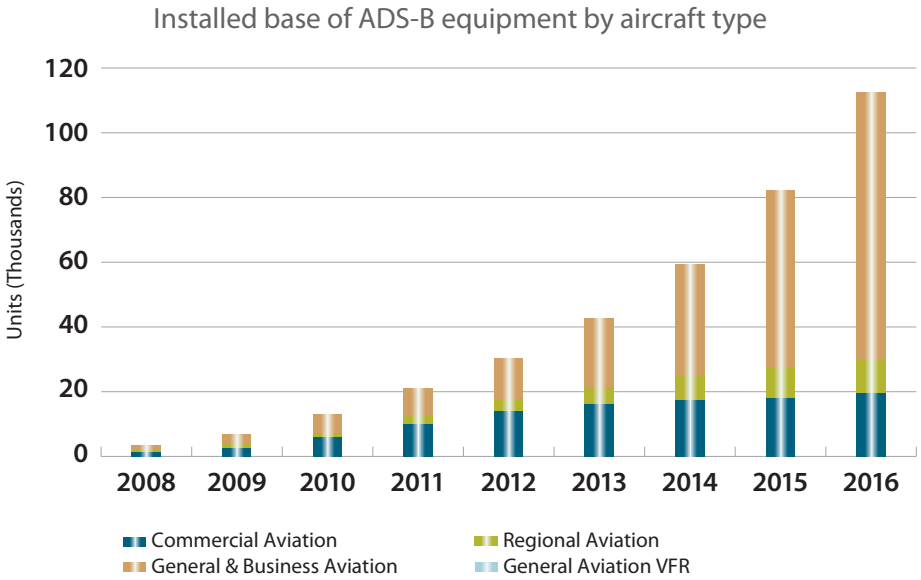
Both will be strongly supported by GNSS and particularly Galileo, as the first contributor to the MEOSAR programme, the next generation Cospas-Sarsat satellite-based search and rescue system.

Europe rolls out Localizer Performance with Vertical Guidance (LPV-200)

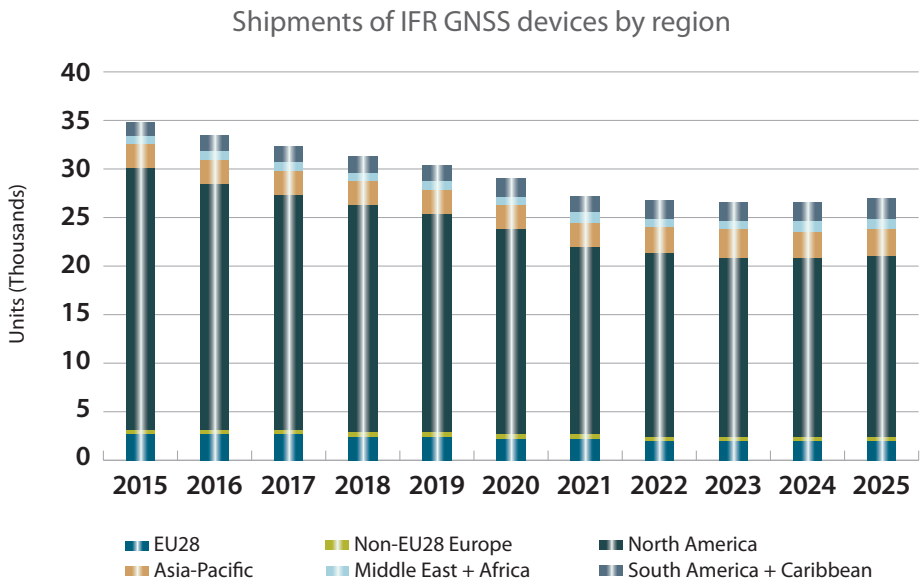
EGNOS was certified to provide LPV-200 (LPV with a land or go around decision height of 200ft above the runway) in 2015. This represents an extremely cost-efficient alternative to Instrument Landing Systems Category I (ILS CAT I), which provides equivalent capabilities at significant cost to the aerodrome.

US encourages early adoption of Automatic Dependent Surveillance – Broadcast (ADS-B) in General Aviation

Historically, GA adoption of ADS-B has lagged behind commercial and regional (see chart), who gain greater benefits from adoption. During 2016, the FAA, in collaboration with AOPA launched a programme to encourage early installation of ADS-B systems ahead of the Jan 1 2020 deadline (the original mandate was published in May 2010). This will have increased sales of ADS-B, although limited by the capacity of workshops to deliver installations, and will continue to do so until 2020. Within Europe, the SPI IR mandate for ADS-B carriage is under review. In combination with developments from SESAR this is expected to lead to increased uptake of ADS-B among European GA.



US' declining GA vs Middle East and Asia's growing Commercial Aviation



Middle East and Asia growth for Commercial Aviation…

The distribution of **GNSS** sales globally is expected to shift to regions currently experiencing unprecedented growth in both General and Commercial aviation – for example, China. The global reliance on **GNSS** is expected to result in increasing use of the multiple constellations beginning with the **VFR segment** deploying mass market receivers.

In addition, the **Middle East** is a major hotspot for growth within commercial aviation, with **Airbus** forecasting growth of 6% until 2034, and driving a requirement for 2,460 new aircraft. This is leading to national authorities implementing airspace modernisation programs to support traffic growth and comply with **ICAO** recommendations on the implementation of PBN internationally as per the **ICAO ASBUs**. For example, the **Gulf Cooperation Council** is currently developing their plans for implementation of **PBN** within their upper airspace by 2025, which continue the drive for **GNSS** in the region.

… while North American GA remains the largest segment

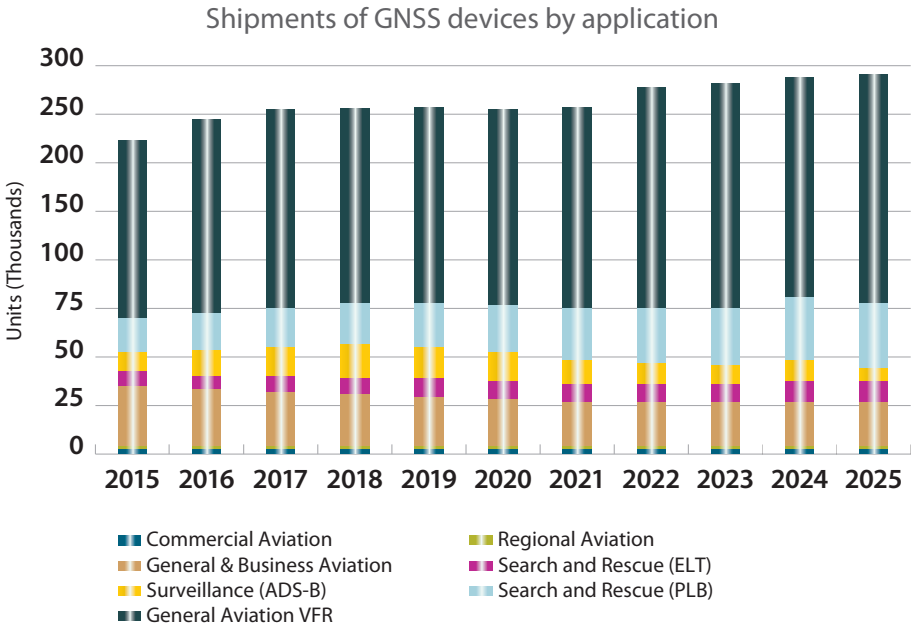
North American GA, and particularly **VFR aircraft** remains the **largest market in aviation**, and dominates the charts (as shown by NA in the chart above, and GA VFR in the chart right). However, in recent years, the volume of new **sales** of GA aircraft has seen a **sharp decline** due to global economic factors and uncertainty[1]. This has impacted both the **VFR** and **IFR** segments with some market leading products having suffered significant sale falls as a result.

ELT/PLBs sales remain static …

FAA regulations regarding **ELTs** (and **PLBs**) are less demanding than EU (as described in the previous page), furthermore the market is more mature, which results in traction of older, **non-GNSS PLBs**, and correspondingly lower demand per pilot. The **EASA** regulation and ICAO GADSS drive growth in **PLB and ELT** sales.

… while PBN enables rationalisation of ground infrastructure

Implementing PBN procedures provides an opportunity for rationalisation of **traditional terrestrial navigation infrastructure**. The rate at which this can happen is limited by the capability of all airspace users to adapt at the same pace. This is part of an **air/ground synchronisation** challenge that needs the full support of both **airspace users** and **air navigation service providers**. This is another contributor to the short term pressures on retrofit sales and the growing trend to universal **GNSS** equipage within aviation.



[1] In Market Report 4, the ELT data series was presented twice (labelled both PLB and ELT), the correct series are presented in this chart.

R&D, expansion, and regulation support rise of European GNSS within aviation

Helios project: developing second generation of ELTs including Galileo return link

The **HELIOS** project aims at providing a Second Generation range of Beacons (ELT, EPIRBs and PLBs) designed to operate with the full capability of the new MEOSAR Programme and using Galileo SAR Return Link Service (RLS). The project represents €4.9 mln of investment between the GSA and industry, and will run until 2019. Coordinated by Orolia McMurdo, market leader in beacons development, the project will deliver ELT, EPIRB and PLB using Galileo RLS and obtain type approval. The project brings in worldwide experience, and provides a vehicle for European Industry to lead the way in safer, innovative systems.

Galileo SAR service picks up signals emitted from distress beacons in the **406-406,1 MHz** band and broadcasts it to dedicated ground stations (MEOLUTs), which then passes it to the rescue centres. Galileo Forward Link Service is in Initial Operation Capability phase. A unique return link alert informing the sender that his message has been received is planned by end of 2018. Within Horizon 2020, the Galileo MEOSAR RLS Improvement for Better Civil Aviation Security (**GRICAS**) project is presently developing an operational concept using the Galileo SAR service to maximise rescue effectiveness by activating beacons in-flight when detecting abnormal flightsituations.

5-Lives project: expanding the use of European GNSS in rotorcraft operations

Search, Challenge, Flight, Care, Rescue for Lives (**5-LIVES**), focuses on rotorcraft operations, particularly where life is at risk. Fostering research in innovative concepts, the project demonstrates the feasibility of advanced navigation procedures in constraining environments, as well as demonstrate the operational gains these have in historically inaccessible markets (e.g. **VFR**). The benefits will accrue to Helicopter Emergency Medical Services (**HEMS**), search and rescue and firefighting operations.

The project will also demonstrate the benefits of using **Galileo** and **EGNOS** in heterogeneous search and rescue scenarios as it has never been done before: on the one hand, maritime search and rescue assisted by an **EGNSS-enabled drones**; on the other hand, evacuation of fireman-in-distress in a firefighting operation by equipping with **EGNSS** technology all ground units and the rescue helicopter.

The 5-LIVES Advisory Group (**FLAG**) has been created to join helicopter operators and national aviation authorities in an effort to harmonise the implementation of rotorcraft **EGNSS** operations at a European level.

The possibility of EGNOS expansion

EU regulation **2013/1285** sets out the possibility for **EGNOS** services to be "extended to other regions of the world" in particular those associated with the **Single European Sky** and those in the **European Neighbourhood Policy**. The latest EGNOS Safety-of-Life Service Definition Document was released in September 2016, with significant extension of **APV-I** and **LPV-200** coverage towards the southwest of Europe.

The **EGNOS** roadmap sets out an expansion of the service area to 72°, inclusion of a new **RIM** in the eastern Mediterranean in 2018.

Linked to this expansion is the inclusion of **APV-I, NPA** and **LPV-200** up to this latitude in **Norway** and **Finland**. Additionally **APV-I** and **LPV-200** availability will be improved to cover Malta and Greek Islands (increasing availability levels in Cyprus).

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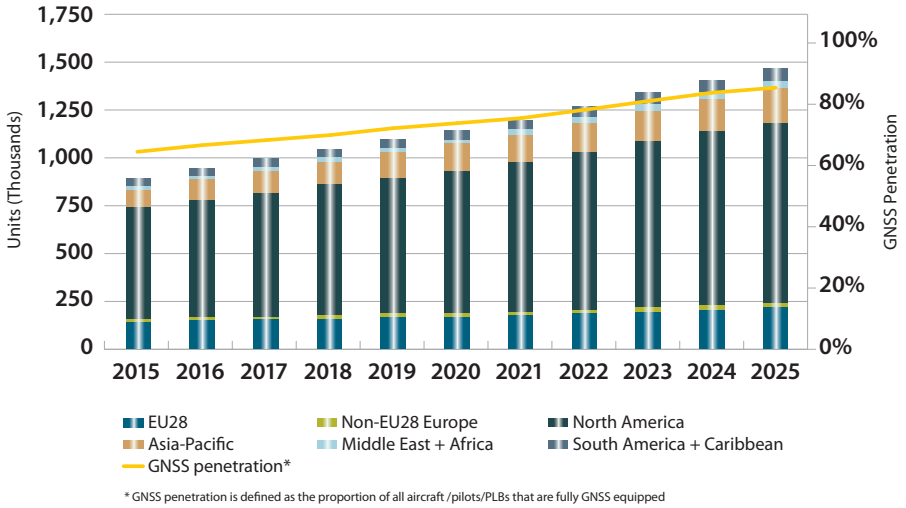
Regulators: the gatekeepers of change

Integrity of **PVT** is essential for aviation. **MC/MF** provides one way in which increases in integrity can be realised and are being standardised – e.g. through **EUROCAE WG-62** – with:

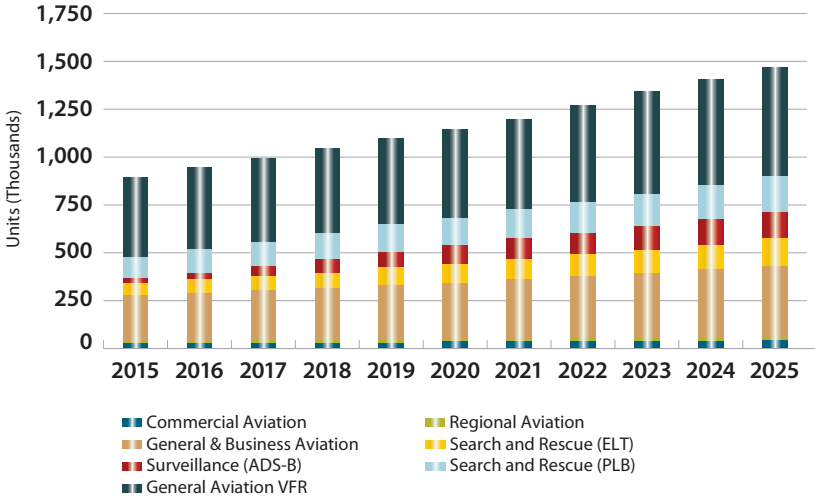
- Guidance on single constellation Galileo receivers in 2016.
- **MOPS** for GPS and Galileo with L1/L5 E1/E5a planned for 2017.
- A standard for multi-constellation **SBAS** (i.e. corrections for both GPS and Galileo) is expected later.

Installed base of GNSS devices by region

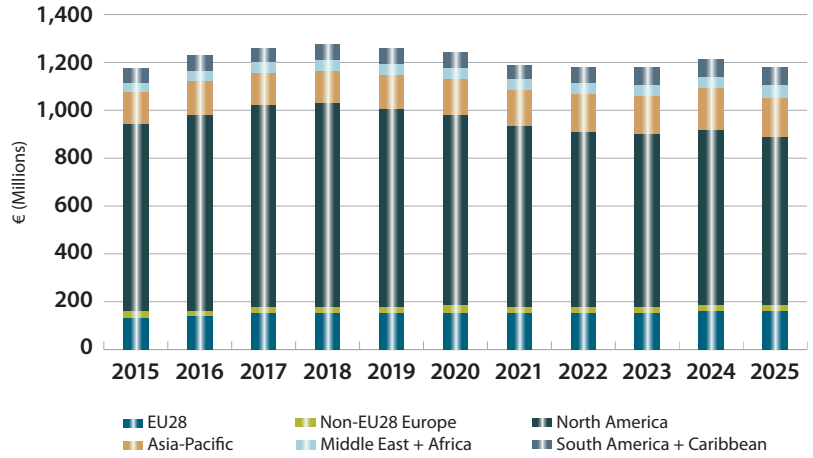


* GNSS penetration is defined as the proportion of all aircraft /pilots/PLBs that are fully GNSS equipped

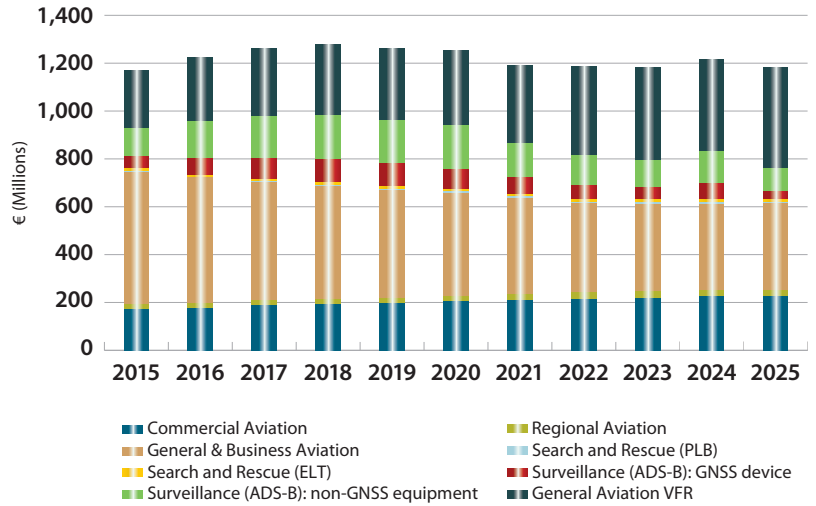
Installed base of GNSS devices by application



Revenue of GNSS device sales by region



Revenue of GNSS device sales by application



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 some other regions 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 for the viability of a service.
- **Asset Management** includes such functions as fleet management, need-based maintenance, infrastructure charges and inter-modal transfers. GNSS is increasingly seen as a standard source of positioning and timing 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 System (DAS)** uses real-time geo-location to help train drivers operate their trains (driver assistance). The goal of a DAS is to enable an optimised operation of train traffic.

What you can read in this chapter

- **Key trends:** GNSS enables safety increases and cost reductions.
- **User perspective:** GNSS is becoming a key enabler in safety and non-safety critical applications.
- **Industry:** List of main players by value chain segments.
- **Recent developments:** Driver Advisory Systems (DAS) adjusting the driving to optimise the traffic flow and save energy and money.
- **Future market evolution:** GNSS will become standard equipment within a decade.
- **Focus on European GNSS:** EGNSS on the way to be introduced in safety critical applications.
- **Reference charts:** Annual evolution of GNSS devices' installed base and revenues by application and region.

NEW **Driver Advisory Systems** quantified in this edition of the GNSS Market Report.

GNSS enables safety increases and cost reductions

Key Market Trends

- GNSS is becoming a generic system widely used in non-safety relevant applications.
- GNSS based solutions can offer enhanced safety for lower cost, e.g. as investigated in railway signalling.
- GNSS begins to be implemented also for safety relevant applications with different maturity depending on the region, e.g. in India, China and the Middle East.

Different levels of maturity for GNSS consideration in Rail application

The way GNSS is used for train applications is different from one region to another. The number of initiatives in the world shows the consideration provided to Rail and GNSS developments.

In Europe, investigations are on-going to include GNSS as a complementing system for safety relevant operations in the frame of the European Rail Traffic Management System (ERTMS). As a strong demonstration of the willingness of Europe to consider GNSS as an innovative solution to decrease costs, GNSS technology has been included in the ERTMS roadmap and is referred to as one of the five key game changers of the future railway signalling systems. Shift2Rail, the first European rail joint technology initiative for the railways, has been launched as a concrete action to accelerate the integration of advanced technologies. This initiative will foster the use of GNSS in innovative rail product solutions.

In the US, PTC (Positive Train Control) implementation is on its way. PTC combines control, communications, and information systems safety, security, precision, and efficiency for train movements and includes GNSS as a technology for positioning of the train.

Russia developed an Integrated Train Protection System (called KLUB-U) using both GPS and GLONASS technologies for train positioning.

China is currently strongly investing in infrastructure modernisation with the construction of new railways. GNSS based localisation systems are already used on some rail lines. The entry into operation of BeiDou, planned in 2020, will contribute to the wider-scale deployment of such solutions, and not only in China.

Rail infrastructure in the Middle East and North Africa has experienced huge growth, especially regarding railway construction in the last 10 years, and with heavy investments planned ($200 bln). The champion in this region is Saudi Arabia where half of the investments were made, followed by Algeria and Qatar.

In the Asian region, India benefits from one of the largest railway networks requiring emphasis on the safety of the applications. Huge investments are planned by the Indian government and trials are on-going to deploy Satellite Imaging for Rail Navigation (SIMRAN) providing real time passenger information system thanks to GPS.

In the Rail segment, safety comes first

The introduction of rail applications must consider the constraints in the specific railway environment in order to **find adequate solutions complemented by sensors for train positioning** (e.g. limited satellite visibility due to tunnels, significant multipath or even electromagnetic interference).

Important work has been conducted for safety relevant rail applications to agree on **rail safety relevant requirement** matching with the expected performance requirements. Preliminary accuracy and integrity requirements have been identified within UNISIG, which is influencing also the development of **ERTMS specifications for Command and Control Systems**. Experimentations and measurement campaigns are underway to **complete GNSS requirements** with respect to rail safety applications.

The growth of GNSS adoption is expected to continue in **non-safety relevant applications**. Many rail freight cars, for which GNSS could be used in asset tracking, currently contain no power supply. Alternative solutions and their associated costs are investigated (such as battery and advanced receivers in terms of power efficiency).

GNSS is becoming a game-changer in safety and non-safety critical applications

Perspective Use of GNSS in Rail

GNSS is already used in applications in which people's safety is not at stake, such as passenger information applications, which are mainly mature applications.

The main axes of development for GNSS applications in Rail are safety relevant and liability relevant applications. The European GNSS differentiators can play a key role in these applications. Within the ERTMS framework, GNSS could be used as a means to introduce the virtual balise in the ERTMS ETCS Level 2/3 and to provide the train integrity monitoring function for the ETCS Level 3.

Outside the ERTMS framework, GNSS is already being deployed for train control most commonly in the USA, for Positive Train Control applications.

GNSS integration in safety relevant applications has reached different levels of maturity and readiness. Automatic train operation, ERTMS/ETCS and automatic train protection are still at a conceptual levels. Low density line signalling, train approaching warnings and traffic management are more advanced and close to be ready for operations.

