WITH AN ANALYSIS OF GNSS USER TECHNOLOGY

ISSN 2443-5236

GNSS MARKET REPORT

ISSUE 4

March 2015 Issue 4

European GNSS Agency

More information on the European Union is available on the Internet (http://europa.eu).
Luxembourg: Publications Office of the European Union, 2015

ISBN 978-92-9206-013-8
doi:10.2878/251572

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European
Global Navigation
Satellite Systems
Agency

Dear Reader,

With the volume of global data doubling every two years, we are living in exciting times. As part of this reality, location information matters now more than ever before.

I am pleased to introduce the **4th edition of the GSA's GNSS Market Report**, presenting an overview and quantification of the GNSS market of today and the future. We specifically look at the global GNSS market in terms of shipments, revenues and installed base of receivers, with an outlook up to 2023.

In addition to the traditional market analysis of previous reports, this edition includes a number of innovations:

- A user perspective on GNSS applications. GNSS technology exists in a dynamic, multi-sensor context where user needs are a final, ubiquitous position, regardless of which technology provides it. Still, we confirm that GNSS is and will remain the main source for outdoor positioning information.
- New insights on GNSS user technology, including the results from our first receiver capabilities analysis of the top global manufacturers.
- Insights on the GNSS industry and estimated regional shares of the supply side of the GNSS downstream market.
- A more detailed regional breakdown of the GNSS market, concluding that the future development of GNSS applications depends, to a large degree, on emerging economies. Alongside EU28 and North America, we now take a more in-depth look at Non-EU28 Europe, Asia-Pacific, Middle East and Africa, as well as South America and Caribbean regions.
- The addition of an eighth market segment, Timing & Synchronisation, complementing the previously analysed segments of LBS, Road, Aviation, Rail, Maritime, Surveying and Agriculture.
- Additional applications: in Maritime - recreational navigation, fishing vessels and Personal Locator Beacons (PLBs), in Aviation - Emergency Locator Transmitters (ELTs) and Search and Rescue PLBs, in Road - digital tachograph and in LBS - PLBs.

I hope this GSA publication will support your planning and decision-making, and create tangible benefits for your stakeholders. We look forward to receiving your feedback and continuing to work with you in fostering the GNSS market.

Carlo des Dorides
Executive Director

The European GNSS Agency (GSA)
Prague, March 2015

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Introduction to the GNSS market

What is GNSS?

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

- **Global constellations:**
  - **GPS:** The first GNSS, fully operational since 1995, is managed by the US Department of Defence.
  - **GLONASS:** The Russian GNSS, completed in 1995 and fully operational since 2011, is managed by the Russian Aerospace Defence Forces.
  - **Galileo:** Europe's GNSS, currently under development as the only civil GNSS, is owned and managed by the European Union.
  - **BeiDou (COMPASS):** The Chinese GNSS, set to supersede the COMPASS regional system operating since 2000, is managed by the governmental China Satellite Navigation Office.
- **Satellite-Based Augmentation Systems** (SBAS), such as EGNOS (Europe), WAAS (North America), GAGAN (India) and MSAS (Japan).

What aspects of GNSS are important?

GNSS is used for many types of applications, covering the mass market, professional and safety-critical applications – each requiring different service levels (Open Service, Safety of Life, Search and Rescue). Depending on user needs, important features of GNSS include:

- **Availability:** Percentage of time the minimum number of satellites are in view, so the position, navigation or timing solution can be computed by the user.
- **Accuracy:** 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:** Additional user information on the reliability of the signal within the operational requirements.
- **Robustness to spoofing and jamming:** Authentication information provided to users ensuring the signal comes from a satellite in space (enabling sensitive applications).
- **Indoor penetration:** Ability of signal to penetrate inside buildings, e.g. through windows.

GNSS market

The GNSS market comprises products (receivers and devices) and services using GNSS-based positioning as a significant enabler.

Core and enabled markets

This Market Report primarily considers the core GNSS market. For multi-function devices (e.g. smartphones), the core market includes the value of GNSS functionality only, rather than the full device price and service revenues directly attributable to GNSS functionality (e.g. data downloaded by smartphones over cellular networks to use Location-Based Services). For multi-function devices, a correction factor is taken into account. For example:

- **GNSS-enabled smartphone:** Only the value of GNSS chipsets is counted, estimated at 1% of the retail price.
- **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.
- **Precision Agriculture system:** The retail value of the GNSS receivers, maps, and navigation software is counted.
- **Search and Rescue devices:** For Personal Locator Beacons (PLBs) and Emergency Locator Transmitters (ELTs), only the price differential between GNSS and non-GNSS devices is included.

The Executive Summary also presents results for the enabled market, which represents the services and devices enabled by GNSS, and includes the core market. For the enabled market, the entire retail value of the smartphone is included.

Terminology used in the 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.

Geographic coverage

- European Union (EU28);
- North America (incl. USA, Canada, Mexico);
- Asia-Pacific (incl. China, Japan, Australia, India, Korea Republic);
- NonEU28 Europe (incl. Norway, Switzerland, Russia, Ukraine);
- Middle-East and Africa (incl. Turkey, Israel, South Africa, UAE, Saudi Arabia);
- South America and Caribbean (incl. Brazil, Argentina, Colombia, Guatemala).

Almost 4 billion GNSS devices used worldwide, with all regions experiencing growth

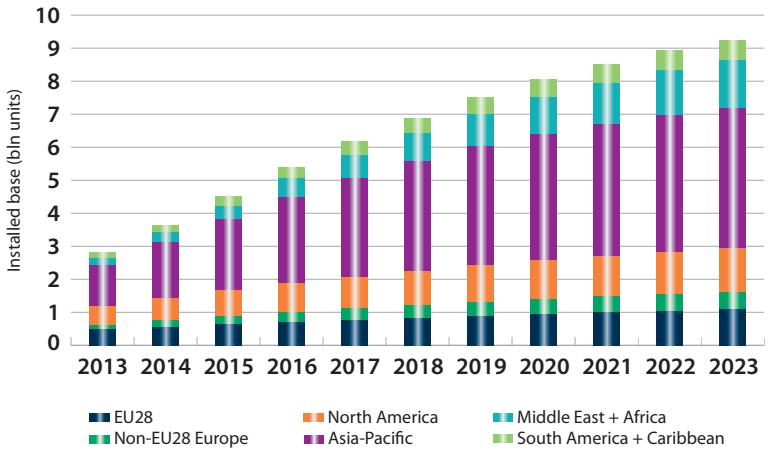
GNSS is used around the globe, with **3.6 bln GNSS devices in use in 2014**. By 2019, this is forecasted to increase to over 7 bln – for an average of one device per person on the planet.

Smartphones continue to dominate (3.08 bln in 2014), being the most popular platform to access Location-Based Services, followed by devices used for road applications (0.26 bln). Other devices may be less numerous, but billions of passengers, professionals, consumers and citizens worldwide benefit from their application in efficient and safe transport networks, in productive and sustainable agriculture, surveying, and critical infrastructures.

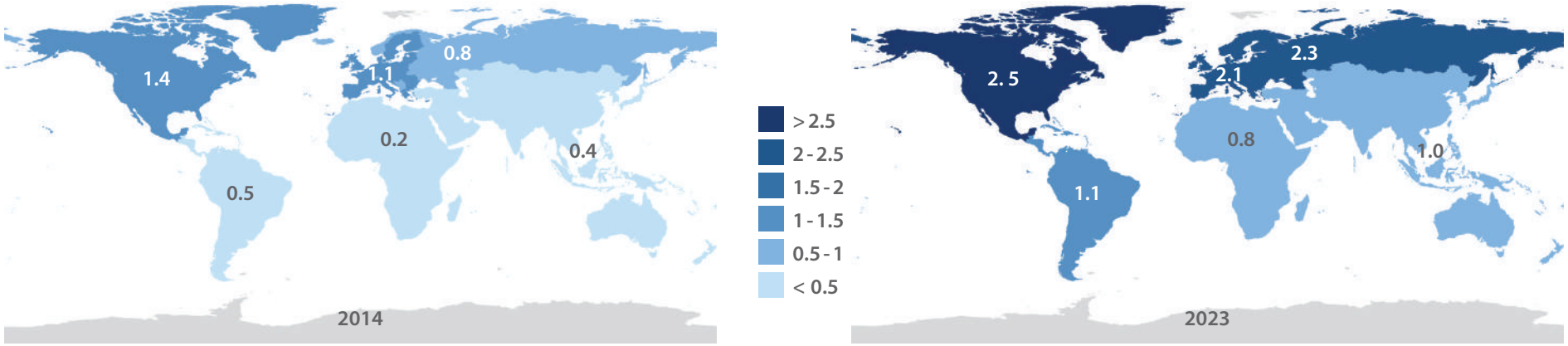
At the regional level, the installed base in the mature regions of EU28 and North America will grow steadily (8% p.a.) through 2023. **The primary region of global market growth will be Asia-Pacific**, which is forecasted to grow 11% p.a. from 1.7 bln in 2014 to 4.2 bln devices in 2023 – more than the EU and North America combined. The Middle East and Africa will grow at the fastest rate (19% p.a.), but starting from a low base.

As a result, the 'digital divide' is forecasted to narrow. Although there is significant regional variation in GNSS penetration in terms of devices per capita, the up-take of smartphones in emerging regions will change the situation in almost every corner of the world.

Installed base of GNSS devices by region

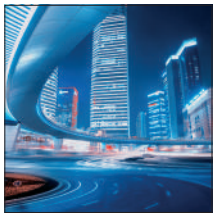


GNSS devices per capita: 2014 and 2023



GNSS is used in a dynamic environment of relevant macro trends

Smart cities



In 2014, 54% of the world's population lived in urban areas, and it is predicted that by 2050 this will increase to 66%. **In the largest 500 European cities, more than 200 mln people are constantly moving** from one place to another and want to find the quickest and easiest way to do so.

The smart cities concept tackles this challenge. An intelligent urban management approach covering various utilities (e.g. transport, energy, water, waste...) can contribute to making cities more sustainable and allow for more effective and efficient management of them.

Thanks to its easy implementation for various smart mobility and LBS applications, GNSS is supporting the smart cities concept. Especially when **implemented in a hybrid positioning solution, GNSS delivers location information regardless of the environment**. Among many others, GNSS can be part of autonomous driving solutions, travel optimisation and such automatic transactions as entering a tolled road section or a car park.

Big data

The volume of global data doubles every two years, and data has become a key asset for our economy and societies. 'Big data' refers to large amounts of data produced very quickly by an abundance of diverse sources: geographical, weather, research, transport, energy consumption and health. Data can either be created by people or generated by machines, such as GNSS receivers or Earth Observation satellite imagery. For example:

- In the **Road segment**, GNSS-based positioning of vehicles contributes to the production of 'floating' car data, a source for traffic modelling and management.
- Similar applications exist in the **LBS segment**, with smartphones generating data with positioning information by actions performed by their owners.

Notably, the emergence of big data implies a special attention to privacy concerns, mainly related to the use of data by entities such as governments, authorities and commercial companies for purposes beyond that of the original data generation and collection.

Multimodal logistics

GNSS-based solutions are particularly well-suited for on-the-route positioning, enabling operators to **monitor goods and assets during their transfer** between different transport nodes and hubs. GNSS-based data such as positioning and timing can be combined with information on the status of the container and the cargo, as well as with RFID positioning for asset and goods identification at hubs. This information is transmitted to logistic operators and their clients to improve efficiency and effectiveness of transport activities, as well as to manage emergencies by knowing where to act if anything goes wrong.

For many reasons, **containers are the optimal target for GNSS** in a multimodal perspective. For example, they are widely adopted and their capacity is high enough to invest in a GNSS-based device. Containers are also already equipped with an ISO 6346 BIC code, which identifies the owner and the principal operator.

Internet-of-Things and Machine-to-Machine communication

The so-called 'Internet of Things' (IoT) refers to a major development in the role of the Internet: the interconnectivity of uniquely identifiable devices. Thanks to IPV6, **all physical objects can now have a unique address** and, thus, communicate.

Beyond improving productivity and efficiency of organisations, IoT solutions are changing our daily lives. According to Harbor Research, the global IoT market could hit €1 trillion in 2020 with applications in almost every sector of the economy, from automotive to consumer electronics, healthcare, manufacturing and logistics.

As many IoT applications require positioning information of each 'thing' (e.g. tracking of luggage, bike, bus, pet, coat), **IoT could provide a significant knock-on demand boost for GNSS capabilities in several market segments**.

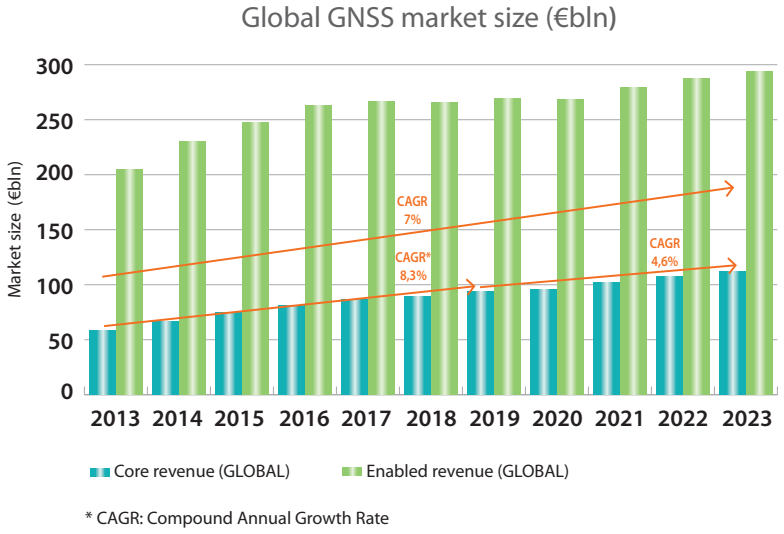
Photo credit: © Thinkstock

LBS and Road dominate cumulative GNSS revenues, driven by booming sales of smartphones, in-vehicle devices, location-aware applications and data services

Global GNSS downstream market

The global core **GNSS downstream market** is forecasted to increase by 8.3% annually between 2013 and 2019 before slowing down to 4.6% towards 2023. This means the GNSS downstream market is expected to grow, on average, faster (7%) than the forecasted global GDP during this period (6.6%).

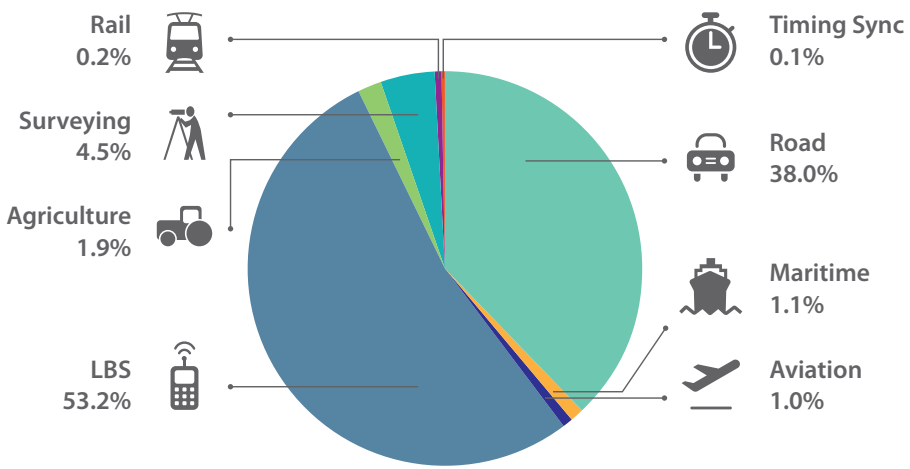
In 2020, the drop in smartphone prices will offset the growing volumes for the first time, resulting in a decline in total **enabled** revenues. However, driven by additional applications – especially in the Road segment – total enabled revenues will grow again starting in 2021.



* CAGR: Compound Annual Growth Rate

Core revenues refer to the value of only GNSS chipsets in a device, whereas enabled revenues include the full retail price of smartphones.

Cumulative core revenue 2013-2023



GNSS market by application

Applications in the **LBS and Road segments dominate the cumulative revenue**, with a combined total of more than 91%. Smartphone and tablet applications continue to be alternatives to dedicated specific devices (i.e. for road and maritime navigation).

The LBS segment progresses further with insurance companies offering smartphone-based insurance telematics and high-end LBS devices with multi-constellation capabilities penetrating the market. It is expected that high-end smartphones will even replace some devices dedicated to professional, high-precision applications.

Major industry actors lead GNSS devices supply and SMEs are involved especially in value-added applications and services

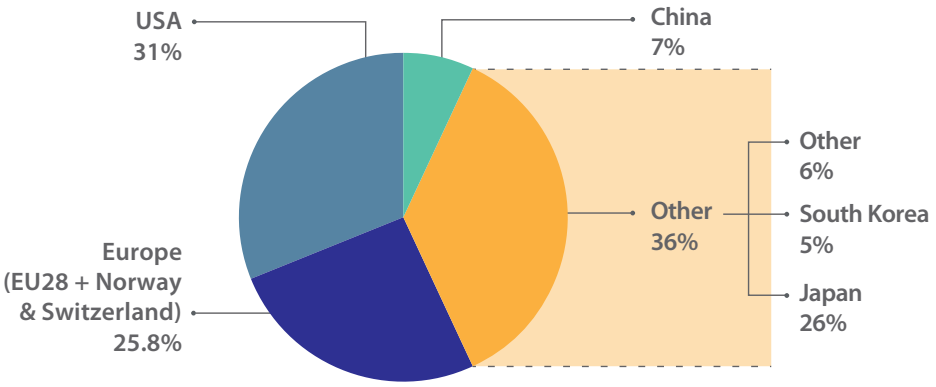
The GNSS downstream industry

The GNSS downstream industry is characterised by a few very large companies and a plethora of SMEs. The big players in the GNSS industry have embarked on **multiple take-overs** in recent years, implying **consolidation** at the top. In 2012, the top five companies by GNSS related turnover accounted for 34% of turnover, and the largest company had 12% of the global market.

A recent **GSA study on the GNSS industry** estimates the proportion of the market held by companies in each world region based on the companies' registered headquarters (latest available financial data for 2012). Almost **900 companies active in GNSS** have been analysed.

The pie chart below shows the study's results with comparison of the size of GNSS industry by region, focused on the counties/regions operating their own GNSS system (USA-GPS, Europe-Galileo, China-Beidou).

GNSS Industry Share by Region (% split of revenues; 2012)



The United States continues to lead, still experiencing the advantage of being the first mover, followed by Japan and Europe. China's growing GNSS industry is difficult to fully assess due to data limitations, while difficulties estimating Russia's share come from the fact the GNSS industry there is predominantly state-owned.

* Source: The European App Economy 2014 Report, Vision Mobile

Global market players

The GNSS downstream industry is broadly classified into three groups of companies:

- **Components manufacturers**, producing receivers for stand-alone use or integration into systems, including chipsets, antennas and safety beacons.
- **Systems integrators**, integrating GNSS capability into larger products, such as vehicles and consumer electronics, as well as dedicated GNSS devices such as PNDs.
- **Value-added service providers**, whose services improve access and use of GNSS, including map providers, augmentation service providers and GNSS calibration or testing activities.

Top 10 companies in each group based on 2012 revenues:

Component manufacturers		System integrators		Value-added service providers	
Qualcomm	USA	Toyota	JP	Google	USA
Trimble Navigation	USA	Garmin	USA	Pioneer	JP
Broadcom	USA	General Motors	USA	Denso	JP
CSR	UK	Volkswagen	DE	Clarion	JP
Laird	UK	Ford	USA	Here Global	NL
Furuno Electric	JP	Apple	USA	Tomtom	NL
Rockwell Collins	USA	Samsung Electronics	KR	Microsoft	USA
Texas Instruments	USA	Nissan	JP	Jeppesen Sanderson	USA
Cobham	UK	China First Automob.	CN	Trimble Navigation	USA
Hexagon	SE	Honda	JP	Telenav	USA

Global database of GNSS companies
The full global list of GNSS companies is available in the Market section of the GSA website.
Please visit: http://www.gsa.europa.eu/

The GNSS market is highly consolidated, especially at the level of component manufacturers, representing the core GNSS industry. The system integrators are mostly car manufacturers and smartphone vendors, for which the GNSS represents only a small part of their product offering (similar in the case of value-added providers).

There is a high potential for application developers, including SMEs and start-ups, on top of the major market players. Users download more data and applications, and the global app economy (which GNSS apps are part of) is growing at an annual rate of 27% globally*.

European companies account for one quarter of the global GNSS market

EU shipments and revenues

Shipments of GNSS devices in Europe will more than double within the next 20 years (growing from 208 mln units in 2013 to 427 mln in 2023). **Revenues** will follow a similar path, increasing from 11 bln in 2013 to almost 20 bln in 2023.

The European GNSS downstream industry

European companies account for 25.8% of the global GNSS downstream market (2012), with substantial variation across the value chain and market segments.

In **components manufacturing**, European companies are strong in **Road**, **Rail** and **Aviation**. Laird plc. has the widest application of components among European firms, with its antennas used in multiple market segments.
European companies are the global leader for system integration in **Rail**, and have a strong position in **Maritime** and **Road**. For system integrators, Hexagon AB (includes Leica Geosystems and Novatel) plays a key role in multiple segments.

Europe is also strong in development of **value-added applications**, with **innovation being driven by SMEs** and start-ups, among others. One of the priorities of the EU is to strengthen its economic value and competitivness by creating opportunities for SMEs and using their potential for innovation. The experience of EU GNSS R&D projects proves that SMEs are especially strong in **applications for fleet management, vehicle tracking and recreation/tourism**.

EU market share

The table below shows the regional market shares for component manufacturers and system integrators in 2012 for each market segment (except for Timing & Synchronisation).

	Component manufacturers (Europe: 23%)			System integrators (Europe: 26%)		
	Europe*	North America	Asia+Russia	Europe*	North America	Asia+Russia
	11%	80%	8%	7%	31%	61%
	48%	25%	27%	29%	21%	50%
	30%	63%	7%	18%	65%	18%
	38%	41%	21%	72%	17%	11%
	28%	13%	53%	47%	35%	18%
	10%	63%	28%	28%	46%	26%
	24%	62%	14%	27%	48%	26%

Value-added services are not tied to the market segments in the same way, but aggregate values amount to **Europe: 21%, North America: 44%, and Asia+Russia: 34%.**

European R&D Programmes support competitiveness of the EU industry and involve SMEs

FP7

GNSS R&D was funded under the Transport theme in the **7th Framework Programme for Research and Technological Development (FP7)**. Running from 2007 to 2013, the strategic objectives of **FP7 GNSS R&D** were to: create economic value for Europe, ensure European competitiveness, maximise public benefits by supporting application development, and increase trade and wider international cooperation.

Over three calls managed by European GNSS Agency (GSA), a portfolio of **86 R&D GNSS projects** with an average size of €1.2 mln were funded with a total grant budget of **~€66 mln**. Projects covered a wide range of market segments: Road, LBS, Precision, Professional and Scientific Applications, International Cooperation, Aviation, Rail, Maritime. There was a strong SME focus amongst the **425 beneficiaries, with 40% of GNSS funds awarded to SMEs**. The **FP7 GNSS R&D Programme** managed by the European GNSS Agency (GSA) generated tangible results by the end of 2014: 13 patents/trademarks registered, 44 commercial solutions and 77 working prototypes.

Horizon 2020 (H2020)

Horizon 2020 is the EU Research and Innovation programme with nearly **€80 bln** of funding available for the period of 2014 to 2020. **The European GNSS (EGNSS)** applications are part of the Space Theme, having synergies with topics on societal challenges. **Two EGNSS calls were opened so far, with a budget of €38m and €25m respectively**. The projects are expected to develop applications in the **key GNSS segments of Road, Aviation, LBS, Maritime, Rail, Agriculture and Surveying/Mapping**.

Actions under the H2020-Galileo address the **development of innovative products, applications, feasibility studies and market tests** that can have a substantial impact on growth and strengthening of European innovative know-how, economy and strategic sectors.

'Key drivers' for maximum impact of the projects include:
- Focus on sustainable competitiveness, innovation and growth
- Measures to leverage engagement of industry, including SMEs
- Development of new knowledge and contributing to skills
- Deployment of enabling technologies
- Support to strong partnership with Member States
- Strategic approach to international cooperation

European GNSS: serving user needs now and in the future

The European Geostationary Navigation Overlay Service (EGNOS) is a satellite-based augmentation system that increases the accuracy of GPS positioning and provides information on its reliability in Europe. EGNOS provides three services: Open Service, Safety of Life and EGNOS Data Access Service (EDAS).

Galileo is the European GNSS under civilian control, providing standalone navigation, positioning and timing information worldwide. 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, responding to the diverse needs of different user communities.

EGNSS value proposition responds to diverse user requirements

User Groups of	Mass Market Consumer Applications	Workforce, Fleet, Traffic and Asset Management	Liability-critical Applications*	Safety-critical Applications	High Precision Applications	Timing Applications For Financial Services, Energy and Telecom
Relevant Market Segments	LBS, Road, VFR General Aviation, Maritime (leisure boats navigation), Rail (passenger information)	LBS, Road, Rail and Agriculture (farm and livestock mgmt)	Road (tolling operators, insurance telematics), LBS (mobile payments), Maritime (fisheries, marine park management)	Aviation, Road, LBS (emergency caller location), Rail and Maritime	Agriculture and Surveying	Timing & Synchronization
EGNOS	Accuracy, especially in remote areas	Accuracy, sometimes integrity	Integrity, accuracy	Integrity, accuracy, compliance with safety requirements and standards	Accuracy	Potentially improved quality of synchronization
Galileo	Availability, better resistance to multipath, accuracy, time to first fix (TTFF)	Availability, better resistance to mutipath, 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

USER-ORIENTED STRATEGY FOR EUROPEAN GNSS TO MEET USER NEEDS

The European GNSS Agency implements a user-oriented approach committed to continuous improvement of services based on user needs and feedback.

European GNSS Service Centres

EGNOS users are served with a 24/7 Helpdesk, provided by EGNOS Service Provider (ESSP). The Helpdesk is a direct point of contact related to the EGNOS system, its performances and applications. The users can contact it via the website: http://egnos-user-support.essp-sas.eu/egnos_ops/

The European GNSS Service Centre (GSC) is defined to provide the interface between the Galileo system and users of the Galileo services. The precursor GSC Nucleus is already providing services to the user community via Helpdesk. Up to the end of 2014, more than 26,000 visitors from 154 different countries have used the web portal: www.gsc-europa.eu

New GSA's tool to improve user satisfaction

EGNOS User Satisfaction Survey measures user satisfaction towards EGNOS services. The gathered metrics and KPIs are used to improve the quality of the services provided and better meeting users needs. In 2014, the first survey was performed in all key market segments.

http://egnos-portal.gsa.europa.eu/egnos-users-satisfaction-survey

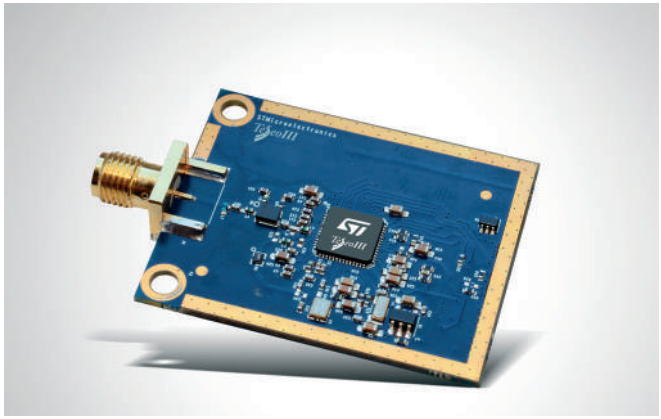
GNSS USER TECHNOLOGY TRENDS

GNSS remains the main source of outdoor positioning information

Position information with GNSS technology, most often via the use of smartphones, has become an important part of modern life. GNSS exists in a dynamic, multi-sensor context where the users need a final ubiquitous position, no matter which technology provides it. Still, when considering GNSS in the context of other macro trends and emerging positioning technologies, GNSS remains the main source of outdoor positioning information.

There are many general trends regarding GNSS devices:

- Over the past decade **improving batteries and power consumption** has been the central focus of producers, resulting in the reality of truly portable GNSS device enabling 'always on' GNSS positioning.
- **Miniaturisation of technology**, including GNSS chipsets, is moving towards very small devices attached to high value or sensitive goods, allowing for the tracking of their location throughout the transport chain. The advent of flexible electronics will allow GNSS receivers to be included in clothing and other personal items that could assist in locating lost and stolen items.
- More and more **receivers are becoming "connected"**. One weakness of GNSS has been the time taken for a receiver to acquire (find and lock onto) the satellite signal. This is ameliorated by using assistance data provided over mobile networks, giving the receiver orbital information about the satellites and allowing for a faster location fix to be found.



* CDMA: Code division multiple access

- Another important trend is that **multi-purpose devices with new software applications are replacing dedicated hardware devices** within the consumer electronics sector. Increasing **convergence of devices** and the ability to deliver applications through software instead of dedicated hardware (e.g. smartphone navigation apps in cars replacing PNDs) may counter-balance the proliferation of micro-receivers.

Challenges to location information

The rise in the number of sensors and the collection of data on devices *and* in objects creates the 'big data' reality. Location information is expected to be attached to all data.
Privacy concerns remain, but the popularity of social media demonstrates the willingness of consumers to trade privacy and data ownership for functionality and convenience.

How are GNSS chipsets and receivers changing?

- Manufacturers are already equipping their devices with multi-constellation capabilities, taking advantage of available services (see next page for details).
- The evolution of GPS and the introduction of Galileo will lead to more transmission frequencies at higher transmission power, improving availability, robustness, accuracy and urban coverage.
- GLONASS is being changed to utilise the CDMA* signal access scheme (as are other constellations), improving the interoperability of devices.
- The need for higher accuracy is also motivating receiver manufacturers to offer multi-frequency solutions for professtional applications.

