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Outlook on Galileo differentiators

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LIST OF ACRONYMS

ADAS	Advanced Driver Assistance Systems
AIS	Automatic Identification System
ANSPs	Air Navigation Service Providers
CAD	Cooperative and Automated Driving
CAP	Common Agricultural Policy
CCAM	Cooperative, Connected and Automated Mobility
DCN	Digital Cellular Network
DP	Dynamic Positioning
ELTs	Emergency Locator Transmitters
EPIRBs	Emergency Position Indicating Radio Beacons
EU	European Union
EUSPA	European Union Agency for the Space Programme
EWSS	Emergency Warning Satellite Service
G2V2	Second-generation smart tachographs version 2
GMDSS	Global Maritime Distress and Safety System
GNSS	Global Navigation Satellite System
GSC	European GNSS Service Centre
HAS	High Accuracy Service
IALA	International Association of Marine Aids to Navigation and Lighthouse Authorities
ICD	Interface Control Document
IDD	Internet Data Distribution
IMO	International Maritime Organisation
IMUs	Inertial Measurement Units
IVS	In-Vehicle Systems
MASS	Maritime Autonomous Surface Ships

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MED	Maritime Equipment Directive
NFC	Near Field Communication
NTRIP	Networked Transport of RTCM via Internet Protocol
OEMs	Original Equipment Manufacturers
OSNMA	Open Service Navigation Message Authentication
PLBs	Personal Locator Beacons
PMR	Professional Mobile Radio
PMUs	Phasor Measurement Units
PNT	Positioning, Navigation and Timing
PPP	Precise Point Positioning
PRS	Public Regulated Service
PSTN	Public Switched Telephone Network
PVT	Position, Velocity, and Time
RBA	Remote Beacon Activation
RFI	Radio-frequency interference
RLM	Return Link Message
RLS	Return Link Service
RTK	Real Time Kinematics
RUC	Road User Charging
SAR	Search and Rescue
SARPs	Standards and Recommended Practices
SAS	Signal Authentication Service
SDD	Service Definition Document
SL2	Service Level 2
SOLAS	Safety-of-Life At Sea
T&S	Timing and Synchronisation
TS	Timing Service

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TSM	Timing Service Message
TTFF	Time to First Fix
TWC	Two-Way Communication
UCP	User Consultation Platform
UTC	Coordinated Universal Time
VDES	VHF Data Exchange System
VLL	Very Low Level
VMS	Vessel Monitoring System

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1 EXECUTIVE SUMMARY

This outlook provides an overview of the market status and forecast of downstream solutions that leverage Galileo differentiators, with focus on priority applications across different market segments.

Currently, Galileo differentiators include the High Accuracy Service (**HAS**), the Open Service Navigation Message Authentication (**OSNMA**) and Search and Rescue Return Link Service (**SAR/Galileo RLS**). They represent a decisive step forward in Europe's positioning, navigation, and timing (PNT) capabilities:

- HAS introduces free, global high-accuracy corrections for precise positioning
- OSNMA establishes the world's first open navigation message authentication service to ensure the authenticity of navigation messages; and
- RLS provides confirmation that a users' beacon distress signal has been received and their position computed.

Collectively, the differentiators strengthen accuracy, security, safety and resilience within the European GNSS ecosystem in a broad range of market segments.

The analysis presented in this document shows that adoption dynamics for these differentiators vary by sector and service. Some markets already driven by clear operational needs, such as **smart tachographs**, **hydrographic surveying**, and **PLB-enabled SAR**, are progressing rapidly. Others, including **autonomous mobility**, **timing and synchronisation**, and **urban drone operations**, show steady evolution. Adoption is presented by means of 10-year forecasts and each case is complemented with a concrete example of an early adopter.

Across all domains, the differentiators are increasingly seen not as standalone features, but as foundational elements of resilient, modern PNT architectures.

Looking ahead, the differentiators are expected to play an even more significant role as Europe advances toward greater automation, secure digital mobility, robust critical infrastructure, and next-generation public safety services.

Galileo differentiators are not only technical enhancements but **strategic capabilities shaping Europe's digital and operational landscape**. Their growing maturity, combined with expanding **EU industry adoption**, signals a future in which Galileo increasingly underpins essential services, advanced applications and societal resilience across Europe and beyond.

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2 INTRODUCTION

Galileo, the EU´s Global Navigation Satellite System (GNSS), is a civilian system designed to enable **various satellite-based navigation services** and applications for a broad spectrum of sectors and users, ranging from aviation and maritime to agriculture and location-based services[1], providing Europe and European citizens with independence and sovereignty in the provision of positioning services.