Overview of the main user requirements in Rail

The table depicts, in alphabetical order, the key user requirements as assessed through the GSA's continuous monitoring with the user community. Only high priority requirements are shown, i.e. other requirements might also be relevant for considered applications, and the table is subject to updates. Information on the parameters is provided in Annex 2.

	Non-safety critical applications			Safety critical applications	
Applications	**Asset management**	**Passenger information**	**Driver assistance**	**Train Control and Signalling**	**Traffic Management**
Key GNSS requirements	Accuracy Availability	Accuracy Availability	Accuracy Availability	Accuracy Availability Integrity Robustness	Accuracy Availability Integrity Robustness
Other requirements	Connectivity Power Consumption	Connectivity (communication link)	Connectivity (communication link) Interoperability	Interoperability	Interoperability

ERTMS/ETCS Specifications

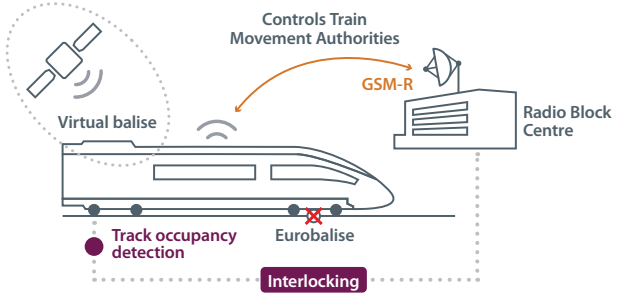
The European Rail Traffic Management System (ERTMS) initiative aims to provide a new generation of train control and signalling capabilities (ETCS - European Train Control System), which includes automatic train protection by continuously supervising train speed and braking.
ERTMS has two basic components:

- ETCS, the European Train Control System, is an automatic train protection system (ATP) to replace the existing national ATP-systems.
- GSM-R, radio system standard for signalling data transmission.

The ERTMS technology has different levels of capacity and performance. In level 1, 'Eurobalise' radio beacons transmit trackside signals as a movement authority to the train equipment. The maximum speed and braking curve are obtained and automatic train protection is ensured with these data. In level 2, it is possible to remove trackside equipment, as the trains automatically report, on a regular basis, their navigation data to a Radio Block Centre, which transmits back the next movement authority. Level 3 does not rely on trackside equipment for the train location and train integrity supervision.

ERTMS will intervene if the train over-speeds, to bring it back to safe levels. It works as a safe monitoring system that is supervising the speed of each train based on track and train data. Precise knowledge of the train speed, thus, is a central topic in the ERTMS developments.

In the year 2016, GNSS was identified as one of the key technological game changers of future ETCS, within which the virtual balise technology could potentially be included.



Picture source: NGTC Network of End Users, Prague 7.7.2016

Rail Value Chain

COMPONENTS AND RECEIVER MANUFACTURERS

- AEROANTENNA TECHNOLOGY
- BEIJING BDSTAR NAVIGATION
- BROADCOM
- ERWIN KAYSER-THREDE*
- GARMIN
- KYOCERA CORPORATION
- NOTTINGHAM SCIENTIFIC LIMITED*
- PC TEL
- SEPTENTRIO*
- SITRONIX TECHNOLOGY CORPORATION
- TAI-SAW TECHNOLOGY
- TE CONNECTIVITY*
- TRIMBLE NAVIGATION
- YAGEO CORPORATION

SYSTEM INTEGRATORS

- ALSTOM TRANSPORT*
- ANSALDO STS
- AZD PRAHA*
- BOMBARDIER
- CRRC CORPORATION LIMITED
- GENERAL ELECTRIC
- GMV*
- HITACHI
- KINTETSU RAILCAR ENGINEERING
- MITSUBISHI
- SIEMENS*
- XIAMEN YAXON NETWORK

TRAIN MANUFACTURERS

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

TRAIN OWNERS / OPERATORS

TRAIN OPERATION COMPANIES & FREIGHT OPERATING COMPANIES:

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

ROLLING STOCK OPERATING COMPANIES:

- Consortia
- Investment Banks
- National Companies

INFRASTRUCTURE MANAGERS

- ADIF*
- DEUTSCHE BAHN*
- NETWORK RAIL*
- RFI*
- SNCF*
- Urban Transport Operators

The Value chain considers the key global and European companies involved in the GNSS downstream activities.
* European based companies. The world region is referred to the headquarter of the company, the actual area of activity might be wider.

The European[1] GNSS industry in the global arena

The rail industry is spread in Europe, Asia/Russia and North America, considering components and receivers as well as system integrators.
European companies have a **market share of 31%** among components and receivers manufacturers, the market being dominated by North American companies. The top 3 European companies are: Septentrio, TE Connectivity and Erwin Kayser-Threde.
European companies are ranked at the second place among system integrators, **controlling 33% of the market**, where key operators have strong exports both to North America and Asia. The top 3 European companies are **Alstom, AZD Praha** and **Siemens**. Since Market Report 4, the EU share has decreased. This is primarily due to the acquisition of Ansaldo STS by Hitachi, Ansaldo STS controlling 35% of the market share on its own.

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

Driver Advisory Systems (DAS): adjusting the driving to optimise the traffic flow and save energy and money

Driver Advisory Systems principles

The DAS (Driver Advisory System) allows the exchange of information between the railway system and the human operator (the driver), with the purpose of **optimizing the driving of the train**. The on-train system calculates an energy efficient speed profile to achieve the pre-planned or dynamically updated train timings, and generates detailed driver advice to follow the profile and achieve the timings. The control centre is responsible for conflict detection and calculation of new target train timings. GNSS is used as one of the sensors in the DAS equipment.
The main applications targeted by the DAS system are:

- **Real time location** allowing traffic management by conflict detection and providing accurate location report.
- **Speed management** enabling low energy driving, increasing reliability on arrivals time and allowing proper management of braking before conflict.

The DAS systems can be classified into two main categories:

- **Standalone DAS** (S-DAS) has all data downloaded to train at or prior to journey start. It realises a static exchange of information.
- **Connected DAS** (C-DAS) realises a communications link to the Control Centre (or Traffic Management Centre) in each controlled area in which the train operates. This enables the provision of schedule, routing and speed restriction updates to trains in near real time, and also receipt of information from trains to the Infrastructure Manager control centre to improve regulation decisions. It aims to optimise the traffic flow of the railways as a whole by dynamic re-planning of the timetable to avoid conflicts.

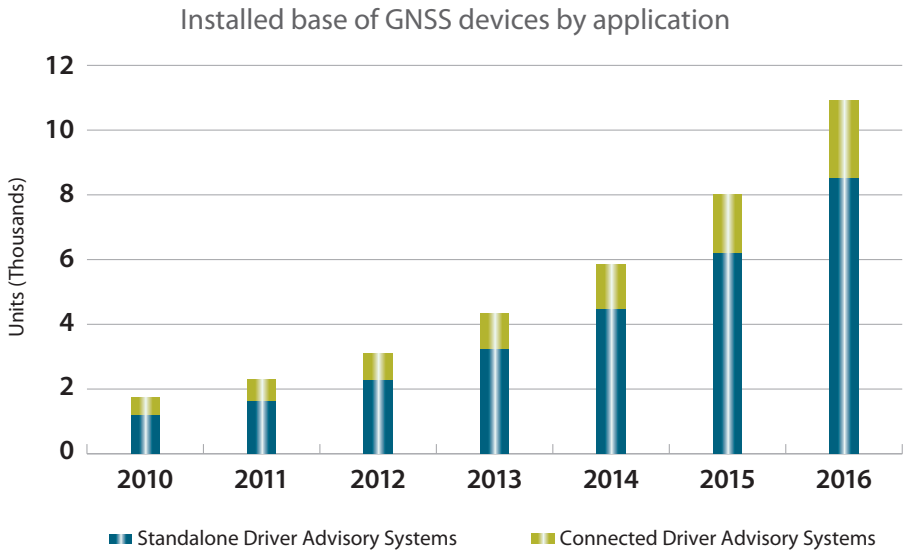
Markets Targeted

The first market targeted by DAS is freight and low density line trains looking at **savings in energy consumption**. The second market of interest is passenger and high density line trains for which the benefits are obtained through **line capacity optimisation and conflict management**.
As indicated by the analysis of CUBRIS made with the GREENSPEED product, **one to several tens of million euros could be saved** by speed management thanks to DAS.

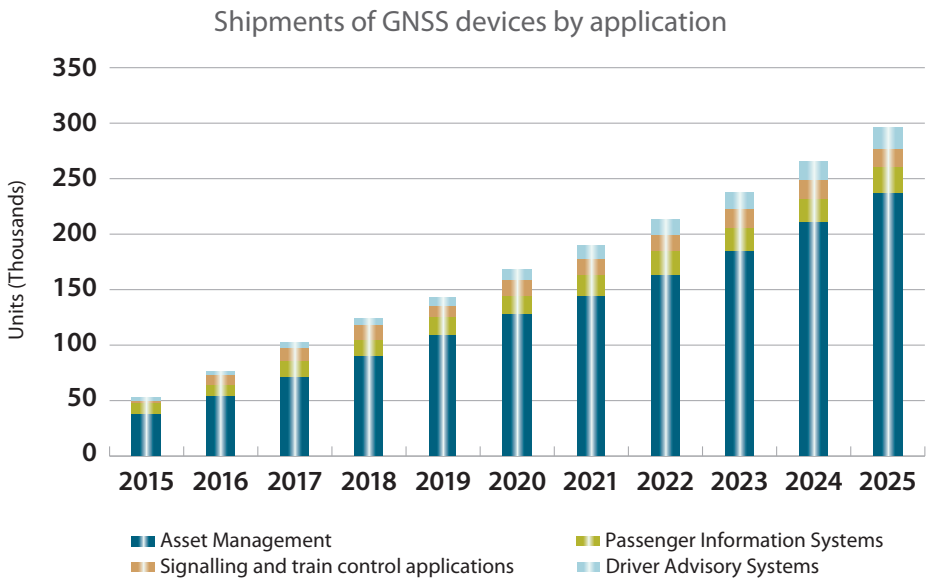
DAS market trends

The number of installed devices has **quadrupled over the last 5 years**. While the standalone systems still dominate the market, the connected driver advisory systems have experienced a more important growth over the past.

DAS systems have been deployed mainly for **freight traffic** in Europe. Trials have been conducted in France, Germany, Sweden, Norway and Spain. DAS is deployed in the UK for diesel and electric high speed passenger trains and freight trains. 75% of the passenger trains are equipped with DAS in Denmark.



GNSS will become standard equipment within a decade



The asset management application is expected to be driving shipments of GNSS devices. For around **220,000 trains** in the world dedicated to freight, the number of wagons that could be potentially equipped with GNSS is around **2.8 million**.

In the coming years, **safety relevant applications** (Signalling and train control) based on GNSS will be increasingly developed. These applications require a **very high level of performance** and depending on the strategy regarding those safety critical applications, GNSS may be used as:

- a primary means of localisation to enforce safe train movement in the US with PTC.
- a potential solution to deploy less Eurobalises while increasing location accuracy in Europe with ERTMS.

In any case, GNSS is to be considered as an **innovative solution** permitting to cut operational costs while increasing safety.

As an example, trackside equipment investment and maintenance such as balises or automatic block protection equipment (track circuit or axle counter) are very costly. **GNSS is an opportunity** to reduce reliance on balises and therefore to decrease infrastructure costs. At the same time, interoperability considerations must be carefully evaluated as is the case in the current on-going ERTMS work.

GNSS penetration is likely to continue to increase in the upcoming years. The availability of Galileo will also strengthen this trend as it solves possible sovereignty issues, being civilian operated, and it provides authentication on top of more accurate and more reliable position solutions in combination with other constellations.

RHINOS project: toward an optimised integrity architecture for ERTMS

RHINOS aims at improving the use of EGNSS for the European Railways Train Management System (ERTMS) to meet regional and global market needs. RHINOS adds value to EGNSS by leveraging the results from prior and ongoing projects, and developing a Railway High Integrity Navigation Overlay Architecture. RHINOS's main outcome is an Integrity Architecture optimised for ERTMS and assessed by an international team of experts. The landscape is to share the existing GNSS infrastructure for safety critical applications, and developing specific add on features for meeting fail-safety principles of railway signalling in a cost efficient manner. Protection level for integrity monitoring of train position includes the assessment and mitigation of multipath effects in rail environment. RHINOS contributes to a standard architecture leveraging on the EU-US Cooperation Agreement on ARAIM.

NGTC Project: Virtual Balise proof of concept with EGNOS

Train localisation with GNSS was one of the tasks of the **NGTC** project aiming at assessing the functionality of the Virtual Balise into the ERTMS ecosystem. NGTC involved urban and mainline railway organisations to analyse the commonalities and differences of required functionality of both ETCS and CBTC systems. For the first time a group of GNSS experts, coordinated by GSA, has been involved in the WP-7 satellite, to work together with the rail team to understand each other specific safety requirements and to reach a coordinated and agreed position on the application of GNSS in the ETCS operational conditions. A relevant achievement of the joint technical activities was the first preliminary safety analysis demonstrating the implementation of the Virtual Balise with the existing EGNOS performance. Results of NGTC concerning the receiver, rail environment, track data base, engineering rules, other GNSS applications, safety analysis and roadmap will be the basis for contributing to the next R&D projects.

EGNSS on the way to be introduced in safety critical applications

Galileo is in the starting block. **The initial operational capability** declared in December 2016 **allows real experience of Galileo operational signals** to foster the use of EGNSS by the the railway community.

The multiconstellation environment, with interoperability of GALILEO with GPS, permits to **enhance currently achievable performances** especially regarding availability and accuracy. This will reinforce the use of GNSS in rail applications in the future.

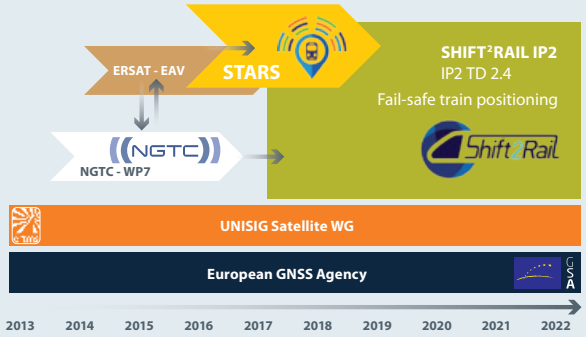
EGNOS, thanks to its capability to improve the accuracy of the positioning solution and to **provide integrity**, can contribute to the determination of train locations without dense trackside infrastructure. Investigations are currently on-going to characterise the expected level of performance for rail applications by using GPS with EGNOS augmentation, specifically for **safety relevant applications** such as railway signalling. EGNOS can further support railway logistics applications such as the monitoring of freight and dangerous goods movement. The next version of EGNOS will augment Galileo signals which may further **enhance the service quality** offered by EGNOS to the railway community.

STARS Project: GNSS performance prediction for ERTMS

The **STARS** project paves the way for the future EGNSS deployment in safety relevant railway applications. By evolving the ERTMS/ETCS standard, it will be possible to reduce the cost of the future railway signalling systems. STARS project is proposing an universal approach to predict the achievable GNSS performance in a railway environment, especially for safety critical applications within ERTMS. The STARS roadmap in the figure below shows that the UNISIG and GSA strategy is aligned.

The project will provide key evidence on the predicted level of accuracy, availability and safety performances in the railway environment. It is expected that the economic benefits analysis done in the project sustained by interoperable concepts and equipment will boost the inclusion of GNSS services into ERTMS/ETCS standard.

More information on: **www.stars-rail.eu**



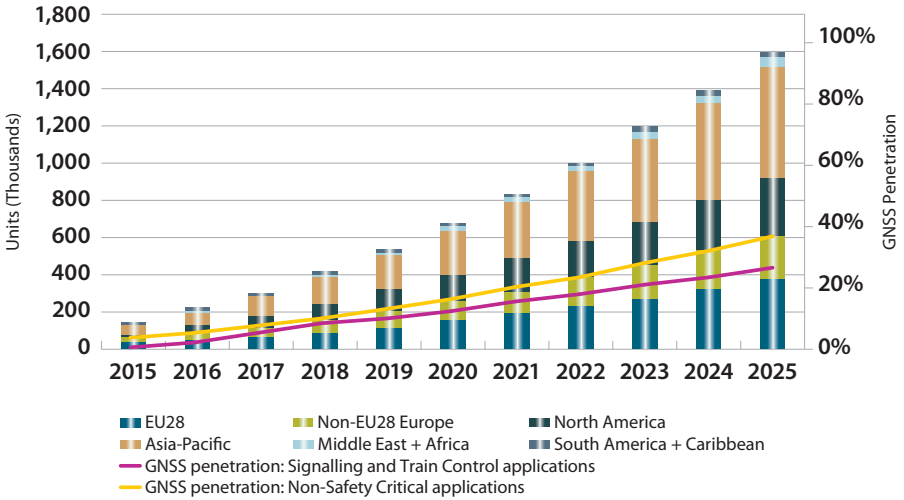
ERSAT EAV: Looking at the harmonisation of the European ERTMS standard

ERSAT EAV project verifies the suitability of EGNSS (EGNOS and Galileo early services) for safety railway application, in particular in regional lines scenarios. In this context, a safe localisation of the trains, based on satellite technologies, will be defined and developed, leading the way for the harmonisation with the European ERTMS standard, by implementing the solution on a pilot line as reference. The ERSAT EAV project will prioritise the EGNSS uptake for the rail sector, fostering the competition and the innovation of the European space, rail industry and research community. It is also enhancing a strong coordination and synergy with the specific sector of European Railways and the main actors involved, building up a system centred on the ERTMS platform.

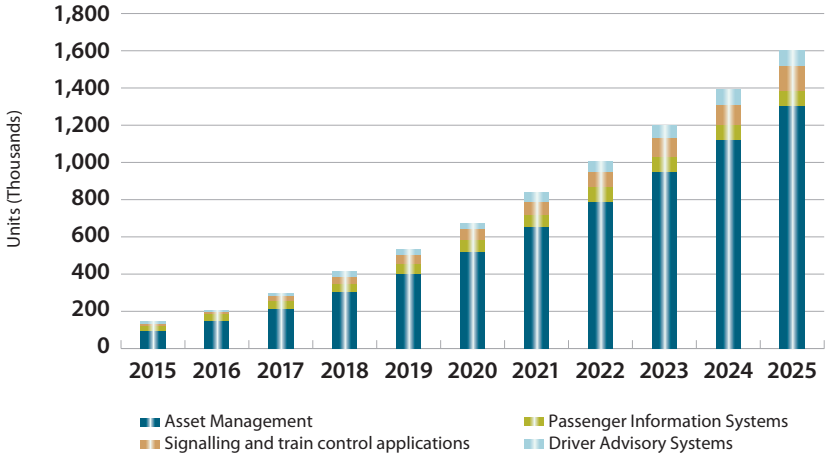
As of the 24th February 2017, the testing of the ERSAT EAV system has been completed in Sardinia. The end goal is to have this new technology approved and certified according to the standards on a European-wide scale, with the first line being activated in Italy by 2020.

More information on:
www.gsa.europa.eu/gnss-applications/segment/rail/european-gnss-action-ersat-eav-project

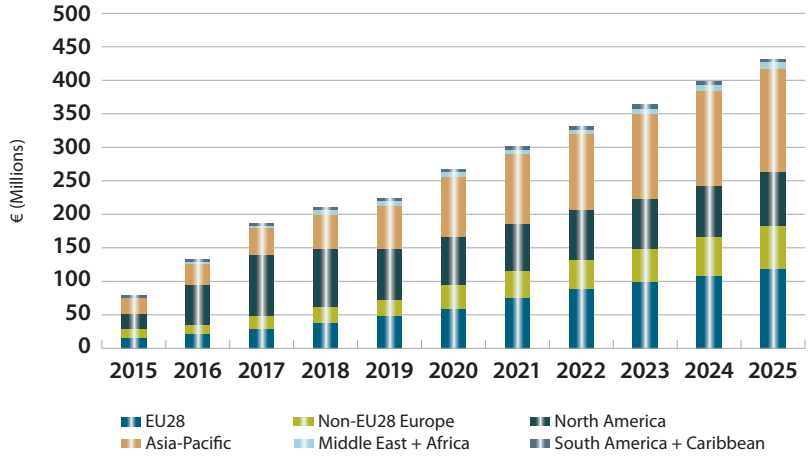
Installed base of GNSS devices by region



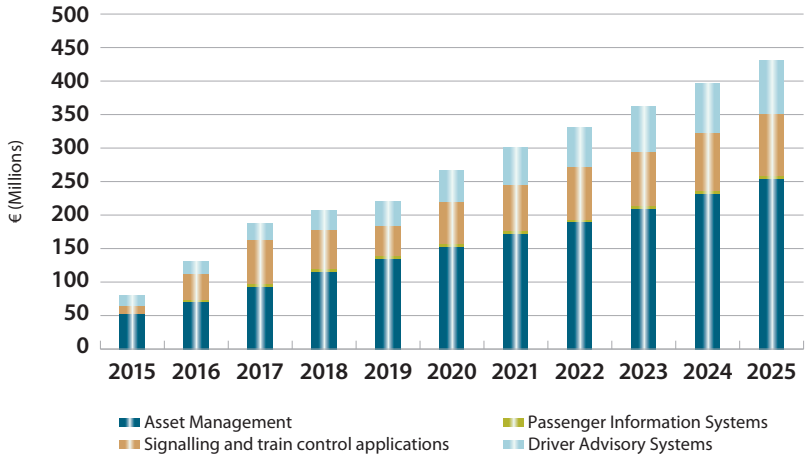
Installed base of GNSS devices by application



Revenue of GNSS device sales by region



Revenue of GNSS device sales by application



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**
  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 used to ensure safe navigation also in inland waterways (rivers, canals, lakes and estuaries).

Positioning

- **Traffic management 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:** Multi-constellation GNSS is becoming the go-to solution for a wide range of maritime applications.
- **User perspective:** GNSS offers significant benefits to both the direct users and beyond.
- **Industry:** List of main players by value chain segments.
- **Recent developments:** Maritime GNSS shipments witness a year-to-year growth, with recreational navigation dominating the segment.
- **Future market evolution:** In a connected maritime environment, GNSS is a key enabler for both traditional and innovative shipping operations.
- **Focus on European GNSS:** EGNSS set to be a key differentiator in the maritime domain with special focus on Navigation and SAR applications.
- **Reference charts:** Annual evolution of GNSS devices' installed base and revenues by by application and region.