Combining sensors improves performance

Complementary positioning techniques – such as cellular network based positioning, Bluetooth beacons and localisation using Wi-Fi base stations – can be combined with GNSS to improve performance. This typically supplements coverage in such challenging environments as urban canyons, reduces time to first position fix (by providing a starting point, albeit less accurate than GNSS), increases accuracy, or simply provides redundancy.

More advanced GNSS receivers also use inerial sensors and odometry information to help improve the positioning solution, particularly in adverse environments.

New GSA analysis of receiver capabilities proves that multi-constellation is becoming a standard feature in today's user equipment

This year the GSA conducted an **independent analysis of the GNSS capabilities** of the main chipset and receiver manufacturers. This analysis is focused on a selection of the global top 31 companies* (by market segment consistent with the list in respective value chains) and a review of their publicly available technical documentation on the product portfolio. In principle, only manufacturers with more than 1% global market share by market segment were included.

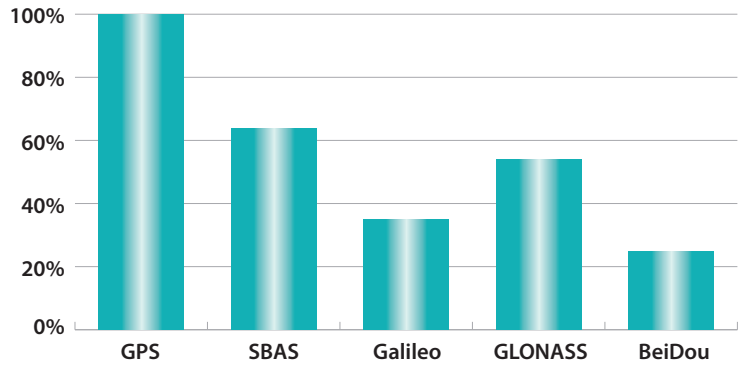
The analysis assesses the capabilities of **more than 300 receivers, chipsets and modules** currently available on the market**. The parameters researched include such technical information specifications as GNSS core constellation capabilities, SBAS constellation capabilities and the market segments to which the manufacturers sell their products.

In the presented results, each device is weighted equally, regardless of whether it is a chipset or a receiver and no matter what its sales volume. The results should therefore be interpreted not as the split of constellations utilised by end users, but rather the split of constellations available in manufacturers' offerings. As some receiver models are used in more than one market segment, it is impossible to have a direct match between general analysis charts and segment charts.

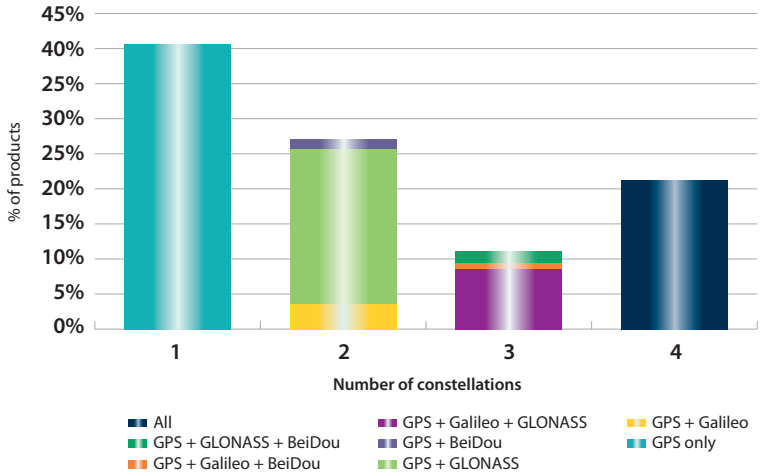
The **"Capability of GNSS devices"** chart shows the percentage of available receivers capable of tracking the SBAS, GPS, Galileo, GLONASS and BeiDou constellations. GPS is naturally present in all devices, followed by GLONASS. Galileo and BeiDou are progressively adopted by the leading manufacturers. In some cases, the full capability of GNSS receivers (chipsets/modules) is not necessarily used in the products/devices (e.g. SBAS capability in LBS segment).

The **"Supported constellation by receivers"** chart shows the percentage of available receivers capable of tracking signals from one GNSS (i.e. GPS only), two GNSS (i.e. GPS + Galileo, GPS + GLONASS, GPS + BeiDou), three GNSS (i.e. GPS + Galileo + GLONASS, GPS + Galileo + BeiDou, GPS + GLONASS + BeiDou) or tracking signals from all constellations at the same time. The percentages add up to 100%. We can conclude that almost 60% of all available receivers, chipsets and modules are supporting a minimum of two constellations, showing that multi-constellation is becoming a standard feature across all market segments.

Capability of GNSS receivers – All segments



Supported constellations by receivers – All segments



* Analysed manufacturers: CSR, Furuno, Hemisphere GNSS, Japan Radio Co., Leica Geosystems AG, Mediatek, NavCom Technology, Nottingham Scientific Ltd, NovAtel, Orolia, Septentrio, STMicroelectronics, Topcon, Trimble, U-blox, Avidyne, Broadcom, Esterline, Garmin, Honeywell, Infineon, Intel, John Deere, Kongsberg, Omnicom, Qualcomm, Rockwell Collins, SkyTraq Technology, Texas Instruments, THALES Avionics, Universal Aviation.

** Please note that the capability of GNSS devices presented in Market Report Issue 3 cannot be compared with the ones from the current edition due to different group of manufacturers used in the analysis.

Location-Based Services (LBS)

GNSS applications

GNSS applications are supported by several categories of devices, mainly smartphones and tablets, but also specific equipment such as tracking devices, digital cameras, portable computers and fitness gear. These devices support a multitude of **applications** tailor-made to satisfy different usage conditions and needs, including:

- **Navigation**: Route planning and turn-by-turn instructions based on GNSS positioning support both pedestrian and road navigation. Sensor fusion is enabling the uptake of indoor navigation.
- **Mapping & GIS**: Smartphones enable users to become map creators.*
- **Geo marketing and advertising**: Consumer preferences are combined with positioning data to provide personalised offers to potential customers and create market opportunities for retailers.
- **Safety and emergency**: GNSS, in combination with network based methods, provides accurate emergency caller location.
- **Enterprise applications**: Mobile workforce management and tracking solutions are implemented by companies to improve productivity.
- **Sports**: GNSS enables monitoring of users' performance through a variety of fitness applications, such as step counters and personal trainers.
- **Games and augmented reality**: Positioning and virtual information are combined to entertain the user and improve everyday life.
- **Social networking**: Friend locators provided by dedicated apps or embedded in social networks use GNSS to help keep in touch and share travel information.

* Professional mapping applications are covered in the Surveying segment.

In this chapter

- **Key trends**: Almost 3 bln mobile applications currently in use rely on positioning information.
- **Industry**: List of main players by value chain segment.
- **Recent developments**: More than 1 bln smartphones were shipped in 2013, with the Asia-Pacific region taking a leading role.
- **Future market evolution**: The market for smartphones will further grow by 6.2% per year until 2023.
- **User technology**: Integration of handset and network based technologies provides the best performance for consumer applications.
- **Focus on European GNSS**: European GNSS contributes to better performance in multi-constellation solutions.
- **Reference charts**: Yearly evolution of GNSS devices' installed base and revenues by segment and geographic area.

NEW! This issue of the GNSS Market Report includes a new application platform: Search and Rescue Personal Locator Beacons (PLBs).

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Almost 3 bln mobile applications currently in use rely on positioning information

Key market trends

- The LBS market continues to grow, with high end devices now commonly making use of multi-constellation and hybrid positioning.
- The development of successful apps continues to drive the global growth of the smartphone market.
- Context-aware applications leveraging on location information make up almost half of this total, with games and entertainment representing the largest categories.

Apps

Navigation, social networking, travel, games, entertainment, fitness and sports, healthcare

On average, more than **70 apps** per device are downloaded by users, although 50% of users have never paid more than $1 for an app.
Downloads of apps that rely on positioning data will hit 7.5 bln by 2019, up from 2.8 bln in 2014.

App stores

Google and Apple dominate the app stores market with more than 50 billion downloads combined from the two stores in 2013.
Google Play surpassed the Apple App Store in terms of downloads and apps in store. However, Apple generated higher revenues by a factor of five.

Total unique apps in store – December 2014

- Google Play 1.43 mln apps
- Apple App Store 1.21 mln apps
- Windows Phone Store 300 k apps
- Amazon Appstore 293 k apps
- Blackberry World 130 k apps

Technology

- GNSS, Wi-Fi and NFC are now integrated into a single Integrated Circuit (IC) platform
- Multi-constellation GNSS chipsets are implemented into high end devices
- Technological advancements in indoor positioning will enable new applications

Users

- Smartphone and tablet owners, people with illnesses or disabilities, workforce, outdoor activity enthusiasts.
- Global installed base of GNSS enabled handsets: 3.1 bln in 2014, up to 5.2 bln in 2017 (many users have more than one device).

Source: Juniper Research, Statistic Brain, Statista 2014, appFigures 2015.

Photo credit: © Thinkstock

LBS Value Chain

COMPONENTS MANUFACTURERS (RECEIVERS AND OTHERS)

QUALCOMM
BROADCOM
CSR-SIRF*
TEXAS INSTRUMENTS
MEDIATEK
STM*
U-BLOX AG*
FUJITSU LTD
SKYTRAQ
INTEL

DEVICE VENDORS

SMARTPHONE/TABLET:
SAMSUNG, APPLE, LG, MICROSOFT, ZTE, HTC, XIAOMI, LENOVO, HUAWEI, MALATA, BLACKBERRY LIMITED

CAMERAS:
CANON, NIKON, SONY

WATCHES:
GARMIN, MICROSOFT, SUUNTO*, TIMEX*

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

PEOPLE TRACKING:
GARMIN,
POCKET FINDER, SPOT
TELTONIKA

OEMS:**
PEGATRON, WISTRON

SERVICE & CONTENT PROVIDERS

APPLE
GARMIN
GOOGLE
NOKIA HERE*
TOMTOM*
Assistance Data Providers
Mobile Network Operators

APP DEVELOPERS/ RETAILERS

APP DEVELOPERS:
APPLE, ELECTRONIC ARTS, GOOGLE, MICROSOFT, NOKIA HERE*, TRIPADVISOR, YELP, ZYNGA, and Many Small App Developers.

RETAILERS:
Airlines, Banks, General Retailers, Media Companies, Mobile Network Operators, Transport Providers, Vehicle Manufacturers.

APP STORES

GOOGLE PLAY
APPLE APP STORE
WINDOWS PHONE STORE
AMAZON APP STORE
BLACKBERRY WORLD

The EU GNSS industry on the global arena

The LBS segment is dominated by non-EU players, with North American companies leading the chipset market and Asian companies holding the majority of handsets revenues. European players are strong in applications development. In 2013 the European "App economy" generated €17.5 billion in revenues and employed 1.8 million people. By 2018 it is forecasted to contribute €63 billion to the EU economy and employ 4.8 million people. EU policy measures on roaming tariffs are fostering the usage of smartphones and apps beyond national borders. Price reductions of over 80% since 2007 resulted in a 630% increase of the roaming market.

* European companies
** OEM: Original Equipment Manufacturer

Value chain considers the key global and European companies involved in the GNSS dowstream activities.

More than 1 bln smartphones were shipped in 2013, with Asia-Pacific taking the leading role

Continuous and fast-paced economic growth quickly led **Asia-Pacific** to become the largest regional LBS market in terms of devices, with a total of 480 mln shipments in 2013. **North America** and **Europe** accounted for 285 mln and 195 mln shipments respectively.

Smartphones represent the overwhelming majority of shipments. Their versatility and growing affordability are key drivers behind their rapid and massive growth, which affected sales of consumer electronics products in other market segments (such as those of PNDs in Road). In 2013, smartphone shipments experienced a tenfold increase from 2007. There is also **a large second-hand smartphone market**, carrying over more than 50 mln devices per year from North America to developing countries.

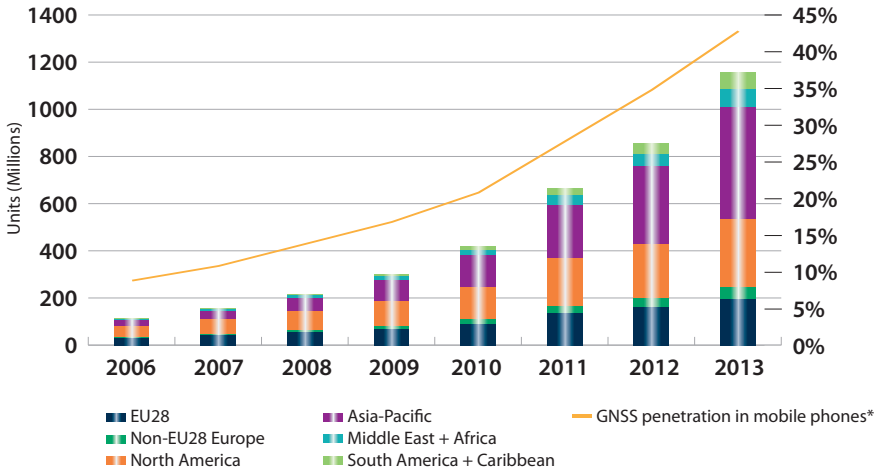
Other GNSS-enabled devices accounted for around 100 mln units in 2013. Among them, tablets represented the second largest application. Their shipments experienced a 640% increase between 2010 and 2013, with major regional markets being **North America**, **Europe** and **Asia**.

The **wearable band market** exploded in the first half of 2014, recording a 700% year-to-year increase. High end smart watches feature assisted, multi-constellation GNSS capabilities combined with 3G or better connectivity. **North America** and **Europe** are leading regions in terms of shipments.

Smartphones evolution: increasing accessibility of GNSS enabled platforms

2007: Apple launches the first iPhone.
2008: The second iPhone model (3G), **incorporating a GNSS receiver**, is released, followed by HTC Dream, the first smartphone running with Android. In the next two years, Android is implemented also in Samsung and Motorola handsets and its market success is due to the flexibility offered to manufacturers and app developers.
2010: Symbian holds around 40% of the market, Android some 20%, while iOS and Blackberry retain about 15%. Windows Phone devices are released. **All best-selling smartphones** have now **GNSS capabilities**.
In **2011** The first smartphones with **multi-constellation chipsets** (GPS and GLONASS) are marketed.
In **2012** about 80% of smartphones shipped worldwide have GNSS capability.
2013: More than 1 billion smartphones are shipped worldwide. Android accounts for almost 80% of the market for operating systems.

Shipments of GNSS devices by region



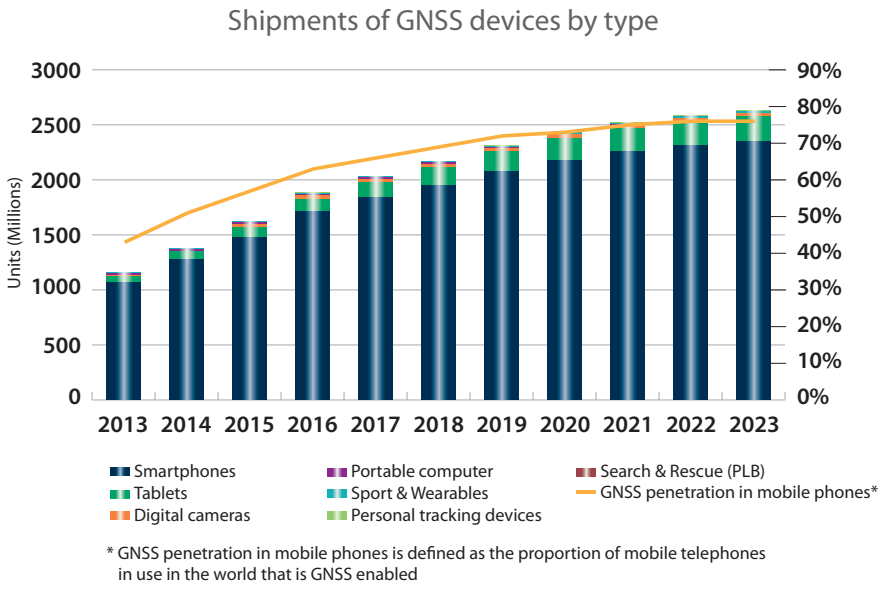
* GNSS penetration in mobile phones is defined as the proportion of mobile telephones in use in the world that is GNSS enabled

Location-enabled games: From treasure hunting to augmented reality

In 2000, the GPS treasure hunt **Geocaching** represented one of the first location-based games.

Now it is enjoyed by 6 million players and games such as **Ingress** integrate positioning, augmented reality and open maps, that use real environments as virtual playgrounds, transform the real world into a landscape for a global strategy game.

The market for smartphones will grow by 6.2% per year through 2023



* GNSS penetration in mobile phones is defined as the proportion of mobile telephones in use in the world that is GNSS enabled

Extraordinary GNSS growth in LBS will continue over the next years, in line with the increasing GNSS penetration. In 2020, more than 2 bln units will be shipped every year, and up to more than 2.5 bln units by 2023. By then, the installed base of GNSS devices will reach almost 9 billion units (see reference chart on page 23). **Asia-Pacific** will play a major role in driving growth in smartphone shipments.

Shipments of **wearables**, including GNSS fitness devices, smart watches and glasses, will further increase to 14 mln units by 2023*.

Personal tracking devices represent a high value market niche and will gain prominence, as technological advancements will enable devices to hit the mass market and increase the competitiveness of available solutions. The main applications include, among others, elderly/illness monitoring, family locators, offender monitoring, and lone worker protection. Shipments of personal tracking devices are foreseen to increase from 250,000 units in 2013 to 6.5 million units in 2023, and the currently fragmented market will progressively consolidate. Generated revenues are expected to grow from €20 mln to €660 mln.

In the context of LBS, **Personal Locator Beacons (PLBs)** assist rescue authorities in their search to locate people in distress, including hikers and other adventurers on land and employees working in remote areas. In 2014, around 10,000 PLBs for land applications were produced worldwide.

Increased accessibility of high end smartphones, modular phones and wearables: three trends that could reshape the LBS market

Increased accessibility of high-end smartphones: the release of the first smartphone with high-tech features together with extremely aggressive pricing compared to other products, was announced in 2014 by the Chinese company OnePlus. Devices like this make the high-end smartphones more accesible and could have a disruptive impact on the market by heavily reducing profit margins for the key players in the near future.

The modular phone: the strategy adopted by Google with its Project Ara relies on creating a low-price smartphone modular hardware ecosystem with customisation possibilities combined with high-performing features. The aim is to offer modular phones constituted of interchangeable parts that allow the function and price flexibility needed to satisfy different needs.

Wearables: while the smart bands market is already exploding, glasses or similar wearable computers could have a major impact on the market for LBS devices. Google Glass, a connected head-mounted display combining smartphone capabilities (messaging, internet search, social apps, navigation, video and picture capture, etc.) with enhanced ease of use, even if never reached mass production, is a an example of the smart eyewear technology.

* This report adopts a conservative approach in forecasting future shipments for these devices, due to uncertainty of future manufacturers' choices of GNSS chipsets implementation into wearables.

Integration of handset and network-based technologies provides best performance for consumer applications

Mobile operators and application developers are showing a growing interest in using location data as an enabler for numerous enterprise, consumer and public safety services. Location data can support various forms of fraud management and secure authentication services. Operators also leverage location data for advertising and analytic applications.

Location Based Services rely on multiple location technologies, often combined with additional smartphone sensors. In fact, location data comes from:

- **handset-based technologies**, such as GNSS, with computations performed mainly in the handset; and
- **network-based technologies** (e.g. Cell-ID, RF Pattern Matching and U-TDOA) with computations performed mainly in the network.

Moreover, the advent of hybrid technologies such as A-GNSS and OTDOA - with intelligence in both the handset and the network - addresses user demand for access the location data in any environment.

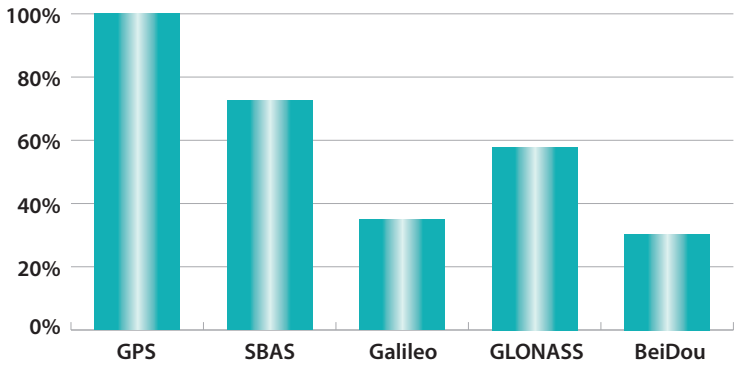
In this perspective, GNSS with other location technologies (accelerometer, gyroscope, compass) compliment each other, provide reliable location information augmented with data from sensors in the handset.

GNSS is the location technology providing the best accuracy in open sky situations, especially in areas with few telecom towers. In indoor situations, Wi-Fi and other network-based technologies are commonly used.

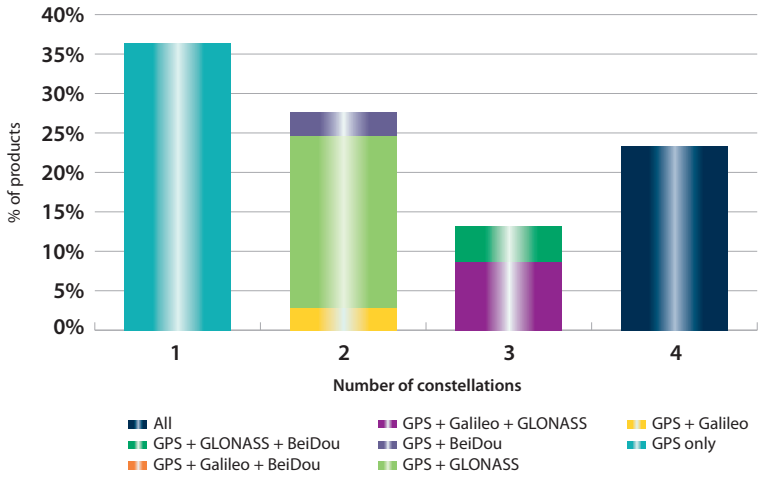
The trend of integrating **multiple GNSS constellations in smartphone chipsets** started in 2011 with the emergence of the first GPS/GLONASS devices. The high penetration of GLONASS was supported by the announcement of a 25% tax on mobile phones imported to Russia without such capability. More recently, smartphones employing Galileo and BeiDou have also entered the market.

The charts below present the detailed view on 2014 LBS chipset capabilities.* Currently more than 60% of all chipsets used in consumer devices support at least two constellations.

Capability of GNSS receivers – LBS segment



Supported constellations by receivers – LBS segment



* For the methodology applied to the charts please go to page 15 of the Report.

European GNSS contributes to better performance in multi-constellation solutions

EGNOS improves GPS accuracy, mostly by reducing the negative impact of ionosphere on the calculated position. It could benefit consumer applications that make use of more accurate location information, especially in remote areas where network-based methods are less effective.

Galileo for ARA awarded GSA Special Prize in 2014 European Satellite Navigation Competition

The European Satellite Navigation Competition (ESNC) is an international innovation competition recognising the best ideas in the field of satellite navigation. The GSA is a sponsor of the Special Prize for the most promising application idea for European GNSS.

The 2014 GSA Special Prize was awarded to the project **"Galileo for ARA – Design of a new Galileo Module for ARA platform"**, developed by Elecnor Deimos. Building upon the outcomes of the FP7 GRIP and ENCORE projects, this solution aims to use the E5 signal to provide high accuracy positioning to Google's modular phone.

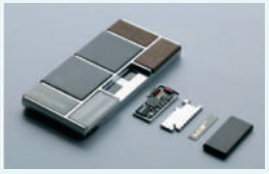
Much has been achieved with smartphones, and now is the time to enable new possibilities for the development of applications with high accuracy requirements.

More specifically, the integration of the **E5 Galileo receiver module** will enhance accuracy, while the antenna interface module will provide better performance. This will offer centimetre-level accuracy at a competitive price. The concept of solution relies on:

- E5 GALILEO receiver modules to offer enhanced accuracy ;
- Antenna interface module to provide better performance;
- Better precision in positioning (centimetre-level accuracy);
- Multipath-resistant solution (better for pedestrian users and urban environments).

Benefits of high precision would be available to the mass market and apply to a wide range of applications, including surveying, land management, automatic parking and many others.

More information at: http://www.gsa.europa.eu/news



The development of LBS is driven by different needs, depending on the application: mobility, productivity, safety, etc. To satisfy these needs, the key requirements for GNSS are The Time To First Fix (TTFF), accuracy and availability.

Galileo satellites will further improve signal availability, thus enhancing continuity of service for LBS in urban and challenging environments. By contributing to multi-constellation solutions, Galileo can satisfy the need for higher accuracy and fast TTFF of such demanding applications as personal tracking.

E112 and the role of E-GNSS

Based on the EU legislation, Member States are required to ensure that caller location information is available free of charge to authorities handling emergency calls, with location criteria to be laid down by competent authorities. Currently there is a gap between citizens' expectations and available emergency location solutions.

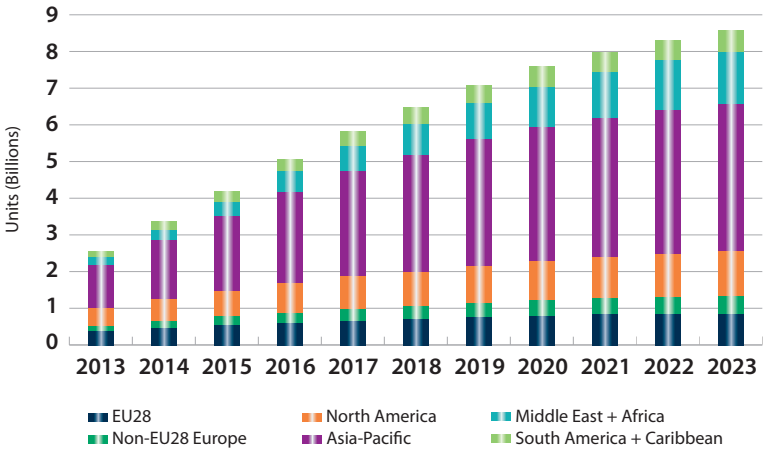
The European Commission is evaluating the possibility of requiring portable devices to be equipped with Galileo and EGNOS chipsets, thus enabling devices to automatically send accurate location data as part of any emergency 112 call. Galileo and EGNOS are expected to improve the caller location in E112 thanks to their better performance (accuracy, availability, TTFF) at no additional costs, the possibility to rely on the EU-owned infrastructure under civilian control and the existence of potential synergies with eCall.

ELAASTIC will create a comprehensive, innovative EGNSS-enhanced location platform

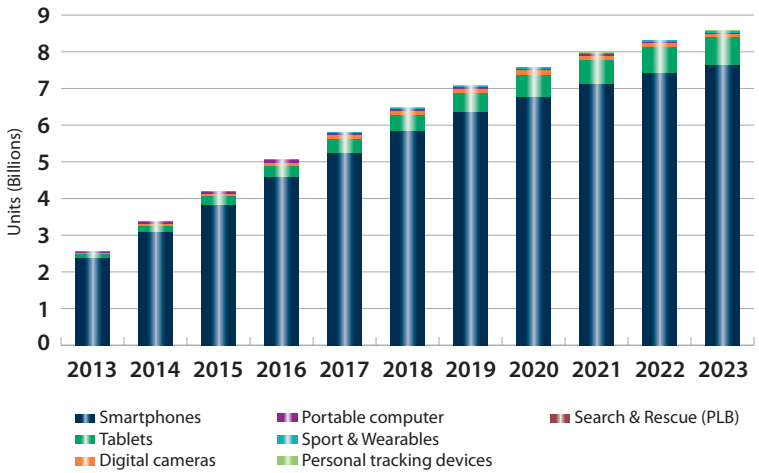
The ELAASTIC project aims at developing an innovative platform for the LBS and Machine-to-Machine (M2M) markets. The platform will act as an enabler, integrating several location technologies (Galileo, EGNOS, other GNSS, Wi-Fi, Cell-ID) to serve many applications, fostering the penetration of Galileo into the LBS and M2M markets. More specifically, ELAASTIC outputs will include:

- A new "Location As A Service" platform, focused on delivering reliable positioning technologies.
- An optimized end-to-end set of location services with full consistency between the Galileo signals, the chipset's capabilities and additional location infrastructure.
- A system compliant with industry standards for location (e.g. OMA SUPL 2.0).
- The opportunity for application developers to rapidly take advantage of Galileo's benefits
- An ecosystem to ease the deployment of services for emergency caller location.