With respect to other GNSS, Galileo already offers a range of high-performance and differentiating services worldwide, which include the High Accuracy Service (**HAS**), the Open Service Navigation Message Authentication (**OSNMA**) and the Search and Rescue Return Link Service (**SAR**). Additional services, like the Emergency Warning Satellite Service (**EWSS**), the Public Regulated Service (**PRS**)[2], and the Signal Authentication Service (**SAS**), are in distinct phases of development and deployment.

Together, these services represent major advances, enhancing accuracy, authentication, safety, and resilience.

As the entity responsible for the exploitation of Galileo and the wider EU Space Programme, **EUSPA** plays a pivotal role in bringing these innovations into operational use. In particular, EUSPA helps ensure that Galileo's capabilities translate into tangible benefits for European citizens, businesses, and public authorities.

In a context where these differentiators are being adopted in various market segments, **the objective of this outlook is to present the technical benefits, market relevance, and strategic potential of each differentiator**.

Each differentiator is, in addition, illustrated through practical implementation examples that highlight innovation, operational impact, and visible market momentum.

[1] For example, Galileo is already embedded in everyday products such as in-vehicle navigation devices and mobile phones (4.5 billion).

[2] The PRS is an encrypted navigation service for government-authorised users and sensitive applications that require high continuity. It is not part of the scope of this report.

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3 Market of the Galileo differentiators

The **Galileo** satellite navigation system distinguishes itself from other GNSS constellations by offering **unique, advanced services** that enhance accuracy, authenticity, safety, and resilience. These differentiators, namely High Accuracy Service (**HAS**), Open Service Navigation Message Authentication (**OSNMA**) and Search and Rescue Return Link Service (**SAR RLS**), are critical for modern high-reliability applications across mobility, critical infrastructure, emergency response, and high-precision sectors.

The following table offers an overview of Galileo differentiators, including both the operational and the under development ones.

Table 1 - Galileo differentiators

Differentiator	Status	What it is	What makes it unique	Why it matters
High Accuracy Service (HAS)	Operational	Free Precise Point Positioning (PPP) corrections enabling decimetre-level accuracy.	Global PPP with <20 cm horizontal and <40 cm vertical accuracy.	Critical for accuracy-dependent applications (robotics, agriculture, drones, surveying).
Open Service Navigation Message Authentication (OSNMA)	Operational	Authentication of Galileo navigation messages using cryptographic signatures.	Global free GNSS data authentication service.	Facilitates detection of spoofing events and enhances trust and resilience for critical infrastructure, transport, and timing services.
Search and Rescue Return Link Service (SAR RLS)	Operational	Part of the global Cospas-Sarsat MEOSAR system enabling fast detection and location of distress beacons.	Global Return Link Service (RLS) confirming users that their distress signal was received.	Directly supports lifesaving missions with faster detection, accurate location, and user reassurance.
Emergency Warning Satellite Service (EWSS)	Under development	Satellite-based delivery of hazard alerts (e.g., earthquakes, floods, fires) directly to users' devices.	Works even when mobile networks are congested or down; supports wide-area, fast alerting.	Essential for disaster response and public safety, especially in remote regions or during network outages.
Signal Authentication Service (SAS)	Under development	Authentication of Galileo Signal in Space, complementing OSNMA.	Global free service enabling authenticated PVT solution fix.	Provides mitigation to spoofing and enhances trust and resilience for critical infrastructure, transport, and timing services.
Timing Service (TS)	Under development	Precise timing signals from onboard atomic clocks that allow receivers to synchronize with Coordinated	Global free service disseminating the Timing Service Message (TSM) that conveys the	Provides various levels of trust of the timing solution to Critical Infrastructure users

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		Universal Time (UTC).	status of the Galileo signal	

These capabilities strengthen Europe's autonomous Positioning, Navigation and Timing (PNT) framework and enable applications that require **trustworthy, secure, and high-performance** navigation signals.

The increase in the use of Galileo goes hand in hand with the wide range of Galileo-enabled devices and services that are continually appearing on the market. Indeed, GNSS equipment manufacturers soon realised about the benefits that these services are bringing to end users across many markets.

To facilitate the access to information regarding on-the-market receivers implementing Galileo differentiators, EUSPA is compiling several lists that are available in the European GNSS Service Centre (GSC) website:

- Receivers implementing Galileo HAS
- Receivers implementing Galileo OSNMA
- Receivers implementing Galileo SAR RLS

These lists are regularly updated by EUSPA and include not only information about manufacturers and models but also about the main market segments or applications covered.

The availability of receivers targeting a specific market segment is an indicator of each service's suitability for it. Therefore, the lists provide interesting hints about the GNSS downstream industry's viewpoint when it comes to the relevance of Galileo services in each market segment.

The following sections aim at presenting the forecasted market penetration for each of the Galileo differentiators already operational i.e. for HAS, OSNMA and SAR RLS, in specific segments and at receiver level. This will be visualised by means of S-curves, showing the predicted adoption rates over a 10-year period.