NEW **AIS-SARTs and AIS-MOBs** quantified in this edition of the GNSS Market Report.

Multi-constellation GNSS is becoming the go-to solution for maritime applications

Key Market Trends

- GNSS has become the primary means of obtaining Position, Navigation and Timing (PNT) information at sea.
- SAR beacon manufacturers are preparing for multi-constellation GNSS, opening the path for Galileo penetration in all type of SAR beacons.
- GNSS is a key enabler for both traditional and innovative maritime applications and operations such as the use of drones and the development of smart ships.

Galileo receives important IMO recognition for adoption in maritime

Since May 2016, Galileo can be put on the same level as the American GPS, the Russian GLONASS and the Chinese BeiDou as it **was recognised by the International Maritime Organization (IMO) as a part of the World-Wide Radio Navigation System (WWRNS)**. Galileo, with the Return Link functionality expected by 2018, will offer a unique contribution to the industry of maritime GNSS applications. This official recognition represents a major milestone for the adoption of Galileo for use in commercial shipping and a boost for the current trend towards multi-constellation GNSS receivers.

GNSS plays an important role in offshore oil and gas activities

The offshore energy industry uses augmentation systems and services (SBAS, DGNSS, PPP and RTK) that improve GNSS performance for various activities ranging from the initial surveying and offshore construction phase to drilling and the dynamic positioning of vessels near the platforms and construction sites. This industry requires precise, repeatable and reliable positioning information and therefore opts for commercial solutions.

During the construction phase of offshore platforms the use of GPS/GLONASS dual-constellation receivers is currently the go-to choice, as the higher availability allows for continuous operations. The inclusion of GLONASS is especially useful for offshore activities in the northern hemisphere as the Russian satellite constellation provides a better service in this region due to the abundance of ground stations.

Once the oil and gas platforms are operative, they follow extremely stringent safety regulations according to which they need to use two independent GNSS systems. This is to ensure redundancy at all times and to enable dynamic comparison between both systems for integrity. All these requirements are made to ensure maximum safety for operators, equipment and environment. Due to these stringent requirements, all market solutions rely on the full use of all available GNSS constellations. Once Galileo is fully operational it will provide increased availability contributing to a resilient PNT solution and to the efficiency of search and rescue operations.

GNSS is ubiquitous in a wide range of SAR beacons

The **COSPAS-SARSAT programme** recognises all beacons that transmit a signal on the 406MHz distress frequency band. In the maritime domain the **EPIRBs** and **EPIRB-AIS** are the main types of Search and Rescue (SAR) beacons used as they are mandatory and registered to a unique vessel. **PLBs**, which are registered to individuals, are often additionally used on-board of maritime vessels. Both of these beacons are GNSS-enabled providing the SAR response teams with a more accurate estimation of where the distress call is coming from. Several beacon manufacturers already offer multi-constellation SAR beacons.

On top of these beacons, the maritime user also has the choice to equip an **AIS-SART** or **AIS-MOB**. These SAR devices use Automatic Identification System technology to communicate through the VHF band with nearby vessels transmitting a GNSS position. This feature enables nearby vessels to receive the distress signal on their chart plotter or ECDIS allowing them to provide first assistance. Whereas a SART is mandatory for all SOLAS vessels above 300GT, AIS-MOBs are often used by fishermen, off-shore installation personnel and recreational boaters.

European and global installed base of SAR beacons (2016)




Beacon type	EPIRBs	PLBs	AIS-SARTs	AIS-MOBs
Price	€ 500-715	€ 230-350	€ 480-550	€ 210-280
EU28 installed base	54,000	105,000	5,000	70,000
Global installed base	185,000	343,000	16,000	100,000

The numbers refer to GNSS-enabled devices only, given prices are market averages.

GNSS offers significant benefits to both the direct users and beyond

Overview of the main user requirements in Maritime

The table depicts, in alphabetical order, the key user requirements as assessed through the GSA's continuous monitoring with the user community. Only high priority requirements are shown, i.e. other requirements might also be relevant for considered applications, and the table is subject to updates. Information on the parameters is provided in Annex 2.

Applications	Navigation[1]	Ship Operations	Traffic Management & Tracking	Search & Rescue	Port Operations	Engineering & Offshore
Key GNSS requirements	Accuracy Availability Continuity Integrity Robustness	Accuracy Availability Continuity Integrity Robustness	Availability Continuity	Availability	Accuracy Availability Integrity Robustness	Accuracy Availability Integrity Robustness TTFF
Other requirements	Interoperability	Interoperability	Connectivity	Connectivity (incl. return link), Power consumption Resiliency	Interoperability	Interoperability

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

GNSS substantially improves Search and Rescue response

Although GNSS plays a key role in the day-to-day activities of the coast guard, it has especially proven to be a significant differentiator for the so-called Search and Rescue (SAR) activities. In case of a man overboard situation or a vessel in distress, an emergency call is launched on the 406MHz emergency frequency by activating a SAR beacon such as a EPIRB or PLB. Once the coast guard or the Joint Rescue Coordination Centres receive the distress call, the GNSS information (if available) may be used simultaneously with the independent COSPAS-SARSAT process to localise the person or vessel in distress.

The combination of this information allows for a swift and coordinated response. This significantly reduces the time needed to reach the people in distress and increases the chances of survival. In case of EPIRB-AIS, AIS-SART and AIS-MOB the GNSS position is transmitted via AIS, which may be received by the rescue boats and helicopters in a typical range of 4nm.

The use of GNSS, the availability of digital maps plotting the position of ships and the SAR beacon registry have significantly improved the response rate of SAR teams and contributed to numerous lives saved over the past decade.

Use of Big Data and AIS analytics on the rise in the maritime industry

© Getty Images

Similar to other industries, digitalisation is also entering the maritime segment. One of the most sophisticated examples so far is the use of **AIS data for Big Data analytics**.

The Automatic Identification System (AIS), which automatically shares vessel information with other vessels and coastal authorities, is perceived as a major added value in the aid for collision avoidance between vessels. However, AIS data has proven to offer a whole lot more than just collision avoidance assistance.

The existence of dedicated web services that collect AIS-data on a daily basis across the world have shown how this data and the information it contains is shaping the future of the maritime industry. By collecting the AIS-data of all maritime vessels an enormous database can be constructed, with both historical and real-time data.

These **data can be transformed into information** on port calls, time spent in ports, passage crossings, etc. providing valuable information to fleet managers and shipping companies. However, it doesn't stop there.

The combination of an AIS-database with other databases (e.g. fishing grounds, maintenance logs, weather and sea conditions etc.) allow the users to **improve productiveness and efficiency**, provide better planning of optimal routes, etc.

Although the vessel crew, fleet managers and big shipping companies are the main beneficiaries of these data analytics, the potential **group of users expands beyond the direct users**. Maritime enthusiasts, financial institutions and service suppliers outside the industry can all benefit from this type of information.

Maritime Value Chain

The Value chain considers the key global and European companies involved in the GNSS downstream activities.
* European based companies. The world region is referred to the headquarter of the company, the actual area of activity might be wider.

The European[1] GNSS industry in the global arena

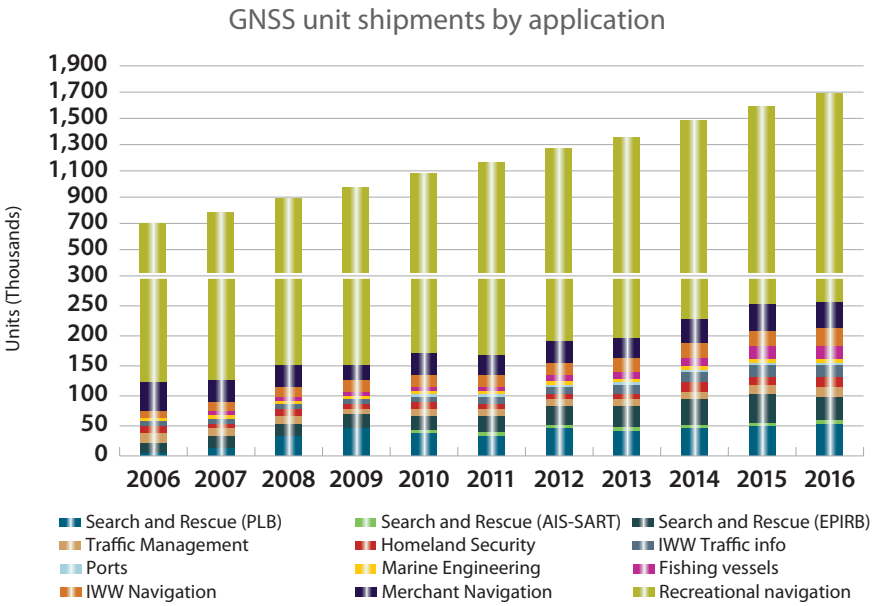
In 2015, European companies led by Hexagon, Orolia and Cobham, generated 43% of the global GNSS revenues of the **component and receiver manufacturers** industry. They were in second place behind Asian companies, which retained 47% of the global market share. Global revenues generated by **system integrators** are dominated by Garmin (28%) and Navico (23%), which both have a focus on the mass market of recreational navigation. European companies, including Navico, Kongsberg Maritime and Safran, retained altogether a share of around 35% of the global revenues, putting the European companies at the same market share of North-American companies.

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

**New lay-out of the value chain

In this edition of the Market Report, additional attention is given to the key market players in the field of Search and Rescue along the value chain. SAR beacon manufacturers and the users of positioning data for SAR response have been added.

Maritime GNSS shipments witnessed a sustained growth, with recreational navigation dominating the segment



The total amount of **GNSS shipments for 2016 accumulated to 1.7 mln units** across the three main categories of applications (i.e. navigation, positioning and Search and Rescue) considered in this market report. Since 2006, when the total amount of shipments accounted for 700,000 units, the maritime GNSS unit shipments saw a 9% CAGR.

Around 83% of the total 2016 shipments, or 1.4 mln units, are shipments of **recreational navigation** devices. With an estimated addressable market of **30 mln** vessels worldwide, this market segment presents the largest customer base for maritime GNSS devices (see box below for more info).

The application group comprising all type of **Search and Rescue (SAR) beacons** accounted for 135,000 shipments in 2016 with the shipments of PLBs accounting for 40% of total SAR beacon shipments. PLBs are extremely popular in North America and the increasingly higher uptake of GNSS in PLBs plays an important role in the increase of GNSS shipments. Since the market introduction of AIS MOBs in 2012, the large majority of the shipments were registered in the EU28.

Finally, **merchant navigation** units reached annual sales of 45,000 units, whereas GNSS units used for inland **waterways navigation** and the **monitoring of fishing vessels** both reached 27,000 units in 2016.

GNSS for recreational boating is more than just navigation

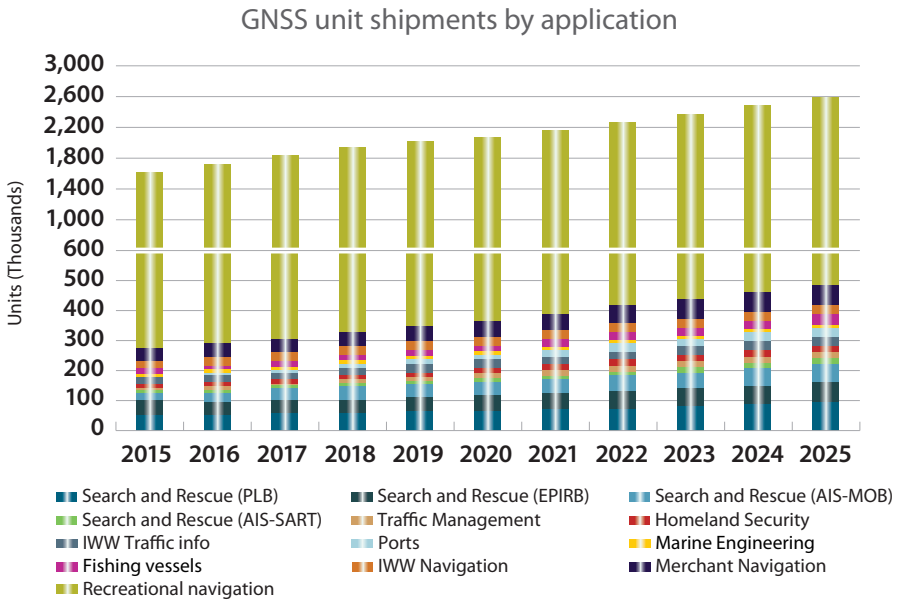
With approximately **30 mln** recreational vessels worldwide, the addressable market for GNSS far exceeds the market of commercial and fishing vessels (almost 3 mln vessels worldwide). As the current penetration rate of GNSS devices on-board recreational vessels is around 22%, there is still a high market potential for the adoption of GNSS equipment.

Looking at the different types of applications tailored to the recreational segment, there are the more traditional applications such as **navigation devices** up to high-end solutions such as **autopilot and automated docking applications**. More and more recreational boaters are also equipping **AIS-MOB** SAR beacons when they travel near the shores and coastlines or opt for **PLBs** when they sail across the oceans.

When it comes to EGNSS, EGNOS is also playing an upcoming role in the recreational maritime segment as is evident in the example of the EGNOS 52 Super Series Regatta that took place in Cascais, Portugal in October 2016.

EGNOS gave its name to this regatta, playing an important role during the most critical part of the race: at the start. By using EGNOS, navigators were given the means to be at the right place at exactly the right time.

In a connected maritime environment, GNSS is a key enabler for both traditional and innovative shipping operations



Due to a significant untapped addressable market of recreational vessels, the **recreational navigation** segment is expected to continue dominating the annual shipments of GNSS devices with expected shipments of 1.7 mln units in 2020 and 2.1 mln units in 2025. By 2025, it is estimated that sales of recreational navigation units will generate more than €800 mln in sales, 57% of the total maritime GNSS market value.

Shipments of all types of **Search and Rescue beacons** are expected to reach 240,000 units by 2025 and are likely to continue growing during the second half of next decade. The combination of regulated beacons such as EPIRBs and SARTs, commercial success of GNSS-enabled beacons with AIS technology and the recent launch of the Galileo Search and Rescue Service is likely to boost the uptake of search and rescue beacons beyond 2025.

Merchant navigation device shipments will hit 70,000 units by 2025 up from 43,000 in 2015. The installed base of GNSS-enabled navigation systems in merchant vessels is forecasted to approach 400,000 units in 2025.

Over the next decade, **North America followed by Asia-Pacific and the European Union** will remain the largest market in terms of shipments and installed base. Global revenues will grow by a CAGR of 5.2% between 2015 and 2025, achieving total revenues of €1.4 bln.

GNSS, Earth Observation and drones at the forefront of Maritime Surveillance

For its daily activities, the **European Maritime Safety Agency (EMSA)** is relying more and more on the use of satellite data provided by both **(E)GNSS and Earth Observation** constellations such as Copernicus and the Sentinel Satellites. Following recent developments in the drones industry, EMSA is also preparing for the **use of drones** for its activities to complement the use of satellites, patrol boats and AIS Analytics.

By deploying a large number of drones, EMSA would be able to increase its operational scope and monitor all of the so-called hotspots around Europe's maritime borders. The drones will provide a valuable contribution to the Maritime Surveillance operations such as:

- Detection of survival crafts and humans at sea;
- Receiving and relaying AIS messages and activating a 406MHz distress signal;
- Support FRONTEX with maritime border patrol;
- Oil spill detection, monitoring and support to response operations;
- Monitoring services to identify illegal, unreported and unregulated (IUU) fishing.

A look into the future: Smart Ships navigate our oceans

Similar as to how connected and autonomous cars will become a reality in the not so distant future, our seas and oceans might see the advent of Smart and Autonomous Ships. It is expected that 20 years from now, ship intelligence driven by the smart use of Big Data will shape the maritime industry in general and the type of vessels in particular.

One of the biggest drivers behind the idea of these Smart and Autonomous Vessels is to increase the overall safety of vessels and crew. Smart Ships will be able to support the crew in avoiding human errors which are still seen as the main cause (60%) of collisions and groundings. Another important driver is to lower annual costs. With fuel, CAPEX and crew costs accounting for an overwhelming share of the total costs, the vessels of the future will allow for reduced crew expenses, efficient fuel consumption and result in lower total CAPEX costs.

First steps towards Smart Ships are taken by the strategic partnership between Rolls-Royce and the Finnish VTT Research Centre to launch a first remote-controlled local vessel at the end of this decade and Kongsberg's involvement in the opening of a first test bed for Autonomous Ship technology in Northern Norway.

EGNSS set to be a key differentiator in the maritime domain

With the launch of the Galileo Initial Services, the Galileo Search and Rescue Service will help operators in a more efficient and effective way when responding to an emergency distress alert.

The Galileo SAR Service will also act as Europe's contribution to the international COSPAS-SARSAT programme and due to their operation in the Medium-altitude Earth Orbit will complement the existing LEOSAR and GEOSAR systems.

The Galileo system will comprise two components, namely an automatic forward link distress call (initial service declared on Dec 2016) and a unique return link alert service that will inform the sender of the distress call that their message has been received (initial service to be declared by end 2018). These features, combined with the official IMO recognition of Galileo will pave the way for the adoption of multi-constellation Search and Rescue beacons worldwide.

With the official IMO recognition of Galileo as part of WWRNS, the next step for EGNSS in the maritime segment is to receive official recognition for EGNOS.

For several years, EGNOS is being used by the maritime and inland waterways community. The launch of a new study by the GSA in the field of an EGNOS Maritime Safety Service will only further strengthen the use and the potential of EGNOS in maritime applications.

Focusing on navigation in harbours and inland waterways, this Safety Service is expected to provide another source of differential corrections and integrity information to complement the current IALA DGNSS infrastructure.

HORIZON 2020

SAT406M project: first affordable wrist-worn satellite PLB for maritime users with Galileo return link

Source: SAT406

Designed for anybody performing outdoor, remotely and often risky activities including sole mariners, sailors, travellers and pilots, the wrist-worn PLB improved during the H2020 project **SAT406M** is an affordably produced, easy-to-carry and user-friendly Search and Rescue beacon. Moreover, **the developed PLB is designed to process the Galileo Return Link Messages.**

Designed and developed by Mobit Telecom, based on already existing registered patents, the aim is to make the use of search and Rescue beacons popular, affordable and usable for every person needing one. Despite its relative small size compared with a regular PLB, the SAT406M is able to stay in operation for 24h in harsh environments and temperatures of -20°C and has around 10m water resistance.

SAT406M was a 2014 regional winner of the European Satellite Navigation Competition.

More information on: **http://www.sat406.com/**

New SafePilot version available on iTunes to improve pilotage operations

Marimatech, a Danish manufacturer of maritime equipment and a key stakeholder to the FP7 **SafePort** project concluded in 2012, introduced the first release of SafePilot iPad software for Portable Pilot Units in June 2013.

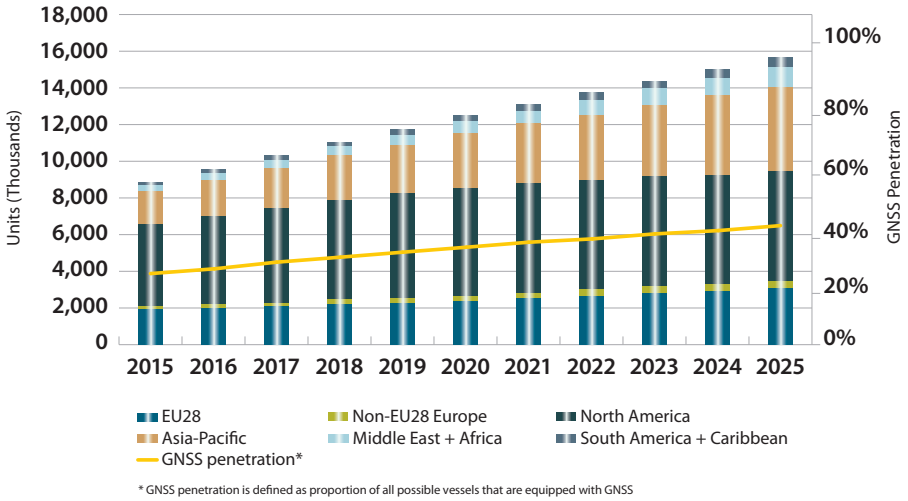
Today, Marimatech as part of Trelleborg Marine Systems **continues developing new versions of the software** in close cooperation with the marine pilot community that can be downloaded from iTunes.

SafePilot offers the **best possible user experience** adding unbeatable features with integration of requirements from pilots of practical functions, easy and handy operations as well as flexible software packages.

Whereas the basic version is designed for internal GNSS usage only, users can download a **Pro Navigation module** that supports external GNSS and has AIS device support.