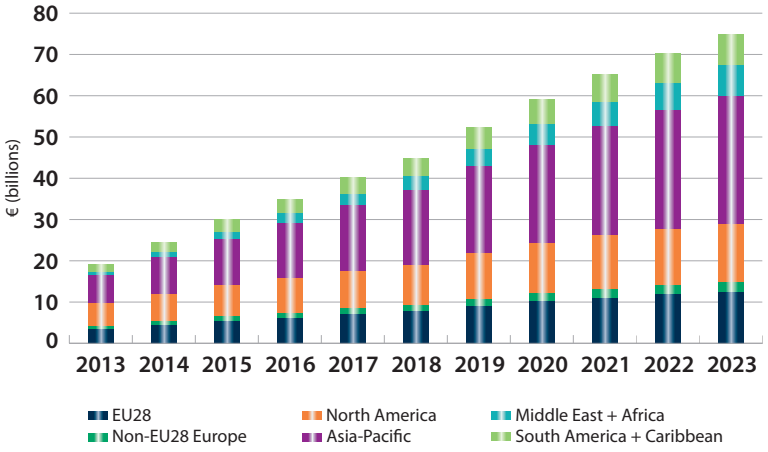
Installed base of GNSS devices by region



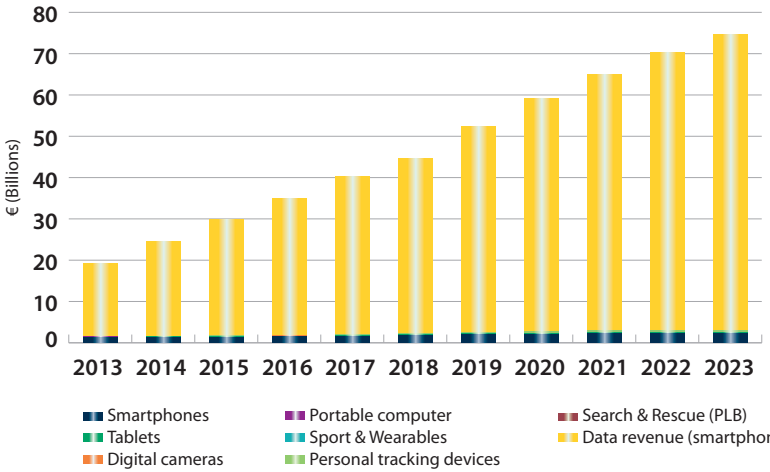
Installed base of GNSS devices by application



Core revenue of GNSS device sales by region



Core revenue of GNSS device sales by application



* Only data revenue arising from the use of Location-based services is considered

Road

GNSS applications

- Smart mobility applications improve the efficiency, effectiveness and comfort of road transportation through:
  - **Navigation** : the most widespread application, providing turn-by-turn indications to drivers through Portable Navigation Devices (PNDs) and In-Vehicle Systems (IVS).
  - **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, processing this traffic information to be distributed to users and other interested parties.

- **Safety-critical applications** leverage precise and secure positioning in situations with potential harm to humans or damage to a system/environment:
  - In **connected vehicles** GNSS positioning will be integrated with the information coming from other sensors and communication technologies in in-vehicle systems (IVS), enhancing the safety and comfort of the driver.
  - **Dangerous goods tracking** can be done by transmitting GNSS-based positioning data on the vehicles, carrying them along with other information about the status of the cargo.

- **Liability applications** the positioning data provided by liability applications are linked to legal and economic liabilities:
  - In **Road User Charging (RUC)** GNSS-OBUs support toll operators in charging based on the actual use of the roads and in managing 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:
  - The GNSS-enabled IVS are used in regulated applications, such as the pan- European **eCall** or the **ERA-GLONASS** in Russia, which send an emergency call to 112 in the case of an accident, thus accelerating emergency assistance to drivers.
  - **Enhanced digital tachographs** leverage GNSS positioning to support road enforcers, recording the position of a given vehicle at different points during the working day.

In this chapter

- **Key trends**: Regulated applications and new commercial solutions will further drive GNSS growth.
- **Industry**: List of main players by value chain segment.
- **Recent developments:** In-vehicle system shipments outnumbered PNDs for the first time in 2013.
- **Future market evolution**: New applications will double the size of the market in the next ten years.
- **User technology**: Development of standards and sensor fusion as enablers of emerging innovative applications.
- **Focus on European GNSS**: EGNOS and Galileo contribute to accurate and reliable positioning.
- **Reference charts**: Yearly evolution of GNSS devices' installed base and revenues by segment and geographic area.

NEW! This issue of the GNSS Market Report includes a new application: Digital Tacograph.

©iStock

Regulated applications and new commercial solutions will further drive GNSS growth

Key market trends

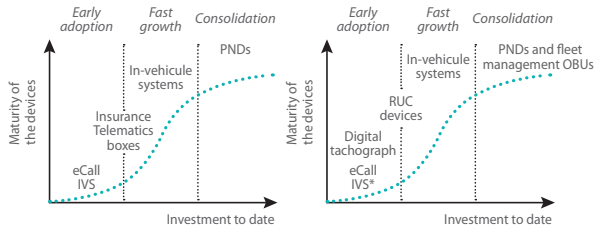
- Policy developments, fast pace of innovation, new applications and commercial advantages from positioning information will further drive market penetration.
- Implementation decisions in Europe and existing use cases confirm the competitiveness of GNSS as a road tolling solution.

GNSS-enabled applications in Road transportation provide different benefits to end users, including improvements to productivity, safety, and the monitoring of operations and goods. GNSS enables manufacturers and system integrators to offer many added value services e.g.:

- PNDs produce Floating Car Data processed in road traffic monitoring services.
- In-vehicle systems support cooperative ITS and other safety-critical applications.

Industry players install on board own devices in vehicles, as the added value provided by positioning information is higher than the cost of hardware.

Current level of maturity of GNSS devices in Road



	Number of private vehicles (2015)
EU	247 mln vehicles
World	907 mln vehicles

	Number of commercial vehicles (2015)	
	Light	Heavy
EU	33 mln vehicles	6 mln vehicles
World	305 mln vehicles	140 mln vehicles

The boom of applications is leading to GNSS penetration in the EU exceeding 100%. The most mature services will be supported by a single, multi-service GNSS unit. The need for more robust solutions and the economies of scale is paving the way to the commercialisation of multi-constellation and multi-frequency GNSS receivers in vehicles.

Existing opportunities continue the **convergence with other GNSS segments**, especially LBS, as smartphone applications are replacing PNDs.

* The uptake of eCall for heavy vehicles depends on future regulatory developments.

GNSS has become the preferred solution for electronic tolling

Thanks to its flexibility, GNSS-based tolling is being increasingly adopted. With GNSS-based tolling, users can be charged based on different criteria (type of road, time, distance, vehicle type, level of emissions), all of which are easily modifiable over space and time. Other benefits of GNSS in complex new networks include low transaction costs, minimal environmental impact and additional revenues from value added services.

At the end of 2014, the unique flexibility of GNSS enabled **Slovakia to scale up GNSS-based tolling network operations in only three months:**

- The charged network increased 7.5 times from 2,477 to 17,762 kilometres.
- Covered roads were extended to all motorways, 1st, 2nd and 3rd class roads.
- Traffic of vehicles weighing more than 12 tons is monitored through GNSS on restricted roads.

Slovakia has experienced the largest extension of road tolling networks worldwide so far.

Slovakian RUC Network

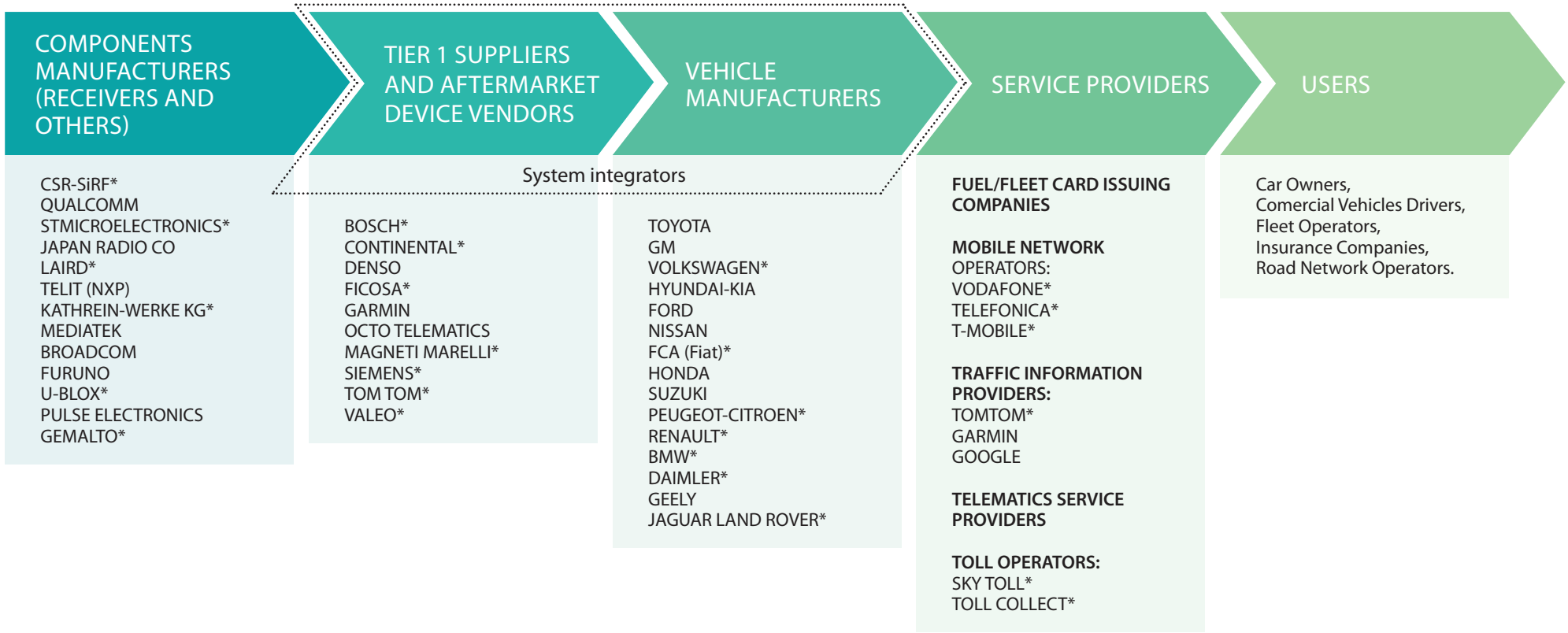
RUC network until 31/12/2013
RUC network added from 01/01/2014

Source: SkyToll

In addition to Slovakia, Germany, Switzerland and Hungary have successfully implemented GNSS-based tolling. Other countries are also leveraging the benefits:

- Belgium and Russia have launched similar projects implementing GNSS-based schemes.
- France, Finland, Bulgaria, Denmark, The Netherlands and Lithuania have all declared their interest in GNSS-based schemes.

Road Value Chain



The EU GNSS industry in the global arena

In Europe, the Road GNSS industry is concentrated in component and receiver manufacturers (48%), with North American and Asian manufacturers sharing the rest of the market. For system integrators, the European automotive industry plays a strong role, but behind Asia (see GNSS Market Overview section of the Report for more information). Key European market players are chipset manufacturers CSR and STMICROELECTRONICS, antenna manufacturer Laird, car manufacturers Volkswagen, FCA (Fiat), and tier 1 supplier Bosch.

* European companies

Value chain considers the key global and European companies involved in the GNSS dowstream activities.

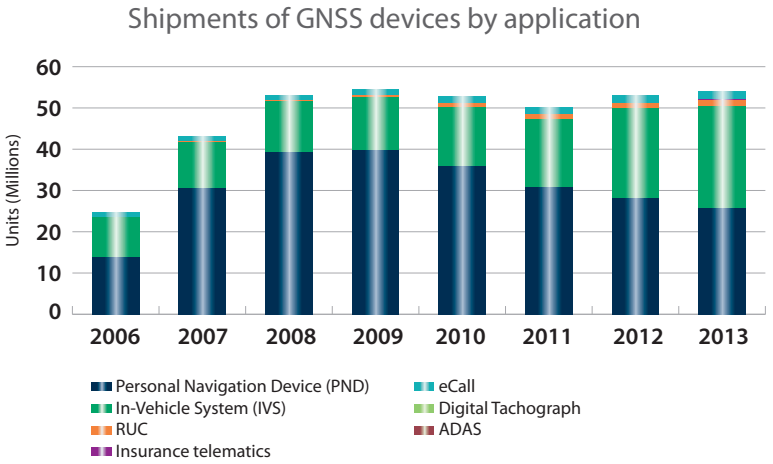
In-vehicle system shipments outnumbered PNDs for the first time in 2013

Since 2008, annual GNSS shipments worldwide have stabilised to 50 mln units per year thanks to the success of navigation solutions, in particular Portable Navigation Devices (PNDs). GNSS units provided by such companies as TomTom and Garmin accounted for almost 80% of shipments in 2008.

In the last five years, **smartphones had a disruptive impact on the PND market.*** This was in large part due to the improvement in GNSS receiver performance (e.g. AGNSS and multi-constellation), introduction of supporting technologies thanks to sensor fusion (e.g. dead reckoning), as well as the progressive increase in screen size and user friendliness of navigation apps for road navigation with pre-installed and self-updating maps.

The decrease in PND sales has been compensated by the growth of **In-Vehicle Systems (IVS)** shipments, which experienced an average annual increase of 11% from 2009 to 2013. Such growth is motivated by the commercial opportunities offered by IVS as a platform, enabling **navigation** and **connected vehicles**, as well as many other GNSS-enabled services that meet user demand for comfort, infotainment and safety. This trend means that automotive manufacturers, such as Toyota, General Motors, Volkswagen, Ford and Nissan, have become the largest system integrators of GNSS-based solutions.

A number of additional applications, including road user charging (RUC), insurance telematics and eCall, accounted for 3 mln additional units shipped in 2013.

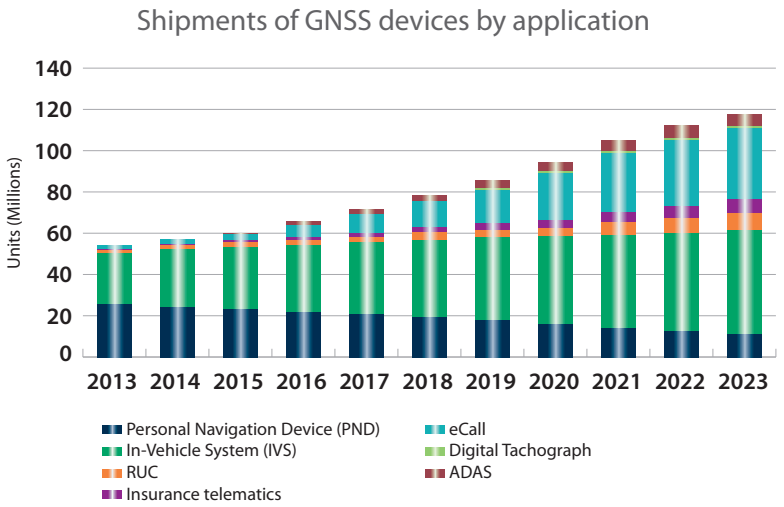


A Short History of Road Navigation

'80s: The aftermarket system called Etak was launched in the mid-1980s. It relied on dead-reckoning and mapping data stored on cassettes.
'90s: Appearance of the first navigation systems using GPS and relying on maps stored on CDs.
1998: Debut of PNDs such as Garmin StreetPilot, costing more than 500 dollars.
2000s: Advent of navigation systems with maps stored on hard drives, including the first added value features like lane guidance and traffic information.
2002: Telenav develops a mobile navigation product for Motorola phones using an external GPS receiver.
2003: Navigator was created for BlackBerry 7520, RIM's first GPS-enabled device.
2007: The iPhone hits the market, paving the way for the boom in navigation apps.
2011: Smartphones start to outperform dedicated devices in GNSS navigation performance.
2013: While smartphone apps continue to boom, IVS shipments outnumber those of PNDs.

* Smartphones are included in the LBS segment section of the GNSS Market Report.

New applications will double the size of the market in the next ten years



The **road navigation PNDs market** has reached full maturity. In the coming years, In-Vehicle Systems (IVS) and smartphone apps with pre-installed and self-updating maps will progressively replace PNDs. In the future, automotive manufacturers will take advantage of IVS to provide value added services, such as connected and autonomous vehicles and other safety-critical applications.

PND manufacturers are reacting with the launch of **HUD (head-up display) devices**, including the Garmin HUD, which deliver navigation cues, along with such information as speed and time to destination while allowing the driver to keep their eyes on the road. HUD innovation is creating market opportunity for new players focused on usability and user experience, such as Navdy.

Regulated applications will drive further growth in the Road market for GNSS. In particular, eCall-like systems worldwide (such as ERA GLONASS in Russia) are foreseen to account for 30 mln shipments in 2020.

Among commercial applications, insurance telematics solutions are foreseen to progressively penetrate the market, with annual shipments hitting 5 mln units in 2020.

A look into the near future: GNSS supporting autonomous driving

Autonomous vehicles can take over activities traditionally performed by the driver, thanks to their ability to sense the environment, navigate and, if combined with connected vehicle solutions, communicate with other vehicles and road infrastructure. Widespread adoption of autonomous driving can reduce traffic accidents and improve traffic flow, as well as improve driver comfort.

Autonomous vehicles are enabled by the combination of different technologies and sensors, allowing the IVS to identify the optimal path of action. GNSS plays a key role by providing relevant inputs for integrated navigation, such as vehicle location and speed. Multiple constellation, horizontal protection levels and advanced detection techniques provided by computer vision or LiDAR will be combined to ensure the robustness of the final positioning.

This market generates huge business opportunities. Several automotive manufacturers are thus investing heavily in developing the technology. Already, the Mercedes S-Class Sedan is capable of following traffic, automatically braking and maintaining its lane. In 2017, General Motors is planning to launch a new Cadillac using advanced cruise control on highways. The magnitude of opportunities has also attracted new players to the automotive market, including Google and its Self-Driving Car.

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Development of standards and sensor fusion as enablers of emerging innovative applications

Given the principle of GNSS positioning - with performances highly influenced by the conditions of the operational environment - and the need to ensure appropriate performance throughout the equipment's lifetime, the development of **standards** and **certification** references on positioning performance is fundamental for device vendors and service providers, especially when it concerns safety-critical applications.

In this context, European Standardisation Organisations aim to produce standards for the use of geo-positioning services for navigation and localisation applications. These aim to produce **procedures for the establishment of performances of road transport systems based on GNSS**.

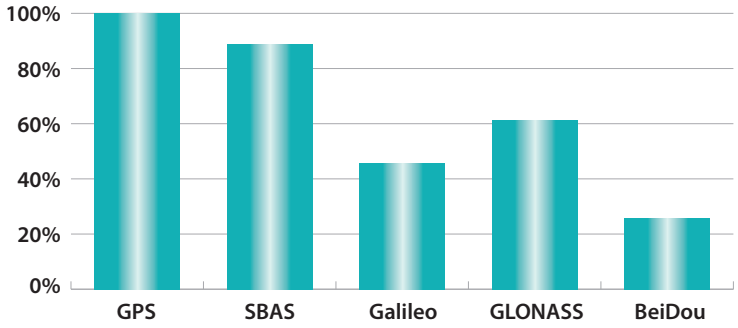
The development of such standards will certainly have a positive impact on future road ITS industry developments, especially in regards to the need to provide industry with the highest practicable degree of uniformity in the provision and operation of GNSS services.

Additionally, the automotive industry agrees on the future view of a sensors' fusion, with GNSS as a core component, integrated into a car to provide enhanced positioning capabilities to be used with a plethora of innovative applications.

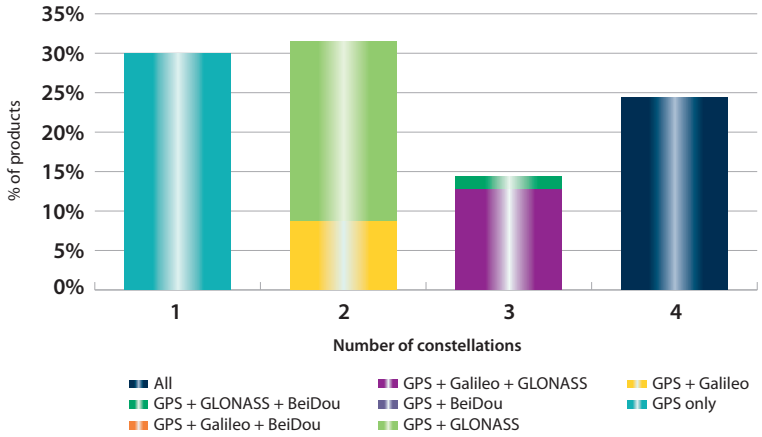
The combination of computer vision, 3D Maps, LIDAR, and pattern recognition technologies with GNSS enables the driverless car concept and other applications. Similarly, R&D projects have already demonstrated that the integration of GNSS with Vehicular Ad-Hoc Networks (VANET) communications allows the computation of "Local Protection Level" ellipses around the vehicle that can be used, for example, for safety-related applications.

The charts below show that GLONASS and Galileo are the most adopted constellations following GPS.* This is in light of the **eCall and the ERA-GLONASS emergency call** projects soon to be operational in Europe and Russia respectively. These projects aim to automatically send an emergency call to 112 in case of an accident, thus accelerating emergency assistance to drivers.

Capability of GNSS receivers – Road segment



Supported constellations by receivers – Road segment



* For the methodology applied to the charts please go to page 15 of the Report.

EGNOS and Galileo contribute to accurate and reliable positioning

EGNOS improves GPS accuracy and provides information on the reliability of the positioning information. As a result, there are national RUC schemes already considering EGNOS (e.g. Slovakia and Belgium), and initiatives to track dangerous goods and to support the localisation of vehicles within the pan-European eCall initiative.

Galileo will bring immediate benefits to the Road segment by increasing availability through multi-constellation. In particular, applications in urban environments will be positively impacted. Galileo is expected to provide authentication, ensuring that the position is computed with a real satellite signal and not a spoofed one. This unique feature will enhance the level of security of applications such as RUC, digital tachographs and insurance telematics.

European EGNSS R&D Programmes support the competitiveness of the EU industry

GAIN paves the way to environmentally friendly road mobility

Innovative solutions such as GNSS can mitigate the negative economic, social and environmental impact of increasing road traffic.

The GAIN project implemented an Enhanced Active Green Driving (EAGD) system where Vehicle-to-Vehicle communication is integrated with positioning algorithms based on EGNOS/EDAS, detecting and mitigating multipath in urban areas. The GAIN dynamic information system allows more accurate real-time speed optimisation and reduced fuel consumption. In 2014, the solution was successfully tested in real scenarios, including roundabouts and crosswalk approaches.

More information at http://www.gain-project.eu

Source: GAIN project

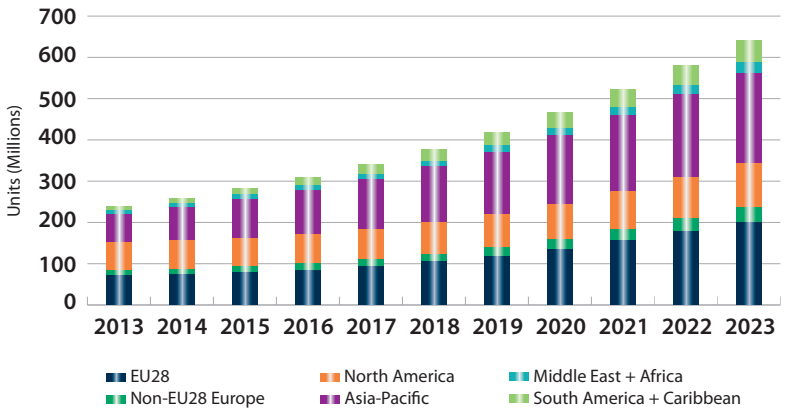
FOSTER ITS to ensure more secure positioning and timing

The growth of liability critical applications such as RUC, insurance telematics and digital tachographs will require an increasingly secure positioning with respect to interferences like jamming or spoofing.

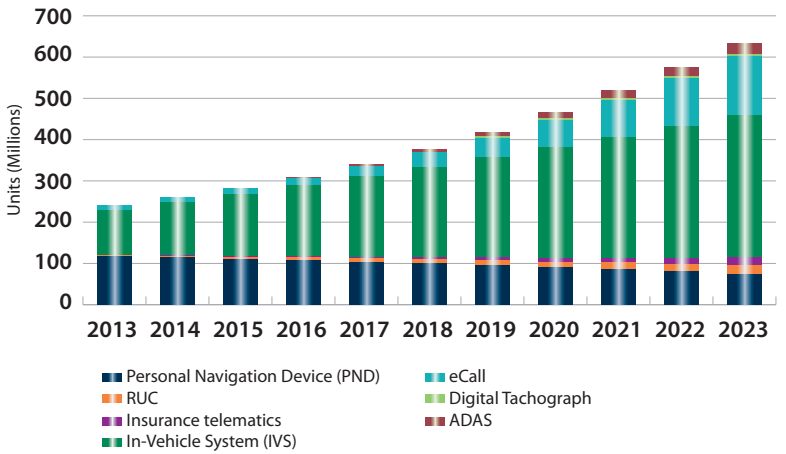
The FOSTER ITS project deals specifically with this need for robust positioning. Building upon the outputs of the TACOT project, FOSTER ITS is addressing solutions for attack detection and confidence in Position Velocity and Time (PVT) data by developing a secured multi-constellation GNSS module. Planned outcomes of this project include the rapid marketing of a multi-constellation module with different possible features, along with a development kit for system integrators to assess its performance.

© Courtesy of Siemens Electronic Tolling

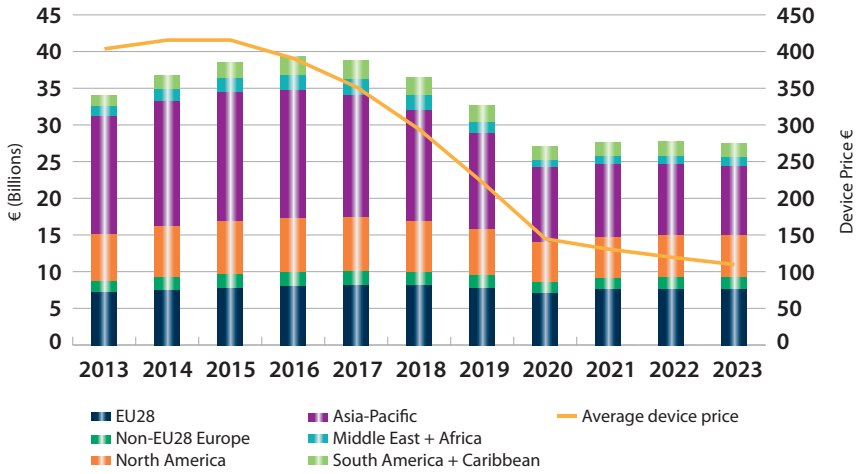
Installed base of GNSS devices by region



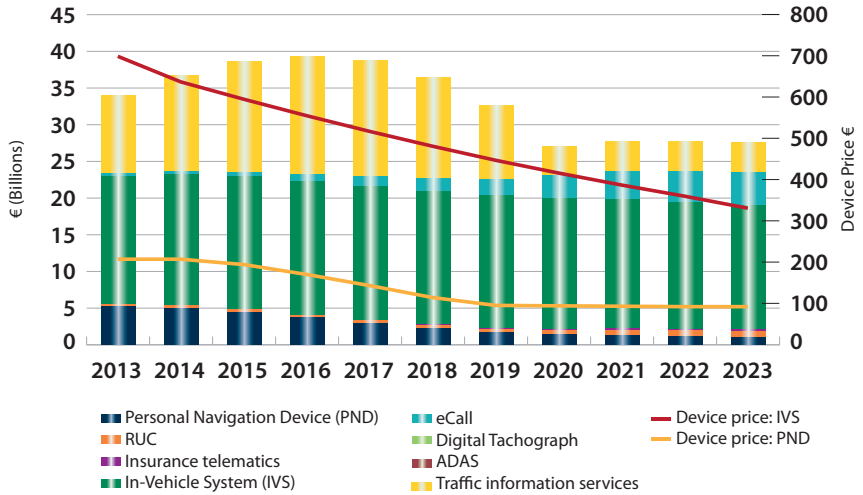
Installed base of GNSS devices by application



Core revenue from GNSS device sales and services by region



Core revenue from GNSS device sales and services by application



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 en-route flight and when approaching airports.
- 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 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.

* This issue of the GNSS Market Report does not include figures for surveillance devices.

In this chapter

- **Key trends**: GNSS benefits almost a billion European passenger journeys each year.
- **Industry:** List of main players by value chain segment.
- **Recent developments:** Historical shipments remained stable between 2008 and 2013.
- **Future market evolution:** IFR devices are reaching a plateau, while VFR continues to grow.
- **User technology:** Multi-GNSS solutions to deliver improved integrity, accuracy and continuity.
- **Focus on European GNSS:** EGNOS remains a key enabler for Aviation as preparations are made for Galileo.
- **Reference charts:** Yearly evolution of GNSS devices' installed base and revenues by segment and geographic area.

NEW! This issue of the GNSS Market Report includes two new applications: Search and Rescue ELTs and Search and Rescue PLBs.

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GNSS benefits almost a billion European passenger journeys each year

Key market trends

- Usage of GNSS navigation is rising, particularly for Performance Based Navigation (PBN).
- SBAS-based procedures are increasingly available at many European aerodromes and operators are equipping aircraft with SBAS enabled avionics.
- GNSS enabled ELTs are also gaining importance in Aviation.
- GNSS is more utilised in surveillance through technologies like ADS-B and as a component of the data connection services.

What is the Aviation market?

The aviation industry continues to grow. According to Eurostat, in recent years passenger numbers are up within the EU by 1-2%. Most people are familiar with flying to go on holiday or a business trip, which is termed Commercial Aviation. However, Aviation comprises of more than just commercial passanger 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.

The move to Performance-Based Navigation drives GNSS uptake

Performance-Based Navigation (PBN), which is increasingly being used, places requirements on the quality and accuracy of aircraft navigation along predefined routes, on an instrument approach procedure or in designated airspace. GNSS enables PBN and provides navigation guidance for all phases of flight, from en-route to precision approach.