Specific examples will also be provided to illustrate the differentiator's technical implementation and demonstrate its practical impact in real-world operational scenarios.

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4 GALILEO HAS

4.1 Definition and purpose

The Galileo High Accuracy Service (HAS) is a free high-accuracy positioning service for applications requiring higher accuracy than that offered by the Galileo Open Service. HAS provides corrections for both Galileo and GPS, which enables users of both systems to achieve unprecedented **decimetre-level accuracy** using only the information disseminated by these GNSSs.

The HAS **Initial Service** is operational since January 24th, 2023, and work is currently on-going to achieve **Full Service in 2027**.

A high-level, introductory description of HAS, including its up-to-date planned implementation roadmap and an overview of the addressable markets, is available in its Information Note.

A full description of the service is available in its Service Definition Document (SDD).

Lower level technical details are available in its SIS Interface Control Document (ICD), Internet Data Distribution (IDD) ICD, Reference User Algorithm Technical Note and Galileo E6-B/C Codes Technical Note.

4.2 Key benefits

- **Global coverage:** because corrections are broadcast via the SIS, it works anywhere, including remote areas where Real Time Kinematics (RTK) or terrestrial networks are unavailable.
- **Affordability:** HAS is an open access and free of charge service, different from other subscription-based commercial augmentation services (e.g. some RTK services).
- **Simplicity**: non-experts benefit from easy setup: no ground stations, no complex configurations, just reliable high-accuracy positioning.

4.3 Market potential

Industries undergoing rapid **automation,** such as **automotive, robotics, logistics, and manufacturing**, are increasingly dependent on accurate and reliable positioning, driving interest in high-accuracy GNSS services. In this context, HAS emerges as an appealing solution thanks to its global availability, satellite-based corrections, and **independence from terrestrial networks**.

Actually, HAS becomes relevant when compared to traditional augmentation methods like RTK. While RTK can achieve higher accuracy under ideal conditions, **HAS** adds resilience as **part of multi-layered positioning architectures**, particularly when combined with RTK and onboard sensors to prevent outages.

These characteristics position HAS as a valuable alternative or complement to RTK, especially in remote areas where ground-based stations or network corrections are limited or unavailable.

Economic factors further strengthen its appeal: the service is **free, reduces dependence on proprietary correction** networks, and **simplifies global integration,** an advantage for sectors such as automotive, logistics, and drones. Its cost-effectiveness and worldwide availability are fostering international interest beyond Europe.

The following table provides an overview of the applications expected to mostly benefit from the Galileo HAS.

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Table 2 – Market segments mostly benefitted from HAS

Markets	Applications
Agriculture	This is a market with high potential. A wide range of precision farming applications for certain type of crops can benefit from dm-level accuracy, including automated steering, machinery guidance, variable rate applications or field delineation.
Aviation and Drones	The 20 cm positioning accuracy provided by HAS can be relevant, in the open or specific drones categories, for applications like drones positioning and navigation in urban environments. This is, however, a price sensitive market.
Consumer Solutions, Tourism and Health	HAS is expected to become useful in smartphone-based mapping applications or visually impaired support. It is also beneficial when integrated in robotics as a complement or back-up to RTK for open environment navigation.
Forestry	With accuracy requirements in the 30cm – 1m range and typically conducted in harsh environments (i.e. under tree canopy), applications like automatic steering, machinery guidance or forest asset management will benefit from HAS.
Geomatics	An early-adopter market, as a significant amount of surveying equipment manufacturers has already enabled HAS in their devices for applications such as GIS/mapping, cadastre in rural areas/land consolidation as well as surveying across a great deal of environments.
Maritime and Inland Waterways	This is a market with high potential. Waterborne transportation and engineering operations are already benefitting thanks to the increased level of accuracy offered globally by HAS.
Rail	Adoption is expected for non-safety critical rail applications with horizontal accuracy requirements ranging from 10 cm to 1 m, like trackside shunting operations or structural monitoring.
Road & Automotive	The accuracy of HAS is in line with the target positioning performances from the segment. However, applications such as automated driving require additional critical performances, such as integrity, to ensure safe navigation. These will be achieved by integrating various sensors and navigation technologies (including RTK) in a hybrid solution.
Space	HAS provides access to real time Precise Orbit Determination, without assistance from ground systems, simplifying the spaceborne architecture and as a consequence in full alignment of the needs from New Space users.

At hardware level, implementing HAS requires **specific antennas and chipsets** capable of receiving the Galileo E6 signal, and sufficient onboard **processing power for PPP algorithms**. These technical requirements might generate **costs.** Nevertheless, an ever-growing number of chipset receiver manufacturers are embedding HAS, making it more accessible and therefore also affordable. Indeed, as chipset manufacturers integrate HAS into their products, the service can be embedded into a broader range of applications.