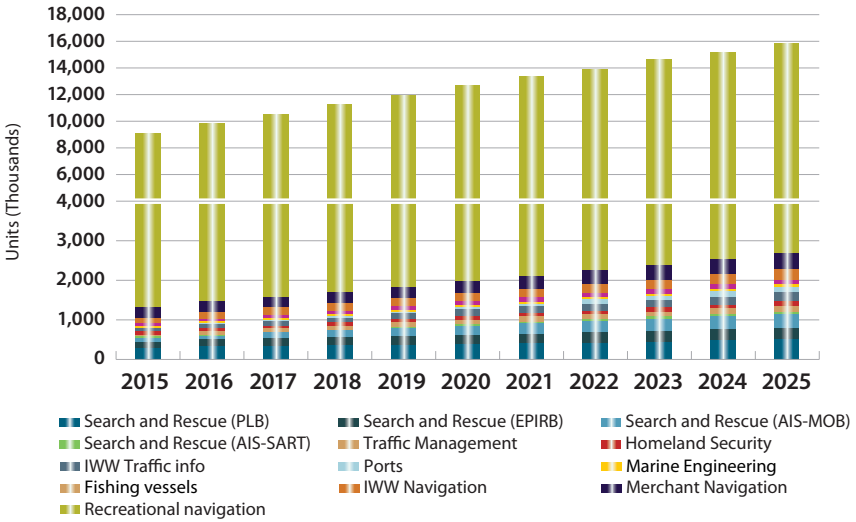
© Trelleborg

Installed base of GNSS devices by region

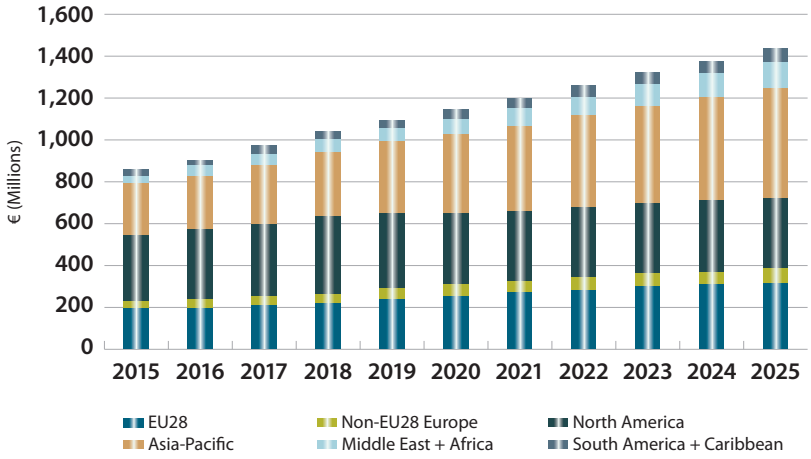


* GNSS penetration is defined as proportion of all possible vessels that are equipped with GNSS

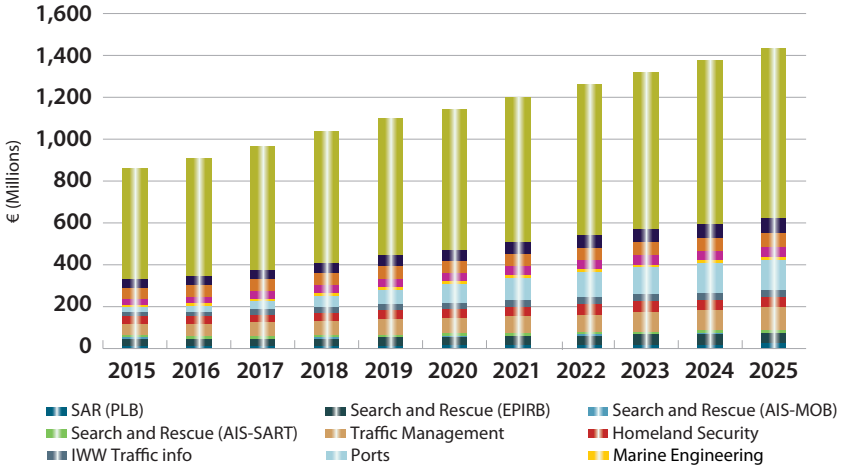
Installed base of GNSS devices by application



Revenue of GNSS device sales by region



Revenue of GNSS device sales by application



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

Agriculture

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.
- **Forest management** makes use of GNSS positioning for different forestry tasks such as identification and mapping of damage and areas under stress, location of clear-cut areas, sample plots and roads.

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).

What you can read in this chapter

- **Key trends:** GNSS stimulates integrated farm management's uptake, as new applications take off.
- **User perspective:** Interoperability and ease of use are key requirements of precision farmers.
- **Industry:** List of main players by value chain segments.
- **Recent developments:** Precision agriculture solutions registered growth across applications.
- **Future market evolution:** Growth of emerging markets will further push adoption of GNSS.
- **Focus on European GNSS:** EGNSS to foster the further adoption of precision agriculture.
- **Reference charts:** Annual evolution of GNSS devices' installed base and revenues by application and region.

NEW **Forest Management** quantified in this edition of the GNSS Market Report

GNSS stimulates integrated farm management's uptake, as new applications take off

Key Market Trends

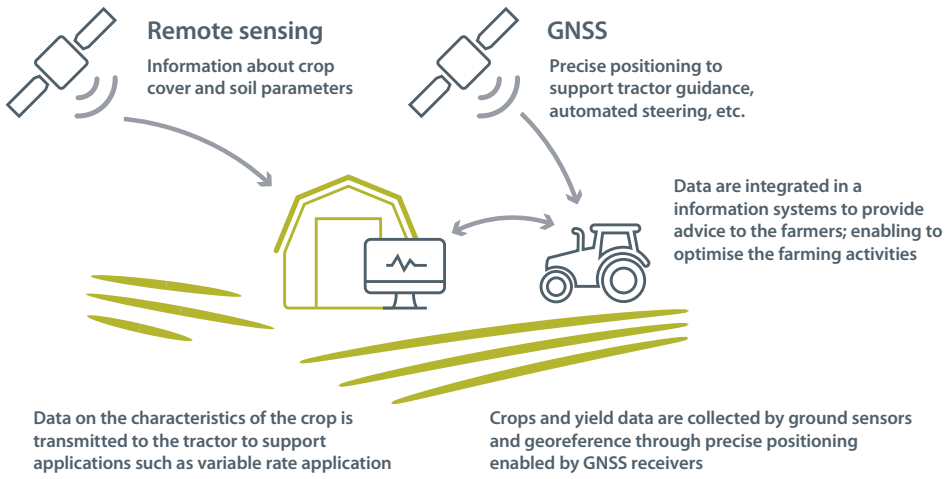
- GNSS applications are used across all phases of the agricultural life cycle and represent a key enabler for the integrated farm management comprehensive concept.
- The drones uptake is increasing and growing in popularity in commercial applications, with agriculture likely to be one of the largest users of drone technology.
- IoT has been the source of new and more productive ways to farm, owing to the use of easy-to-install and affordable sensors. The US is leading and worldwide the segment is growing at a CAGR of 20%.

Integrated farm management fostered by precision agriculture

Integrated farm management constitutes a holistic management approach of the farm. The aim of integrated farm management is to increase the productivity of agricultural cultivation through informed management processes based on the big data paradigm, improving the efficiency of the utilisation of existing assets as well as of natural and anthropogenic resources, in line with sustainable agriculture principles.

Decisions are supported by software services based on data generated by space systems (GNSS and Earth observation), as well as by terrestrial technologies. In this context, precision agriculture perfectly fits the concept of integrated farm management, which is based on a cross-linked unit approach of the farm and it equally constitutes a tool for integrated farm management itself.

The current uptake of integrated farm management is of approximately 10% in the EU and estimates place it at 30-40% by 2020. All major players involved in precision agriculture are currently equally developing integrated farm management solutions, offering farmers the possibility to maximise the performance of their machines, resources and businesses.



Forest management market bound to grow and go mobile

Since forest management constitutes an activity with an inherent locational component, GNSS is beneficial in different phases of forestry activities. The applications of GNSS are the following: handheld devices for field control, hardware in machine guidance and software.

The market is in a rapid state of change at the moment. The potential of reaching higher accuracy (one meter), once turned into reality, will result in growing adoption of GNSS across forest applications.

The sales of smartphones' complementary devices (via Bluetooth) that increase location accuracy will soar in the next years. The mapping software market is forecasted to increase by approximately 30% in the next 15 years, with the US and Europe having the highest sales. The GNSS hardware in machine guidance is relatively recent on the market and its use will increase across regions, with new equipment including machine guidance, positioning and additional maps. The current size of the market is estimated at around 13.5 million euros.

Usage of drones poised to maintain its upward trend

Drones are used in precision farming support, encompassing a wide range of applications, including crop and field analysis, mid-season crop health monitoring, planting, crop spraying and cattle herd monitoring.

It is estimated that the biggest growth area for drones' use over the next decade will involve specifically precision farming, due to the possibility to acquire information cheaply, safely, and quickly. The Association for Unmanned Vehicle Systems International estimates that farms will eventually account for an 80% share of the commercial drones market. Regulation can come into play by either fostering or hindering the adoption of drones. The latter applies for instance in Europe. Drones are foreseen to bring substantial benefits: corn, soybean and wheat farmers could save an estimated 1.18 billion euros annually in the US by deriving the benefits of using drones, which include:

1. **Increase in yields** by spotting potentially yield-limiting problems
2. **Savings in time** by covering the entire field in less time than a croup scout could
3. **Ease of use:** drones are easy to operate and able to hover even in difficult access areas
4. **Removal of human error**, by capturing data that cannot be seen by the human eye
5. **Operational capability** also in case of clouds, as opposed to aerial and satellite imagery

Interoperability and ease of use are key requirements of precision farmers

Overview of the main user requirements in Agriculture

The table depicts, in alphabetical order, the key user requirements as assessed through the GSA's continuous monitoring with the user community. Only high priority requirements are shown, i.e. other requirements might also be relevant for considered applications, and the table is subject to updates. Information on the parameters is provided in Annex 2.

	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	Accuracy (sub-metre) Availability Continuity	Accuracy (sub-decimetre) Availability Continuity	Accuracy (sub-metre to metre) Availability	Accuracy (sub-metre to metre) Availability Authentication
Other requirements	Connectivity	Connectivity Interoperability	Connectivity Interoperability	Connectivity Interoperability Traceability

Incompatibilities bring about difficulties for user

Some users have experienced difficulties, because of "language problems" between farm equipment, farm management programmes and software programmes, as well as incompatibilities between components. The standardisation of interfaces is the key solution to minimise the incompatibility between different brands of hardware and software.

Since the industry has been trying to tackle this difficulty, several initiatives were started. A case in point are the Agricultural Industry Electronics Foundation (AEF) activities, which provide the necessary support for introducing guidelines to ISO standards in agricultural electrical and electronic systems.

In both the US and Europe, projects dealing with the improvement of standardisation are under development. In the US, under the Standardized Precision Ag Data Exchange (SPADE) Project agricultural suppliers of hardware, software, services etc. cooperate for improved data exchange and interoperability. Their goal is to make Data Sharing & Interoperability a reality for precision agriculture. In Europe, the FP7 project FUTUREFARM dealt with data interchange standards and the adoption of standards in European agriculture. Europe has so far agreed on some data standards, for instance for animal ID in Precision Livestock Farming.

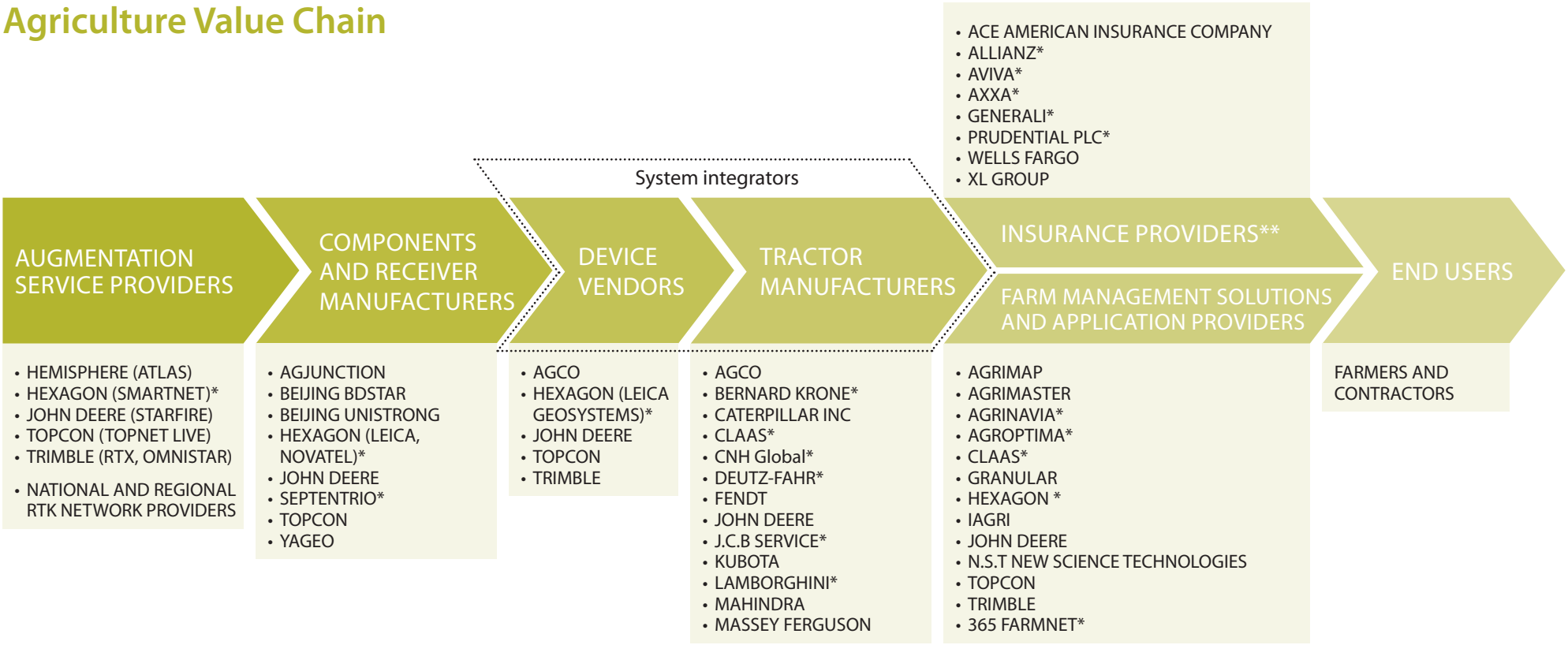
How data are empowering farmers: from big data to smart data

The role of the farmer is the one of the **principal decision maker**, which poses important challenges. The farmers need support/guidance in the decision making process to be able to plan ahead, as well as during the harvesting cycle. The data collected from the field can have a **double role** in this regard, supporting on-the-field and on-the-spot decisions, hence **operational needs**, as well as more **strategic solutions and decisions**. The strategic solutions can refer to whether a certain type of crop should be cultivated or not, to the rotation of the crops etc.

Another salient aspect is the capability to use the information for reporting in the frame of **legislative compliance**. In this particular regard, **automated digital documentation**, within the digital farm, could alleviate the administrative burden of farmers to demonstrate compliance with legislation.

The above-mentioned ideas are in line with the rise of the farming 4.0, which refers to a farm that is data-pushed, GNSS-assisted, and IoT-ready. The challenge for the current technology is the transformation of the big data into smart data, which is easily used by farmers. By fully accomplishing this, the relation between the human, the technology and the animal or the land could be considerably improved.

Agriculture Value Chain



The Value chain considers the key global and European companies involved in the GNSS downstream activities.
* European based companies. The world region is referred to the headquarter of the company, the actual area of activity might be wider.

The European[1] GNSS industry in the global arena

Europe covers 6% of the global market for GNSS **components and receivers**, with Hexagon and Septentrio being the two main European players. The North American company Trimble is leading with 38% of the market, the runner-up being another North American company, John Deere. European companies service 42% of the global system integrator market, the main companies being Hexagon AB, CNH Industrial and Bernard Krone.

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

**New lay-out of the value chain

In this edition of the Market Report, additional attention is given to insurance providers, as agricultural insurance schemes have become more widespread, in both developed and developing countries. The value chain considers the key global and European companies involved in the GNSS downstream activities.

Precision agriculture solutions registered growth across applications

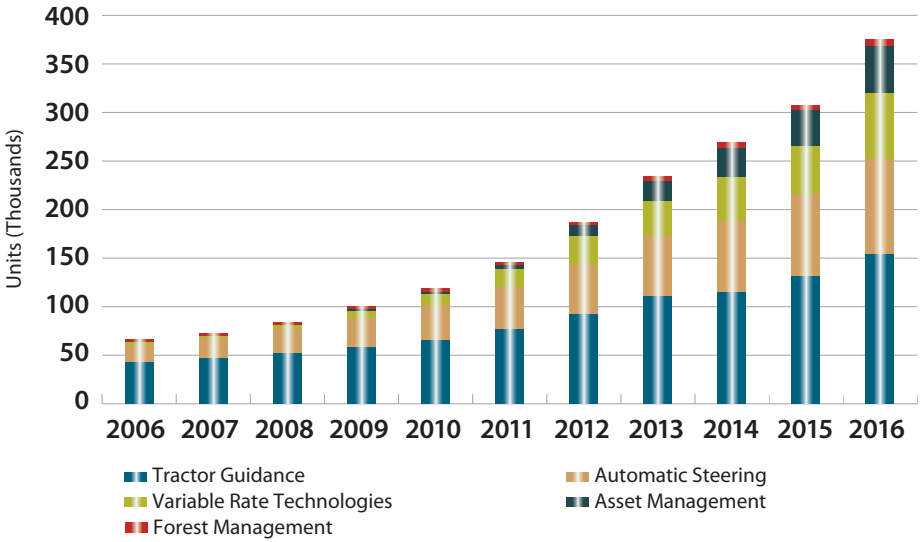
Tractor Guidance continued to constitute the most spread application from 2006 up to 2016, confirming the trend of the high penetration rate and accounting for 41% of the shipments of all devices in 2016 and more than 700,000 units as installed base in the same year.

Automatic Steering, the second application in terms of annual shipment, has grown at a higher rate than Tractor Guidance, showing that there is a growing interest and need for a superior level of accuracy. The adoption of automatic steering and the positive results obtained by farmers while using these systems have been encouraging farmers to subsequently use new, innovative farm practices with small investment costs attached.

With regard to **Variable Rate Technologies (VRTs)**, the application has been growing at a constantly high rate, reaching 67,000 shipments in 2016. It is often used in conjunction with other precision technologies, confirming through its increasing use the fact that agriculture is becoming one of the fastest growing tech sectors, across regions.

Asset Management solutions have annually increased in adoption since 2006, amounting to an installed base of 153,000 units in 2016. **Forest Management solutions** constitute a niche market, encompassing machine guidance and tree management solutions.[1]

Shipments of GNSS devices by application



GNSS supports the traceability of products across the supply chain

Geo-traceability regards the collection of information about a product and the guarantee of the visibility of the data to other points in the supply chain. It creates trust for the consumers, through additional information on the origin of the ingredients and production methods. It can be used to supply proof of the origin of the processed products and their ingredients, which in turn is used by producers to potentially justify a higher price of the products. The food traceability market is projected to grow at a CAGR of 9% by 2019.

A variety of tools support traceability in general, amongst which GNSS, sensors, barcodes, RFID tags, label printers, etc. Cloud applications maintained by companies via cell signal or Wi-Fi address the collection of traceability data. The data are mostly stored in databases, which allow to follow products from their origin farm, processing, transportation, delivery and the end customer.

There is potential for GNSS to act in synergy with Copernicus to provide valuable data for traceability purposes. Copernicus can, for instance, provide support for the gathering of data through mapping services.

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GNSS-based applications make life easier for farmers

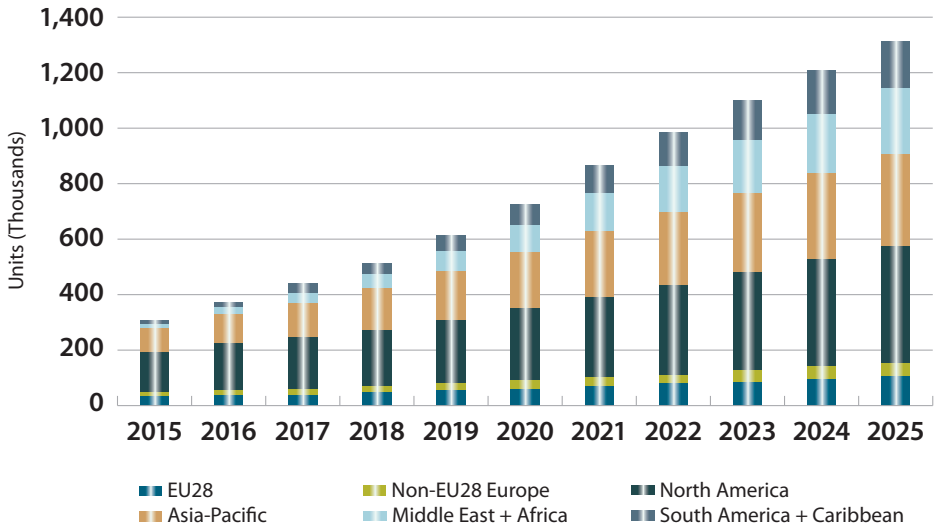
From a technical standpoint, GNSS provides support in guidance system applications, for instance for the creation of straight and evenly spaced lines in the field or for curve guidance modes. Automatic tracking features are also supported by GNSS tracking. These systems are usually compatible with smartphones and tablets. Moreover, the GPS component supports mobile mapping, providing the data that can be afterwards downloaded into a GIS (geographic information system) to feed a range of software applications.

The software allows farmers to control farm operations by accumulating, analysing and exploiting data over several years. The precision farming software market is expected to reach 1.34 billion euros by 2020, at a CAGR of 15.1% from 2014 and 2020. In 2014, Europe and the Americas were the market leaders, with APAC being the fastest-growing region. Precision farming software applications' growth depends on the expected improvement in their capability to help farmers achieve higher productivity, and increased financial gains, by helping them to efficiently plan and maintain data bases, thus making activities in farms easier.

Growth of emerging markets will further push adoption of GNSS

North America is currently the most technologically advanced region and the heartland of precision agriculture, with the highest installed base, followed by Asia-Pacific. The shipments in North America will increase more than two fold between 2015 and 2025, proving that precision agriculture is progressively prominent amongst farmers from this region and that the industry is committed to technological innovations.
Asia-Pacific will continue to expand its installed base, albeit at a slower pace than in the period 2006-2015, reaching 330,000 shipments in 2025. Countries such as China, India and Australia are the main adopters of precision agriculture. The burgeoning demand in food due to rising human populations and the economic growth of the region drives the interest for precision agriculture. The smallest farms, which is the case of most farms in the APAC region, will be the first ones to become mainstream adopters of autonomous feeding systems.
Europe (both EU28 and Non-EU28 Europe regions together) will grow at a moderately more sustained pace, reaching 157,000 shipments in 2025. The challenges faced by precision agriculture in Europe regard the size and diversity of agricultural structures.
Middle East and Africa, together with **South America and the Caribbean** will register the highest growth, partly due to the currently low levels of adoption and the fact that technology initially used in developed countries is becoming more accessible. Affordable and smart technology solutions are gaining ground in Africa, a region with much untapped potential. Maize and rice are amongst the cultures having benefitted from advanced technologies. In MEA, the shipments will grow from 14,000 in 2015 to 239,000 in 2025.

Shipments of GNSS devices by region



HORIZON 2020 Mistrale COREGAL

The use of GNSS reflected signals (GNSS-r) in agriculture takes new shades

GNSS reflectometry refers to measurements from the reflections of Earth navigation signals originating from GNSS systems. It has a large spectrum of applications ranging from weather forecast to climate research.

Even though reflectometry is far from new on the market, the drones used in the H2020 **MISTRALE** project are proposing new use cases. The project deals with soil moisture management and involves the development of a prototype of GNSS-R sensor fixed into a drone. The **application** consists of the provision of drone-based soil moisture maps to complement satellite and field measurements. The sensor developed can also be used for other devices. Moreover, other fields can benefit from moisture maps, such as irrigation water management, disaster management or environmental assessments, etc.