Surveillance supplements ground based radars with GNSS

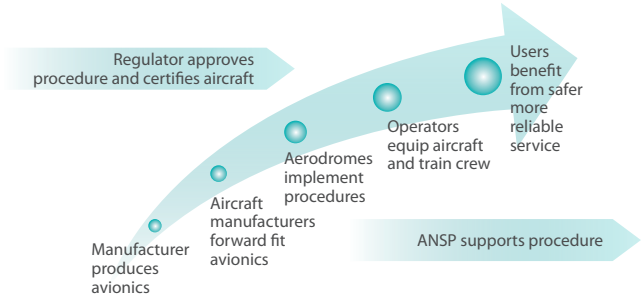
ADS-B uses GNSS to allow aircraft to inform others (aircraft and controllers) of their location. Its increase is being driven by regulations, such as the Federal Aviation Administration (FAA) mandate* to equip ADS-B by 2020. ADS-B is also designed to be interoperable with existing requirements for surveillance transponders, which aircraft must equip. This is being supported by Air Navigation Service Providers (ANSP) who can utilise the technology to cover areas they previously couldn't, such as Avinor (the Norwegian ANSP), who are deploying an ADS-B system for their North Sea operations.

* 14 CFR §92.225 and §91.227

ELTs required on aircraft

For IFR, Emergency Locator Transmitters (ELTs) have been in use for some time. For every aircraft carrying 19 or more passengers, ICAO Annex 6 recommends that all aeroplanes carry an automatic ELT. Their use is increasing, as any aircraft obtaining a certificate of airworthiness issued after July 2008 must be equipped with at least one automatic ELT.
Although in VFR ELTs are not required, many pilots carry handheld PLBs.

How do users benefits from GNSS in aviation?



Increasing GNSS and SBAS use

GNSS will become an ever more critical infrastructure to aviation as more flight procedures are designed to take advantage of PBN. **EGNOS-enabled instrument approach procedures to LPV minima are being rolled out across Europe**. Localiser performance with vertical guidance (LPV) is an instrument approach procedure that provides lateral and vertical guidance based on GPS augmented by SBAS (EGNOS/WAAS) and allows a 250 ft decision height, improving safety and allowing operations to continue in adverse weather conditions. This benefits the economy and environment by reducing the occurrences of aircraft being forced to re-route to alternative airports during bad weather.

Aviation Value Chain

DEVICE MANUFACTURERS

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

AIRCRAFT MANUFACTURERS

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

AIRLINES / AIRCRAFT OWNERS

MAIN AIRLINES ALLIANCES
ONEWORLD
SKYTEAM
STAR ALLIANCE

USER GROUP ASSOCIATIONS
European Business Aviation Association (EBAA)
European Regions Airline Association (ERA)
European Helicopter Association (EHA)
Aircraft Owners and Pilots Association (AOPA)
European Low Fares Airline Association (ELFAA)

AIR NAVIGATION SERVICE PROVIDERS

MAIN ORGANISATIONS:
Civil Air Navigation Services Organisation (CANSO)
International Civil Aviation Organization (ICAO)

AERODROMES

International Airports
Regional Airports
Private Airports

The EU GNSS industry in the global arena

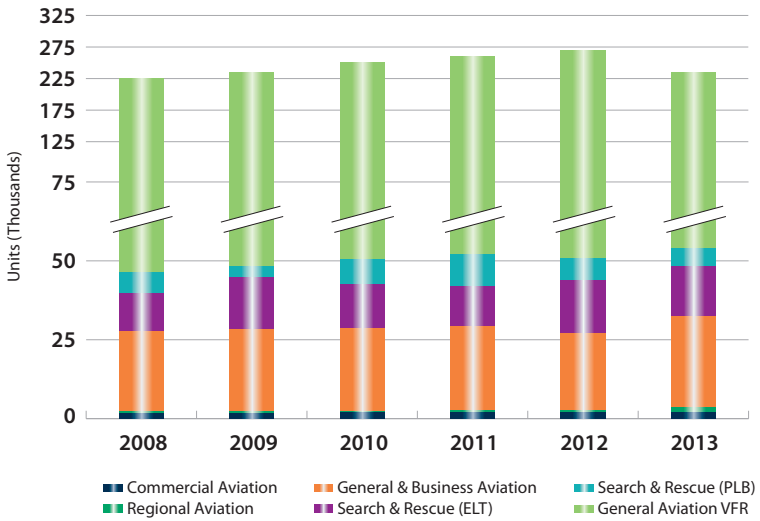
The aviation industry has historically been dominated by avionics manufacturers from the United States. Globally, two of the top three avionics manufacturers (Honeywell and Rockwell Collins) are based there. The European Thales Avionics, as the main avionics integrator for Airbus, has also seen its market share increase in tandem with the success of the aircraft integrator. Thales is a key partner within SESAR, actively developing and validating new avionics as part of SESAR initiatives in the areas of multi-constellation GNSS, GBAS and enhanced ADS-B.

* European companies and organisations

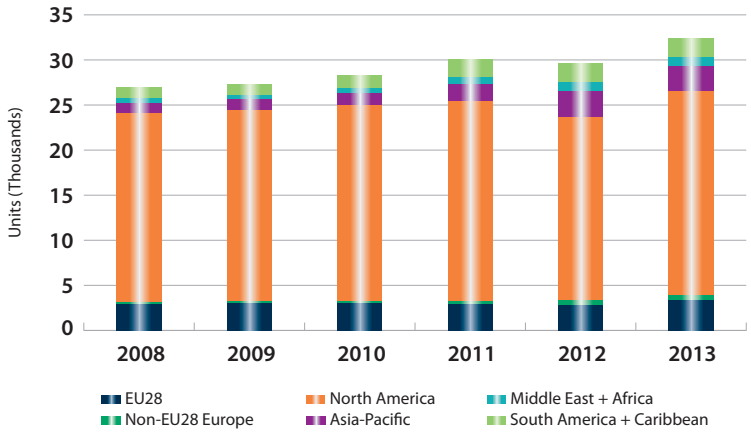
Value chain considers the key global and European companies involved in the GNSS dowstream activities.

Historical shipments remained stable between 2008 and 2013

Shipments of GNSS devices by application



Shipments of IFR GNSS devices by region



GNSS is included in all modern aircraft, whereas SBAS capable receivers are usually found as standard fit only in modern business and general aviation aircraft.

General Aviation is the largest aviation sub-segment, with more aircraft and pilots than the business, regional, and commercial segments combined. The vast majority of these are located in North America. Sales in this segment are dominated by **VFR users** who upgrade their devices more frequently to ensure they have the latest functionality or application. In 2013, **North America** had a 70% share of shipments of GA VFR GNSS devices, followed by the **EU28** region with 20%. Such equipment often does not have **installation costs** (as carry on devices) and can be purchased for around €1,000 per unit - substantially less than for IFR General Aviation where it costs €10,000 - €30,000 to equip each aircraft (although this provides IFR users more capabilities – e.g. LPV approach procedures). Equipping within Commercial Aviation costs substantially more than this, in the order of €100,000 and up.

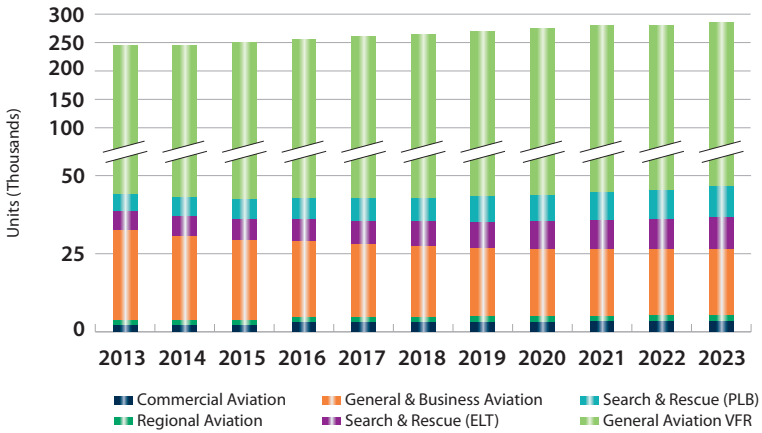
Due to the cost of devices certified for IFR use, most Commercial, Regional, and Business Aviation aircraft are retrofitted with enhanced avionics only once during the aircraft's lifetime (often around 30 years).

New for this year's market report is the inclusion of Search and Rescue ELTs and PLBs into the chart data. The number of ELTs shipped is far exceeded by the PLBs. This is primarily due to the PLBs being used by smaller aircraft of less than six seats, which are much more numeruous. Commercial, Regional and Business Aviation tend to be the prime target for ELTs.

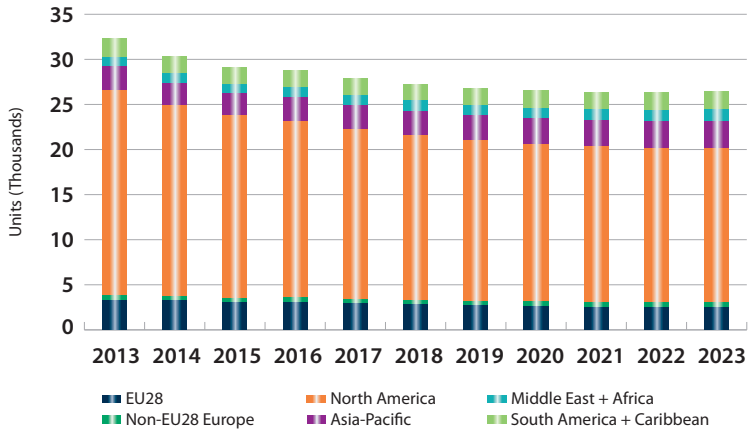
© istock

IFR devices are reaching plateau, while VFR continues to grow

Shipments of GNSS devices by application



Shipments of IFR GNSS devices by region



Shipments of IFR devices are expected to fall and plateau around the 15,000 per annum level, due to the increased equipage penetration of GNSS devices within an already strong market segment. The retrofit market continues to dominate the aviation market – especially in General and Business Aviation, where pilots are keen to adopt the latest technology and with GNSS enabled procedures beginning to open previously inaccessible aerodromes.

Commercial Aviation is expected to continue using APV Baro approach procedures (at airports where ILS is not available) until Ground Based Augmentation Systems (GBAS) CAT II and CAT III become available, which should increase interest in retrofits. However, the ubiquitous nature of SBAS in aviation receivers would be expected to lead to Commercial Aviation users eventually having SBAS on board.

Future developments in equipment are expected to focus on the **integration of multi-constellation** and enable capabilities such as Advanced RAIM (A-RAIM), which uses two independent GNSS core constellations to monitor position integrity. This is expected to lead to additional benefits in the more remote regions where the installation of terrestrial navigation aids can be limited by available resources or security.

The number of **PLB devices** shipped is expected to grow, continuing to exceed the number of **ELT devices** shipped. **North America** is by far the largest market region in terms of aircraft, pilots and GNSS equipment, followed by **the EU28**, which is reflected in GNSS device shipments.

The major growth areas for Commercial Aviation will be Asia Pacific and Middle East and Africa. In particular, **Asia Pacific growth** is expected to outpace all other regions in the near future, with the region purchasing nearly double the number of aircraft forecasted for Europe. There will be also a long-term, strong demand in Asia for the most costly GNSS receivers.

The UAV market is taking off

Unmanned Aerial Vehicles (UAVs) are an emerging and promising market for GNSS in Aviation, thanks to their need for precise positioning and orientation. UAVs were initially used for military and security purposes. However, a wide range of civil applications will further drive market growth. The market for UAVs is not quantified in this market report, but other sources estimate it at about $7 bln*, with forecasts predicting a steady increase of annual revenues over the next decade. Civil applications that have already become popular include geographic survey and mapping, scientific applications (such as ash cloud inspection) and pipeline/power-line inspection.

* Teal Group Corporation, 2013

Multi-GNSS solutions to deliver improved integrity, accuracy and continuity

GNSS developments in Aviation focus on enabling navigation applications, such as advanced Required Navigation Performance (RNP) and aerodrome manoeuvring, by leveraging **multi-constellation/multi-frequency GNSS solutions**. The technical requirements are being developed in this context to allow the aviation industry to benefit from improved integrity, accuracy and continuity. The transition to multi-constellation will also enable the introduction of **Advanced Receiver Autonomous Integrity Monitoring (ARAIM)**, which will extend the benefits of LPV performances to those areas of the world not currently serviced by SBAS systems like EGNOS.

The provision of these capabilities in more integrated platforms is expected to provide significant benefits to aircraft that have been typically limited in space or capability. For example, the helicopter industry is expected to benefit from EGNOS and new Instrument Flight Procedures (IFP), allowing flights to occur under Instrument Flight Rules (IFR), not only access to helipads in low visibility conditions. New developments include:

- **Point in Space (PinS) procedures to LPV minima:** they effectively enable cloud break procedures to allow landing in adverse weather conditions without the need for costly ground infrastructure.
- **Low-level RNP routes:** they allow for more suitable operations during the en-route phase of flight. As a consequence, it enables a helicopter to remain outside icing conditions that would be encountered if higher en-route altitudes needed to be flown.
- **Simultaneous Non-interfering Approaches (SNI):** specific implementation of PinS approach procedures combined with low level routes enable IFR helicopters to operate to and from airports without conflicting with fixed-wing traffic or requiring dedicated runway slots.

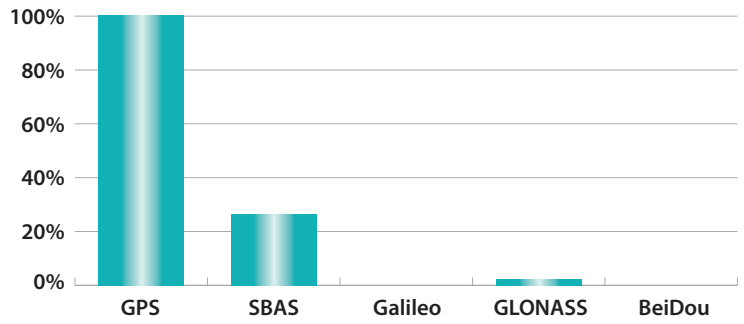
For fixed wing, the availability of multi-constellation/multi-frequency GNSS is expected to enable the capabilities of other approach aids such as GBAS CAT II and III.

Applications on the aerodrome surface would also benefit from Multi-GNSS and ARAIM enabled receivers as accuracy is expected to improve enough to support the ability of performing on-board integrity and accuracy checks and thus enabling ground based navigation assistance. This could include automated taxi guidance, especially in low visibility conditions and display to the pilot the relative positions of other aircraft.

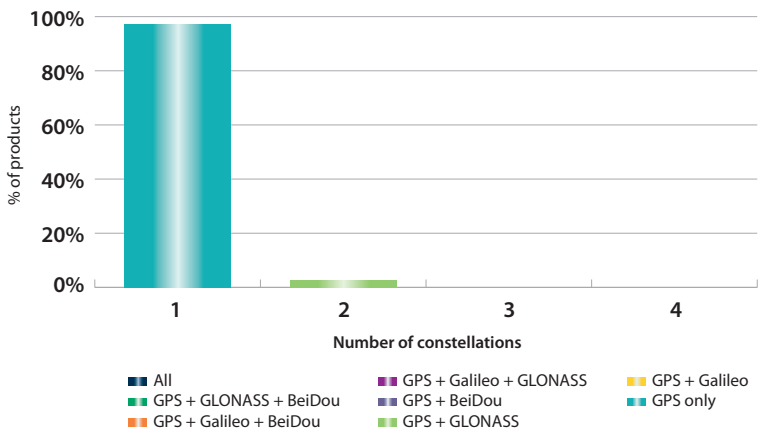
In addition to navigation, applications such as **Spaced Based ADS-B** (Automatic Dependent Surveillance Broadcast) are expected to benefit from the aircraft position reporting enhanced by multi-GNSS also in oceanic and remote regions of the globe. Such solutions would have been of direct benefit in the aircraft searches for both AF447 and MH370, both lost over the sea, away from their initial route.

The safety requirements, **certification and the necessity to comply with international standards** are naturally slowing down the adoption of multi-constellation compared to non-regulated markets. The majority of GNSS devices in offering today are GPS only, with more than 20% penetration of SBAS.*

Capability of GNSS receivers – Aviation segment



Supported constellations by receivers – Aviation segment



* For the methodology applied to the charts please go to page 15 of the Report.

EGNOS a key enabler for Aviation whilst preparations are made for Galileo

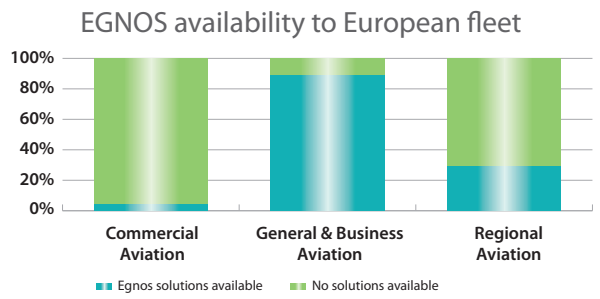
EGNOS An increased number of European Regional, Business and General Aviation operators are equipping their aircraft with EGNOS certified avionics, allowing them to take advantage of already published procedures. It gives them the competitive advantage of continuing to offer services and reducing flying time in adverse weather conditions.

With the advent of NPA25/2013, which places EGNOS approach procedures on the private pilot licence course, LPV is on course to become not only a widely deployed procedure, but one that is widely incorporated into pilot training, meaning all new IFR pilots will be certified to fly LPV approaches. As a result, when the LPV training becomes part of standard IFR training, there will be no need for specific approvals for pilots to fly LPV approaches.

Availability of EGNOS in Europe is increasing

Key to ensuring the uptake of EGNOS in Europe is the availability of avionics that can be installed on the European aircraft fleet. Over the past years, the European GNSS Agency has been supporting projects focused on increasing the availability of procedures, along with working with regulators to ensure the availability of upgrade solutions.

A small fraction of aircraft have EGNOS solutions available as forward fit option, but for the majority the ability to retrofit aircraft was perceived as being the main hurdle. Our analysis shows that although the solution is now available for the majority of the General and Business Aviation fleet, there is much lower availability within the Commercial and Regional segments where upgrade costs are significantly higher. For rotorcraft (considered within General and Business Aviation) there is an increasing demand for EGNOS enabled operations (e.g. PinS), but the segment is currently lacking suitable retrofit paths compared to fixed-wing aircraft, as the rotorcraft options are more challenging from a certification perspective.



* The chart shows the percentage of aircraft within the fleet which have an EGNOS solution available to them, VFR is not included as the devices are hand held.

GALILEO Galileo, as part of a multi-constellation and multi-frequency navigation solution, will enable ever more accurate PBN routes, maximising the capacity of airspace around the world. Innovative techniques such as GBAS approaches (with minima at CAT II or CAT III standards) are expected to be possible using multi-constellation/multi-frequency GNSS, which will enable A-RAIM.

Work is on-going within ICAO to produce standards for the use of Galileo in Aviation. EUROCAE is addressing standardisation issues in its Working Group 62. This will cover:

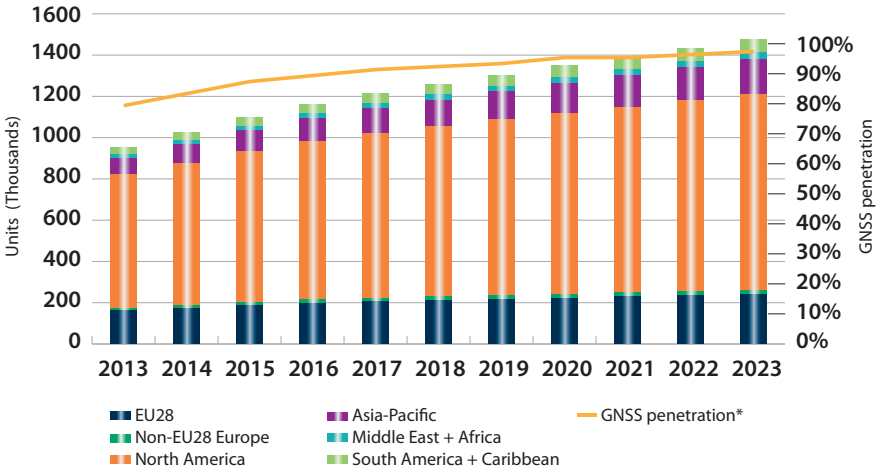
- Recommendations for operational use of GNSS;
- Airborne GPS/Galileo/SBAS receiver equipment Minimum Operational Performance Standards (MOPS); and
- Precision approach for combined Galileo/GPS systems.

"Filling the gap" in GNSS Advanced Procedures and oPerations

FilGAPP was an FP7 funded project ended in 2014, that demonstrated efficient and accurate methods for navigating airspace based on GNSS. Such advanced operations included approaches with curved approach or missed approach segments, delivering such benefits as increased accessibility and safety in mountainous airports, increased accessibility in constraint aerial zones, and reduced noise impact for cities neighbouring airports. The project successfully demonstrated advanced arrival and departure flight operations performed by business and regional operators in German and Spanish airports facing such constraints (Egelsbach, Saarbrucken, Valencia and Pamplona).

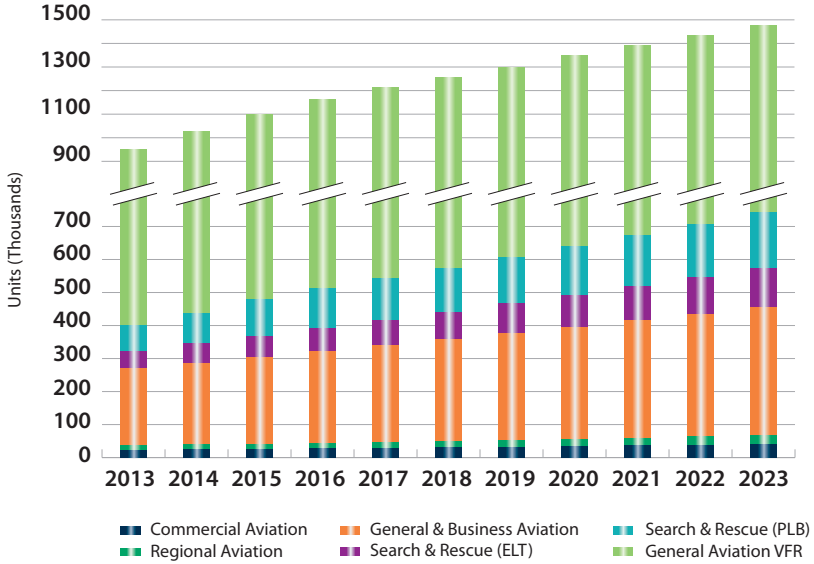
The demonstration was the first time a high-precision, high-integrity missed approach/departure performed in Europe. It was based on innovative flight management systems and a GNSS receiver. The operations, including curved approaches, demonstrated a reduction in the trajectory to be flown – saving fuel and time and reducing the overall environmental impact of the flight. The demonstration flights also validated technical and operational independence from nearby ATC systems, assuring increased operational capacity for airports.

Installed base of GNSS devices by region

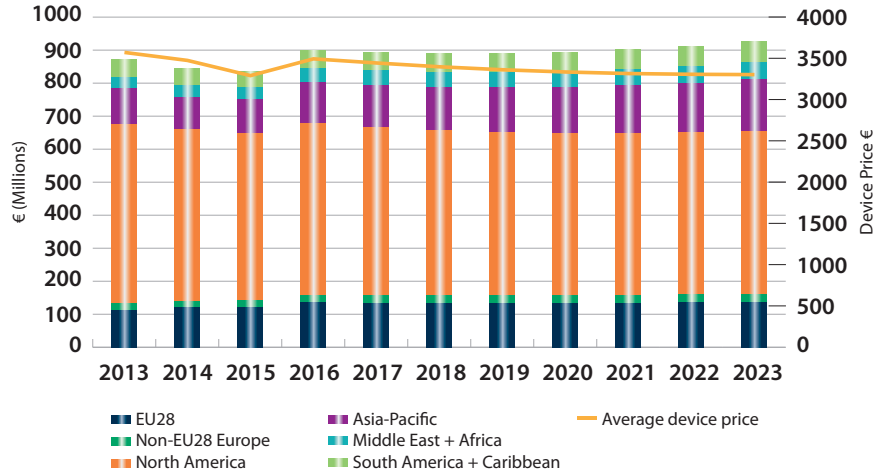


* GNSS penetration is defined as the proportion of all aircraft /pilots/PLBs that are fully GNSS equipped

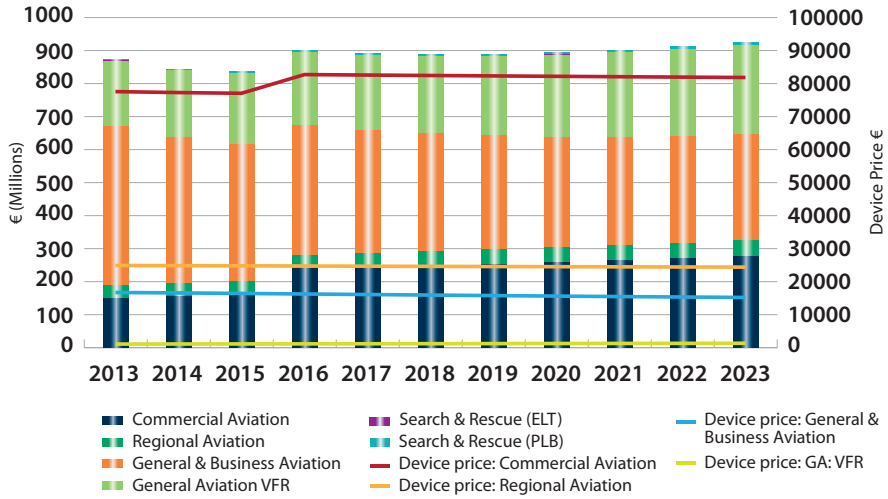
Installed base of GNSS devices by application



Core revenue of GNSS device sales by region



Core revenue of GNSS device sales by application



The use of IFR devices is expected to increase, driven by PBN implementation. Despite increasing GNSS shipments, revenue growth will slow down as the market becomes dominated by forward-fit aircraft (which have a lower cost). The increase of an average price of Commercial Aviation devices in 2016 is due to anticipated retrofits of SBAS capability.

Rail

GNSS applications

- **High Density Command & Control Systems** assist train command and control on main lines, referring primarily to the European Train Control System (ETCS) in Europe and some regions in the rest of 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 small 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.

In this chapter

- **Key trends:** GNSS as a solution to increase safety and reduce costs.
- **Industry:** List of main players by value chain segment.
- **Recent developments:** European and Asia-Pacific regions leading GNSS shipments in Rail.
- **Future market evolution:** GNSS to become standard equipment within a decade.
- **User technology:** GNSS potential in Transit Signal Priority applications.
- **Focus on European GNSS:** European GNSS on the way towards safety-relevant applications.
- **Reference charts:** Evolution of GNSS devices' installed base and revenues by segment and geographic area.

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GNSS: a solution to increase safety and reduce costs

Key market trends

- Non-safety relevant applications in Rail are already widely based on GNSS.
- Safety-relevant applications are emerging with different maturity levels depending on region, e.g. in India, China and the Middle East, GNSS is taking up an important position.
- GNSS based solutions can offer safety at a lower cost, e.g. as investigated in railway signalling.

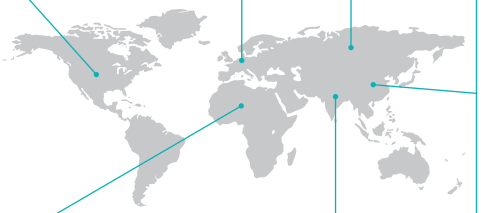
Different levels of maturity for GNSS consideration in Rail applications

The way in which GNSS is used for train applications is different from one region to another. The amount of initiatives in the world shows the consideration given 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). GNSS, being an innovative solution capable of decreasing costs, has been included in the ERTMS roadmap. **Shift2Rail, the first European Joint Undertaking** initiative for railways, has been launched as a concrete action to accelerate the integration of technologies, including the use of GNSS, into rail solutions. The key stakeholders developing the ERTMS technical specifications are **the European Railway Agency** (system authority), **ERTMS Users Group** and and **UNISIG** (a member of UNIFE developing the ERTMS specifications).

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

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



China is investing heavily in infrastructure modernisation with the construction of new railways. GPS 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.

After many years of neglect, rail infrastructure in the **Middle East and North Africa** has experienced a huge growth, especially in railway construction over the last 10 years, and with more significant investments planned ($200bln). The champion 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 applications. Huge investments are planned by the Indian government, and trials are on-going to deploy the Train Collision Avoidance System (TCAS). It is considered as a cost-effective solution thanks to the use of GNSS.

GNSS opportunities for the users

GNSS can bring many benefits depending on types of applications and specific user needs:

- For passengers, there is a strong need of **getting precise travel information**, which is aleady being widely implemented.
- For **asset management**, GNSS is becoming a necessity.
- GNSS enabled signalling applications **provide increased safety and reduce costs** of infrastructure management and operations compared to legacy signalling solutions.

In the Rail segment, safety comes first

- Introduction of rail applications must consider the constraints in the specific railway environment (e.g. limited satellite visibility, significant multipath or even electromagnetic interference).
- GNSS performance compliance to expected requirements for safety-relevant rail applications is being analysed. Accuracy and integrity requirements that are under development within UNISIG are expected to be very stringent.
- The use of GNSS should continue the growth in non-safety-relevant applications. Many rail freight cars, for which GNSS can be used for asset tracking, currently contain no power supply. Alternative solutions and their associated costs are being investigated first.

