Aviation

GNSS applications

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

- **Performance Based Navigation (PBN)**, whereby an aircraft follows a specific procedure or route within a prescribed error margin. These procedures are available in all phases of flight.
- Aircraft should be equipped with **Emergency Locator Transmitters (ELTs)** that help Search and Rescue operations in the event of an incident. Many ELTs utilise GNSS to report their position when triggered.
- In Surveillance, aircraft can automatically report their position to air traffic controllers on the ground and other aircraft equipped with receivers using **Automatic Depended Surveillance – Broadcast (ADS-B)**.

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

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

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

What you can read in this chapter

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

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

The adoption of GNSS in aviation is growing

Key Market Trends

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

What is the Aviation Market?

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

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

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

Rotorcraft operations benefit from GNSS

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

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

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Performance Based Navigation: the future

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

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

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

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

EASA ruling on ELT/PLB comes into force

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

Aviation moves towards GNSS for Navigation and Surveillance

The ARAIM milestone

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

Free Routing for more efficient flight

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

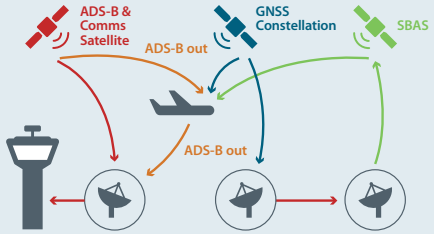
Adoption of GNSS and SBAS enabled operations

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

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

ADS-B Adoption

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



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

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

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

Overview of main user requirements in Aviation

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

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

[1] For demanding PBN manoeuvres, accuracy is an important factor, as a drop below the required level necessitates the procedure to be abandoned. Accuracy nonetheless remains secondary to integrity, availability and continuity.
[2] Accuracy is relevant for certain ground-based ADS-B applications (i.e. airport surveillance); In both cases, accuracy demands are only moderate compared to other market segments.

Aviation Value Chain

DEVICE MANUFACTURERS

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

AIRCRAFT MANUFACTURERS

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

AIRLINES / AIRCRAFT OWNERS

MAIN AIRLINES ALLIANCES

- ONEWORLD
- SKYTEAM
- STAR ALLIANCE

USER GROUP ASSOCIATIONS

- Aircraft Owners and Pilots Association (AOPA)
- European Business Aviation Association (EBAA)
- European Helicopter Association (EHA)
- European Regions Airline Association (ERA)

AIR NAVIGATION SERVICE PROVIDERS

MAIN ORGANISATIONS

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

AERODROMES

- International Airports
- Private Airports
- Regional Airports

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

The European[1] GNSS industry in the global arena

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

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

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

Drones are challenging Aviation's regulators, while existing technologies are deployed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Drones: special requirements in Aviation

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

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

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

ICAO GADSS SARPs come into effect

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

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

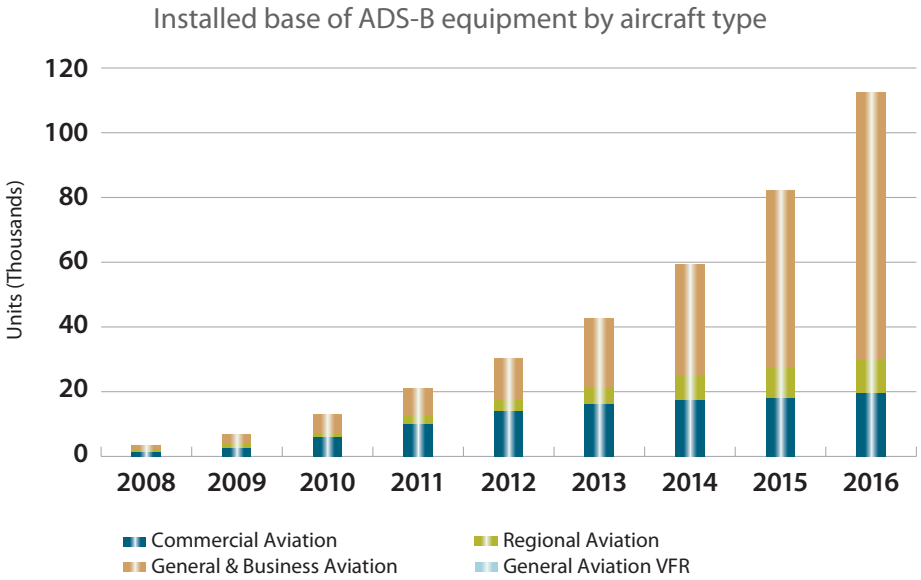
Both will be strongly supported by GNSS and particularly Galileo, as the first contributor to the MEOSAR programme, the next generation Cospas-Sarsat satellite-based search and rescue system.