COREGAL constitutes another example of a H2020 project using GNSS-R and E5. A position and reflectometry Galileo receiver is developed as the main sensor for platform positioning and biomass estimation. The sensor will be used for an unmanned aerial platform and service in scale mapping, in the field of Brazilian forest management.

More information on: **http://www.coregalproject.com/ and http://www.mistrale.eu/**

Livestock tracking: potential and barriers

Livestock tracking refers to the monitoring of herds from overhead, tracking the quantity and activity level of animals on one's property, especially for night-time monitoring. Farmers can monitor the movements of livestock throughout the landscape, plot grazing patterns and see in what areas the livestock have been depleting nutrients in the soil. Moreover, GPS live tracking data gives farmers the possibility to understand how livestock interact with the land.

The barriers faced by these solutions are related to the communication of the position of the animal in environments with limited connectivity, as well as to the battery life. Both device manufacturers and telecommunication providers have been putting forward solutions to these issues. Overcoming these challenges will push the market for wearable electronic devices for livestock. Several companies have developed products with GNSS tracking capability, including features such as geofences.

An FP7 funded project, **E-Track**, worked on a user-friendly tracking software solution, using EGNOS for higher accuracy. Some experts expect livestock tracking to be substantially used by farmers in the next 5-10 years. The expected growth of the market is from around 750 million euros currently, to 1.89 billion euros by 2025.

EGNSS to foster the further adoption of precision agriculture

The use of GNSS in precision farming often means positioning services with sub-decimetre level accuracy, which can only be achieved using augmentation services. Galileo Open Service in combination with RTK or PPP, as well as Commercial Service High Accuracy (CS-HA), features excellent positioning that will further improve the performance of GNSS-assisted agriculture and bring benefits in every phase of the farming operation. As Galileo Initial Services were declared in December 2016, farmers may already benefit from Galileo in a multi-constellation configuration. The resulting benefits to precision farming are many, e.g. better operation in harsh environment, availability, continuity and reliability.

Farming by satellite prize: Linking satellite navigation systems to field operations

The aim of the prize is to promote Europe's GNSS and EO services in agriculture. The prize rewards new ideas and innovations, especially those integrating EGNOS, Galileo or Copernicus. The 2016 Prize winners, from ISA Lille, worked on the optimisation of the properties of the cover crops to improve soil composition by using earth observation data.

GEOPAL project yields marketable results for project partners

The **FP7 GEOPAL** project dealt with a GNSS-based system used for planning logistics in agriculture. The successful results are implemented by the project in the product lines of their respective companies, therefore transferring the R&D outcome in marketable solutions and generating revenues. In addition, at Agritechnica, the CLAAS Group was awarded a silver medal for the solution that was developed within the GEOPAL project – its field route optimisation system that enables 6% average cost reduction for farmers.

More information on: **http://www.geopal-project.eu/**

EGNOS improves precision agriculture solution by providing metre-level accuracy that is widely available. Thus EGNOS eliminates the need for complex and costly equipment and software solutions, and the investment in the required infrastructure of augmentation service providers. EGNOS provides farmers with the opportunity to better control applications, monitor the harvest yield, perform effective in-field data collection, and use manual guidance in cultivation. In the next years, EGNOS is on its way to becoming the preferred entry level technology for precision agriculture in Europe, Africa and the Middle East. This is confirmed by the fact the vast majority of GNSS devices offered today are EGNOS enabled.

AUDITOR project: improving the performance of augmentation services

The objective of AUDITOR is to develop an improved ground-base GNSS augmentation system in terms of both performance and cost and to deliver services based on the augmentation system for agriculture applications.

The target group of the project are farmers around Europe who live in areas where EGNOS coverage is poor or small and medium-sized farms, which cannot afford the cost of a private RTK solution.

The consortium is composed of both companies and research centres working together to advance the objectives of the project, which will finish at the end of 2017.

More information on:
http://www.auditor-project.eu/index.html

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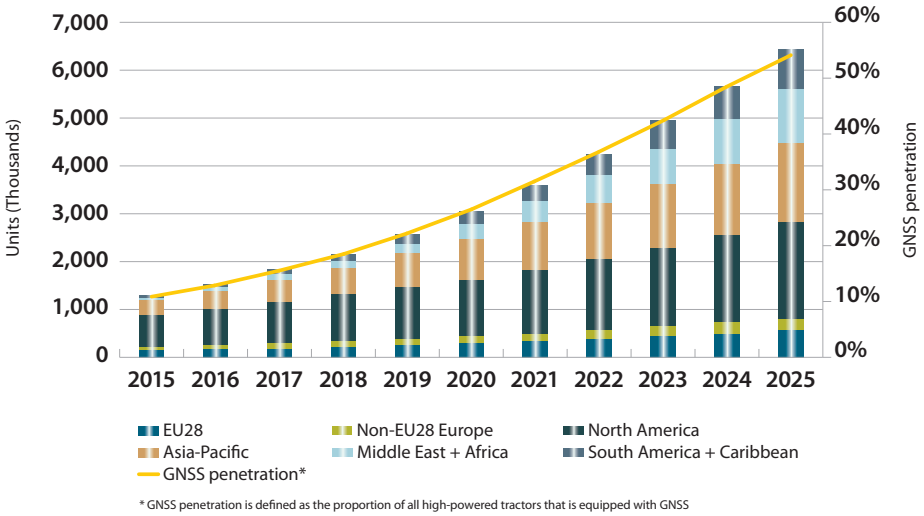
Galileo and EGNOS are supporting the effective implementation of the Common Agricultural Policy (CAP) in Europe

The current CAP reform raised a new opportunity for GNSS due to new requirements, which directly affect how farmers in Europe claim aid for agricultural parcels, new elements in their aid applications as well as subsequent process of administration and control of area-related payments. In particular, GNSS plays a role in measurements needed to prove eligibility for funding and for the performance of on-the-spot checks performed by the public authorities in charge. In conducting such activities, GNSS solutions, often used in a combination with Earth Observation (EO), guarantee time and cost efficiency while minimising the volume of low added-value activities.

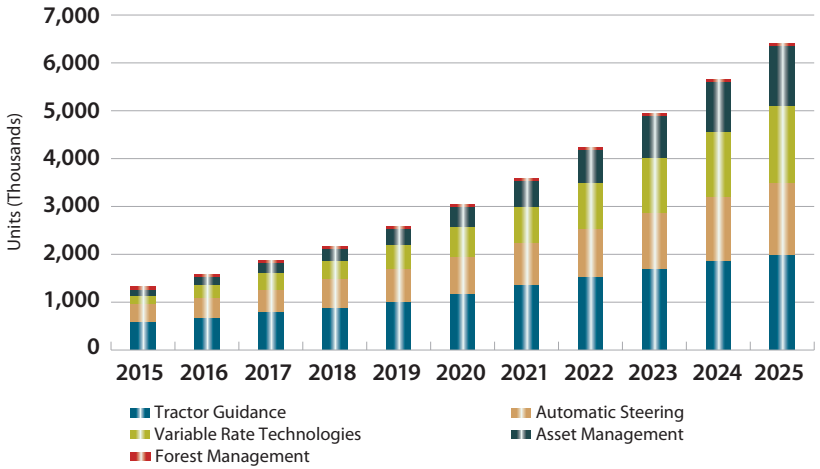
In this frame, EGNOS and Galileo can offer affordable improved accuracy, in addition to increased availability and continuity. The Galileo Open Service Navigation Message Authentication (OS NMA) will potentially simplify and reduce the need of checking activities performed by the authorities through the provision of certified measurements.

Installed base of GNSS devices by region

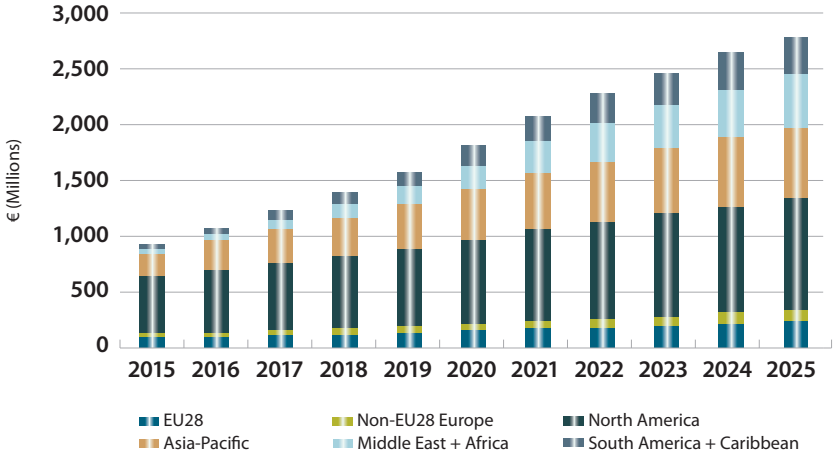


* GNSS penetration is defined as the proportion of all high-powered tractors that is equipped with GNSS

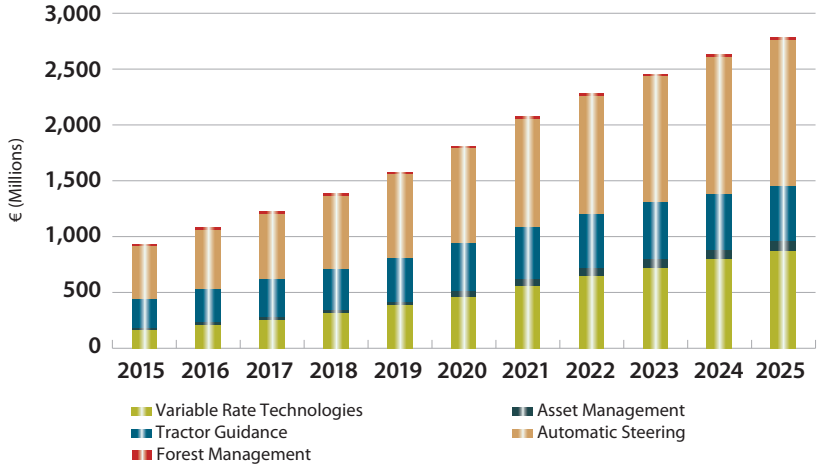
Installed base of GNSS devices by application



Revenue of GNSS device sales by region



Revenue of GNSS device sales by application



Surveying

GNSS applications

Applications in Land Surveying:

- **Cadastral surveying** aims at establishing property boundaries. Fiscal policies such as land taxation rely widely on cadastral surveying.
- **Construction surveying** covers the different construction stages of a building or civil engineering work, whereas machine control applications automate construction activities:
  - **Machine control** applications use GNSS positioning, for example to automatically control the blades and buckets of construction equipment based on information provided by 3D digital design.
  - **Person-based** applications involve topographic surveys for constructions sites, checking levels, performing "as-built" checks or stake out reference points and markers.
- **Mapping:** GNSS is used to define specific location points of interest for cartographic, environmental and urban planning purposes.
- **Mine Surveying:** mine surveying involves measurements and calculations at each stage of mine exploitation, including safety check.
- **Infrastructure Monitoring:** GNSS is used to monitor critical infrastructure and the natural environment to prevent major disaster and promptly intervene in case of emergency.

Applications in Marine Surveying:

- **Marine surveying:** encompasses a wide range of activities (seabed exploration, tide and current estimation, offshore surveying, etc.), and their outcomes are important for maritime navigation.

Augmentation techniques used in surveying

In order to achieve high accuracy, GNSS surveying equipment uses GNSS augmentation techniques that can range from satellite based augmentation systems (SBAS) to DGNSS, PPP and RTK.

Real Time Kinematics (RTK) is an augmentation technique based on differential GNSS that provides real-time cm-level positioning accuracy in the vicinity of a base station. Network RTK implementation relies on networks of stations covering a geographical area of interest which transmit GNSS positioning corrections. RTK data are usually accessible via a subscription fee.

NEW **An overview of RTK market and infrastructures is provided in this section.**

What you can read in this chapter

- **Key trends:** Technology sophistication and services development: how the democratisation of mapping and crowdsourcing data are boosting the industry evolution.
- **User perspective:** User requirements segmentation and need of interoperability bring new challenges and opportunities for the GNSS industry.
- **Industry:** List of main players by value chain segments.
- **Recent developments:** Construction, mapping and cadastral industries stimulated growth in shipments of GNSS surveying equipment.
- **Future market evolution:** Construction activities in Asia-Pacific and North America will drive GNSS growth.
- **European GNSS:** EGNSS set to be key differentiators in mapping and surveying domains.
- **Reference charts:** Annual evolution of GNSS devices' installed base and revenues by application and region.

NEW **Infrastructure Monitoring** quantified in this edition of the GNSS Market Report

Technology sophistication and services development: how the democratisation of mapping and crowdsourcing data are boosting the industry evolution

Key Market Trends

- Incumbent manufacturers are focusing on customers services and assistance to counterbalance Asian manufactures' competitive pricing strategies.
- The integration of GNSS with complementary technologies in land surveying and construction activities is a major push towards interoperability.
- GNSS remains the backbone technology in increasingly sophisticated applications (e.g. 2D mapping move to 3D mapping).

Innovative software and services to cope with Asian competitors

Asian manufacturers are deploying highly competitive pricing strategies; while offering competitive prices; however, with minimal support after purchase. These manufacturers are taking advantage of home market, Asia being the largest consumer of GNSS receivers in the world. This trend, together with the relative maturity of the surveying industry, is decreasing GNSS devices' prices and harshening competition among major players.

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In this newly emerging competitive landscape, western competitors are integrating in their offer powerful software for processing, modelling and analysing captured data and extensive customer assistance, on top of the simple sale of GNSS devices, as a mean of differentiation from Asian cheap manufacturers.

Game of drones: how drones can change surveying

For years, aerial and satellite images have been complementing mapping and surveying activities. Nowadays, drones can cut costs and time, streamlining the imaging process, ensuring flexibility and operators' safety in many activities: mapping; inspection of construction sites, mines and infrastructures; environmental monitoring; and cultural heritage mapping.

© Getty Images

The European regulations governing drones are very different among Member States and this lack of clarity is preventing the uptake of drones, creating uncertain returns on such investments. Thus, regulations will play a crucial role in the coming years in supporting or preventing drone uptake.

Galileo improves availability and continuity while EGNOS can ensure safe navigation by improving accuracy and providing integrity. Authentication capabilities may represent an added-value feature when drones are used to provide certified measurements.

New and emerging GNSS applications and market trends

Democratisation of mapping GNSS devices	The reduction of GNSS receiver prices and the increase in the level of accuracy are transforming mapping into a more accessible activity. In particular, making accurate measurements easier to perform leads the market of positioning devices to the multiplication of integrated, highly performing and easy-to-use tools for an increasing range of positioning applications. Today GNSS receivers are more compact, reliable, highly performant and yet affordable thanks to modularisation. This trend is also prompting the collection of crowdsourcing data.
Crowdsourcing data	Simply using smartphones or any GNSS portable devices, combined with simultaneous localisation and mapping (SLAM) technologies, users become data collectors for mapping activities, especially in urban areas. Crowdsourcing data allows for the mapping of places rather than spaces. Moreover, the crowdsourced satellite signal-to-noise ratio (SNR) measurements can improve GNSS accuracy in urban environments. This massive data collection is expected to change the paradigm of the mapping profession and is enhanced by the democratisation of GNSS mapping devices.
Smart cities	A Smart City is an urban development meant to improve quality of life increasing the efficiency of services and better meeting residents' needs. Different techniques such as EO images combined with EGNSS positioning data, integrated by crowdsourced data and augmented reality can serve this purpose. EGNSS plays a key role also in tracking citizens' mobility, mapping infrastructures, improving waste management, optimising public transport flows or implementing smart port management system.
Uptake of PPP	Users are increasingly seeking high-accuracy and easy to use GNSS solutions with good coverage, and therefore the Precise Point Positioning (PPP) is gaining more surveying users. Major players are offering affordable and user-friendly PPP solutions, providing centimetre level accuracy worldwide, covering also oceans, with no distance limit from the reference stations, with a minimal network infrastructure. These advantages are boosting the uptake of PPP in land and marine construction and mapping.

User requirements segmentation and need of interoperability bring new challenges and opportunities for the GNSS industry

Overview of the main user requirements in Surveying

The table depicts, in alphabetical order, the key user requirements as assessed through the GSA's continuous monitoring with the user community. Only high priority requirements are shown, i.e. other requirements might also be relevant for considered applications, and the table is subject to updates. Information on the parameters is provided in Annex 2.

Applications	**Land surveying** Cadastral, construction, mine surveying, infrastructure monitoring	**Mapping**	**Marine surveying**
Key GNSS requirements	Accuracy (down to centimetre level) Availability Continuity TTFF	Accuracy (down to centimetre level) Availability Continuity	Accuracy (down to centimetre level) Continuity Integrity
Other requirement	Connectivity Interoperability	Connectivity Interoperability	Interoperability Resiliency

In the land surveying market a general trend of polarisation of user requirements and consequent segmentation of the market has been identified: high-end (premium) customers, willing to try new and cutting edge applications; and mainstream (basic) users looking for good value for money, more interested in established technologies. Manufacturers and providers are therefore segmenting their offer portfolio in order to cope with this new user polarisation trend.

Interoperability could further support GNSS adoption

Surveying activities play an ancillary role in several industries. Therefore, compatibility, concerning in particular interfaces and communication links, may enhance the uptake of innovative surveying techniques and expand it to new segments of application.

The need of interoperability also among devices provided by different manufacturers is of key importance. At the moment, many different DGNSS/RTK data formats are available (e.g. RTCM, CMR, etc.), making the use of data coming from different sources and devices quite challenging. Typically, different brands have different levels of interoperability when it comes to receiving augmentation corrections from networks operating with equipment from other players considered as competitors.

In addition, the integration of GNSS with complementary technologies such as Lidar, laser scanners, Remote Sensing, MEMS, robotics, etc. is increasingly spreading. To obtain sophisticated integrated solutions, the setting of a common standard may be beneficial.

Surveying Value Chain

AUGMENTATION SERVICE PROVIDERS

- FUGRO (STARFIX)*
- HEMISPHERE (ATLAS)
- HEXAGON (SMARTNET)*
- JOHN DEERE (STARFIRE)
- TOPCON (TOPNET LIVE)
- TRIMBLE (RTX, OMNISTAR)

NATIONAL AND REGIONAL RTK NETWORK PROVIDERS

COMPONENTS AND RECEIVER MANUFACTURERS

- BEIJING BDSTAR NAVIGATION CO
- BEIJING UNISTRONG SCIENCE & TECHNOLOGY
- CHC
- GNSS-GPS
- HEXAGON (LEICA GEOSYSTEMS, NOVATEL)*
- HI-TARGET SURVEYING INSTRUMENT CO.
- HOLUX TECHNOLOGY, INC.
- JAVAD
- JOHN DEERE
- KONGSBERG*
- LAIRD PLC*
- NORTH SURVEYING*
- RAKON
- SEPTENTRIO*
- SHANGHAI HUACE NAVIGATION
- SOUTH
- SUZHOU FOIF CO. LTD
- TECHNOLOGY
- TOPCON
- TRIMBLE
- YAGEO CORPORATION

SYSTEM INTEGRATORS (RELEVANT ESPECIALLY FOR MACHINE CONTROL)

- BEIJING BDSTAR NAVIGATION
- CATERPILLAR
- HEXAGON*
- HITACHI
- HI-TARGET SURVEYING INSTRUMENT
- J.C.B. SERVICE*
- JOHN DEERE
- KOMATSU
- KONGSBERG*
- TOPCON
- TRIMBLE

SOFTWARE, APPLICATIONS AND ADDED-VALUE SERVICES

- CARLSON
- FUGRO*
- HEMISPHERE
- HEXAGON (LEICA GEOSYSTEMS)*
- HYPACK
- JAVAD
- SEPTENTRIO*
- SOUTH
- STONEX*
- TOPCON
- TRIMBLE

PROFESSIONAL USERS

- CONSTRUCTORS
- ENGINEERS
- ENVIRONMENT PROFESSIONALS
- FARMERS
- MINING COMPANIES
- OIL & GAS COMPANIES
- SCIENTISTS
- SURVEYORS

CUSTOMERS OF SURVEYING SERVICES

- HYDROGRAPHIC OFFICES
- NATURAL RESOURCES MANAGEMENT FIRMS
- OFFSHORE WIND FARMS
- PRIVATE COMPANIES (CONSTRUCTION COMPANIES, INSURANCES, ETC.)INDIVIDUALS
- PUBLIC ORGANISATIONS
- UNDERWATER CABLE & PIPELINE INSTALLERS

The European[1] GNSS industry in the global arena

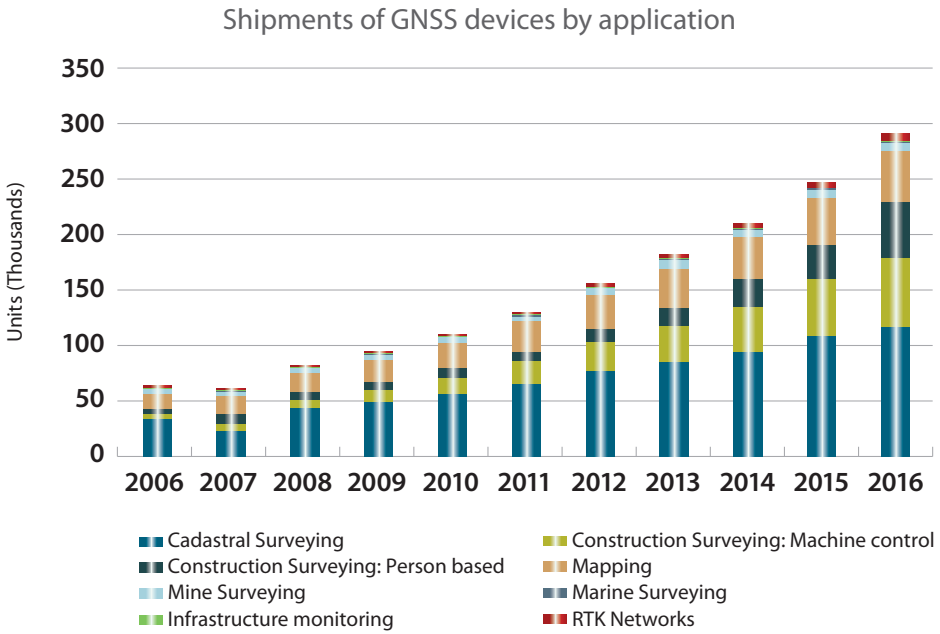
Trimble, Hexagon and Topcon together cover more than 80% of the GNSS receivers and components global production for high precision surveying. Therefore the market continues to be dominated by the established players. In this concentrated market, **European companies** hold more than a third of the market (36%), whereas North America boast 40% of the market, and Asian firms currently cover 24% of the worldwide production.