Rail Value Chain

COMPONENTS MANUFACTURERS (RECEIVERS AND OTHERS	SYSTEM INTEGRATORS	TRAIN MANUFACTURERS	TRAIN OWNERS/ OPERATORS	INFRASTRUCTURE MANAGERS
TRIMBLE SEPTENTRIO* NAVIS GARMIN BROADCOM FURUNO HEXAGON (LEICA GEOSYSTEMS)* OMNICOM U-BLOX* INFINEON TECH*	ANSALDO STS* GENERAL ELECTRIC ALSTOM* SIEMENS* THALES* BOMBARDIER TELESPAZIO* NOTTINGHAM S. L.*	SIEMENS* BOMBARDIER ALSTOM* HITACHI CHINA SOUTH LOCOMOTIVE AND ROLLING STOCK	**TOCs & FOCs**:** DEUTSCHE BAHN* TRENITALIA* SNCF* ARRIVA* COLAS* RENFE* VEOLIA* STAGECOACH* and Urban Transpors Operators **ROSCOs**:** INVESTMENT BANKS, CONSORTIA, NATIONAL COMPANIES	DEUTSCHE BAHN (DE) RFI (IT) SNCF (FR) NETWORK RAIL (UK) ADIF (SP) and Urban Transport Operators

The EU GNSS industry in the global arena

The Rail industry is concentrated in Europe and North America, both in terms of components and receivers and system integrators.

European companies have a market share of 38% among components and receivers, with the segment being dominated by North American companies.

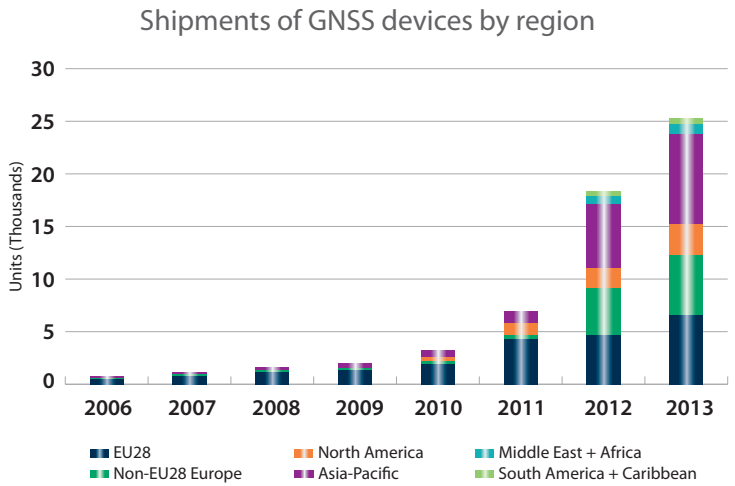
The top three European companies are Septentrio, Hexagon (Leica Geosystems) and U-Blox.

Among system integrators, European companies have a dominant role with 72% of the market, and the key European operators have strong exports in North America and Asia. The top three European companies in this segment are Ansaldo, Alstom and Siemens.

* European companies

** TOC: Train Operating Company, FOC: Freight Operating Company, ROSCO: Rolling Stock Operating Company
Value chain considers the key global and European companies involved in the GNSS dowstream activities.

Europe and Asia-Pacific regions lead GNSS Rail shipments



The existing infrastructure differs greatly across regions, as well as in use. Transport policies, as well as lifestyle and passenger habits, have an impact on the infrastructure.
For instance, **North America** has the second largest railway network in the world, but the second lowest number of passenger journeys among the regions.
On the other hand, the **Asian network** is heavily used for passenger transport. In Europe, Rail has been traditionally strong in terms of both infrastructure availability and usage of trains by passangers.

The size of the railway network and number of passenger journeys per year for each region in 2011

Statistic	Unit	EU28	North America	Asia-Pacific	Non-EU28 Europe	Middle East + Africa	South America + Caribbean
Length of track	th. km	348	317	305	199	42	39
Passenger journeys per year	mln	7,507	78	18,873	2,193	584	24

As a general trend, shipments of GNSS devices have been constantly growing in the last years, with growth significantly intensifying since 2012.

Europe was the early adopter of GNSS and took the majority of shipments in the early years. Europe (encompassing EU28 and non-EU28 Europe) is still the leading region, especially due to high development of non-safety relevant applications related to **passenger information**. In 2013, the European market represented 49% of shipments.

Asia-Pacific is the other main region in terms of GNSS shipments, showing a very dynamic evolution. Rail networks are particularly important in this area. China has heavily invested in rail infrastructure and has the 2nd largest railway network, whereas India has the world's 4th largest railway network. The rapid growth of rail infrastructure and thus applications requires enhanced means for **train management to ensure safety**. GNSS technology contributes to answering this need. The Asia-Pacific market represented 34% of GNSS shipments in 2013.

The **Middle East and Africa** regions are emerging. Heavy investments are planned in the Middle East (particularly in Saudi Arabia and Qatar) and in North Africa (e.g. in Algeria). Apart from these regions, the African market still remains behind. Although Africa's railways are disjointed and disconnected, there is a clear willingness to connect railway networks in different countries. This will require **interoperability** that could partially be provided by GNSS, especially as very few legacy systems are in place and GNSS based systems are more easily deployed.

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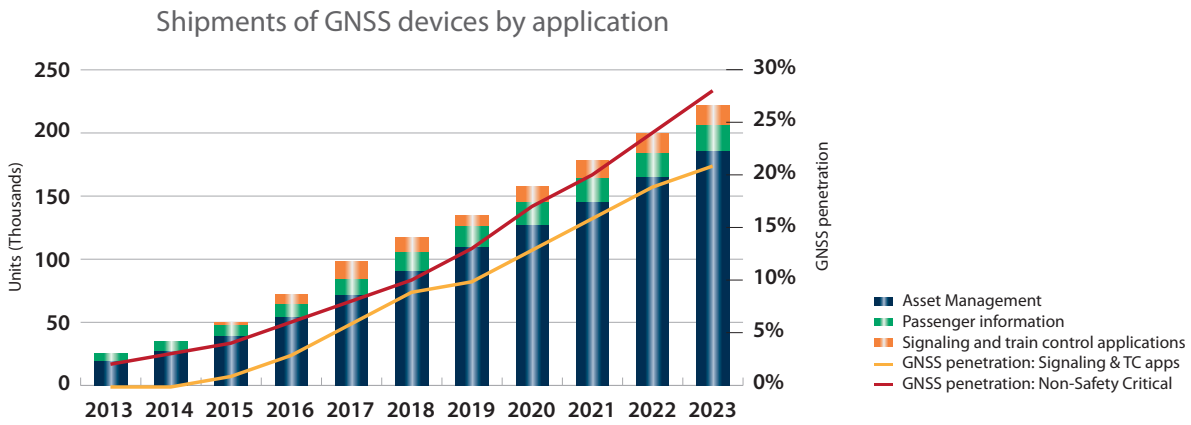
GNSS to become standard equipment within a decade



Asset management applications are currently driving and expected to continue to drive shipments of GNSS devices. For the nearly 220,000 trains in the world dedicated to freight, the number of wagons with GNSS equipment is around 2.8 mln.

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 towards them, GNSS may be used as:

- Primary means as foreseen in the US with PTC;
- A back-up solution as planned in Europe; or
- Even one of the means within a hybrid solution.

In any case, GNSS is to be considered as an innovative solution allowing to **cut operational** costs while also increasing safety. As an example, maintenance of on-board equipment located under the trains, such as balise readers, is very costly. GNSS is an opportunity to reduce reliance on balises and therefore decrease operational costs.

GNSS penetration* will strongly increase in the coming years. The availability of Galileo also strengthen this trend.

There are many on-going activities in Europe to ensure the feasibility of Rail safety-relevant, satellite-based applications capable of being used in operation.

On-going EU-funded R&D: Next Generation Train Control

The NGTC project addresses technical interoperability of different rail systems. The main scope is to analyse the commonality and differences of required functionality for mainline and urban lines, and develop the convergence between the currently used train control and communication systems – determining the level of commonality of architecture, hardware platforms and system design that can be achieved.

In addition, the NGTC project aims to apply new technologies, including GNSS, to the new train control system.

The project is coordinated by UNIFE, the Association of the European Rail Industry, that is contributing to defining the new cotrol systems specifications that will be further develped in the Shift2Rail Joint Undertaking. The project started in 2013 and is planned until August 2016.

* GNSS penetration is defined as the proportion of all possible GNSS devices in the market that are currently in use. In case of Signalling and train control applications, it is assumed that a train with full GNSS adoption will have two GNSS devices. For non-safety critical applications (asset management and passenger information), it is assumed that a fully equipped freight train will have a GNSS device on each wagon, while a fully equipped passenger train has one GNSS device in total. This implies a very significant increase in shipments compared to the way asset management was addressed in the previous edition of the GNSS Market Report.

GNSS potential in Transit Signal Priority applications

Despite the trend to include GNSS in safety-relevant applications, GNSS is currently used in non-safety-relevant ones, such as in passenger information and asset management, where technological innovation plays an important role.

Due to upcoming market opportunities, the **manufacturers are preparing to enter the railway signalling domain**, which belongs within the realm of safety-relevant applications.

The chart on the left below shows that GLONASS is already present in almost 70% of available receivers*, favourably influenced by the deployment of the Russian KLUB-U train control system, using both GPS and GLONASS technologies for train positioning. The inclusion of SBAS is considered relevant and more than 70% of available models have integrated this augmentation.

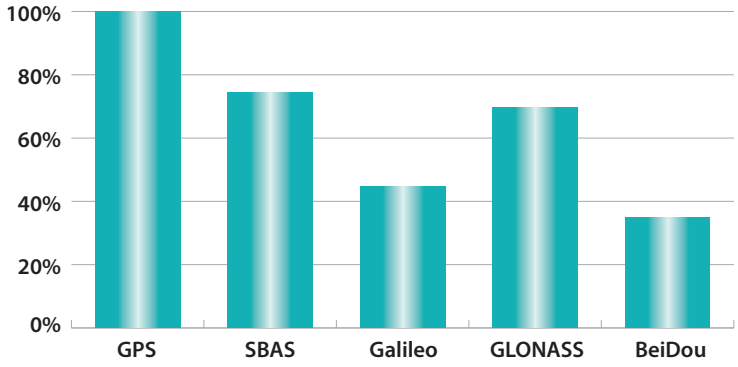
The chart on the right below highlights that multi-constellation is recognised as a valuable feature and the percentage of devices capable to track multiple constellations is c. 75%.

Future applications will benefit from multi-constellation, further enhancing their positioning performance.

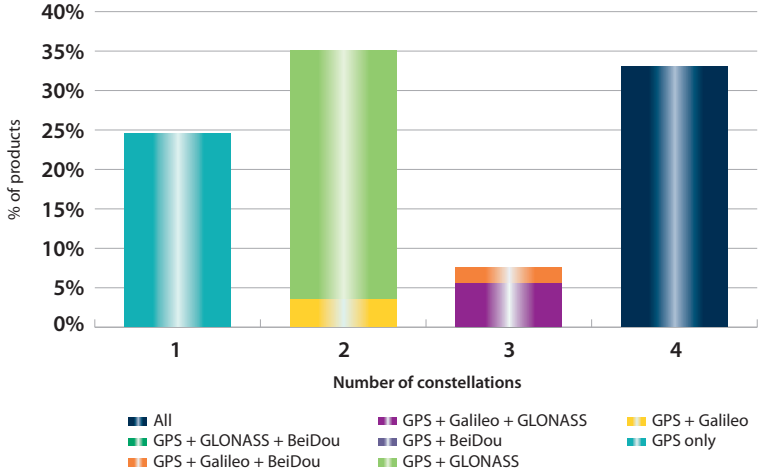
It has also been demonstrated in the course of the Galileo Signal Priority (GSP) FP7 project that the **integration of SBAS, such as EGNOS, is a key enabler for further enhancing GNSS positioning accuracy.**

For example, in **Transit Signal Priority (TSP)** still dominated by conventional technologies such as infrastructure beacons, GNSS provides a new approach that applies on-board intelligence with the same level of reliability provided by the incumbent technology. TSP is an application aimed at improving service and reducing delays for mass transit vehicles, such as trams at intersections controlled by traffic signals. The fact that GNSS allows the "priority request system" to be directly located on the transit vehicle, enables relevant benefits for citizens and the public transport operators. For instance, it results in reduced expenditures, thanks to the lower cost of GNSS OBU compared to roadside equipment, as well as a reduction in delays thanks to reliable real time communication of the position with the traffic management centre (in combination with other technologies).

Capability of GNSS receivers – Rail segment



Supported constellations by receivers – Rail segment



* For the methodology applied to the charts please go to page 15 of the Report.

European GNSS on the way towards safety-relevant applications

European GNSS differentiators

EGNOS, thanks to its capability to both improve accuracy of the positioning solution and provide integrity information, permits the determination of train locations without the need for dense trackside infrastructure. Investigations are currently on-going to characterise the expected level of performance for Rail applications by using GPS and, in the future, Galileo, with EGNOS augmentation – specifically for safety-relevant applications. In the meantime, EGNOS is starting to be used for some of the non-safety relevant applications, e.g. transit signal priority.

The multi-constellation environment, with interoperability of Galileo with GPS, as well as EGNOS augmenting both systems, will permit to enhance currently achievable performance, such as signal availability in difficult environments and final position accuracy. This will reinforce the use of GNSS in rail applications in the future.

European EGNSS R&D Programmes support competitiveness of the EU industry

Story of successful EU-funded R&D: GaLoROI

The GaLoROI project aimed to develop a certified, safety-relevant, satellite-based on-board train localisation unit to be used on low density railway lines. In the project, a European GNSS based train positioning solution was used, instead of conventional railway localisation equipment so, to provide a cost benefit solution for low density lines.

GaLoROI delivered its final conclusions in mid-2014, finding that a satellite based localisation unit for the safety-relevant application in railways was developed and successfully tested (field tests in a railway environment of the functionality and quality of the localisation unit). Further steps after the end of the project rely on the approval of the localisation unit on a track with respective demand for it from the operator and the relevant infrastructure manager.

More information can be found at: http://www.galoroi.eu/

Source: GALOROI project

On-going EU-funded R&D: ERSAT EAV

The main ERSAT EAV objective is to verify the contribution of EGNSS (EGNOS and Galileo) for safety-critical railway applications, in particular in regional lines, for which a safe localisation of the trains based on satellite technologies will be defined and developed. This will pave the way for harmonisation with the European ERTMS standard, by implementing the solution on a pilot line as reference.

In the first phase, the project will measure and evaluate the gaps to be filled in terms of technological criticalities and railway requirements. Then the measurements under real operating conditions will be performed, building models and analysis with the help of simulations. Finally, a system solution will be defined, developed, implemented, tested and validated on the pilot line, as reference for the future standardisation and certification processes.

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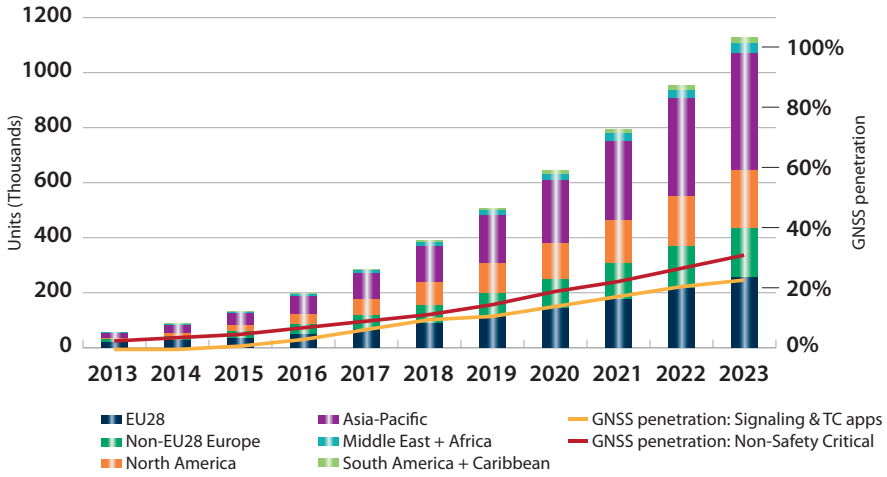
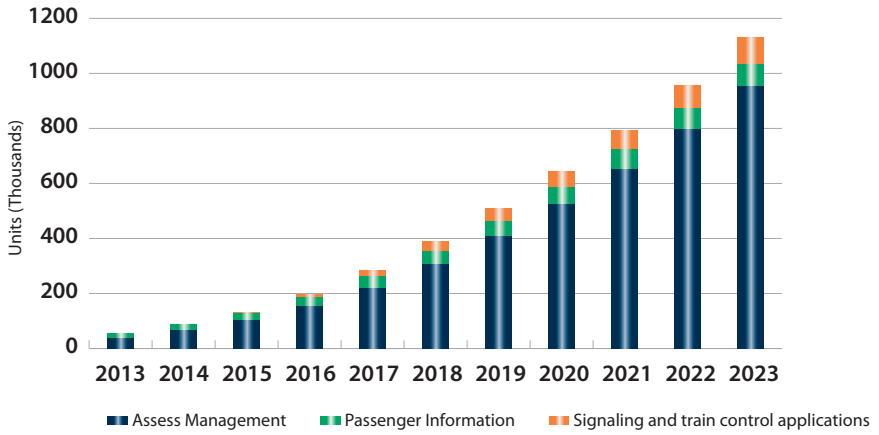
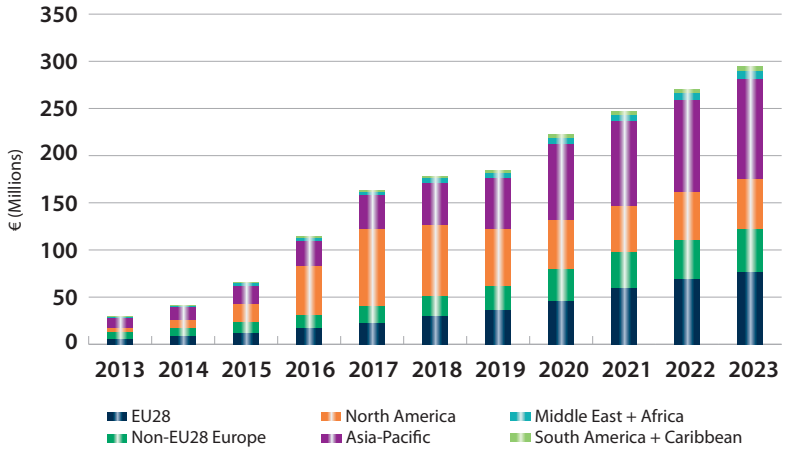
Installed base of GNSS devices by region



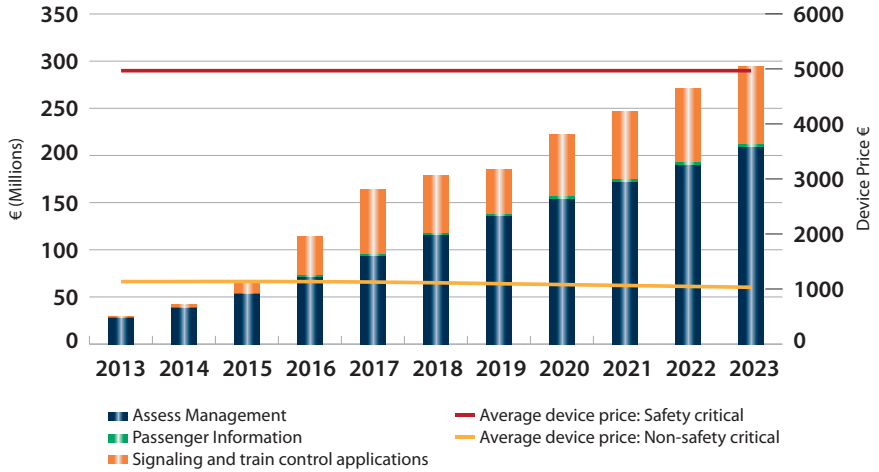
Installed base of GNSS devices by application



Core revenue of GNSS device sales by region



Core revenue of GNSS device sales by application



Maritime

GNSS applications

According to the distinction provided by IMO[1] Resolution A.915(22), GNSS applications can be split into navigation and positioning:

Navigation

- **Sea**
  - **SOLAS[2] vessels:** All passenger ships and cargo ships larger than 500 gross tonnage (300 tons for international voyages) are regulated and rely heavily on GNSS for navigation. At least three devices are typically fitted on vessels for redundancy reasons.
  - **Non-SOLAS vessels:** GNSS systems for maritime navigation are widespread across commercial and recreational vessels, both overseas and in high traffic areas.
- **Inland Waterways (IWW):** GNSS is also used to ensure safe navigation in inland waterways (rivers, canals, lakes and estuaries).

Positioning

- **Traffic management and surveillance:** These activities are supported by GNSS-based systems including **AIS**[3] and **LRIT**[4].
- **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. **EPIRBs**[5] and **PLBs**[6]) transmit, once activated, the necessary information for rescue to authorities via satellite communication.
  - When activated, **AIS-SART**[7] devices continuously transmit an alert message that includes GNSS-based location, which triggers an alarm on all AIS equipped vessels within VHF8 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).

In this chapter

- **Key trends:** GNSS is a key enabler of navigation and positioning marine applications.
- **Industry:** List of main players by value chain segment.
- **Recent developments:** Recreational vessels account for an increasingly large share of GNSS shipments.
- **Future market evolution:** Search and Rescue beacons and recreational navigation will further drive GNSS growth.
- **User technology:** The added value of multi-GNSS receivers led the IMO to invest in the development of new performance standards.
- **Focus on European GNSS:** Accelerated process of IMO recognition in WWRNS[9] will speed up the uptake of Galileo.
- **Reference charts:** Yearly evolution of GNSS devices' installed base and revenues by segment and geographic area.

NEW! This issue of the GNSS Market Report includes three new applications: Recreational navigation, Search and Rescue PLBs and Fishing Vessels.

1 **IMO:** International Maritime Organization
2 **SOLAS:** International Convention for the Safety of Life at Sea
3 **AIS:** Automatic Identification System
4 **LRIT:** Long-Range Identification and Tracking
5 **EPIRBs:** Emergency Position Indicating Radio Beacons
6 **PLBs:** Personal Location Beacons
7 **AIS-SART:** AIS Search and Rescue Transmitter
8 **VHF:** Very High Frequency
9 **WWRNS:** World-Wide Radionavigation System

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GNSS is a key enabler of navigation and positioning marine applications

Key market trends

- The market demand for positioning and navigation supports a wide range of GNSS applications, improving safety and productivity of maritime operations.
- GNSS-enabled solutions are increasingly used to monitor the operations of fishing vessels.
- GNSS is the preferred positioning technology for maritime Search and Rescue solutions.

In the Maritime segment, GNSS is employed to satisfy the demand for **navigation** (in open sea or in specific situations, such as harbour entrances and approaches) and **positioning** (including, among others, vessel monitoring, traffic management, locator beacons for distress situations, etc.) of vessels and crews by different stakeholders.

The **e-Navigation** initiative of the IMO aims to enhance the safety and ease of navigation by integrating all navigational tools in an all-encompassing bridge system. As e-Navigation systems should be resilient, they can drive the uptake of multi-constellation GNSS.

The use of positioning in Maritime is widespread, with different categories of **vessels**, **beacons** and **ports** using GNSS for different purposes.

Global number of vessels, beacons and ports

Vessels	Merchant vessels	Fishing vessels	Recreational vessels	IWW vessels
	81,500 vessels	2.7 million vessels	29.2 million vessels	529,000 vessels
Beacons	EPIRBs		PLBs	
	648 k beacons		580 k beacons	
Ports	Sea ports		Recreational marinas	
	8,289 sea ports		23,380 marinas (in 20 countries)	

The **end users in Maritime** are ship masters, pilots and port authorities. The **beneficiaries** are a much wider category, including passengers, companies served by the maritime supply chain and through logistic applications, and consumers of sea products.

The user needs and **performance requirements** of GNSS solutions depend heavily on the applications, designed to satisfy needs of **improved safety and productivity**. In this sense, accuracy and integrity are key for navigating in restricted waters (e.g. port approach, inland waterways) as well as for positioning applications (e.g. manoeuvring, traffic management, Search and Rescue operations, marine engineering), as per IMO resolution A.915.

GNSS and the control of fishing vessels in the EU

Almost 5 mln tonnes of fish are caught yearly by the 87,500 EU fishing vessels. 70% of the EU vessels belong to Greece, Italy, Spain, France, Croatia and the UK.

Starting in the 1970s, the European Commission progressively legislated fisheries and aquaculture, aiming to **balance resources and exploitation**. This set of legislation evolved into the **EU Common Fisheries Policy (CFP)**, whose most recent reform took effect on 1 January 2014. The EU maritime surveillance system now relies on a series of GNSS-enabled technologies for vessels detection and monitoring:

- The **Vessel Monitoring System (VMS)**, a satellite-based system providing data to fishery authorities at regular intervals on the location, course and speed of EU fishing vessels above 12m. Notably, non-EU vessels of the same size must have an operational satellite tracking device whenever they are in Community waters.
- The **Automatic Identification System (AIS)** is an identification and monitoring system used for maritime safety and security (but also for control purposes), allowing vessels to electronically exchange identification data, position, course and speed. Since May 2014, it has been mandatory on vessels above 15m.

As a result of the regulation, 9,000 fishing vessels are now equipped with VMS devices in the EU, whereas 8,000 are fitted with AIS transceivers.

Maritime Value Chain

MARITIME ORGANISATIONS	COMPONENTS MANUFACTURERS (RECEIVERS AND OTHERS)	SYSTEM INTEGRATORS	SHIP OWNERS/ OPERATORS	PORTS
IMO sets the standards for safety, security of shipping and pollution prevention. **IALA** is an international technical association harmonising aids to navigation.	FURUNO OROLIA* JAPAN RADIO CO HEXAGON (NOVATEL)* TRIMBLE RAKON SAMYUNG ENC LAIRD*	GARMIN LTD. KONGSBERG* NAVICO* JOHNSON OUTDOORS MITSUBISHI SAFRAN* FURUNO RAYMARINE	MAERSK LINE* MSC* CMA CGM GROUP* EVERGREEN APL	Container Ports, Cruise/Ferry Terminals, Marinas.

The EU GNSS industry in the global arena

European companies have a market share of 28% among components and receivers manufacturers, with the market being dominated by Asian players. The top three European companies are Orolia (including McMurdo), Hexagon and Laird.

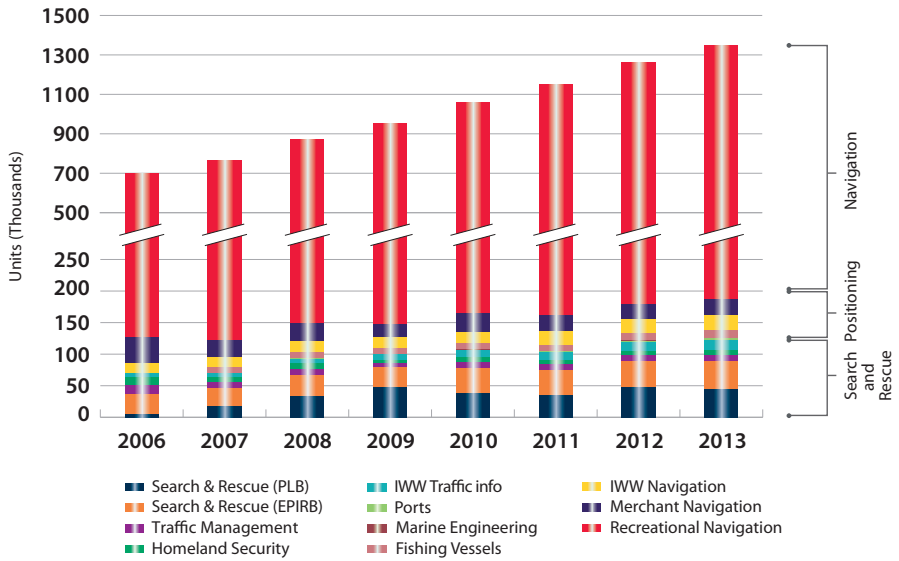
Among system integrators, European companies have a strong presence with a 45% share of the market, compared to North America's 35% share. The top three European companies are Kongsberg, Navico and Safran.

* European companies

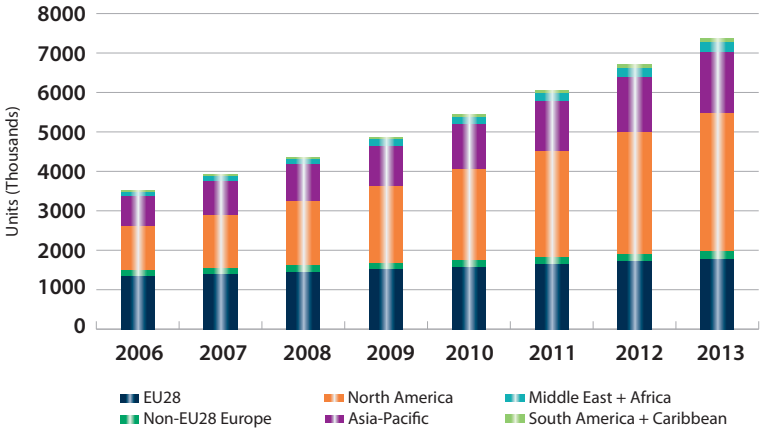
Value chain considers the key global and European companies involved in the GNSS dowstream activities.

Recreational vessels account for an increasingly large share of GNSS shipments

GNSS unit shipments by application



Installed base of GNSS devices by region



According to ICOMIA*, there are around 29 mln recreational vessels in use (defined as rigid hull boats longer than 2.5m and not man-powered), whereas other crafts, including fishing vessels, are estimated to be around 3.3 mln. This explains the relevance of GNSS shipments for **recreational navigation**, despite the fact that GNSS penetration is higher in merchant vessels than in recreational and fishing vessels (87% in merchant against 22% in recreational vessels and 8% in fishing vessels across all applications and globally). Average GNSS penetration is provided in the Maritime reference charts on page 55. North America accounts for the majority of shipments, which in 2013 was recorded at 715,000.