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

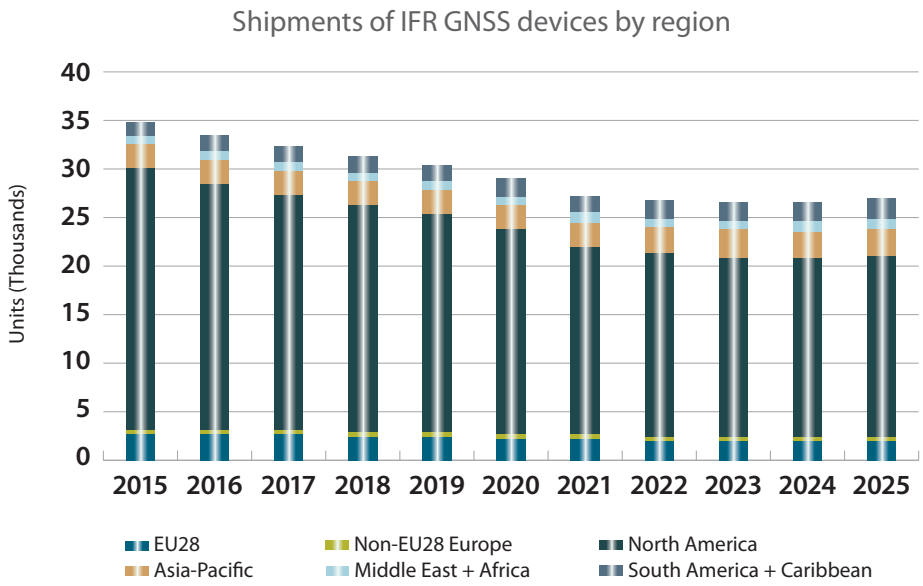
EGNOS was certified to provide LPV-200 (LPV with a land or go around decision height of 200ft above the runway) in 2015. This represents an extremely cost-efficient alternative to Instrument Landing Systems Category I (ILS CAT I), which provides equivalent capabilities at significant cost to the aerodrome.

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

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



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



Middle East and Asia growth for Commercial Aviation…

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

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

… while North American GA remains the largest segment

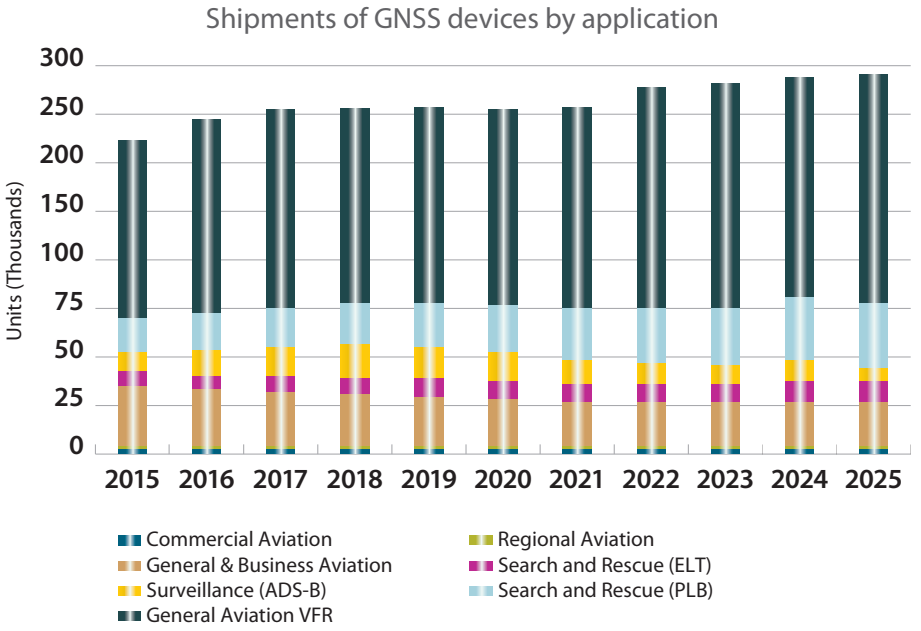
North American GA, and particularly **VFR aircraft** remains the **largest market in aviation**, and dominates the charts (as shown by NA in the chart above, and GA VFR in the chart right). However, in recent years, the volume of new **sales** of GA aircraft has seen a **sharp decline** due to global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