Concerning **system integrators**, different players are active according to the various applications (construction, mapping, marine surveying, etc.). The regional industry shares are pretty evenly distributed among North America (34%), Europe (37%) and Asia (29%). Within this segment, **Hexagon, Kongsberg, and J.C.B** 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 the GNSS downstream activities.
* European based companies. The world region is referred to the headquarter of the company, the actual area of activity might be wider.

Construction, mapping and cadastral industries stimulated growth in shipments of GNSS surveying equipment



The growth in GNSS device shipments experienced in the past ten years has been mainly supported by **Cadastral** Surveying, **Mapping** and **Construction** (both person-based and machine control) which, together, accounted for 95% of the shipments of GNSS devices in 2016. **RTK networks** expanded quite fast (+29% per year on average), while **Infrastructure Monitoring** and **Mine Surveying** remained stable over the period considered.

Asia has experienced quite a steep positive trend, with shipments of surveying equipment growing on average 37% per year within the considered timeframe. Its increased share of shipments in the world (from 12% in 2006 to 39% in 2016) shows that emerging countries are conquering a more and more important role over the international horizon. The same is true also for the Middle-East and Africa, with a smaller order of magnitude (from 1% in 2006 to 11% in 2016). Europe and North America are growing at lower but still relevant pace, around 10% per year.

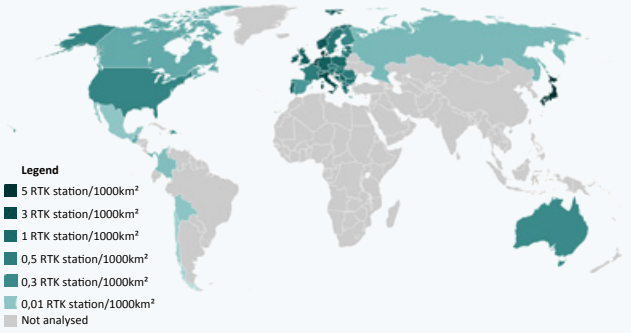
This dynamic involving emerging countries is consistent with the impressive growth of the construction, mapping and cadastral industries: growing population and urbanisation processes require intense property and infrastructure-related activities.

Regarding the relative stability of Mine Surveying and Infrastructure Monitoring, it is obviously depending on the infrastructure they are related to: the number of mines, long bridges (with a suspended span longer that 100m), high-rises (higher than 300m) is reasonable to increase at a quite low pace. This does not mean that those markets are stagnating, they are shifting their focus on services.

RTK networks coverage is quite significant and it is expected to grow in the coming years

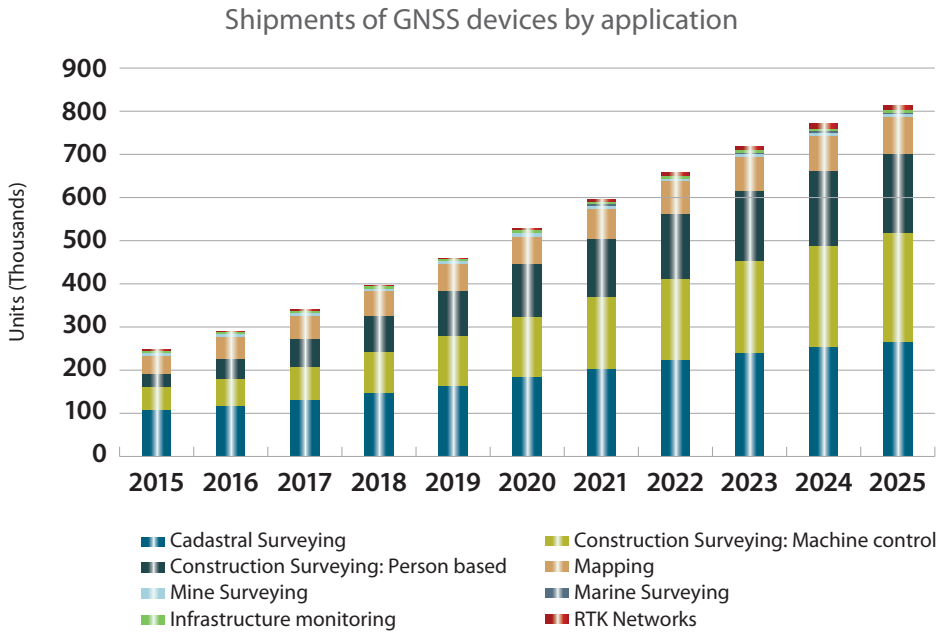
Real Time Kinematic (RTK) is a technique used to enhance the precision of GNSS position. It uses measurements of the phase of the signal's carrier wave and relies on either a single reference station, a network of reference stations or interpolated virtual reference stations (VRS) to provide real-time corrections, offering up to centimetre-level accuracy. Due to the high level of real time accuracy, RTK is particularly suitable for surveying applications such as cadastral surveying, construction activities (road construction, high-rises and infrastructure building) and drones navigation. Considering that RTK solutions provide high accuracy only if the operator is no more than 40 km in distance from a reference station, the coverage of RTK network is very relevant.

The **map** on the right **shows** the **density of RTK reference stations** in the world (number of RTK reference stations/1000 km2). According to the available data, Denmark, Japan, Belgium, Netherlands and Italy boast the highest density of RTK reference stations in the world. However, the RTK network density is not fully meeting user needs at the moment. In the near future, the RTK networks are expected to grow to extend coverage and to densify areas with high number of users. Additionally, China, the UAE, Israel and South Africa and other countries are at least partially covered by different RTK networks, but the complete data was not analysed at the time of writing.



Density of RTK reference stations. Source: VVA Analysis

Construction activities in Asia-Pacific and North America will drive GNSS growth



In the coming decade, a substantial growth of the GNSS surveying market is expected: the total amount of shipments is expected to reach 815,000 units worldwide, representing almost a 4-fold increase over 2015.

In particular, the strong development of the construction sector will drive the growth of GNSS device shipments, involving both machine control and person-based technologies, which are estimated to increase by an average of 19% annually between 2015 and 2025.

Machine control in particular is foreseen to steadily increase over the next decade, with shipments growing from 50,500 units in 2015 to 250,000 in 2025. This activity can be considered a high value discipline, as annual revenues will exceed €1 bln.

In 2025, surveying equipment for cadastral applications is expected to account for around a third of the 815,000 shipments per year. Due to increasing competition and technological advancements, the average price of devices is expected to drop.

By 2025 Asia-Pacific will represent about 54% of total shipments and 56% of the revenues deriving from GNSS equipment in the surveying domain, showing that emerging economies will be driving an expanding market that otherwise would be close to reach its maturity.

Augmented Reality will make construction monitoring simpler and smarter

Augmented Reality (AR) is an interface that overlays digital information onto the user's view, spatially aligned to the current physical environment. As already mentioned on page 21, this technology represents a powerful tool for the construction industry, since it allows for an on-site presentation of information that is registered to the physical surrounding. AR can support the activities of monitoring and documentation of construction progress in an innovative and effective way, superimposing progress as well as planned information onto the user's view of the actual construction site.

In order to exploit the great potential of this new technology, major global players announced collaborations and partnerships with AR enterprises, to collaborate on wearable technology in order to change the way construction and surveying professionals interface with the job site, to support public administration activity and territorial planning and many other surveying applications.

The **H2020 project LARA**, "LBS Augmented Reality Assistive System for Utilities Infrastructure Management through Galileo and EGNOS", will develop a mobile device to assist the utility management professionals on the field. The hand-held, low cost, mobile device will integrate GNSS technology and Augmented Reality (AR) interface.

EGNSS set to be key differentiators in mapping and surveying domains

In order to support the high-end, demanding surveying applications that seek to maximise the accuracy of measurements and signal availability in harsh environment, it is beneficial to update the augmentation infrastructures to Galileo Open Service capabilities (see below). Additionally, Galileo is set to offer the **Commercial Service High Accuracy (CS-HA)** that will meet the level of accuracy required for many applications in cadastral, construction, and mine surveying, while delivering PPP corrections around the world directly via the Galileo satellites (no need for an additional communication channel).

Further benefits of Galileo also include Commercial Service Authentication to ensure the trustworthiness of positioning information.

By providing metre level accuracy with minimal investment, EGNOS represents a cost-effective entry level solution. It satisfies the needs of mapping applications requiring enhanced GPS positioning, by providing added value free of charge.

Municipalities, forestry authorities, utilities and other users benefit from EGNOS performance in mapping. As an example, its advantageous price-quality ratio makes it a suitable technology for the field measurements performed in relation to the Common Agricultural Policy enforcement.

MapKITE project: simultaneous terrestrial and aerial surveying for corridors mapping and smart planning

Roadway, railways, waterways and energy pipelines are just some examples of man-made structures for transportation of goods and people. Accurate mapping of their settlements is then fundamental in modern and growing societies, which require accurate terrain mapping, infrastructure maintenance and inspection, cadastral delimitation, city 3D models, etc.

Corridor mapping can now be performed through a novel approach at a lower cost, and this is due to the mapKITE concept. The H2020 project has carried out real corridor mapping missions with a tandem terrestrial-aerial system (mobile mapping vehicle and a drone), achieving tangible, improved results. By using advanced navigation and orientation systems including EGNOS and Galileo E5 AltBOC, mapKITE can substitute conventional surveying-based ground control points at no extra cost. At the time of writing, the mapKITE system has paved its way through the demanding geo-spatial market.

More information on: **www.mapkite.com**

CLGE Annual Young Surveyors' Prize: fresh ideas to feed the surveying industry evolution

Cecile Deprez is the winner of the 2016 2nd Annual Young Surveyors' Prize awarded by the European GNSS Agency (GSA) for outstanding contributions to Galileo, EGNOS and Copernicus at the Council of Geodetic Surveyors.

Deprez, a PhD student at the University of Liege in Belgium, proposed an idea potentially bringing considerably higher precision to mass-market applications, relying on Google's provision of access to GNSS raw measurements for Android users. The use of the Galileo E5 signal could theoretically offer decimetre positioning precision for Android applications. According to the winner's research, Galileo signals are more precise than GPS alone.

Galileo improves the performance of the RTK and PPP solutions

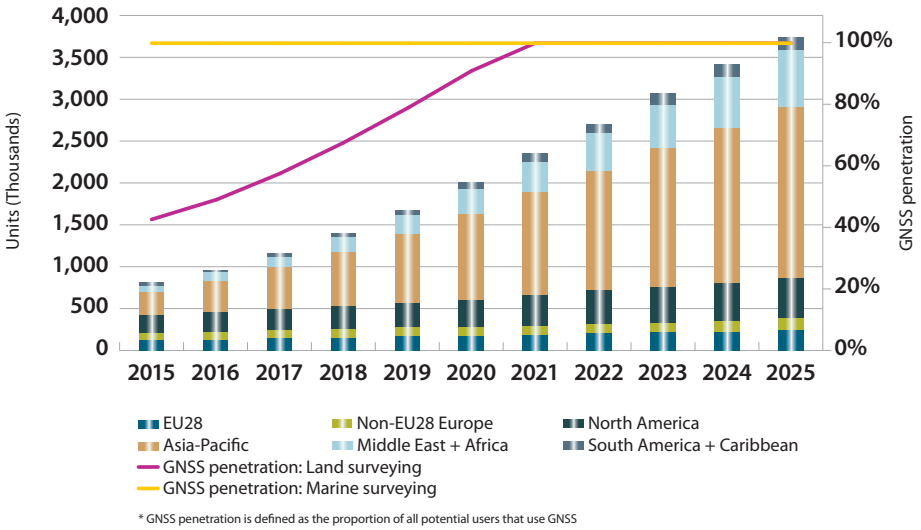
Galileo's free-of-charge Open Service offers either single (E1) or dual frequency (E1/E5), which will further improve the quality of the augmentation services as RTK/DGNSS or PPP. The resulting benefits to surveyors include, especially in multi-constellation environments, increased availability of the satellite signals, continuity and reliability, lead to better operation in harsh environments such as urban/natural canyons or under tree canopies.

Following the Initial Services declaration in December 2016, increasingly many private and public network RTK providers, as well as established PPP providers, are offering Galileo corrections to their customers and this trend is expected to grow further.

Third frequency for ranging

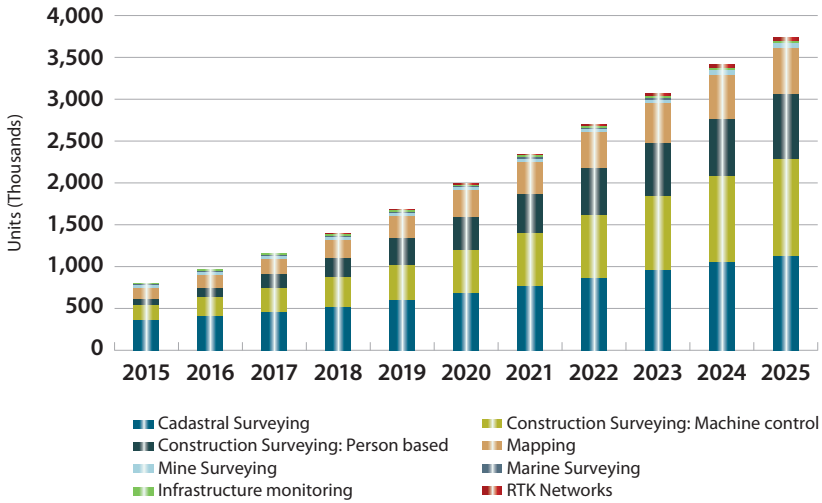
In addition to single and dual-frequency capability in the Galileo Open Service, Galileo E6 is available for ranging. This high-quality signal adds an excellent option for the third frequency required for the linear combination of GNSS observations made on three frequencies (e.g. for faster and more reliable ambiguity resolution in RTK and PPP processing).

Installed base of GNSS devices by region

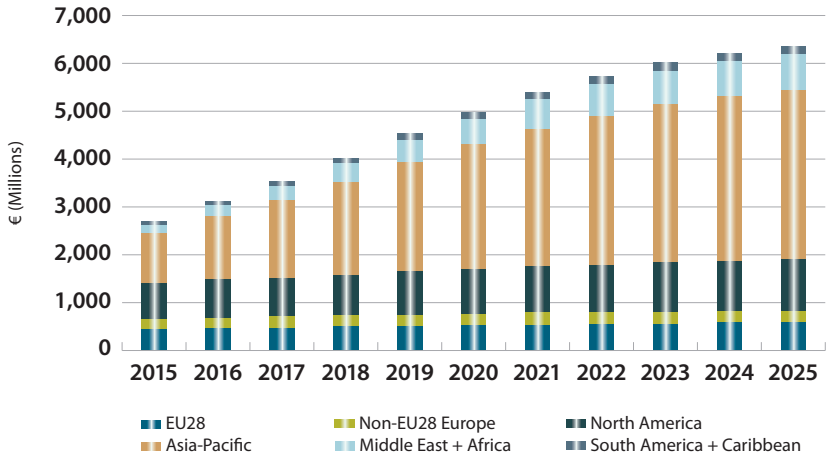


* GNSS penetration is defined as the proportion of all potential users that use GNSS

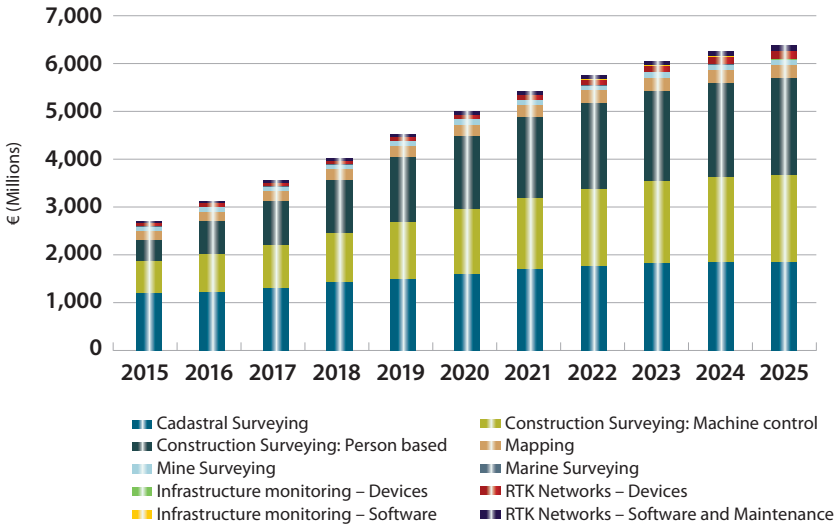
Installed base of GNSS devices by application



Revenue of GNSS device sales and services by region



Revenue of GNSS device sales and services by application



Timing & Synchronisation (T&S)

GNSS applications

- **Telecommunication applications:** Telco operators require accurate and consistent time and frequency at distant points of their networks to face 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 timeslots 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 can be used to provide frequency and phase alignment.
- **Energy applications:** Energy operators require an accurate time source to monitor the energy flow of their networks.
  - **Phasor Measurement Units:** GNSS is used to provide a precise timing marker at nodal points of the networks to ensure its monitoring and protection against failure.
- **Finance applications:** Financial institutions are legally committed to trace operations with a consistent and accurate time scale.
  - **Banks:** GNSS is used for time stamping functions, to log events in a chronological manner and therefore be able to recreate causal links.
  - **Stock Exchanges:** Stock Exchange servers apply time stamps to the trades they execute and to the quotes they establish, GNSS having a key role in this.

What you can read in this chapter

- **Key trends:** GNSS Timing capability is at the core of most vital infrastructures.
- **User perspective:** GNSS helps to offer a wide variety of benefits to end users.
- **Industry:** List of main players by value chain segments.
- **Recent developments:** New legislation expected to boost GNSS device shipments.
- **Future market evolution:** Resilience and improved robustness will be pivotal for future networks.
- **Focus on European GNSS:** EGNSS bringing resilience to Critical Infrastructure.
- **Reference charts:** Annual evolution of GNSS devices' installed base and revenues by application and region.

NEW **Small Cells synchronisation** quantified in this edition of the GNSS Market Report
Analysis extended to **non-EU regions**

GNSS Timing capability is at the core of most vital infrastructures

Key Market Trends

- The Timing capability offered by satellite navigation systems is at the core of most vital infrastructures: telecom networks operation, energy distribution, financial transactions, TV broadcast are some examples of areas where GNSS is used for timing or synchronisation purposes.
- GNSS provides a unique offering to the T&S user communities by delivering a free, stable and very accurate time and frequency source available worldwide.
- Expansion of telecom networks (e.g. Small Cells, 4G) makes GNSS more and more essential, driving future shipments.
- The T&S community is facing many challenges linked to an increased need for resilience, reliability and security, supported by an evolution of the regulation.

GNSS has a long heritage in Timing & Synchronisation

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A wealth of **critical operations** requires access to Timing and Synchronisation. This encompasses the telecom, energy and finance domains that are detailed in this chapter but also other applications such as oil pipeline networks, water distribution networks, railway and maritime transportation networks and Air Traffic Control Systems.

GNSS is widely used by the T&S community as it provides accurate, "low cost" and widely available timing services allowing time, phase and frequency network synchronisation. However, despite a long experience in GNSS, the T&S community is currently facing many challenges linked to an increased need for reliability and security: as detailed in the following page, **cyberattacks on Critical Infrastructure** are an increasing issue and GNSS is obviously subjected to these cybersecurity threats – in particular through jamming and spoofing. To limit the threats operators can rely on local oscillators which play an important role for handover in case of GNSS failure.

Other complementary T&S solutions exist or are being developed: they can be local such as Chip Scale Atomic Clocks (CSAC) or regional such as wide scale network time distribution and eLoran. These technologies have distinct modes of failures that are different from GNSS and provide back up or redundant sources of timing. Besides, protocols such as Precision Time Protocol (PTP), Network Time Protocol (NTP) or Inter-range instrumentation group time codes B (IRIG B) are also widely used in all segments for synchronisation. These protocols may rely on GNSS as Time source. In the case of PTP, clocks synchronisation can achieve sub-microsecond accuracy on a local area network.

Increased GNSS interest for Small Cells synchronisation

Small cells are low-powered radio access nodes that operate in licensed and unlicensed spectrum that have a range of several meters to 1 or 2 kilometres. Small Cell base stations can be deployed at street-level or within buildings and are key elements of the LTE deployment. **Total Cost of Ownership (TCO) for Small Cells is very low** (<1/10) compared to a Macro Cell base station. The **Small Cells market is therefore growing very rapidly** to support the need for greater coverage and increasing mobile broadband traffic.

LTE Small Cells networks synchronisation can rely on GNSS. This is a **potentially promising GNSS market** as the outdoor Small Cells market is expected to grow by 43% CAGR from now until 2020. As of 2015, around 10 mln Small Cells were deployed worldwide.

Telecom

In the telecom segment Satcom, DCN, PMR and PSTN rely on GNSS for phase and time alignments. Moreover, **LTE Small Cells** can also benefit from GNSS for frequency and phase alignment. Several other synchronisation solutions exist (e.g. PTP or SyncE) depending on several factors such as the class of Small Cell (pico, femto, micro), or whether the Small Cell is located indoors or outdoors.

Energy

Smart grid development is under way all over the world. Phasor Measurement Units (PMU) are pivotal to the development of Network Automatic Protection systems. PMU are deployed across remote locations of the power network (nodes) requiring a microsecond level of accuracy. The internal time references are currently based on GNSS receivers.

Finance

Precise synchronisation between financial platforms with wide geographic distribution is required in particular for High Frequency Trading. GNSS is already widely used in the finance domain. This trend should continue with the upcoming **new regulatory frameworks** that will require financial operators to achieve UTC traceability with microsecond Timestamp Resolution (EU - MiFID II Directive, Article 4).

GNSS helps to offer a wide variety of benefits to end users

Overview of the main user requirements in Timing & Synchronisation

The table depicts, in alphabetical order, the key user requirements as assessed through the GSA's continuous monitoring with the user community. Only high priority requirements are shown, i.e. other requirements might also be relevant for considered applications, and the table is subject to updates. Information on the parameters is provided in Annex 2.