Aside from recreational navigation, Search & Rescue represents the most relevant market for GNSS. Since 2009, the shipments of Cospas-Sarsat GNSS-enabled **emergency beacons (EPIRBs and PLBs)** stabilised at around 80,000 units per year (c.a. 40,000 each). The main regional markets are Asia-Pacific and the EU28 for EPIRBs, and North America and Asia-Pacific for PLBs.

On **fishing vessels**, both Vessel Monitoring Systems (VMS) and Automatic Identification Systems (AIS) are used by national authorities to track and monitor the activities of their national fishing fleets. The largest regional market is China, where some 50,000 BeiDou enabled devices are used both for basic communication across the fleet and for monitoring the use of authorised fishing areas, and in particular in contested waters (e.g. Taiwan).

The device market is dominated by market players in different applications

Maritime applications are very diverse and rely on various systems integrating different technologies for specific purposes. The large system integrators are specialised accordingly. Garmin focuses mainly on recreational navigation, Kongsberg provides high-tech professional solutions for merchant fleets and oil and gas applications, whereas Orolia favours Search & Rescue and vessel monitoring solutions. By contrast, Furuno, the largest receiver manufacturer, is active in most maritime applications, including recreational and merchant navigation and vessel monitoring.

Search and Rescue beacons and recreational navigation will drive further GNSS growth

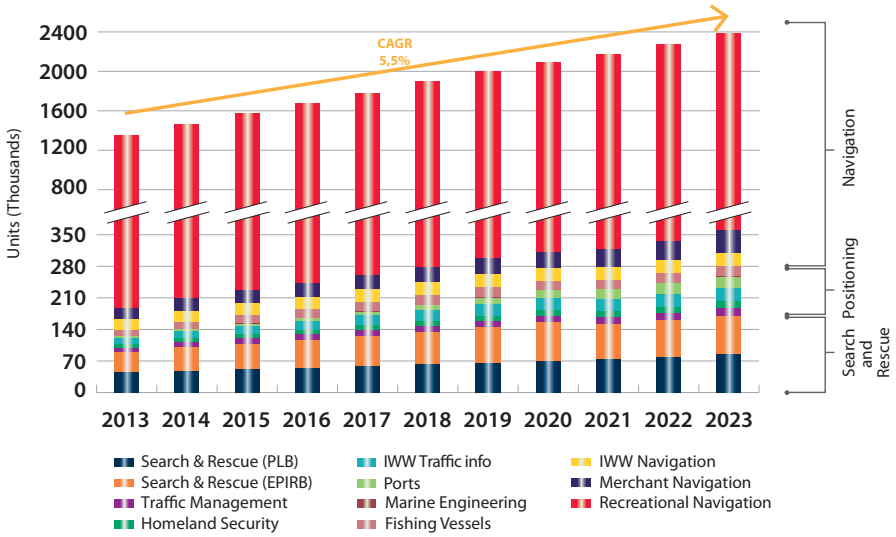
In the coming years, recreational vessels will be responsible for the further growth of GNSS yearly shipments, which will almost double from 1.15 mln units in 2013 to 2.0 mln in 2023.

In **recreational navigation**, GNSS solutions are spreading quickly, as end users have a strong inclination towards technological aids to navigation tools and tend to exhibit robust spending power. Since skippers do not have to rely on mandated equipment, they also use non-professional handheld or portable navigation devices.

GNSS shipments for **merchant navigation** are expected to almost double in the next ten years, reaching some 50,000 units.

Considering the geographical distribution of GNSS devices and revenues, **North America** is expected to remain the most important region in installed GNSS devices for maritime applications, although Asia-Pacific is growing at a faster pace. The installed base of GNSS devices in **Europe** is expected to increase slowly but steadily (see Maritime reference charts on page 55). Overall, the GNSS penetration is expected to double over the next decade, from 20% to 40%.

GNSS unit shipments by application



GNSS is increasingly at the core of Search and Rescue solutions

Search & Rescue beacons used within the Cospas-Sarsat programme significantly contribute to saving human lives, thanks to their capability of transmitting distress messages with global coverage. It is estimated that Cospas-Sarsat provides assistance in saving six lives every day.
In the coming years, both the EPIRBs and PLBs markets are foreseen to grow thanks to technology upgrades, improved operational efficiency, portability and durability. The role of GNSS in providing precise positioning information will be even more central as the penetration of GNSS in EPIRBs is foreseen to grow from 70% to 100% in 2020, whereas in PLBs it is already close to 100%.

In 2014 **AIS SART** devices gained popularity following the Clipper Round the World Yacht Race, where Andrew Taylor was successfully recovered by his crew thanks to his AIS SART beacon. As a result, shipment of devices have skyrocketed during the year (not yet included in the estimates of the market shipments).
The market is evolving rapidly, with end users starting to ask for solutions that combine Cospas-Sarsat and AIS capabilities.

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The added value of multi-GNSS receivers led the IMO to invest in developing new performance standards

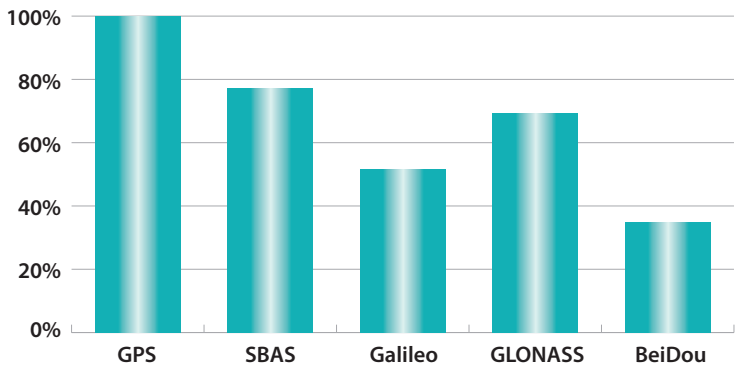
GNSS has become the primary means of navigation in many Maritime applications. The International Maritime Organization (IMO) has set **operational performance requirements for GNSS** to be recognized as World-Wide Radio Navigation Systems (WWRNS). These requirements are used as a benchmark to assess the performance of the potential core systems and their augmentations. They are expressed in the maritime context in terms of accuracy, coverage, availability, continuity and integrity warnings.

The ability to concurrently receive GNSS and augmentation signals from multiple satellites belonging to different constellations allows receivers to have a higher probability of acquiring a greater number of satellites at any single point in time. Consequently, navigation performances will be greatly improved, enhancing the users' experience and increasing the possibility for GNSS receivers to meet IMO performance standards.

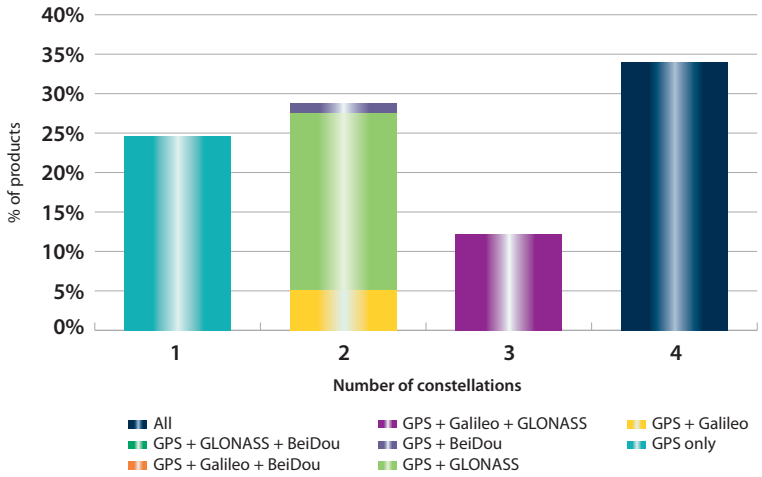
In order to ease the introduction of multi-GNSS receivers into the Maritime segment, **the IMO "Maritime Safety Committee 90" introduced the need to develop new performance standards for navigation receivers**. These new standards will enable full use of the availability, continuity and integrity, as well as increased accuracy, thanks to a combination of multi-constellation GNSS and terrestrial and augmentation systems. To this extent, the IMO "Sub-Committee on Safety of Navigation, Radio Communications and Search & Rescue" is charged with developing "Performance Standards For Multi-System Shipborne Navigation Receivers". The status of the initiative is advanced and such standards are expected to be provided in the course of 2015.

Anticipating the provision of standards, the **adoption of multi-constellation in user equipment has already started**. The charts below show the penetration of SBAS and the four global GNSS systems in the current maritime GNSS devices' offering*. Around 75% of all devices have implemented at least two constellations (see chart on the right). The most popular system, after GPS, is GLONASS, supported by regulatory measures taken by the Russian Federation. Galileo and BeiDou are increasingly present, and more than 30% of receivers are capable of processing all constellations simultaneously.

Capability of GNSS receivers – Maritime segment



Supported constellations by receivers – Maritime segment



* For the methodology applied to the charts please go to page 15 of the Report.

Accelerated process of recognition in WWRNS will speed up Galileo adoption

EGNOS is already supporting **navigation and positioning** applications, both in sea and inland waterways, complementing DGNSS infrastructure. Trials conducted by the European Commission demonstrated EGNOS compatibility with IMO requirements (i.e. accuracy requirements for coastal navigation and horizontal alert limit requirements for navigation areas outside ports) thanks to several tests at different sites.

The benefits of EGNOS are also leveraged in AIS SART beacons, where increased positioning accuracy and reliability can have a real impact on Search and Rescue operations. Finally, EGNOS corrections can be transmitted via AIS in harsh environments, thus contributing to increased safety and social benefits.

The inclusion of the unplanned item 'Recognition of Galileo as a component of the WWRNS' in the 2014-2015 biennial agenda of the MSC Committee of IMO is a major step for the **adoption of Galileo in SOLAS regulated vessels**. Galileo will guarantee the improved signal accuracy and availability required, in particular by positioning applications.

Furthermore, along with the **Forward Link** to transmit distress calls from beacons to Mission Controls Centers, Galileo will provide the unique **Return Link Service** within **COSPAS-SARSAT**, enabling it to inform the casualty of the reception of the distress message. It will thus be the only system providing a two-ways, end-to-end loop.

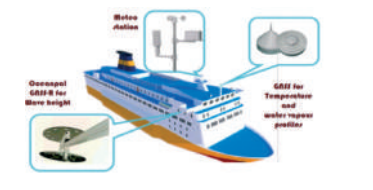
European EGNSS R&D Programmes support the competitiveness of the EU industry

The COSMEMOS project offers benefits for ship routing through cooperative satellite navigation

Marine weather forecasts are constrained by limited sea coverage: insufficient meteorological information raises safety concerns and entail additional economic and environmental costs, as weather conditions (waves and wind) can increase the fuel consumption of commercial ships by up to 12-13%.

The COSMEMOS (COoperative Satellite navigation for MEteo-marine MOdelling and Services) project proved that this gap can be addressed by collecting and processing a large amount of weather data provided by ships while navigating. Outcomes of this R&D project include improved local weather simulations and forecasts and contribute to advanced weather routing and navigation assistance for both commercial and leisure vessels.

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

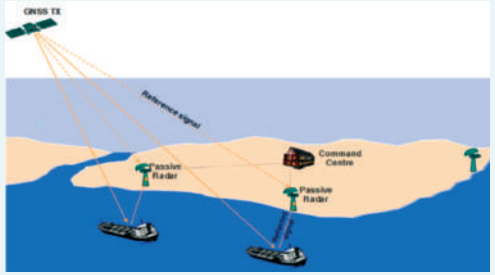


Source: COSMEMOS project

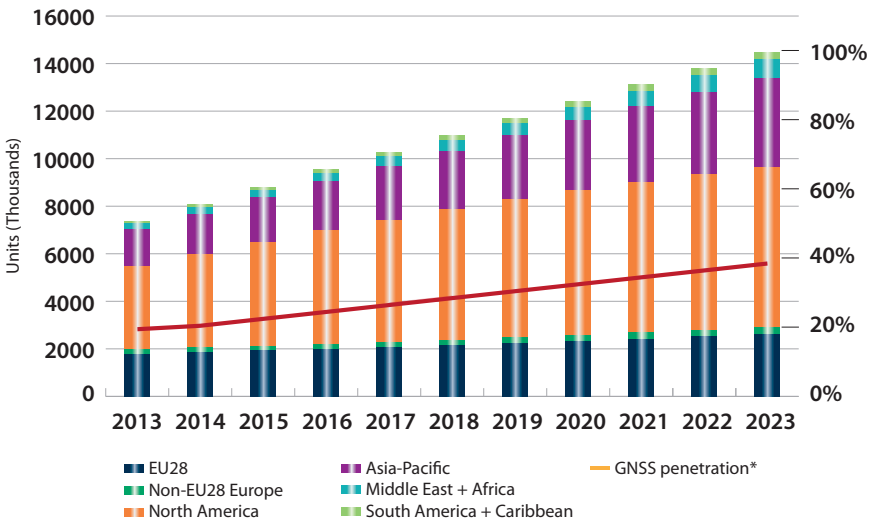
SpyGLASS integrates innovative technologies into Vessel Traffic Management Systems

The recurrence of illegal activities at sea - especially in the Mediterranean Sea – such as clandestine immigration, smuggling and trafficking, have made maritime surveillance a priority.

The SpyGLASS project aims to address this issue by developing a comprehensive solution based on passive bistatic radars (PBRs), installed on the coastline to detect signals transmitted by Galileo and reflected from targets (boats). By making use of the Galileo constellation, this compact and cost-effective system will provide enhanced open-sea monitoring with global coverage.

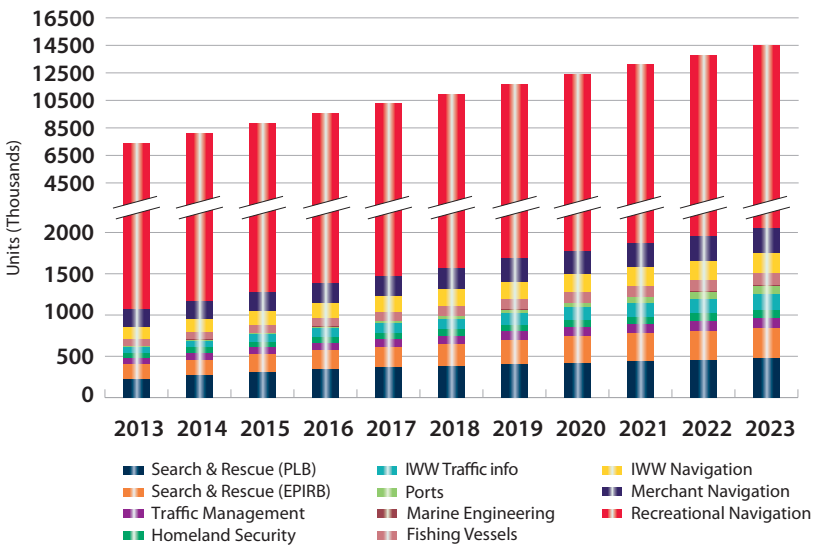


Installed base of GNSS devices by region

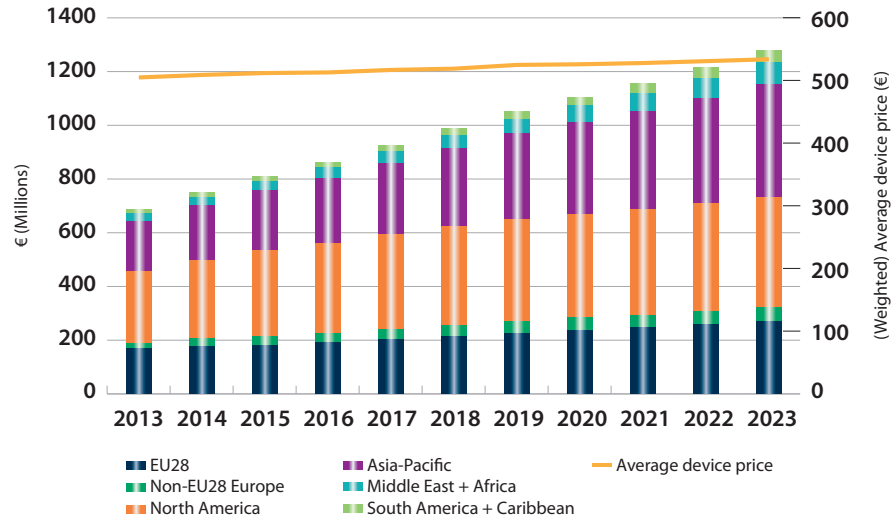


* GNSS penetration is defined as proportion of all possible vessels that are equipped with GNSS

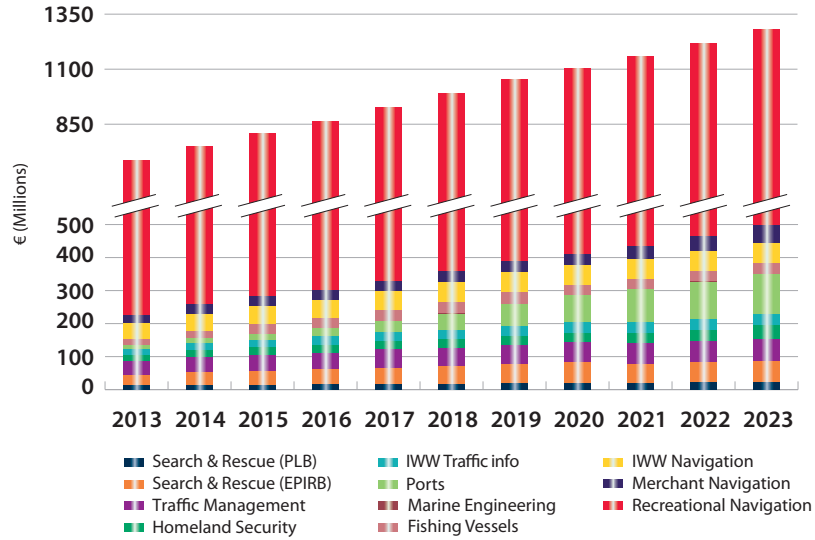
Installed base of GNSS devices by application



Core revenue of GNSS device sales by region



Core revenue of GNSS device sales by application



Agriculture

GNSS applications

Precision agriculture is the application of different technologies and solutions to make farming more efficient, improve crop yield and reduce the environmental impact. Key GNSS enabled applications include:

- **Farm machinery guidance** uses GNSS positioning to assist drivers in following the optimal path, thus minimising risks of overlaps.
- **Automatic steering** completely takes over the steering of farm equipment.
- **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 the 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 on 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 then used in VRT application maps.
- **Livestock tracking** and virtual fencing uses GNSS to track animals and provide virtual fencing.

Agri-logistic applications such as:

- **Farm machinery monitoring and asset management** use real-time GNSS information to monitor the location and mechanical status of equipment and to efficiently manage workflows.
- **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 delineation** is the precise measuring of the boundaries and size of agricultural fields and can be done with GNSS. In the case of the Common Agricultural Policy (CAP) in the EU, GNSS positioning is used by inspectors for on-the-spot checks to investigate non-compliance in the area-based subsidy system.

In this chapter

Precision agriculture boosts farming productivity and helps solve societal challenges

Key market trends

- The uptake of precision agriculture in Europe and worldwide will continue to grow, thanks to the benefits provided to farmers in terms of increased productivity.
- The Asia-Pacific region will progressively challenge the role of North America as the largest GNSS market.
- More demanding users are driving the evolution of precision agriculture towards all-around farm management solutions.
- GNSS supports the agri-environmental policies on both a regional and global scale.

GNSS applications offer high returns on investment

Precision agriculture is the application of different technologies and solutions to manage the variability of agricultural production, improving crop yield and reducing the sector's environmental impact. Precision agriculture systems **increase productivity** in all phases of the agricultural activity, from soil preparation to harvesting:

- Less time is needed per operation;
- Downtime due to fog or nightfall is reduced;
- Soil compaction is minimised by driving over precisely the same tracks;
- Fuel consumption is reduced;
- Savings on input costs (seeds, fertilizers, pesticides) are achieved;
- Soil and plant physicochemical parameters are monitored to ensure the optimal conditions for plant growth.

Innovative applications combine GNSS with other technologies

- **GNSS** enables the precise and reliable positioning of tractors, implements and other assets.
- **Earth Observation** will increasingly support digital applications used for precision agriculture. The European Copernicus Programme aims to develop a comprehensive Earth Observation capability. It provides different sets of information on land cover and valuable information to support precision agriculture solutions that leverage GNSS for positioning.
- **Aerial photography** from airplanes and UAVs can cost-effectively capture data for digital application maps.
- **Optical systems** can be utilised when crops have a row or a trim line that can be followed.

Sophistication of user needs drives the generation of new services

Farmers consider the type of cultivation and the size of their agricultural holding in selecting the optimal GNSS solution to satisfy their needs. High levels of **positioning accuracy** support the most demanding applications, such as automatic steering.

As with any other technology, precision agriculture solutions are also evaluated based on their **reliability** and **cost-effectiveness**.

With time, decision making power by end users has progressively increased. Farmers increasingly demand **ease of use** and **interoperability** of different services offered by various providers. This includes the possibility to integrate precision agriculture, digital mapping and asset management solutions into a single system.

The industry has reacted by starting to offer integrated platforms for **farm management**, which in the future could incorporate and replace services and products focusing only on in-field activities. Apart from reliability and cost-effectiveness for farmers, by addressing the challenges of limited land availability and increasing population, precision farming ensures **sustainability of agriculture**, reduction of **environmental footprint** and **food safety** for society.

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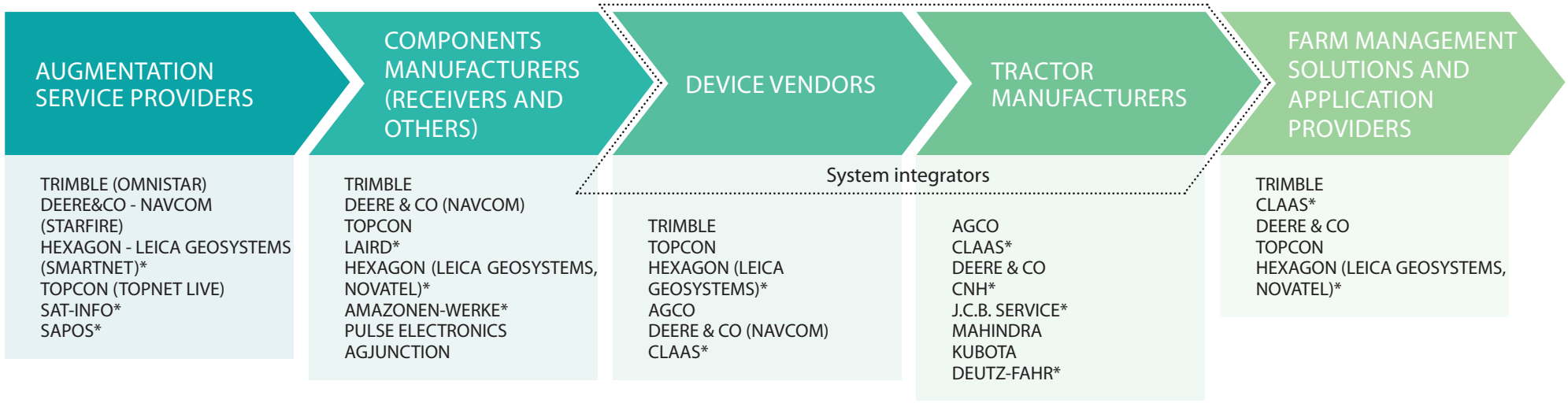
Agriculture Value Chain



The EU GNSS industry in the global arena

In terms of components and receiver manufacturers, European companies have a 10% share of the overall market, with the leading players being Laird, Amazonen-Werke and Hexagon. For system integrators, European companies have a market share of 28%, with the top three players being Hexagon and its subsidiary Leica Geosystems, Claas and CNH. Claas is an application provider and tractor manufacturer. CNH also produces tractors (formerly New Holland and Case).

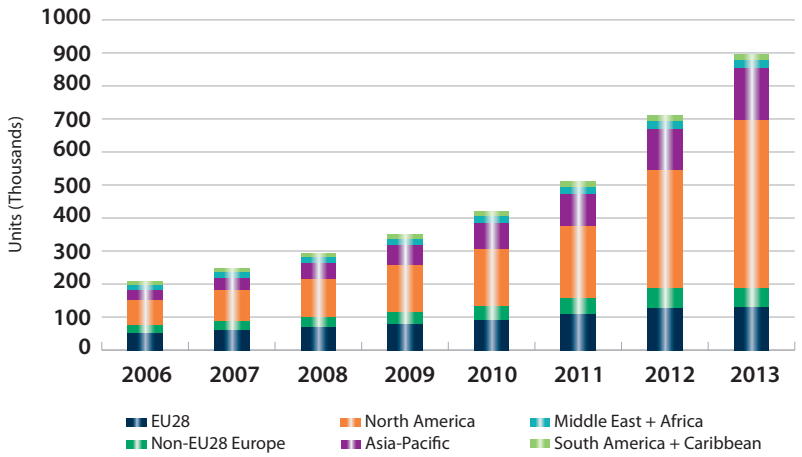
Overall, the GNSS agriculture industry is concentrated in North America, which hosts 63% of the components and receivers market and 46% of the system integrators.

* European companies

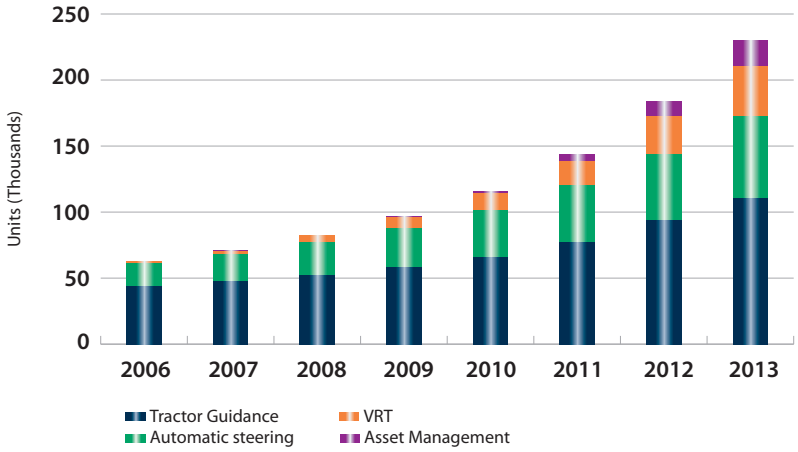
Value chain considers the key global and European companies involved in the GNSS dowstream activities.

North America has driven the growth of precision agriculture solutions

Installed base of GNSS devices by region



Shipments of GNSS devices by application



Between 2006 and 2012, the installed base of GNSS devices worldwide more than tripled, from 200,000 to some 700,000 units.

North America is the most technologically advanced region, accounting for 57% of all GNSS devices in 2013, which are diffused in the 2.5 mln farms found across the United States and Canada. Agricultural holdings are typically large-sized, wealthy and farmed using machine-intensive techniques. Additionally, high costs of labour relative to capital make labour-saving techniques particularly attractive. Major crops include corn, soybeans, wheat and alfalfa.

Asia-Pacific, which is made up of countries with very different agricultural features, is the fastest-growing region in terms of GNSS devices in use – from 0.3% of the total installed base in 2006 to 17% in 2013. **Europe** also experienced an increase in the installed base of GNSS devices, from 51,000 units in 2006 to 129,000 units in 2013. However, this growth has been at a slower pace than the rest of the world (14% per year).

The most mature market is Australia. The increased efficiency provided by GNSS allows farmers there to address such challenges as water shortage and soil fertility, that affect many of Australia's very large farms.

From 2006 to 2013, **Tractor Guidance** remained the most widespread GNSS-based application in Agriculture, accounting for almost 500,000 units in 2013 and a corresponding share of 54% of all devices.

Automatic Steering, which requires a higher level of accuracy, grew significantly thanks to increased adoption in developed countries. This trend confirms that high-accuracy solutions are "addictive" to farmers in that they are not likely to abandon top-end solutions after implementing them.

Variable Rate Technologies (VRTs) are also starting to be increasingly adopted by farmers. GNSS shipments in VRTs grew from near zero in 2006 to 38,000 in 2013.

Asset Management solutions are now starting to complement in-field solutions. Their shipments increased from close to zero in 2006 to 43,000 units in 2013

Growth of advanced applications will push revenues despite the pressure on prices

From 2013 to 2023, annual shipments of GNSS devices are expected to increase more than fivefold – up to almost 1.2 mln units worldwide. Overall, **GNSS penetration*** is foreseen to experience a steady increase over the next decade, reaching 50% by 2023.

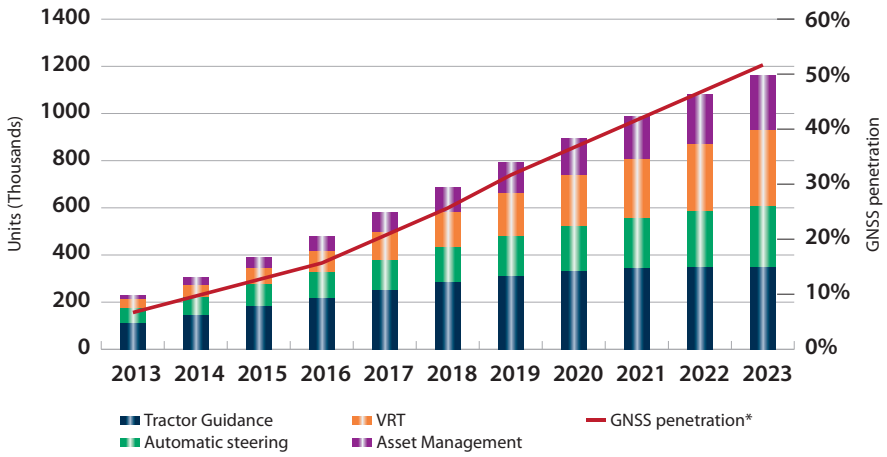
Increasing competition, bargaining power of end users and economies of scale are all expected to contribute to a progressive **decline in the average price** of devices, with the effect of technological advancements only partially compensating price erosion.