ELT/PLBs sales remain static …

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

… while PBN enables rationalisation of ground infrastructure

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



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

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

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

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

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

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

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

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

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

The possibility of EGNOS expansion

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

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

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

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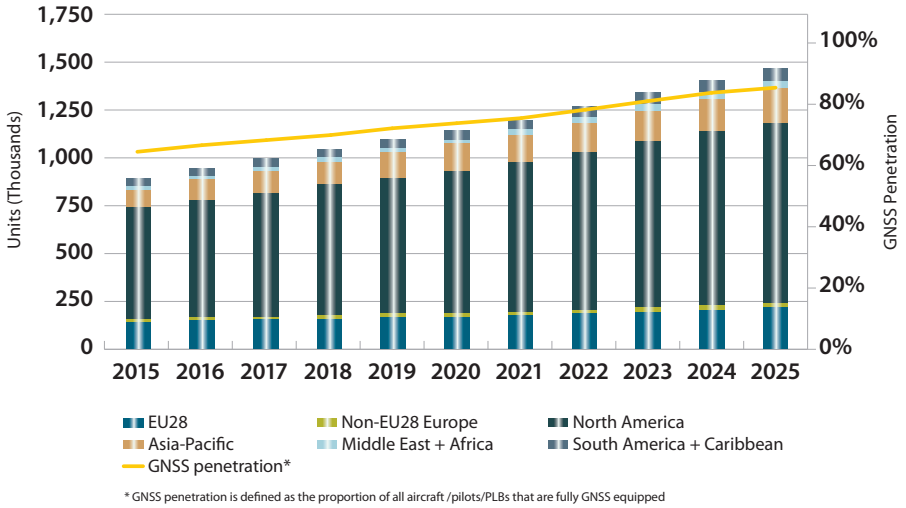
Regulators: the gatekeepers of change

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

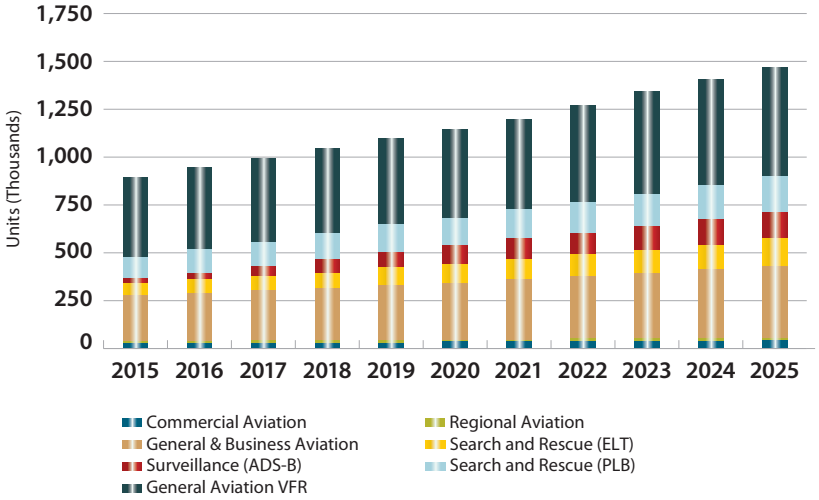
- Guidance on single constellation Galileo receivers in 2016.
- **MOPS** for GPS and Galileo with L1/L5 E1/E5a planned for 2017.
- A standard for multi-constellation **SBAS** (i.e. corrections for both GPS and Galileo) is expected later.

Installed base of GNSS devices by region

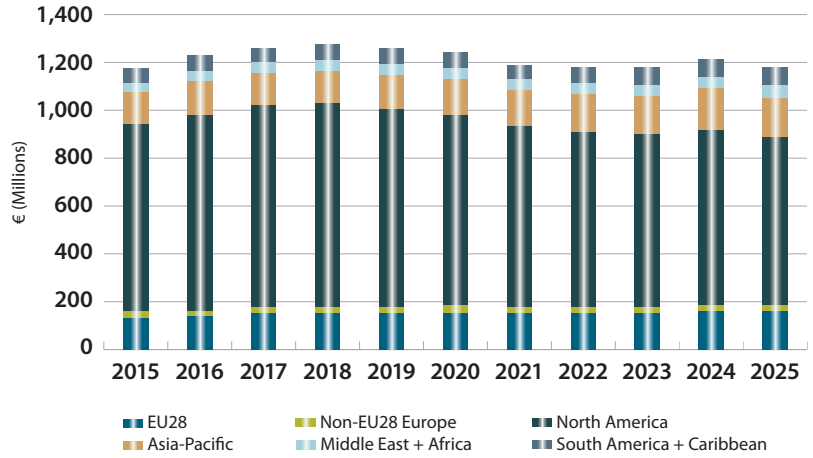


* GNSS penetration is defined as the proportion of all aircraft /pilots/PLBs that are fully GNSS equipped

Installed base of GNSS devices by application



Revenue of GNSS device sales by region



Revenue of GNSS device sales by application