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

Resilience of Critical Infrastructure is an increased concern

At DEFCON 23 a low cost GNSS Software Define Radio (SDR) spoofer was presented. With very limited resources, non-GNSS specialists have successfully spoofed navigation signals. Moreover, the recent GPS timing anomaly (January 26th 2016) reinforced the need for integrity and redundancy of GPS Timing (see box on the right).

With the advent of **new threats on GNSS** and the increased importance of protecting critical infrastructures, **resilience** has become mandatory. Possible impacts of GNSS spoofing attacks and GPS disruptions are therefore taken very seriously at all levels, from network operators to GNSS equipment manufacturers and Critical Infrastructure policy makers. Solutions to mitigate these threats exist (e.g. use of local oscillators, complementary technologies or network architecture design). Moreover, thanks to its unique Open Service Navigation Message Authentication (OS NMA) and Commercial Service Authentication services, Galileo will provide authentication capabilities able to detect and parry spoofing attacks.

Following its Directive on the *"Identification and designation of European critical infrastructures and the assessment of the need to improve their protection"*, the European Commission has considered a new approach to the European Programme for Critical Infrastructure Protection. This new approach aims to combine some key terrestrial and space-borne European assets, including Galileo.

The European Union Agency for Network and Information Security (**ENISA**) is also deeply involved in these activities. In particular ENISA Work Programme 2016 includes activities on *"Network and information security threats"*.

Impact of the January 26th 2016 GPS anomaly

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On the 26th of January 2016, timing users of the GPS system **experienced issues** after a number of GPS satellites broadcasted incorrect information regarding the offset between UTC and the GPS time. Some timing receivers experienced a 13 microsecond offset. Impact and duration experienced by T&S network operators were different depending on the network typology, back up solutions in place or even the location of the network.

For instance, the anomaly impacted the BBC digital audio broadcast system as adjacent transmitters interfered with each other. During this anomaly the time provided by EGNOS remained stable and properly synchronised to UTC.

Possible evolutions of user requirements with Telecom 5G

Digital Cellular Networks rely on GNSS for synchronisation of timeslots and for handover between base stations. In particular LTE requires around 1 microsecond of accuracy. The standardisation of the next generation of Telecom Networks (5G) is underway.

By 2020, 5G is expected to be a **new paradigm** in the Telecom industry. 5G will provide higher data rates and lower latency with new use cases such as Broadband access everywhere, augmented reality and "massive" M2M / IoT.

Even if not completely defined 5G might require even further synchronisation accuracy depending on the technology adopted. EGNSS should be able to contribute to meet these more demanding accuracy performances.

Timing & Synchronisation Value Chain

COMPONENTS AND RECEIVER MANUFACTURERS	DEVICE MANUFACTURERS	SYSTEM INTEGRATORS DESIGN CONSULTANCIES TESTING & MAINTENANCE	NETWORK OPERATORS
• FURUNO • NOVATEL • SEPTENTRIO* • STMICROELECTRONICS* • TRIMBLE • U-BLOX*	• ARBITER • BRANDYWINE • CHRONOS TECHNOLOGY* • ELPROMA* • ENDRUN • FEI-ZYFER • MASTERCLOCK • MEINBERG* • MICROSEMI • OMICRON* • OSCILLOQUARTZ* • SEL • SPECTRACOM* • TEKRON	• ABB* • ACCENTURE • ALSTOM* • CHRONOS TECHNOLOGY* • ERICSSON* • HUAWEI • IBM • JUNIPER • MOTOROLA • NOKIA* • PERSEUS • SIEMENS*	• Banks and Stock Exchanges • Telecom Operators • Transmission System Operators

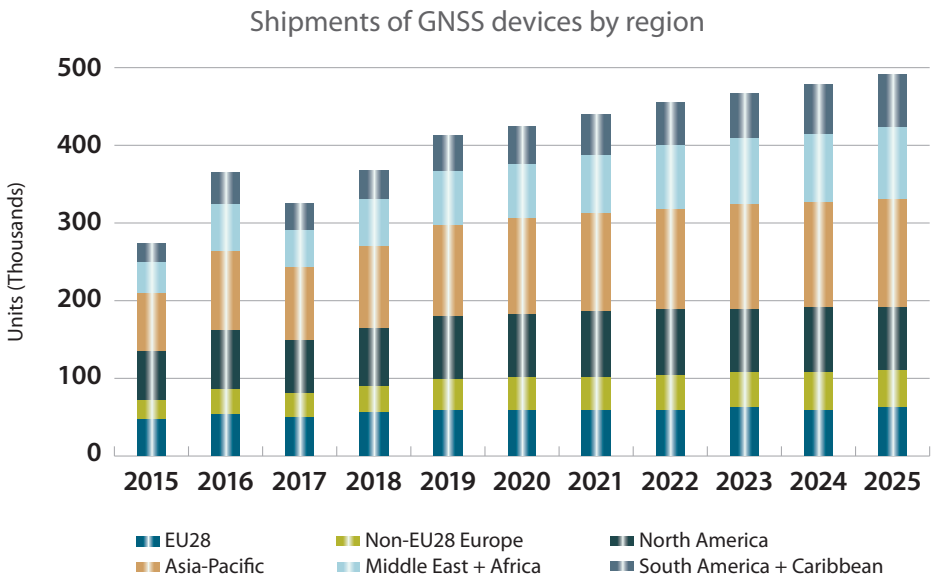
The Value chain considers the key global and European companies involved in the GNSS downstream activities.
* European based companies. The world region is referred to the headquarter of the company, the actual area of activity might be wider.

The European[1] GNSS industry in the global arena

Three of the world's top five GNSS timing device manufacturers are European owned and based (Spectracom, OscilloQuartz, Meinberg). These three companies represent more than 50% of the overall market share.
The top three electricity network infrastructure vendors are European owned and based (ABB, Siemens and Alstom) and two of the top three mobile telecoms infrastructure vendors are European owned and based (Ericsson and Nokia Siemens Networks).
Overall, Europe is a global leader in smart grids, keeping pace with China and the US on smart grid roll out – including some high profile pilots.
Together with North America, Europe is leading the financial industry.

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

New legislation expected to boost GNSS device shipments



Energy and Finance contribute marginally but are critical

In the Energy segment, Asia and North America are ahead of Europe as regards the deployment of PMUs. This is particularly the case in **China** which **has become the largest market in power transmission** and distribution and has therefore been at the cutting edge of smart grids technology. **USA** has also been very **active in synchrophasor deployment** as a response to Energy challenges in the country. It is the result of significant R&D efforts supported by the US Department of Energy (DOE) over a decade.

The Finance industry is clearly driven by North America which represents nearly half of the market. Europe is also very active with new regulation expected to modify the overall landscape (see box on the right).

Telecom: a mature market at the edge of new opportunities

The **GNSS T&S segment** is mainly **driven by the telecommunication sector**, which represents around 90% of the overall GNSS device shipments. This applies to all regions as a result of the Macrocell LTE infrastructure upgrades with nationwide rollouts expected to be finalised in 2015/2016. Consequently, following a peak observed in 2016, shipments are expected to slightly decrease in 2017. However, LTE Small Cells rollouts and 5G investments are expected to revitalise shipments between 2018 and 2022. This will be particularly the case in Asia and North America with Middle East and Africa expected to install new telecom infrastructures.

Currently Small Cells are deployed primarily in regions facing network congestions. Driven by a significant demand in mobile broadcast, **Asia-Pacific** is therefore **the most important market** for **GNSS Small Cells** with approximately 40% of the share, followed by North America and Europe.

Change in finance regulation creates new opportunities

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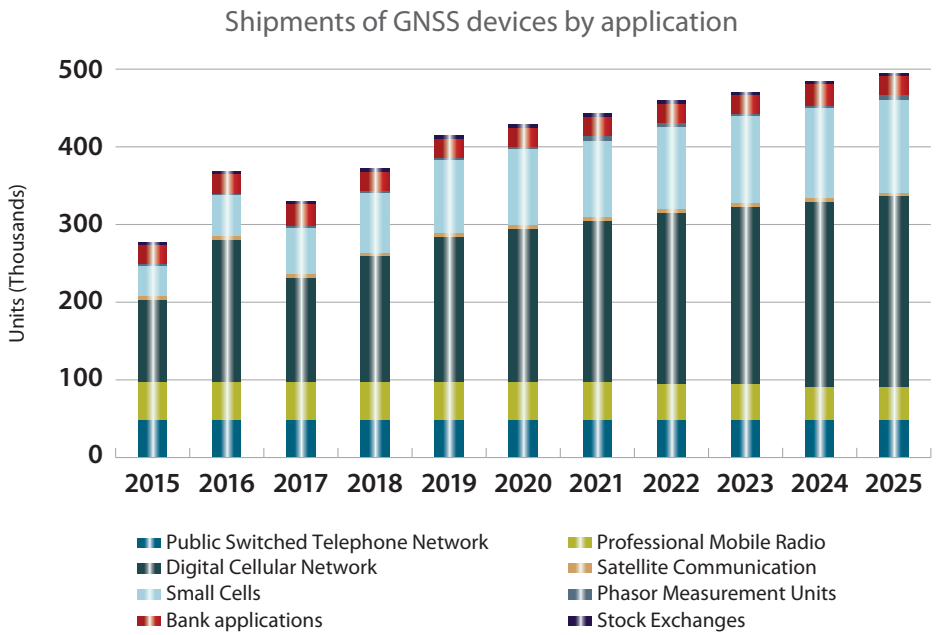
On the 15th of May 2014, the Directive 2014/65/EU on markets in financial instruments (MiFID II Directive) was adopted. **The MiFID II** will take effect from the 3rd of January 2018. To prepare its adoption the European Securities and Markets Authority (ESMA) issued a Regulatory Technical Standards RTS25 on clock synchronisation. Article 4 of RTS25 states that *"Operators of trading venues and their members or participants shall establish a system of traceability to UTC."* The traceability requirement implies to justify how UTC is generated, which means for a financial operator to be able to prove how the time stamp has been created.

A built in-capability such as **Galileo OS NMA** could therefore be seen as an **added value**. Moreover, for the most stringent applications, the regulation requires that clocks should provide 100 microsecond accuracy from UTC and a granularity of the timestamp of 1 microsecond.

MiFID2 does not only impact European financial operators. It also applies to those who do not have a European presence but e.g. who trade on European venues and/or with European counterparties. All these operators will have to comply with MiFID II. Moreover, similar regulations from other countries (USA and Asian countries) are expected soon.

Resilience and improved robustness is pivotal for future networks



Energy and Finance are expected to witness continued growth

The finance segment is mature but a positive impact on sales is expected from forthcoming regulation (in particular MIFIDs II). America, Europe, Middle East & Asia Pacific are ready to get higher protection and could even accept to pay for more robust devices if they increase the security and hence provide a benefit for their operation.

The smart grids deployment is expected to contribute to development of the GNSS market worldwide. The deployment of PMUs in China and USA is already underway and should be growing faster than in EU. Similarly to the finance market, robustness will be key for the future market uptake.

Overall **GNSS T&S shipments** are expected to **grow at a CAGR of 5.3% over 2017 – 2025**, **driven by the Telecom** market which will grow at 5.7% over this period. EU28 and North America should represent around 40% of the shipments in 2017 but Asia Pacific and Middle East should gain market share in the next decade. In terms of revenues, the T&S market could reach €1.2 bln in 2020 and then plateau up to 2025, benefiting from dynamic sales in telecom which will be limiting the effect of price erosion.

5G could open new market opportunities in Telecoms

Vertical market opportunities are **expected for LTE**, in particular in the transport and public safety/security markets which should boost shipments from 2020. The advent of **5G networks should reinforce this trend from 2020**, in particular in the Asia-Pacific region. The peak of 5G network rollouts is expected to occur between 2025 and 2030.

Moreover, **deployment of Small Cells** should have a clear **impact on shipments**. Small Cells shipments are expected to grow significantly between 2015 and 2025. The overall GNSS penetration should be adversely impacted by the Small Cells deployment: indeed GNSS penetration in Small Cells are expected to remain low compared to other synchronisation techniques such as PTP which are better fitted to indoor use cases.

In addition, from 2020, a slight decrease should be expected for PMR as a result of the convergence between LTE and PMR.

Finally no growth of the number of PSTN stations that would integrate GNSS should be expected over 2015 – 2025.

EGNSS bringing resilience to Critical Infrastructure

Galileo provides several key differentiators to the Timing and Synchronisation community, already with the declaration of Initial Services. In particular, Galileo will provide clear benefits to Critical Infrastructure operators thanks to its **increased robustness** against spoofing and an **increased number of satellites** facilitating **integrity monitoring** and ensuring **improved availability**.

Galileo's **authentication** feature, available in the Open Service and in the Commercial Service, will provide resilience against spoofing. Used as a primary source of timing information or as a redundancy solution, Galileo will also improve the **timing service availability**, bringing another independent constellation and frequency agility to T&S operators.

The EGNOS system has been providing its own time service since March 2011. **EGNOS generates** its own time scale known as **ENT** (EGNOS Network Time). The ENT is obtained using information from atomic clocks that are deployed across Ranging Integrity Monitoring Stations (RIMS).

The EGNOS time is continuously cross-checked with UTC through the UTC time realisation of l'Observatoire de Paris, and the offset is transmitted to the user through the EGNOS navigation message (MT12). **EGNOS time information** can be obtained from **GEO satellite** or via the **EDAS service**, which allows users to access EGNOS data online in real time. EGNOS therefore offers a stable time service that is properly synchronised to UTC across all application domains, even during the recent GPS timing anomaly on January 26th 2016.

HORIZON 2020

Demetra Project: Demonstration of EGNSS services based on Time Reference Architecture

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DEMETRA aimed to demonstrate the feasibility of delivering early EGNSS timing services to end users by utilising an operational demonstrator and conducting tests with pilot applications. DEMETRA developed a prototype of a European time disseminator, based on EGNSS, validating the **concept of "time as a service"** and adding new or improved features like time certification, redundancy, resilience, integrity, and improved accuracy.

The nine developed services could become the basis for European timing standards, facilitating the independence from GPS for the timing of critical European infrastructure and fostering the dissemination of common standardised time services across Europe, based on EGNSS. The project has confirmed that the Finance, Energy and Telecom market sectors provide the greatest near-term commercial opportunity for the delivery of the timing services.

More information on: **https://www.demetratime.eu/**

HORIZON 2020

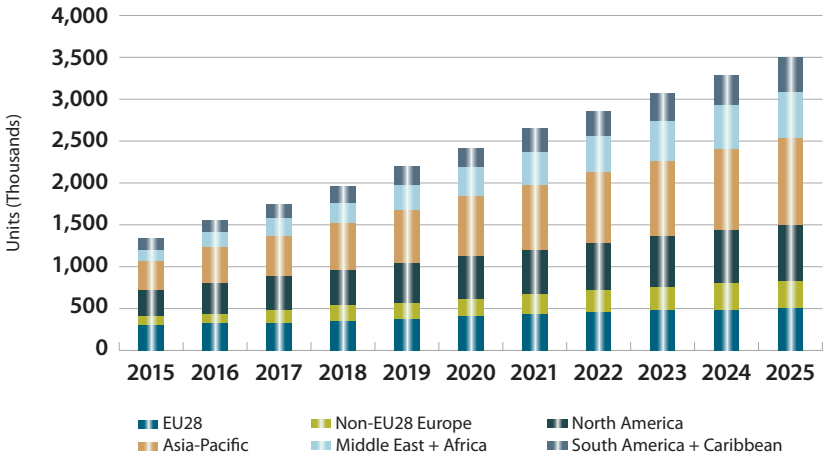
H2020 R&D for Robust EGNSS Timing Services

The project is aimed at defining and validating the concept of a robust stand-alone timing service for Galileo as well as for EGNOS. Under EC coordination the first step is the definition of proper, robust Timing Services for Galileo and EGNOS, including performance figures and mission-level requirements. Various concepts for enhancing the robustness of GNSS timing against threats will be evaluated. The concepts will be validated by processing real data from the EGNOS and Galileo satellites, complemented by simulated data as required. One of the concepts will be receiver level T-RAIM processing (Timing-Received Autonomous Integrity Monitoring), for both single- and multi-constellation receivers.

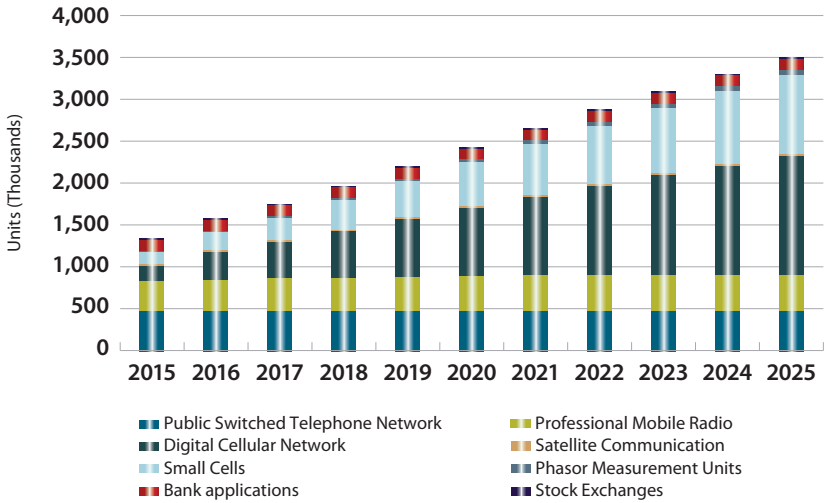
For users requiring accurate synchronisation, the project will design a synchronisation service using the precise time generated by Galileo (GST), but without using the Signal in Space for exchange of synchronisation information.

Standardisation will help to facilitate the manufacturing of timing receivers by providing a commonly accepted reference, and it can foster the introduction of EGNSS. The project will develop a Standardisation and Certification roadmap for the resulting timing and synchronisation concepts.

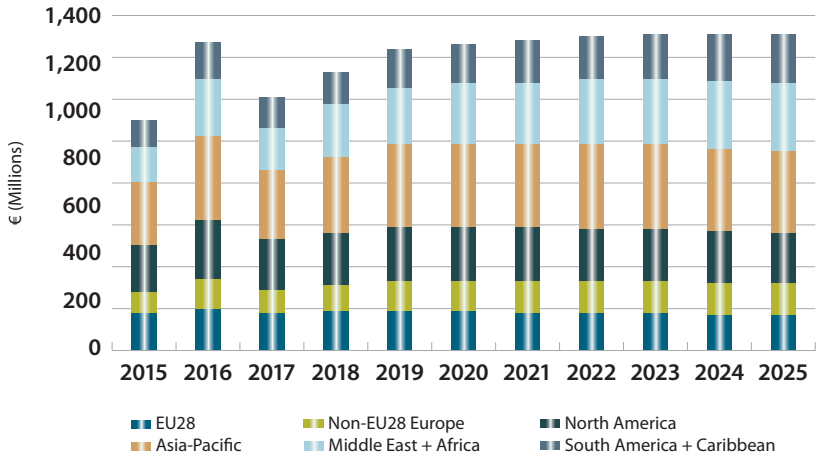
Installed base of GNSS devices by region



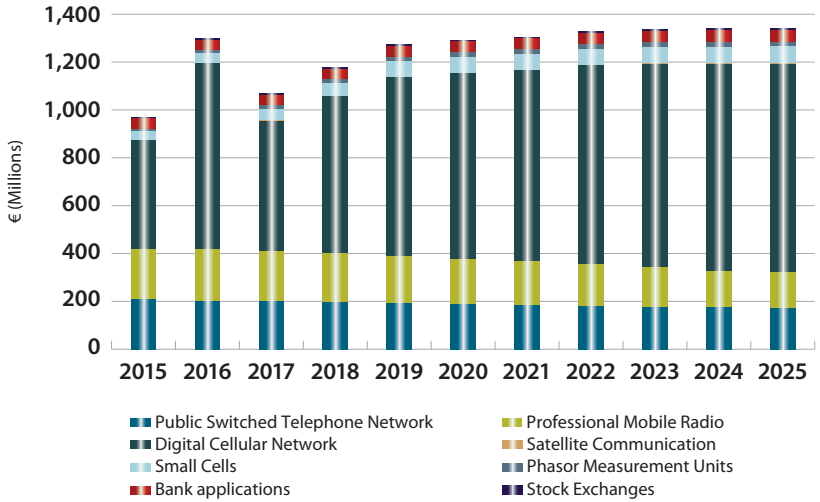
Installed base of GNSS devices by application



Revenue of GNSS device sales by region



Revenue of GNSS device sales by application



Editor's special: Drones

GNSS applications

Depending on their specific payload, drones can enable a vast array of different applications. Whilst the list of drones use cases is almost endless, many of them can be categorised along the following classes of applications:

- **Agriculture & environmental:** Precision agriculture, crop/field/soil monitoring, variable rate applications, livestock tracking, insurance, forest monitoring & management, etc.
- **Surveying:** Infrastructure and environmental monitoring (energy distribution, railways, solar panels,…), cadastral surveying, mine surveying, marine surveying, GIS, photogrammetry, etc.
- **Government:** Police applications, crowd observation, border (including maritime) patrol, security, etc.
- **Public Safety:** SAR operations, firefighting, urgent medicine/medical equipment delivery, other natural disaster monitoring (e.g. floods, earthquakes), etc.
- **Scientific:** Meteorological monitoring, atmospheric measurements, swarm techniques, general R&D, etc.
- **Observations:** Film, photography, TV/other media-broadcasting (e.g. sport events), etc.
- **Communications:** Local coverage broadcasting (e.g. Google/Facebook drone plans for internet access in remote areas).
- **Leisure:** Toys, aero-modalism, self-tracking/filming drones (first person view), drone racing, etc.
- **Goods delivery:** Transport of various types of goods or cargo.
- **Other applications:** Calibration of aviation nav-aids, asset management, advertisement, marketing, entertainment, etc.
- **Military**

Different types of drones are suitable for different applications: fixed wings are more effective in terms of endurance, speed and consequently distance covered, while multirotor are more flexible and thus suitable for complex tasks in challenging environments. With new technologies and harmonised regulation driving the development and uptake of new applications, the above list of drones applications is steadily growing.

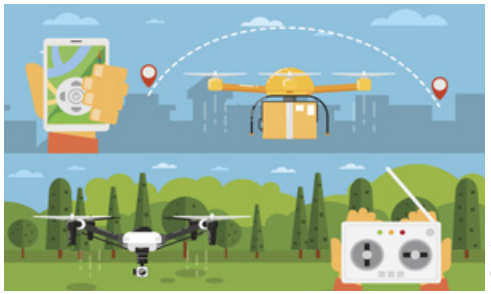
Whilst GNSS is a key technology enabling drones, not all have GNSS receivers on-board.