However, thanks to the sustained growth in GNSS device shipments, and in particular advanced applications, **global revenues** are **expected to increase** in all GNSS-enabled agricultural applications.

Variable Rate Technologies will progressively gain momentum, with revenues increasing from €135 mln in 2013 to €723 mln in 2023. Likewise, revenues from **Asset Management** will grow from €11 mln in 2013 to €102 mln in 2023.

Automatic Steering will generate the largest share of revenues and remain the most expensive application in terms of average price per device. However, it is also expected to experience the fastest price decrease, as high-accuracy applications will become increasingly commoditised worldwide. Overall, revenues associated with **Tractor Guidance** are expected to peak in 2018, at which point they will begin to decline as farmers shift towards more advanced solutions.

Shipments of GNSS devices by application



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

GNSS can improve productivity and help Asia-Pacific tackle challenges

Asia-Pacific is expected to take the driver's seat in terms the adoption of GNSS devices, growing from 156,000 units in 2013 to 2.3 mln units by 2023. In particular, China and India are high-potential countries who play a prominent role in the agriculture-related economy (respectively absorbing 35% and 47% of total employment) and thus exhibit significant room for improvement in terms of production efficiency.

GNSS applications target the **major crop productions** in China and India, including wheat, sugarcane and cotton.

Sustained productivity growth in these countries is needed to solve a series of societal challenges:

- **Urbanization:** as the rural population continues to relocate to cities, there is an increasing shortage of agricultural labour force.
- **Increasing population:** food demand is growing when population is increasing (especially the case of India).
- **Chronic land and water shortages:** available land for cultivation is limited and it is not expected to increase over the coming years. Water shortage is also an increasing issue affecting Agriculture.

By improving agricultural productivity, precision agriculture will significantly help tackle these challenges, in particular as the trend towards mechanisation continues. Growth in the average size of holdings will also play a major role in boosting the uptake of GNSS.

The integration of GNSS into cloud-based systems enhances farm management

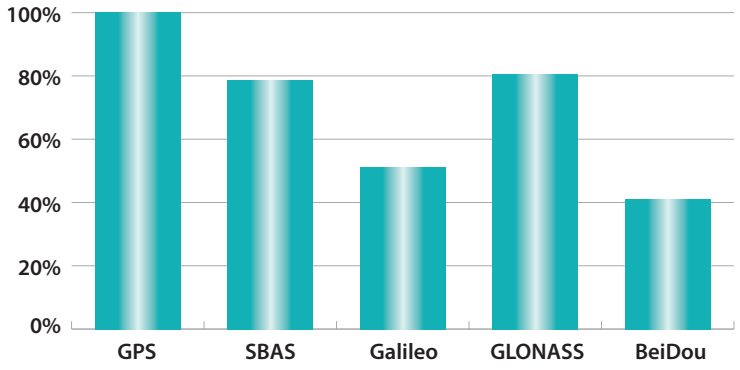
The integration of GNSS positioning in **Farm Management Information Systems (FMIS)**, together with the use of additional information coming from various sensors, has revolutionised precision farming. FMIS is a system for collecting, processing, storing and providing data in the form needed to manage a farm. GNSS links this data to specific geographical coordinates. Additional sensors can be used to enable remote sensing with additional information being provided by Earth Observation systems and meteorological stations.

All these data - integrated into a cloud-based platform for farm management - provide farmers with an **effective decision making tool** capable of improving overall productivity and supporting farmers' activities and choices. In particular, the data is used for monitoring costs, managing human resources and machinery, providing powerful reporting, planning for the future, and monitoring yields.

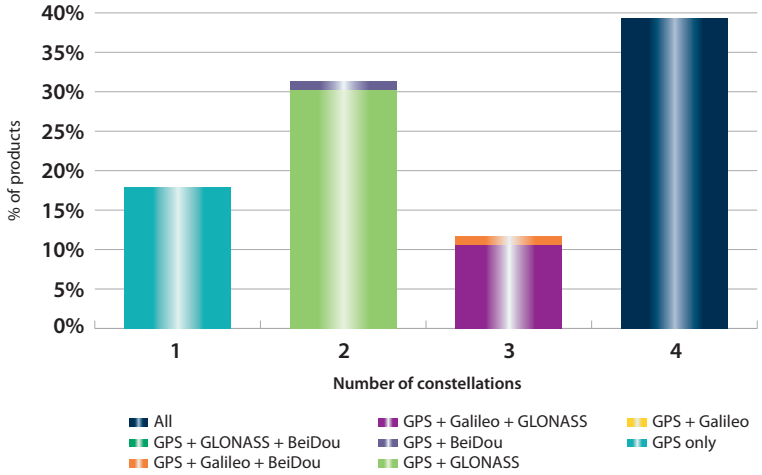
The emergence of more affordable, **dual-frequency and multi-constellation receivers**, as well as evolutions of PPP solutions, will further support precision farming – contributing, for example, to the improvement of GNSS-based machine auto guidance.

The charts below underline how agriculture is one segment making use of advanced GNSS, with almost 80% of devices integrating SBAS and almost 40% of models able to track all 4 constellations*.

Capability of GNSS receivers – Agriculture segment



Supported constellations by receivers – Agriculture segment



* For the methodology applied to the charts please go to page 15 of the Report.

EGNOS and Galileo improve the effectiveness of precision agriculture

EGNOS offers an affordable solution for precision agriculture, enabling farmers to optimise yields, increase labour productivity and reduce driver fatigue – all with minimal investment.
EGNOS supports machinery guidance solutions with sub-metre level accuracy, which is suitable for basic-value crop cultivation (e.g. cereals). It also enables more efficient management of such farming activities as spreading, spraying and harvesting.
As a result, the optimised use of seeds, fertilizers and herbicides – as well as a reduction of fuel and driver fatigue – leads to increased productivity. In other words, EGNOS provides advantages to both farmers (higher profits margins) and society (increased food supply and more environmentally friendly agriculture).

Galileo will further improve the performance of GNSS-assisted agriculture. It will offer enhanced availability and continuity in a multi-constellation environment, as well as improved real-time positioning accuracy based on dual-frequency capability.
The Galileo Commercial Service will provide access to two additional robust signals, delivering a higher data throughput rate and high accuracy down to the centimetre level. It will also offer enhanced independence from ground-based augmentation systems.
A demonstrator for Galileo Commercial Service currently being set up will showcase these capabilities.

European EGNSS R&D Programmes support the competitiveness of the EU industry

The GeoPal project supports logistics operations on the farm

GEOPAL is a GNSS based system used to plan logistics in Agriculture. The system assists farmers in improving efficiency during in-field and inter-field logistic activities. GEOPAL covers the following activities:

- Fleet management and logistics (operations management tools and the required ICT systems);
- Coordination, mission and route planning functionalities for field machinery;
- Closed loop integrated optimal planning, execution of automated field operations and monitoring.

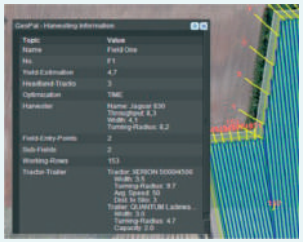
More information available at http://www.geopal-project.eu/

Source: GEOPAL project

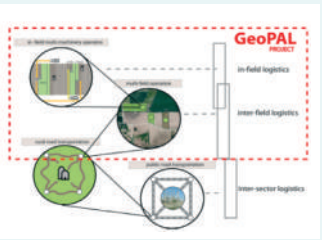
MISTRALE - innovation in flood and soil humidity mapping

The need for efficient water resource management and accurate risk evaluation in Agriculture is increasing, in line with competitiveness and productivity requirements.
The MISTRALE project (Monitoring of Soil Moisture and Water-flooded Areas for AgricuLture and Environment) aims to provide reliable flood and soil humidity mapping to farmers using a small Remotely Piloted Aircraft Systems (RPASs) equipped with a dedicated receiver for GNSS-reflected signals.

This innovative technology will allow for continuous data provision (overcoming both darkness and vegetation issues) with improved mapping and navigation capabilities.
EGNOS and Galileo will be used to improve the navigation capabilities of RPASs.

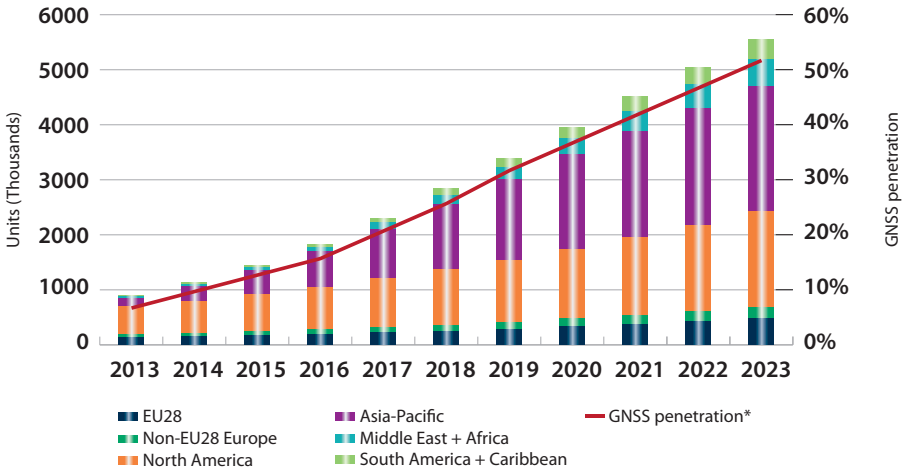


Source: GEOPAL project



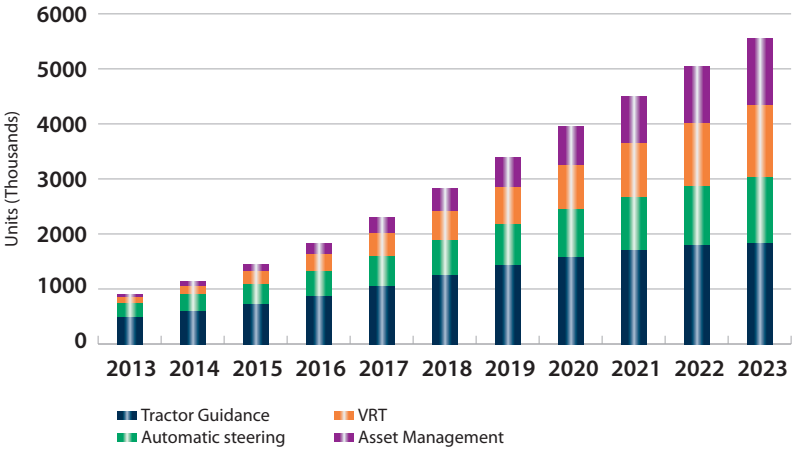
Source: GEOPAL project

Installed base of GNSS devices by region

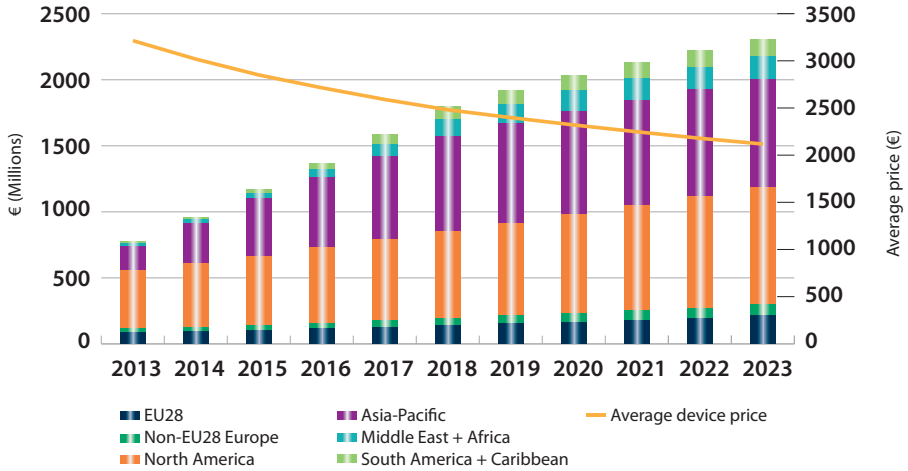


* GNSS penetration is defined as the proportion of all high-powered tractors that is equipped with GNSS

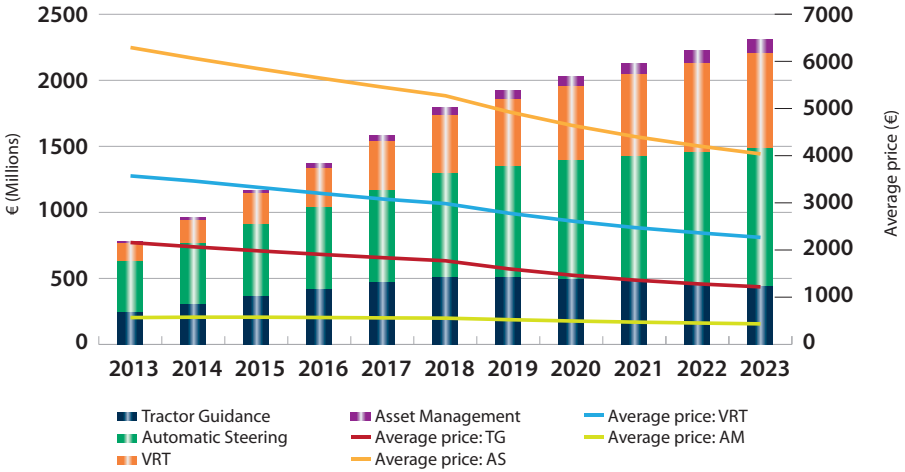
Installed base of GNSS devices by application



Revenue of GNSS device sales by region



Core revenue of GNSS device sales by application



Surveying

GNSS applications

Applications in Land Surveying:

- **Cadastral Surveying** aims to establish property boundaries. Fiscal policies such as land taxation rely heavily on cadastral surveying.
- **Construction Surveying** covers the different construction stages of a building or civil engineering project, whereas machine control applications automate construction activities thanks to GNSS.
  - **Machine control** applications use GNSS positioning, for example, to automatically control the blades and buckets of construction equipment using information provided by 3D digital design.
  - **Person-based** applications enable many positioning tasks, including making surveys, checking levels, performing built checks and staking out reference points and markers.
- **Mapping:** GNSS is used to define specific location points of interest for cartographic, environmental and urban planning purposes.
- **Mining:** mine surveying involves measurements and calculations at each stage of mine exploitation, including a safety check.

Applications in Marine Surveying:

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

In this chapter

- **Key trends:** GNSS supports land and property management activities in mature and emerging markets.
- **Industry:** List of main players by value chain segment.
- **Recent developments:** Property-related activities stimulated growth in shipments of GNSS devices.
- **Future market evolution:** Construction activities in Asia-Pacific and North America will drive GNSS growth.
- **User technology:** Multi-GNSS and multi-frequency receivers - with additional sensors - for enhanced capabilities.
- **Focus on European GNSS:** EGNOS and Galileo satisfy entry-level and advanced application requirements.
- **Reference charts:** Yearly evolution of GNSS devices' installed base and revenues by segment and geographic area.

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GNSS supports land and property management activities in mature and emerging markets

Key market trends

- Strong economic growth and rapid urbanisation in emerging countries fuels the demand for building and cadastral surveying activities in new parts of the world.
- Person-based construction applications and the large market value of machine control drive GNSS uptake.
- Democratisation of mapping: reduction of GNSS receiver prices and increases in accuracy are transforming mapping into a more accessible activity.

GNSS increases construction productivity

Surveying is the discipline of accurately determining the position of points and the distances and angles between them.

GNSS supports construction operations by assisting the operator in both person-based operations and machinery guidance, offering the following benefits:

- **Time savings** such as faster performance of surveying tasks and reducing the number of passes required by graders and excavators.
- **Input and capital savings** thanks to the reduction of machine wear and tear that results from fewer errors, the maximisation of machine utilisation, and savings in fuel costs.
- **Improved quality** due to repeatable and consistent data recording and improved data exchange between design and construction.

The evolution of user needs will drive market growth

In Land and Marine Surveying, GNSS-based instruments satisfy many requirements of a wide range of professional users: constructors, surveyors, engineers, scientists, etc.

- **Accuracy:** depending on the application and the region, accuracy requirements range from cm level (e.g. control survey for construction) to metre level (mapping).
- **Availability:** multi-constellation is required for improving availability in mining activities, as well as in cadastral and construction undertakings in urban canyons.
- **The Time To First Fix (TTFF) and Time-to-Convergence (TTC):** high productivity requirements demand fast TTFF and TTC.
- **Price:** while end-users in developed markets rely on expensive but highly sophisticated equipment with centimetre accuracy, users in large emerging markets tend to favour cost efficiency over accuracy.

This evolution of user needs has enabled Asian players to enter emerging industry, where they are generating economies of scale and cumulating expertise. In the future, competition between established North-American/European companies and Asian manufacturers will increase, not only in emerging markets but also mature ones, possibly reshaping the surveying industry.

The UAV market is taking off

The uptake of Unmanned Aerial Vehicles (UAVs) for civil applications offer new opportunities for using air-based activities:

- UAVs offer rapid, cost-effective and highly automated geospatial data acquisition in small and medium sized areas.
- Both photography and topographic data can be generated.
- Hazardous or difficult to access areas can be surveyed without the need for human access.

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Surveying Value Chain

COMPLEMENTARY INFRASTRUCTURE (AUGMENTATIONS)	COMPONENTS MANUFACTURERS (RECEIVERS AND OTHERS)	SYSTEM INTEGRATORS	SOFTWARE, APPLICATIONS AND ADDED-VALUE SERVICES	PROFESSIONAL USERS	CUSTOMERS
TRIMBLE (OMNISTAR) HEXAGON; LEICA GEO-SYSTEMS (SMARTNET)* TOPCON (TOPNET LIVE) FUGRO (STARFIX)* DEERE & CO; NAVCOM (STARFIRE) ORPHEON* SAPOS* VERIPOS* TERIA*	TRIMBLE HEXAGON (LEICA GEOSYSTEMS, NOVATEL)* TOPCON AGJUNCTION LAIRD* DEERE & CO (NAVCOM)	CATERPILLAR HEXAGON* KOMATSU TRIMBLE KONGSBERG* DEERE & CO TOPCON J.C.B. SERVICE*	TOPCON TRIMBLE HEMISPHERE JAVAD HEXAGON (LEICA GEOSYSTEMS)*	Constructors Educators Engineers Environmentalists Professional Organisations Scientists Surveyors Farmers Oil & Gas Companies	Public Organisations, Private Companies, (including Insurance), Individuals, Natural Resources, Management Firms, Hydrographic Offices, Offshore Wind Farms, Underwater Cable & Pipeline Installers.

The EU GNSS industry in the global arena

Leading GNSS companies in Surveying are multi-national, serving a very diversified market that extends far beyond their original region. To date, companies from established markets still dominate the receivers manufacturers market. Trimble remains the leader, followed by Hexagon and Topcon. Regarding system integrators, the market is comprised of different players according to applications (manufacturers of construction machinery, producers of surveying equipment, specialists in marine applications, etc.). The regional industry shares of the market are divided between North America (ca. 50%), Asia (ca. 25%) and Europe (ca. 25%).

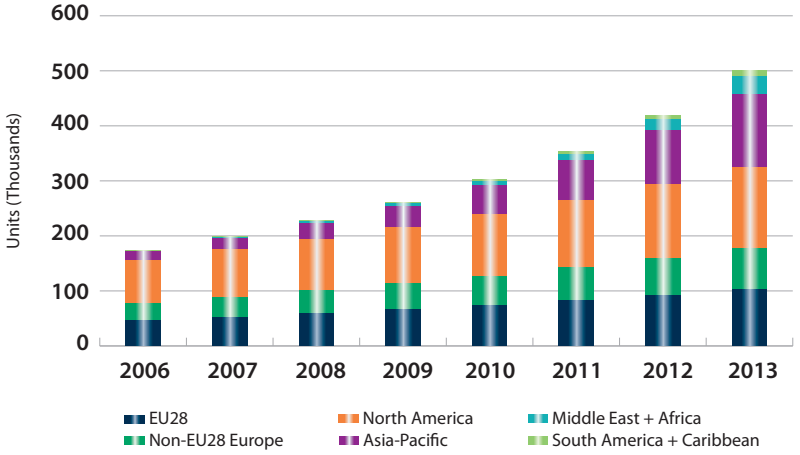
European companies hold about a quarter of the market, both in terms of components and receivers and system integrators. Focusing on components and receivers, the top European companies are Hexagon (including Leica Geosystems) and Laird. Among system integrators, European companies have 27% of the market, with the top three European companies being Hexagon, Kongsberg, and J.C.B.

* European companies

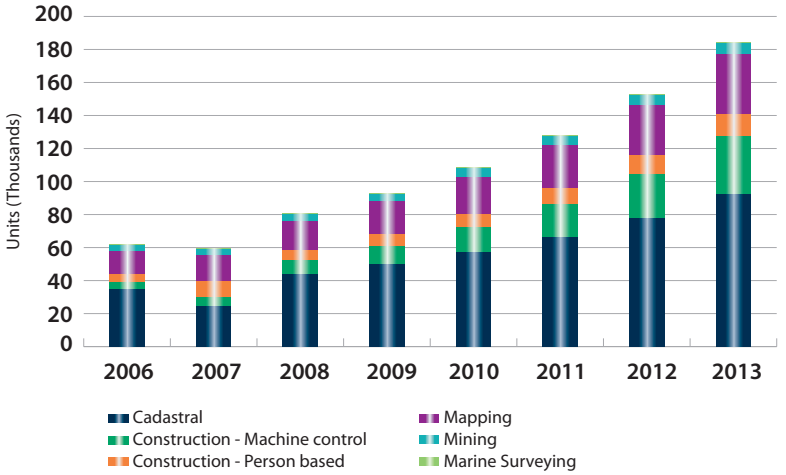
Value chain considers the key global and European companies involved in the GNSS dowstream activities.

Property-related activities stimulated growth in shipments of GNSS devices

Installed base of GNSS devices by region



Shipments of GNSS devices by application



The installed base of GNSS devices has tripled over the past eight years, from 140,000 units in 2006 to 426,000 units in 2013.

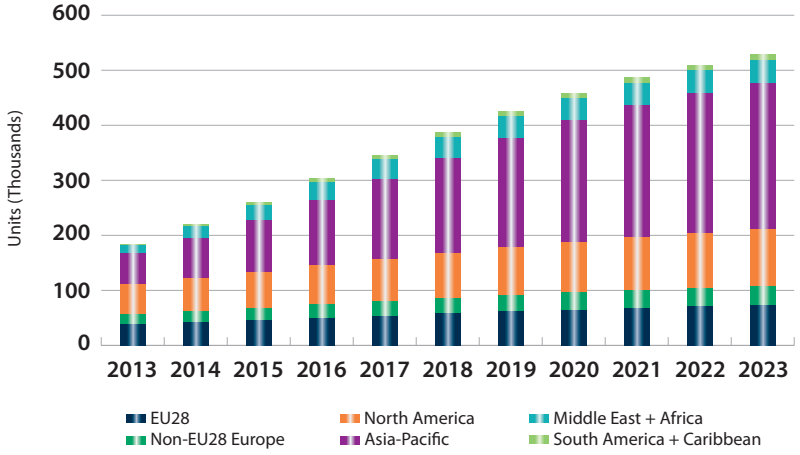
Asia-Pacific in particular experienced a substantial increase, progressively reshaping the market's geographic breakdown. In 2006, **North America** accounted for 44% of GNSS devices in use, but by 2013 this share had reduced to 30%. By contrast, Asia-Pacific has grown from 11% to 30% over the same time period. In other words, GNSS is expanding at a faster pace outside Western regions where it typically doesn't have to compete with legacy systems.

The growth in GNSS device shipments has been supported by **Cadastral Surveying**, **Mapping** and **Construction** (machine control) which, together, accounted for 87% of the installed base in 2013. The demand for cadastral surveys is partly the result of population and income growth in emerging countries and the application of the principle of fair taxation in established markets.

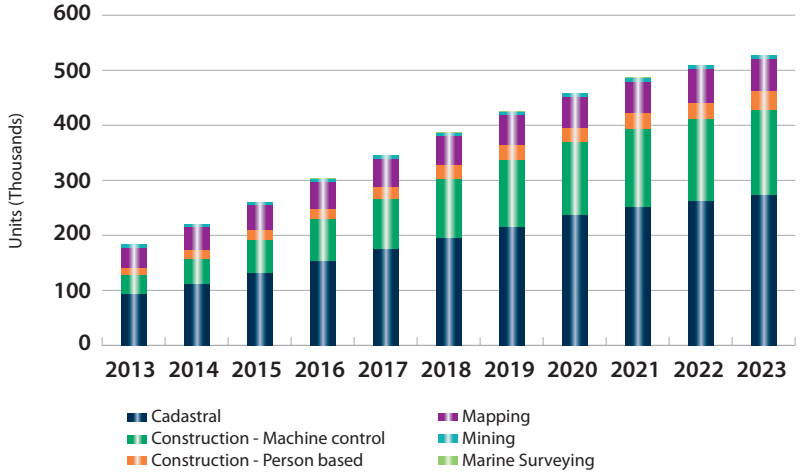
Construction activities also played a significant role in fuelling growth, largely due to the construction boom in emerging markets and the post-crisis recovery in established ones. In 2013, the construction industry in Southeastern Asia grew by 7.5%, vis-à-vis a 4.5% increase in the United States and 4% in Japan, and a 2.5% decrease in Europe.

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

Shipments of GNSS devices by region



Shipments of GNSS devices by application



The sustained development of the construction sector in **Asia-Pacific will drive the growth** of GNSS device shipments, which are estimated to increase by an average of 11% per annum worldwide between 2013 and 2023. Although by 2023 Asia-Pacific will represent about 50% of total shipments, North America and Europe are expected to account for an important share of the market (around 20% and 14% respectively).

Due to increasing competition and technological advancements, the average price of devices is expected to drop. Starting from 2020, price erosion and growth in shipments will compensate each other, stabilising total annual revenues (ca. €4.8 bln, see the reference charts on page 71).

Growth in GNSS devices is expected to be driven by **Cadastral Surveying** and **Construction** activities. In 2023, surveying equipment for cadastral applications is expected to account for around half of the 500,000 shipments per annum.

Machine control is foreseen to steadily increase over the next decade, with shipments growing from 35,000 units in 2013 to 155,000 in 2023. This activity can be considered a high value discipline as annual revenues will exceed €1 bln.

Multi-GNSS and multi-frequencies receivers - with additional sensors - for enhanced capabilities

Surveying represents **the most demanding market segment in terms of accuracy** and, thanks to high purchasing power, it was an early adopter of technological innovation. Once equipment costs decreased, other segments followed in adopting the many features already tested in surveying.

The chart on the right below shows that the vast majority (more than 85%) of GNSS devices offered today use a minimum of two constellations.* In addition, almost 40% of receivers already support four constellations. This is largely explained by the fact that the use of additional satellites improves the overall performance of the service in terms of reliability, The Time To First Fix (TTFF) and availability.

The evolution of Precise Point Positioning for surveying applications

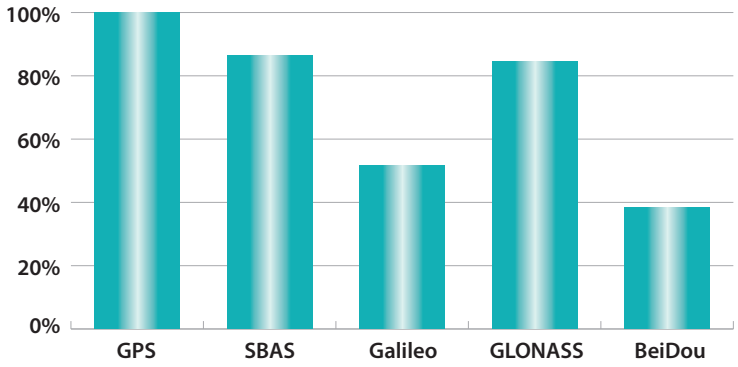
Developed in the 1990s, Precise Point Positioning (PPP) is a technique relying on a single GNSS receiver to provide accurate positioning by using detailed physical models and corrections, and precise orbit and clock products.

In the past, its long time-to-convergence has undermined its attractiveness for real-time applications compared to differential GNSS techniques such as RTK.

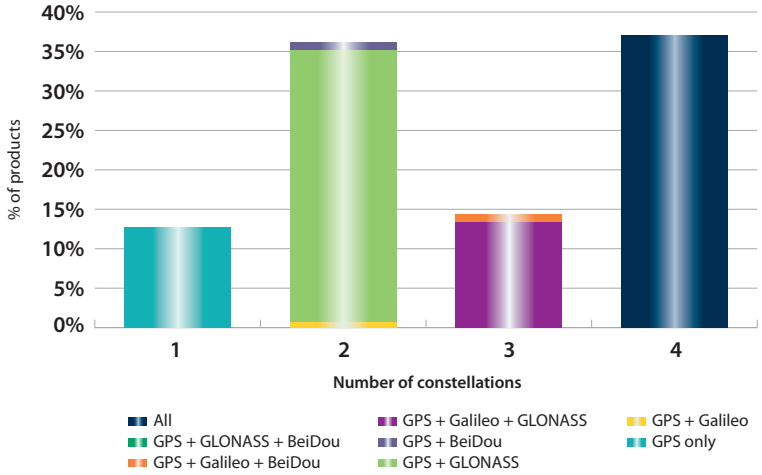
Recent developments in the real-time distribution of correction products have led to several advanced techniques that allow for ambiguity-resolved real-time solutions (PPP-RTK) with achievable accuracy comparable to RTK, and with much faster convergence time for surveying applications.

Surveyors will benefit from triple frequency capacity with Galileo to further reduce convergence time, thus offering PPP as a possible alternative to differential GNSS positioning techniques.

Capability of GNSS receivers – Surveying segment



Supported constellations by receivers – Surveying segment



* For the methodology applied to the charts please go to page 15 of the Report.

EGNOS and Galileo satisfy entry-level and advanced application requirements

By providing sub-metre level accuracy with minimal investment, EGNOS is 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, the Fibre To The Home (FTTH) network deployment in France took advantage of the price-quality ratio of EGNOS enabled receivers for field data collection.

High-end, demanding Surveying applications seek to maximise the accuracy of measurements and signal availability in harsh environments. For instance, Galileo dual frequencies, as well as Commercial Service High Precision (HP), will meet the level of accuracy required for many applications in Cadastral, Construction and Mine Surveying.

More generally, Galileo will offer enhanced performance by providing signals on multiple frequencies and by offering additional satellites in view. Additional benefits of Galileo include Commercial Service authentication, ensuring the trustworthiness of positioning information, as well as stronger signal and higher elevation of satellites.

European EGNSS R&D Programmes support competitiveness of the EU industry

CALIBRA demonstrates the value of GNSS in fast-developing markets

Located across the magnetic equator, Brazil is extremely exposed to ionospheric perturbations that impair the effectiveness of the GNSS-enabled techniques (e.g. RTK and PPP), widely used in high-precision applications.

CALIBRA (Countering GNSS High Accuracy Applications Limitations due to Ionospheric Disturbances in Brazil) project developed, implemented and validated algorithms to mitigate these disruptive ionospheric disturbances.

More information on http://www.calibra-ionosphere.net

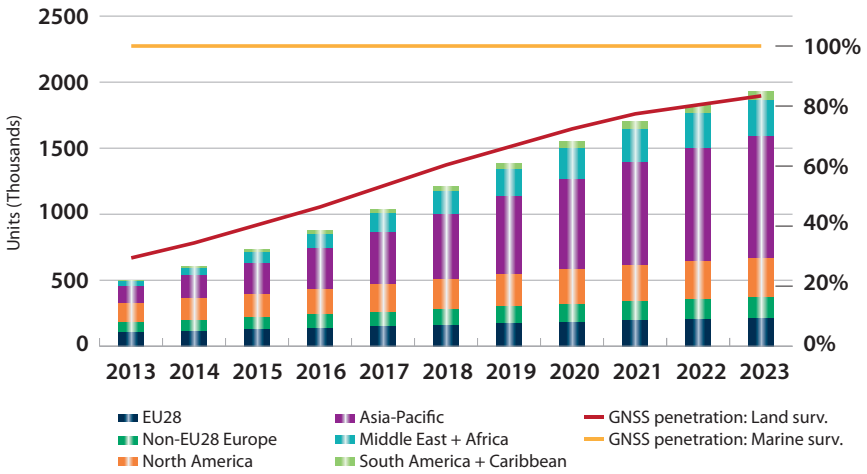
Source: CALIBRA project

MapKITE project devises a dual system for corridor mapping

Mapping areas such as corridors, where access is limited, currently relies on costly and separate terrestrial and aerial missions. The MapKITE project aims to demonstrate that such activities can be performed at lower cost. It looks to accomplish this by creating a dual mapping system that combines a terrestrial vehicle (TV) with an unmanned aircraft (UA) to provide oriented, calibrated and integrated images.

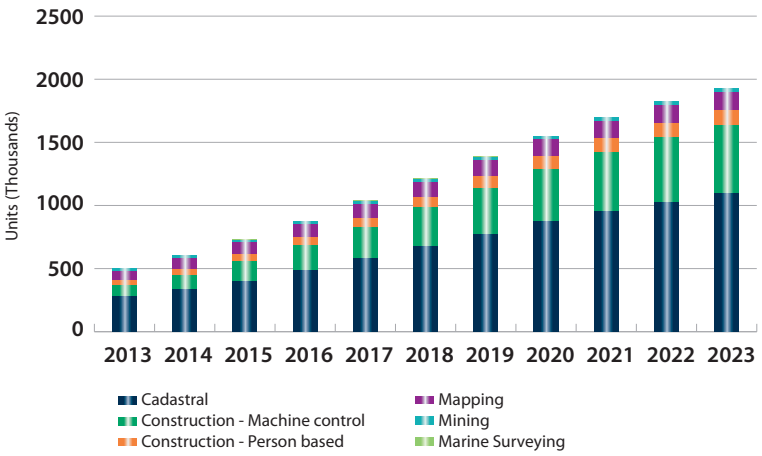
The solution will integrate EGNOS and E5 AltBOC Galileo signals into a navigation payload, therefore benefiting from improved robustness and integrity. This multi-constellation (GPS/Galileo) terrestrial-aerial sensing system is ultimately meant to provide cost-efficient, high resolution mapping. The project will also test the concept's technical and commercial feasibility.

Installed base of GNSS devices by region

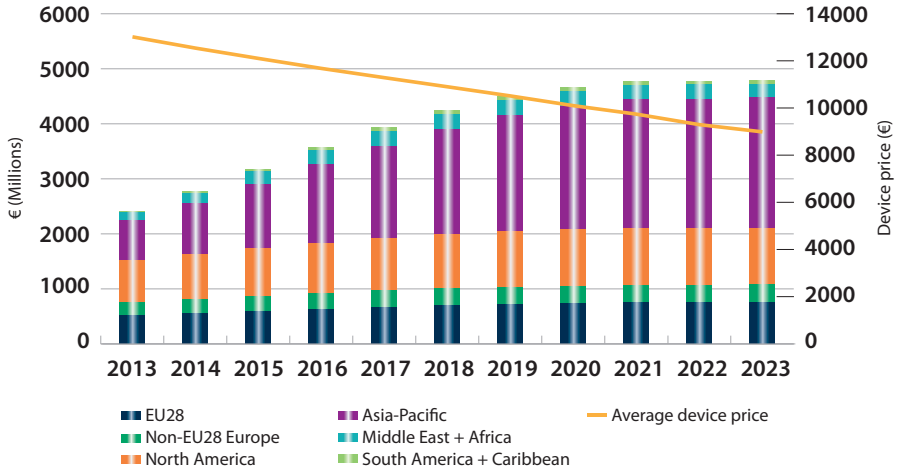


* GNSS penetration is defined as the proportion of all potential users that use GNSS

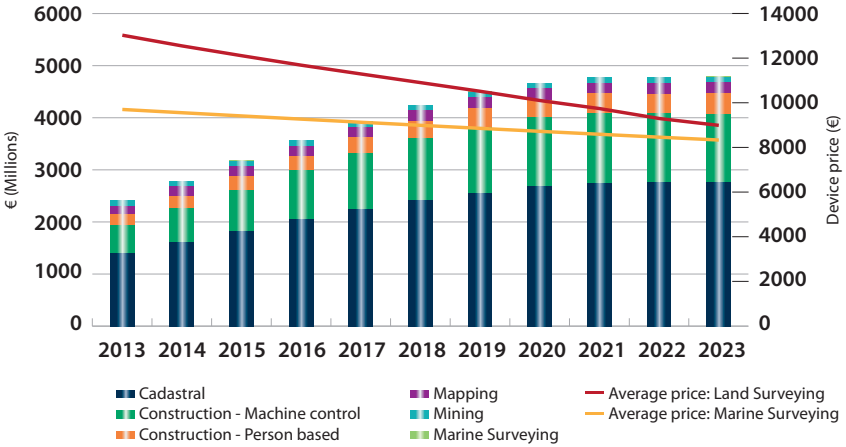
Installed base of GNSS devices by application



Core revenue of GNSS device sales and services by region



Core revenue of GNSS device sales and services by application



Timing & Synchronisation

GNSS applications

This chapter addresses the following areas of use:

- The **Telecommunications** sub-segment uses the GNSS timing function for handover between base stations in wireless communications, time slot management purposes and event logging.The applications analysed in this chapter are **SATCOM, Professional Mobile Radio (PMR)**, **Digital cellular network** and **Public Switched Telephone Network (PSTN)**.
- The **Energy** sub-segment, including power transmission, uses GNSS timing in systems providing frequent measurements relevant to the network status and to determine the location of faults along a transmission line. The application analysed in this chapter is the **Phasor Measurement Unit (PMU)**.
- The **Finance** sub-segment uses GNSS to timestamp financial transactions, allowing one to trace causal relationships and synchronize financial computer systems. The applications analysed in this chapter are **Banks** and **Stock Exchanges**.

Unlike the other segments, the following analysis covers **EU28+Norway only**.

In this chapter

- **Key trends:** GNSS is widely used for Timing & Synchronisation of critical networks.
- **Industry:** List of main players by value chain segment.
- **Future market evolution:** A market dominated by Telecom and benefiting from the roll out of networks.
- **User technology:** Manufacturers propose new capabilities to address the needs of 4G LTE network synchronisation.
- **Focus on European GNSS:** European GNSS can bring improved resilience to Timing & Sync operations.

GNSS is widely used for Timing & Synchronisation of critical networks

Key market trends

- Many Telecom and Energy networks rely on GNSS for synchronisation operations. GNSS is also used to timestamp financial transactions.
- Impact of Timing&Sync service disruption could potentially have serious consequences on the operation of Telecom, Energy and Finance networks.
- There is an emerging need for robust Timing & Synchronisation of these networks.

Key role of Timing and Synchronisation

Precise Time and Synchronisation (Timing&Sync) is crucial to a range of strategic activities. This is especially the case for **Critical Infrastructure** (CI), a system or asset essential for maintaining such vital societal functions as health, safety, security, economic and social well-being of people. GNSS is often used to provide this Timing & Sync service in CI.

GNSS for Timing & Synchronisation

GNSS can be used to provide both Timing & Synchronisation:

- **Timing:** GNSS provides direct and accurate access to Coordinated Universal Time (UTC).
- **Synchronisation:** Synchronisation between receivers at different locations can be established and maintained using GNSS reference time. In addition, a master clock synchronises itself using the time provided by GNSS, redistributing this time to the slave clocks disseminated within the systems.

NTP and PTP are protocols for clock synchronisation between computer systems. They can rely on GNSS as a time source.

User needs

Key stakeholders in Timing&Sync are telecommunication network operators, associations like ENTSO-E in Energy, and regulatory bodies (these are highly regulated markets).

The user needs related to Timing&Sync depend heavily on the application. The accuracy requirements start from low in finance transactions (order of milliseconds) to medium for Energy and most Telecom applications (order of microseconds), whereas Satcom services have high accuracy needs (order of nanoseconds).

There is an increasing interest in GNSS authentication and improved robustness to interference. In Energy, independence and continuity of service are also increasingly valuable. This is part of a global trend of a continuous security improvement.

GNSS role for Timing and Synchronisation applications

Telecom:

In Satellite Communication **(SATCOM)**, GNSS is used for TDMA (Time Division Multiple Access) timing on the satellite links and terrestrial links and NTP (Network Time Protocol) type services for IT/network/satellite monitoring/control.

In **Professional Mobile Radio (PMR)** and **Cellular Networks (Cellular)**, GNSS is used for the synchronisation of timeslots and for handovers between base stations.

In **Public Switched Telephone Networks (PSTN)**, GNSS is used as a backup in case timing information from atomic clocks is lost. GNSS reference time can be used for time of day, traffic timing and time slot management.

Many telecom networks employ local oscillators that enable service to be temporarily maintained in case of GNSS loss.

Energy:

Network automatic protection of systems (Wide Area Measurement Systems/ Wide Area Control Systems) are using **Phasor Measurements Units (PMUs)** as a source of Timing&Sync information for Network Monitoring (current use) and Automatic Protection (future use). Automatic Protection requires a high level of accuracy and redundancy at PMU level.

PMUs are deployed across remote locations of the power network (nodes), with internal time references currently based on GNSS receivers.

Finance:

Financial services rely on very powerful IT systems and networks requiring a high level of availability, security and reliability. GNSS is used for Synchronisation and Time Stamping functions to log events or quotes in a chronologic manner.

There is a widespread use of transfer protocols like NTP/PTP to distribute time (a NTP Primary Server can be connected to about 1500/2000 NTP clients).

Timing & Synchronisation Value Chain

COMPONENTS MANUFACTURERS (RECEIVERS AND OTHERS)	DEVICE MANUFACTURERS	• SYSTEM INTEGRATORS • DESIGN CONSULTANCIES • TESTING & MAINTENANCE	NETWORK OPERATORS
U-BLOX* STM* TRIMBLE FURUNO NOVATEL SEPTENTRIO*	SPECTRACOM* MEINBERG* SYMMETRICOM OSCILLOQUARTZ* TEKRON ARBITER BRANDYWINE ENDRUN FEI-ZYFER MASTERCLOCK OMICRON* SEL	ABB* SIEMENS* ALSTOM* MOTOROLA ERICSSON* Nokia SIEMENS Networks* ACCENTURE* IBM CHRONOS TECHNOLOGY*	Telecom Operators, Transmission System Operators for Electricity, Banks & Stock Exchanges.

The EU 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).

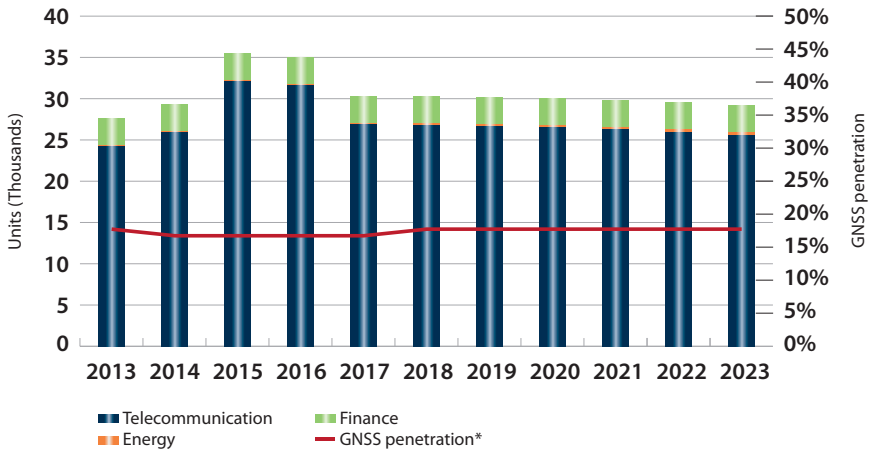
The top three electricity network infrastructure vendors are European owned and based (ABB, Siemens and Alstom) and two of the top three mobile telecoms infrastructure vendors are European owned and based (Ericsson and Nokia Siemens Networks).

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.

* European companies

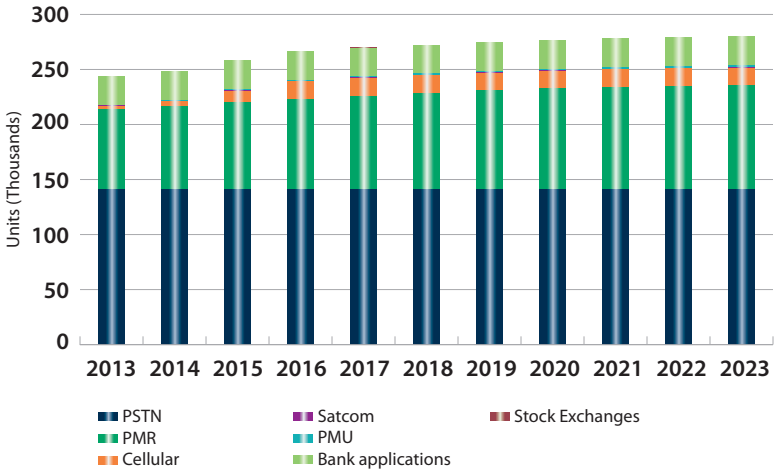
Value chain considers the key global and European companies involved in the GNSS dowstream activities. The presented value chain is global, unlike the rest of the analysis of this segment, which is for EU28+Norway only.

Shipments of GNSS devices by sub-segment



* GNSS penetration is the proportion of all potential users that are equipped with GNSS solutions

Installed base of GNSS devices by application



- Telecommunications expenditure currently accounts for ~3 % of GDP in the EU-28.
- Between 2002 and 2012, household electricity consumption rose in the EU-28 by 10%. Demand is expected to rise at around 1% p.a. until 2050.

The GNSS Timing&Synch segment is mainly driven by the **Telecommunication** sector, which represents around 90% of overall GNSS device shipments.
With the **upgrade of the Energy network**, GNSS penetration is expected to reach 10% in 2017 (compared to 18% of GNSS overall penetration). **GNSS Finance Timing&Sync** is a mature market, where PTP is increasingly considered with an on-going research aimed at optimising its robustness.

The GNSS installed base in the three segments (Telecom, Energy and Finance) in the EU28+Norway should reach 276,000 units in 2020, at which time it is expected to plateau.

Rapid growth is expected in **Mobile Cellular Networks** with investment in 4G, reaching a peak in 2015/2016. The digital Cellular Segment is the most dynamic for Timing&Sync due to the number of LTE base stations expected to be deployed in Europe and its increased dependency on accurate synchronisation (it evolves into LTE- Advanced). For **PMR**, the network infrastructure continues to grow and and along with it, so does GNSS stock. PSTN, PMR and SATCOM are all considered to be mature.

Even if a smaller market size is expected for the Energy sub-segment, an important network upgrade is foreseen in the coming years as use of **improved measurement and control systems (WAMS and WACS) is becoming widespread (smart grids)** with a CAGR(2017-2023) of the GNSS installed base around 15%.

Price of a GNSS timing device can range from €250 (standalone) to €10,000 (high end receivers). For Energy and Telecom, typical device prices are in the order of €3,000-€6,000

Manufacturers propose new capabilities to address the needs of 4G LTE network synchronisation

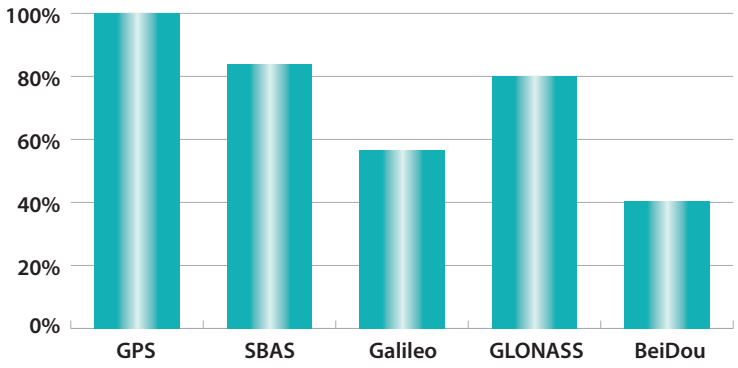
Telecom operators make up the majority of timing solution customers and, as such, are leading the way in the technological advancement. Although all available mobile networks (2G, 3G, 4G LTE) require reliable synchronisation tools, the advanced features of LTE challenge receiver manufacturers with ever greater precision requirements.

The use of **multiple constellations combined with holdover capabilities** helps to more efficiently synchronise networks by improving resilience and stability. A combination of GPS+GLONASS is proposed in around 30% of GNSS chipsets and modules that can be used in a timing environment or application (see the right chart below). Some higher end solutions include other constellations as well, up to four of them, working together with SBAS and other regional augmentations.*

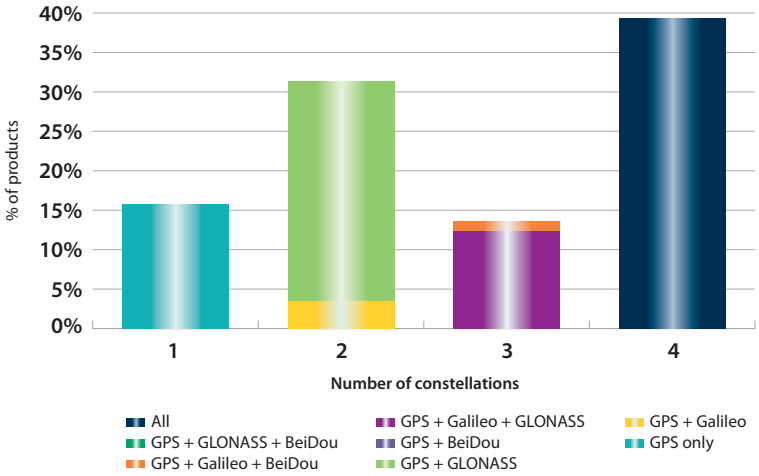
This trend is supported by the fact that manufacturers supplying the high precision segments, Surveying and Agriculture, expand also the multi-constellation capabilities of their timing product lines.

The core of each solution and the main price drivers are the oscillator and interfaces, with high end devices aiming to achieve **near atomic clock precision timing**. Such solutions are suitable for small cells, increasingly used by telecom operators to enhance network capacity and coverage. Infonetics forecasts the global small cell market to grow from a very small base now to $2.7 billion by 2017. Geographically, the same source expects Asia-Pacific to lead the small cell market, with 50% of all units shipped in 2013, followed by EMEA with 34% and North America with 14%.

Capability of GNSS receivers – Timing & Synchronisation segment

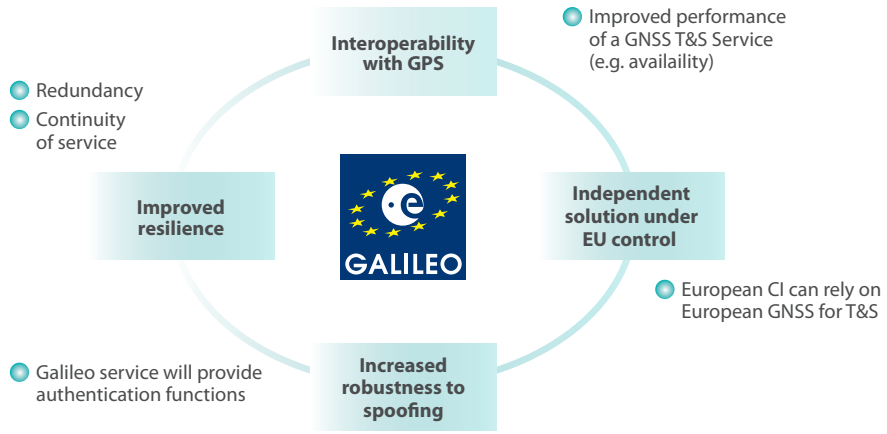


Supported constellations by receivers – Timing & Synchronisation segment



European GNSS can bring improved resilience to Timing & Sync operations

EGNSS differentiators



European EGNSS R&D Programmes support the competitiveness of the EU industry

DEMETRA is a H2020 funded project which aims to demonstrate the feasibility of delivering early EGNSS timing services to end users by utilising an operational demonstrator and conducting tests with pilot applications. An array of important service features that are necessary for a wide variety of users will be added, including high accuracy calibrated time transfer and a monitored and certified remote time stamping. Envisaged end users are telecoms, power transmission, banks, and TV broadcasting networks.

The proposed application will contribute to the independence for the timing of European critical infrastructure and fostering the dissemination of common standardised time services through Europe based on EGNSS.

The European Commission and Critical Infrastructure protection

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.

Interdependencies between critical infrastructures and industry/sectors are clearly recognized. As a result, the Commission will continue to develop the protection and resilience measures already in place while also looking to improve their utility.

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Methodology and sources of information

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, revenue 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 informed by expert opinions 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 sector experts and stakeholders.

Data sources

The model makes use of publicly available information and additional data and reports purchased from private publishers. Primary data sources include:

Eurostat; United Nations Conference on Trade and Development (UNCTAD); United Nations public information; US National Transportation Statistics; US Bureau of Labor Statistics; FP6, FP7, and Horizon 2020 project websites; Bureau van Dijk ORBIS; ABI Research; Berg Insight; International Telecommunication Union (ITU); GSM Association; Organisation Internationale des Constructeurs d'Automobiles (OICA); International Road Assessment Programme (IRAP); Boeing; Airbus; Bombardier; Embraer; General Aviation Manufacturers Association (GAMA); Federal Aviation Administration; Eurocontrol; UIC International Railway Statistics; Equasis; International Council of Marine Industry Associations (ICOMIA); International Cospas-Sarsat Programme (Secretariat); Rivers of the World Atlas; World Shipping Council; Food and Agriculture Organization; Farstad Shipping; Infomines; Clarkson Research Ltd.; Bureau van Dijk BankScope; World Stock Exchanges; Harbor Research; Vision Mobile; Infonetics; Teal Group; EGNOS Service Provider (ESSP); European GNSS Service Centre (GSC); GPS World Receiver Survey; IDC; Juniper Research; Statistic Brain; Statista; appFigures; SkyToll; European Commission; International Maritime Organization (IMO); International Convention for the Safety of Life at Sea (SOLAS).

Disclaimer

The GNSS Market Report Issue 4 was carried out by the European GNSS Agency in cooperation with the European Commission and with the support of London Economics, Helios, VVA, Egis and FDC.

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.

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ABAS	Airborne Based Augmentation System
ACCEPTA	ACCelerating EGNOS adoPTion in Aviation
ACTS	Authenticated and Certified time Solution
ADS-B	Automatic Depended Surveillance – Broadcast
ADAS	Advanced Driver Assistance System
AGNSS	Assisted GNSS
AIS	Automatic Identification System
AIS-SART	AIS Search and Rescue Transmitter
ANSP	Air Navigation Service Provider
AOPA	Aircraft Owners and Pilots Association
APV	Approach Procedure with Vertical guidance
ARAIM	Advanced Receiver Autonomous Integrity Monitoring
BA	Business Aviation
BRIC	Refers to: Brazil, Russia, India, China
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
COSMEMOS	Coperative Satellite navigation for MEteo-marine MOdelling and Services
COSPAS-SARSAT	Russian Cosmicheskaya Sistyema Poiska Avariynich Sudow - Search and Rescue Satellite-Aided Tracking (International Satellite System For Search and Rescue)
CS	(Galileo) Commercial Service
DGNSS	Differential Global Navigation Satellite System
DGPS	Differential Global Positioning System
DT	Digital Tachograph
EAGD	Enhanced Active Green Driving
EC	European Commission
EDAS	EGNOS Data Access Service
EETS	European Electronic Tolling Service
EGNOS	European Geostationary Navigation Overlay Service
EGNSS	European GNSS
ELT	Emergency Locator Transmitter
EPIRB	Emergency Positioning Indication Radio Beacon
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
EU28	European Union (28 Member States)
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
GA	General Aviation
GAGAN	GPS Aided Geo Augmented Navigation
GAMA	General Aviation Manufacturers Association
GBAS	Ground Based Augmentation System
GDP	Gross Domestic Product
GLONASS	Russian GLObalnaya NAvigatsionnaya Sputnikovaya Sistema (Global Navigation Satellite System)
GNSS	Global Navigation Satellite System
GPS	Global Positioning System
GSA	European GNSS Agency
GSM	Global System for Mobile Communications
HP	High Precision
HUD	Head-up display
H2020	Horizon 2020
IC	Integrated Chipset
ICAO	International Civil Aviation Organisation
ICOMIA	International Council of Marine Industry Associations
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
KLUB-U	Russian Compleksnoye Lokomotivnoye Ustroystvo Bezopasnossti - Unifitzirovannoy (Integrated Train Protection System)
LBS	Location Based Service
LPV	Localizer Performance with Vertical guidance
LRIT	Long Range Identification and Tracking System
LTE	Long-Term Evolution, commonly known as 4G LTE
MEOSAR	Medium Earth Orbit Search and Rescue satellites
MOPS	Minimum Operational Performance Standards
MSAS	Multi-functional Satellite Augmentation System
M2M	Machine-To-Machine
NFC	Near-Field Communication
NPA	Notice of Proposed Amendment
NTP	Network Time Protocol
O-TDOA	Observed Time Difference Of Arrival
OBU	On-Board Unit
OMA	Open Mobile Alliance
OS	(Galileo) Open Service
PBN	Performance Based Navigation
PBR	Passive Bistatic Radars
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
PPP	Precise Poing 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
RA	Regional Aviation
RFID	Radio-Frequency IDentification
RIMS	Ranging and Integrity Monitoring Stations
RNP	Required Navigation Performance
ROSCO	Rolling Stock Operating Company
RPAS	Remotely Piloted Aircraft Systems
RTK	Real Time Kinematic
RUC	Road User Charging
R&D	Research and Development
SAR	Search and Rescue
SATCOM	Satellite Communications
SBAS	Space Based Augmentation System
SIS	Signal In Space
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
UAV	Unmanned Aerial Vehicle
UNCTAD	United Nations Conference on Trade and Development
VFR	Visual Flight Rules
VTS	Vessel Traffic Services
VMS	Vessel Monitoring System
U-TDOA	Uplink-Time Difference of Arrival
UTC	Coordinated Universal Time
VGI	Volunteered Geographical Information
VHF	Very High Frequency
VRT	Variable Rate Technology
WAAS	Wide Area Augmentation System
WAMS	Wide Area Measurement Systems
WWRNS	World-Wide Radio Navigation System

The European Commission

The European Commission (EC) is responsible for 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 Infrastructure;
- managing the provision of quality services that ensure user satisfaction in the most cost-efficient manner;
- engaging market stakeholders to develop innovative and effective applications, value-added services and user technology that promote the achievement of full European GNSS adoption;
- ensuring that European GNSS services and operations are thoroughly secure, safe and accessible.

Integrated Market Development at the GSA

The **GSA GNSS Market Report** is a product of ongoing market development activities that aim to:

- **Stay close to the user and value chain**, involving the 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 E-GNSS penetration.

- **Build and implement E-GNSS market strategy**, with market players and institutional stakeholders, including: fostering the use of EGNOS in aviation, agriculture, maritime, road, rail and surveying; preparing the market for take-up 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, and more results on the way.

The European GNSS Agency: linking space to user needs.

European Commission

European GNSS Agency

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ISBN 978-92-9206-013-8 – TS-AB-15-001-EN-N