What you can read in this chapter

- **Key trends:** The key role of GNSS in a rapidly evolving environment.
- **Global drone Market:** The emerging market of drones reaches new altitudes.
- **European GNSS:** EGNSS improve robustness and safety of navigation of drones.

The key role of GNSS in a rapidly evolving environment

GNSS in drones – a key enabler ensuring safe navigation and reliability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GNSS is essential for commercial drones. It informs drone operators about the drone's position at all time and allows for safe navigation. GNSS-based positioning information is also used to geo-reference the images acquired through GNSS equipped sensors (such as for reflectometry) and cameras.

Regarding the professional use of drones, the need of a highly accurate and reliable performance strongly depends on the specific application. In general, it is very likely that an increase in the use of multi-constellation receivers will take place, enabled by advancements in improved battery endurance.

The increasing pressure for better safety, reliability and jamming immunity will foster the uptake of dual frequency multi-constellation solutions, as in the case of conventional (manned) aviation.

Challenges to increased uptake of drones

Although drones have already found widespread deployment across almost all market segments, continued growth of the drone segment will depend on developments in the following domains:


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- Harmonised **regulation** across EU and beyond
- **Integration** of drones with manned aircraft in non-segregated airspace
- Advancements in Detect-and-Avoid (DAA) **technologies**
- Creation of robust Command & Control (C2) **communication** link
- Implementation of Concept of Operation (CONOPS) in a manner proportionate to the **risk** of the specific drone operation
- Improving **airworthiness**
- **Pilot** and **training** aspects (e.g. testing, certification, recognition between countries)
- **Contingency** aspects

A clear regulatory framework is expected to boost the industry


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The uptake of drone technologies in Europe is currently limited due to the fragmented regulations on the use of drones by different Member States (MS) with regards to policies on authorisation, certification and spatial limitations.

Europe comprises a number of MS, including France, Italy and Spain, with very drone-friendly regulation alongside countries such as Germany, the Netherlands, Ireland and Lithuania that feature a more constrained approach to regulation. In Czech Republic, Finland, Sweden and the UK, drones can mostly be operated in segregated airspace. Some non-EU countries, e.g. Canada, have embraced comparatively liberal, risk-based approaches to drone regulation, allowing them to fly with no weight, height or lateral constraints assuming they have permission.

European drone regulation involves a wide range of stakeholders that include ICAO, EASA, JARUS, EC, ECTL, EUROCAE, NATO, EDA, as well as major industry players and representatives of airspace users. EASA is currently developing regulations which are intended to address the full scope of drone operations within the EU over all weight categories. The priority is ensuring that the introduction of drone operations does not impact the safety of other airspace users and enables a harmonised deployment across the EU. Addressing this goal will enable an incremental increase in the number of commercial operations authorised in non-segregated environments whilst minimising the impact on drone use in other areas.

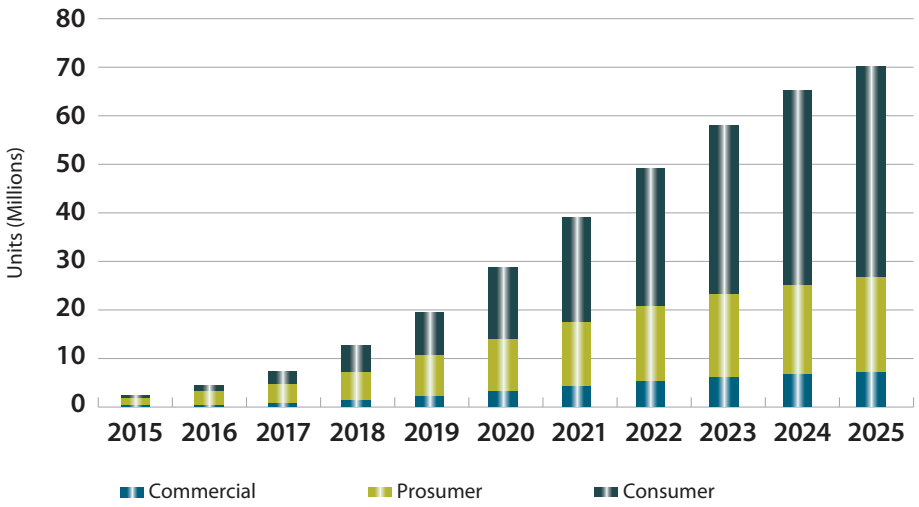
Key challenges for future regulation involve establishing requirements in terms of distance from populated areas and critical infrastructure, as well as finding a common approach to pilot licensing and regulating BVLOS operations. Particularly the regulations on BVLOS will have to be crafted carefully to allow drone uptake whilst ensuring that relaxed regulation does not increase potential risks from drones.

According to the Commission's Roadmap for the integration of civil drones into the European Aviation System, the time period 2019-2023 will see the full integration of VLOS and EVLOS in day-to-day civil aviation operations. EASA rules are expected to progressively apply to civil drones across different size/weight classes.

By 2024-2028, the evolution of technical and operational rules is expected to lead to an alleviation of residual restrictions, with drones free to operate in most non-segregated airspace. Not only mixing with manned aviation, drones will then also follow the same ATM procedures and ensuring the same level of safety and security.

The emerging market of drones reaches new altitudes

Installed base of GNSS devices by application[1]



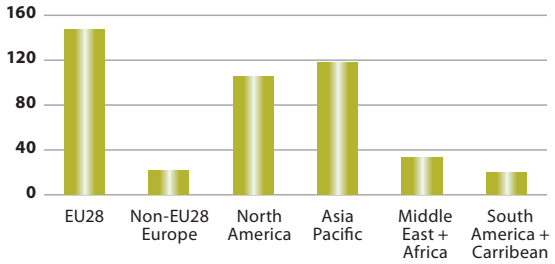
Drones will be a global phenomenon

In many markets North America represents the largest region. However, in the world of drones, the EU and Asia pacific regions will provide just as large a market. Agriculture alone could be a $350 million market in 2025.

The expected growth of the market is huge, meaning that today's market is only nascent, and could change significantly depending on new applications which are as yet unimagined.

The global distribution of the market is reflected in the distribution of manufacturers.

Number of manufacturers by region

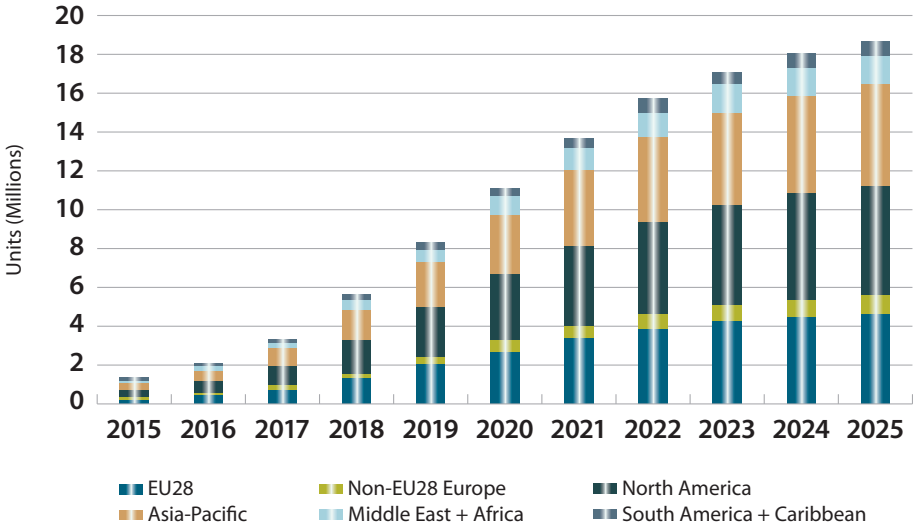


Drones will grow to outstrip any other user base in the aviation market

The number of drones is predicted to exceed all other aviation user groups combined, by an order of magnitude, within this year. Even so, drone flight procedures must be regulated within the aviation market, by agencies unused to the volume of users and devices.

The typical drones will be a consumer level product, with limited range and restricted flight capabilities, making the regulatory task relatively simple. However, the number of prosumer and commercial application drones will grow to exceed other aviation groups very rapidly. The most ambitious applications involve BVLOS operations (see slide 46), and this presents new challenges for regulators. For such applications GNSS not only presents the most obvious choice for flight control functionality, but in many cases becomes the only choice. The potential public benefit of such applications[1], combined with the already large existing installed base, provides strong pressure for decisive regulatory support.

Shipments of GNSS devices by region



[1] The following definitions are adopted:
- **Professional** – drones used solely for commercial applications and which invariably are better equipped. These are always assumed to be GNSS equipped.
- **Prosumer** – drones which may be used for commercial applications but are also affordable for some recreational use.
- **Consumer** – drones used primarily for recreational use. Due to their cost and nature, the types of sensors and cameras which may be carried on this category is limited. The integration of GNSS on these devices is limited due to the intended market and planned use of the platform. These platforms do not have the expandability or levels of automation demonstrated in the commercial and prosumer categories.

EGNSS improve robustness and safety of navigation of drones

More and more drones are integrating EGNSS

In order to navigate efficiently and safely, drones generally require GNSS support. In this regard, Galileo and EGNOS can provide a significant added value with respect to other constellations. To date, very few platforms use multi-constellation GNSS for navigation purposes as current drones primarily use single-frequency GPS L1 receivers to navigate.

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EGNOS corrections provide end users in Europe with a free-of-charge means to improve the reliability and integrity of augmented signals. As these are enabling factors for urban area operations, they are expected to support EGNOS adoption. EGNOS not only allows for **improved robustness**, greater **safety of navigation** and day-to-day operations, but also supports specialised applications such as **geo-fencing**. Generating substantial performance enhancements, EGNSS can effectively contribute to the integration of drones in non-segregated airspace.

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Galileo features several performance parameters that are highly relevant for drone applications. Drawing on Galileo's free-of-charge **authentication** information, drone users will soon be able to gain additional trust in the veracity of their position whilst being protected from **malicious interferences** such as spoofing.

The integration of Galileo-embedded multi-constellation GNSS in new drones is set to strongly increase the **accuracy** and **continuity** of the received signals, thus directly contributing to an improved safety of navigation. Furthermore, the enhanced authentication provided by the Galileo Commercial Service might open up new possibilities as regards the regulation of drones, particularly concerning liability aspects. Galileo could support the deployment of ADS-B for drones surveillance.

There are already some drone receivers available at the beginning of 2017, with more to hit the market yet this year. Users can refer to www.usegalileo.eu for the latest information on EGNSS-ready drone receivers.

AVIATION GRANT PROGRAMME EGNOS

REAL – Developing EGNOS-assisted landings for RPAS

The REAL project aims at developing an **EGNOS-based navigation and surveillance sensor** that will be ready to be coupled with a generic drone autopilot and ground station system. A key objective of the project is to contribute to the **approval** of innovative **drone operations** by leveraging on the high levels of accuracy and integrity provided by EGNOS.

The project will investigate two specific scenarios validating EGNOS for drones. In one scenario, EGNOS supports the rapid transportation of urgent medicines from a central healthcare facility to a given inaccessible area, ensuring that drones fly along a low-level route below 150 m. In the second scenario, EGNOS contributes to fire extinguishing operations carried out by drones. In this scenario, a ground operator controls the drone operations, ensuring that the platform is hovering above the other fire extinction traffic.

HORIZON 2020 SKYOPENER

SkyOpener – Operation Management Systems (OMS) for RPAS

SkyOpener aims to provide a system called Remotely Piloted Aircraft System Operation Management System (RPAS-OMS) that enables national ANSPs to manage the full process of drone operations. It aims to enable the use of drones for civilian applications by contributing to the roadmap for the integration of civil drones into non-segregated airspace. The envisaged scope is extensive and foresees that ANSP will have full operational management, starting with a flight request generated by the drone operator to ensuring continuous surveillance during all phases of the flight.

For SkyOpener, the use EGNOS and GALILEO is a major opportunity to provide enhanced navigation services in terms of integrity and positioning accuracy. Leveraging on their additional performance, SkyOpener will develop a system and operational processes that allows ANSPs to manage Very Low Level (VLL) drone operations. The project will moreover serve to demonstrate two additional applications, the e-TOD (electronic-Terrain Obstacle Database) and the surveillance of critical infrastructure, both of which will directly benefit from EGNSS.

Annex 1: Methodology

Methodology

The present GNSS Market Report applies the 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 receivers.

Where possible historical values are anchored to actual data in order to ensure a high level of accuracy. Assumptions are confronted with expert opinions in each market segment and application and model results are cross-checked against the most recent market research reports from independent sources before being validated through an iterative consultation process with involving pertinent sector experts and stakeholders.

Data 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; 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; Grand View Research; GSM Association; Harbor Research; Hitachi; IBM; IDC; Infomines; Infonetics; Informa Economics and Measure; 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); 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; 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; Sensors Magazine; Siemens; Statista; Statistic Brain; Technavio; TTG Transportation Technology; Teal Group; The Verge; TrendForce; TNS/Google; UAVGlobal; 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 Shipping Council; World Stock Exchange; Xinhua.

Disclaimer

The GNSS Market Report issue 5 was carried out by the European GNSS Agency in cooperation with the European Commission and with the support of VVA, Egis, Helios, FDC and London Economics.

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.europa.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: percentage of time over a specified time interval that a sufficient number of satellites are transmitting a usable ranging signal within view of 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 position (absolute positioning). This is expressed as the value within which a specified proportion of samples would fall if measured. Typical values for accuracy range from tens of meters to centimetres for 95% of samples. Accuracy is typically stated as 2D (horizontal), 3D (Horizontal and height) or time.

Continuity: ability to provide the required performance during an operation without interruption once the operation has started. Continuity is usually expressed as the risk of a discontinuity and depends entirely on the timeframe of the application (e.g. an application that requires 10 minutes of uninterrupted service has a different continuity figure than one requiring two hours of uninterrupted service, even if using the same receiver and services). A typical value is $1x10^{-4}$ over the course of the procedure where the system is in use.

Integrity: the measure of trust that can be placed in the correctness of the position or time estimate provided by the receiver. This is usually expressed as the probability of a user being exposed to an error larger than alert limits without warning.

The way integrity is ensured and assessed, and the means of delivering integrity related information to the user are highly application dependent.

Throughout this report, "integrity" 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 by other applications and sectors.

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. Activation means subtly different things depending on the status of the data the receiver has access to.

Robustness: the ability of systems or system elements to withstand a level of interferences and/or jamming without significant degradation or loss of performance.

For some users robustness may have a different meaning, such as the ability of the solution to respond following a severe shadowing event. For the purpose of this document, robustness is defined as the ability of the solution to mitigate interference.

Authentication: the ability of the system to assure the users that they are utilising signals and/or data from a trustworthy source (e.g. GNSS constellation), and thus protecting sensitive applications from spoofing threats.

Other requirements and performance parameters

Power consumption: 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. This requirement is important for devices with a limited battery life-span such as smartphones and tablets, drones and asset management devices.

Resiliency: 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: this requirement 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 comprises long-range communication technologies such as 3G and LTE as well as short-range technologies such as Bluetooth and NFC.

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: 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.

2D	Two Dimensional
3D	Three Dimensional
ABAS	Airborne Based Augmentation System
ACTS	Authenticated and Certified time Solution
ADS-B	Automatic Depended Surveillance – Broadcast
ADAS	Advanced Driver Assistance System
ADT	Autonomous Distress Tracking
AGNSS	Assisted GNSS
AIS	Automatic Identification System
AIS-MOB	AIS Man Overboard
AIS-SART	AIS Search and Rescue Transmitter
AltBOC	Alternative BOC Modulation
ANSP	Air Navigation Service Provider
AOPA	Aircraft Owners and Pilots Association
APAC	Asia-Pacific
ARAIM	Advanced Receiver Autonomous Integrity Monitoring
ASBU	Aviation System Block Upgrade
ATM	Air Traffic Management
BA	Business Aviation
BRIC	Refers to: Brazil, Russia, India, China
BVLOS	Beyond Visible Line of Site
CA	Commercial Aviation
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
CBTC	Communications-Based Train Control
CCS	Command and Control System
CFP	Common Fisheries Policy
CI	Critical Infrastructure
COMPASS/ BeiDou	Chinese global positioning system under development
CORS	Continuously Operating Reference Stations
COSPAS-SARSAT	Russian Cosmicheskaya Sistyema Poiska Avariynich Sudow - Search and Rescue Satellite-Aided Tracking (International Satellite System
CS	(Galileo) Commercial Service
CS-HA	(Galileo) Commercial Service High Accuracy
DAS	Driver Advisory Systems
DGNSS	Differential Global Navigation Satellite System
DGPS	Differential Global Positioning System
DT	Digital Tachograph
EASA	European Aviation Safety Agency
EC	European Commission
ECDIS	Electronic Chart Display and Information System
EDAS	EGNOS Data Access Service
ELT	Emergency Locator Transmitter
EGNSS	European GNSS
ENT	EGNOS Network Time
ERA GLONASS	Accident Emergency Response System of GLONASS
ERSAT- EAV	ERtms on SATellite Enabling Application and Verification
ERTMS	European Rail Traffic Management System
ESA	European Space Agency
ETCS	European Train Control System
EU	European Union
EUROCAE	European Organization for Civil Aviation Equipment
EU28	European Union (28 Member States)
EVLOS	Enhanced Visual Line Of Sight
FAA	Federal Aviation Administration
FAO	Food and Agriculture Organisation
FMIS	Farm Management Information Systems
FOC	Full Operational Capability
FOC	Freight Operating Company
FP7	7th Framework Programme for Research and Technological Development
FTTH	Fibre To The Home
FRA	Free Route Airspace
GA	General Aviation
GADSS	Global Aeronautical Distress Safety Systems
GAGAN	GPS Aided Geo Augmented Navigation
GAMA	General Aviation Manufacturers Association
GBAS	Ground Based Augmentation System
GDP	Gross Domestic Product
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
H2020	Horizon 2020
HEMS	Helicopter Emergency Service
HP	High Precision
HUD	Head-up display
IALA	International Association of Marine Aids to Navigation and Lighthouse Authorities
IATA	International Air Transport Association
IC	Integrated Chipset
ICAO	International Civil Aviation Organisation
IFP	Instrument Flight Procedures
IFR	Instrument Flight Rules
ILS	Instrument Landing System
IMES	Indoor Messaging System
IMO	International Maritime Organisation

INS	Inertial Navigation System
IOC	Initial Operational Capability
IoT	Internet of Things
IOV	In-Orbit Validation
IP	Internet Protocol
IRAP	International Road Assessment Programme
ITS	Intelligent Transport System
ITU	International Telecommunication Union
IVS	In-Vehicle System
IWW	Inland Waterways
LBS	Location Based Service
LoC	Lines of Code
LPV	Localizer Performance with Vertical guidance
LRIT	Long Range Identification and Tracking System
LTE	Long-Term Evolution, commonly known as 4G LTE
MC/MF	Multi-Constellation/Multi-Frequency
MEMS	Micro-Electro-Mechanical Systems
MEOSAR	Medium Earth Orbit Search and Rescue satellites
MOPS	Minimum Operational Performance Standards
MSAS	Multi-functional Satellite Augmentation System
M2M	Machine-To-Machine
NA	North America
NFC	Near-Field Communication
(OS) NMA	(Open Service) Navigation Message Authentication
NPA	Notice of Proposed Amendment
NTP	Network Time Protocol
O-TDOA	Observed Time Difference Of Arrival
OBU	On-Board Unit
OEM	Original Equipment Manufacturer (as used in Automotive domain)
OMA	Open Mobile Alliance
OS	(Galileo) Open Service
PBN	Performance Based Navigation
PBR	Passive Bistatic Radars
PCP	Pilot Common Project
PDA	Personal Digital Assistant
PERNASVIP	PERsonal NAvigation System for Visually disabled People
PinS	Point in Space
PLB	Personal Location Beacon
PMR	Professional Mobile Radio
PMU	Phasor Measurement Unit
PND	Portable Navigation Device
PNT	Position, Navigation, Timing
PPP	Precise Point Positioning
PPUI	Pay Per Use Insurance
PRS	Public Regulated Service
PSTN	Public Switched Telephone Network
PTC	Positive Train Control
PTP	Precise Time Protocol
PVT	Position, Velocity, Timing
RFID	Radio-Frequency IDentification
RIMS	Ranging and Integrity Monitoring Stations
RLS	Return Link Service
RNAV	aRea NAVigation
RNP	Required Navigation Performance
ROSCO	Rolling Stock Operating Company
RPAS	Remotely Piloted Aircraft Systems (drones)
RTK	Real Time Kinematic
RUC	Road User Charging
R&D	Research and Development
SAR	Search and Rescue
SARP	Standards and Recommended Practices
SATCOM	Satellite Communications
SBAS	Space Based Augmentation System
SDM	SESAR Deployment Manager
SIMRAN	Satellite Imaging for Rail Navigation
SIS	Signal In Space
SLAM	Simultaneous Location And Mapping
SME	Small and Medium-sized Enterprises
SMS	Short Message Service
SoL	Safety of Life
SOLAS	International Convention for the Safety of Life at Sea
SUPL	Secure User Plane Location
T&S	Timing and Synchronisation
TACOT	Trusted multi-application receiver for trucks
TCAS	Train Collision Avoidance System
TDMA	Time Division Multiple Access
TOC	Train Operating Company
TTC	Time To Convergence
TTFF	Time To First Fix
U-TDOA	Uplink-Time Difference of Arrival
UNCTAD	United Nations Conference on Trade and Development
UTC	Coordinated Universal Time
VFR	Visual Flight Rules
VLOS	Visual Line Of Sight
VMS	Vessel Monitoring System
VGI	Volunteered Geographical Information
VHF	Very High Frequency
VRT	Variable Rate Technology
VTS	Vessel Traffic Services
WAAS	Wide Area Augmentation System
WAMS	Wide Area Measurement Systems
WIFI	Wireless Fidelity. Wireless communication protocols
WWRNS	World-Wide Radio Navigation System

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, added-value 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.

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:** leveraging results for EGNSS adoption and EU industry competitiveness, including 150 demonstrations of EGNSS applications; 45 products, 80 prototypes, 13 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.

European
Global Navigation
Satellite Systems
Agency

market@gsa.europa.eu
www.gsa.europa.eu

@EU_GNSS
@EGNOSPortal
Facebook.com/EuropeanGnssAgency

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