On the other hand, concerns about **energy consumption**, particularly for battery-dependent devices, like smartphones or IoT, are still to be addressed. Current technical limitations still also include **long convergence times** and delays in reacquiring full precision. These are **challenges** for applications like **autonomous vehicles**, where instantaneous and highly reliable positioning is essential.

The next sub-chapters focus on two specific market segments: Maritime and Agriculture. These two market segments are amongst those with the highest potential for HAS and, indeed, several solutions have already been deployed commercially for the benefit of their end customers. The expected uptake of HAS in specific applications is presented.

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4.4 HAS for Maritime

Galileo HAS, offering free of charge horizontal and vertical high accuracy without the need of an expensive and complex infrastructure, paves the way for innovative and competitive maritime solutions both on- and off-shore.

4.4.1 Service applicability

The maritime sector sees high-accuracy GNSS as a way to improve safety, efficiency, and reliability, especially for tasks like docking and navigating in congested waters. User needs for SOLAS vessels are framed by strict **international rules** prioritizing accuracy, integrity, continuity, and availability, with IMO resolutions setting the baseline and requiring multi-constellation receivers that provide PVT with integrity monitoring**.** Since IMO sets the rules for SOLAS, the focus of this chapter is on those applications outside the IMO that could be interested in HAS.

In this context, HAS is likely to enter as a **complementary or backup capability**, with uptake determined by specific operational contexts, performance demands and the maturity of hybrid GNSS-sensor solutions. Indeed, Galileo **HAS** can meet some **accuracy needs** in applications of marine engineering such as some **dredging operations, hydrographic surveying and dynamic positioning**.

In the following sub-chapters, the paper will explore the use of HAS for hydrographic surveying.

4.4.2 HAS for hydrographic surveying

4.4.2.1 Overview

Accurate seabed mapping is essential for safe navigation, port construction, dredging operations, offshore energy projects, and environmental monitoring. These activities rely on hydrographic surveys that measure **depth and underwater topography with high precision**, where **vertical accuracy** is the most critical requirement. Even small depth errors can compromise navigation routes, distort dredging estimates, or undermine engineering plans. However, achieving this level of accuracy is challenging, as uncorrected GNSS errors, combined with vessel motion, often lead to vertical uncertainties of half a metre or more. Such inaccuracies can result in flawed seabed maps, requiring costly and time-consuming re-surveys or post-processing.

From the latest EUSPA User Needs and Requirements Document for Maritime and Inland Waterways, the GNSS requirements for hydrographic surveying can be compared against the performance of HAS. Since the most stringent requirement refer to 1 to 2m horizontal accuracy (although this can differ case by case depending on the type of operation, as sometimes dm-level accuracy could be needed), the horizontal accuracy performance by HAS would meet these requirements.

Current hydrographic operations depend on a complex mix of acoustic and positioning technologies: multibeam echo sounders, side-scan sonar, and LiDAR, all supported by GNSS solutions such as RTK and SBAS and inertial sensors to determine precise vessel position and orientation. Near the coast, **RTK** is used to obtain high accuracy, but it requires a nearby reference station, making it **unusable in remote or offshore environments**. This creates a gap in operations, as surveyors lack a simple, rapid-deployment solution for achieving high accuracy far from shore.

In this context, Galileo **HAS** offers a valuable alternative by delivering high horizontal and **vertical accuracy without** relying on local **infrastructure**, which is often unavailable in coastal and offshore areas. Because HAS is **subscription-free** and accessible to any user with a compatible receiver, it also provides notable economic

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advantages. Its ability to maintain accurate positioning in remote regions strengthens operational reliability, reduces the need for repeated surveys, accelerates project timelines, and supports the production of dependable depth data for maritime construction and navigation. In addition, HAS helps **futureproof hydrographic operations** by aligning with emerging requirements for autonomous vessels and resilient PNT systems.

4.4.2.2 Expected uptake

The adoption of Galileo HAS in the maritime domain is expected to evolve gradually, beginning with limited use in 2026–2027 where the service will mainly support non-critical or complementary functions. Broader uptake is anticipated around 2030–2031.

The case of **marine surveying and mapping** is less constrained by regulation, allowing **quicker adoption** of new GNSS technologies; HAS-enabled receivers are already available from many manufacturers like ANAVS, SinoGNSS, Kongsberg Discovery, FLIR Transpondertech AB, Hemisphere and Spaceopal.

Initial uptake remains low due to the dominance of established high-end providers like Trimble and Hexagon, but long-term penetration is expected to rise, potentially reaching full adoption of HAS in European high-end receivers by 2040, supported by shorter convergence times with Service Level 2 (SL2) and a typical equipment lifetime of around six years.

The following charts offer an overview of the expected uptake of HAS in marine surveying and mapping applications:

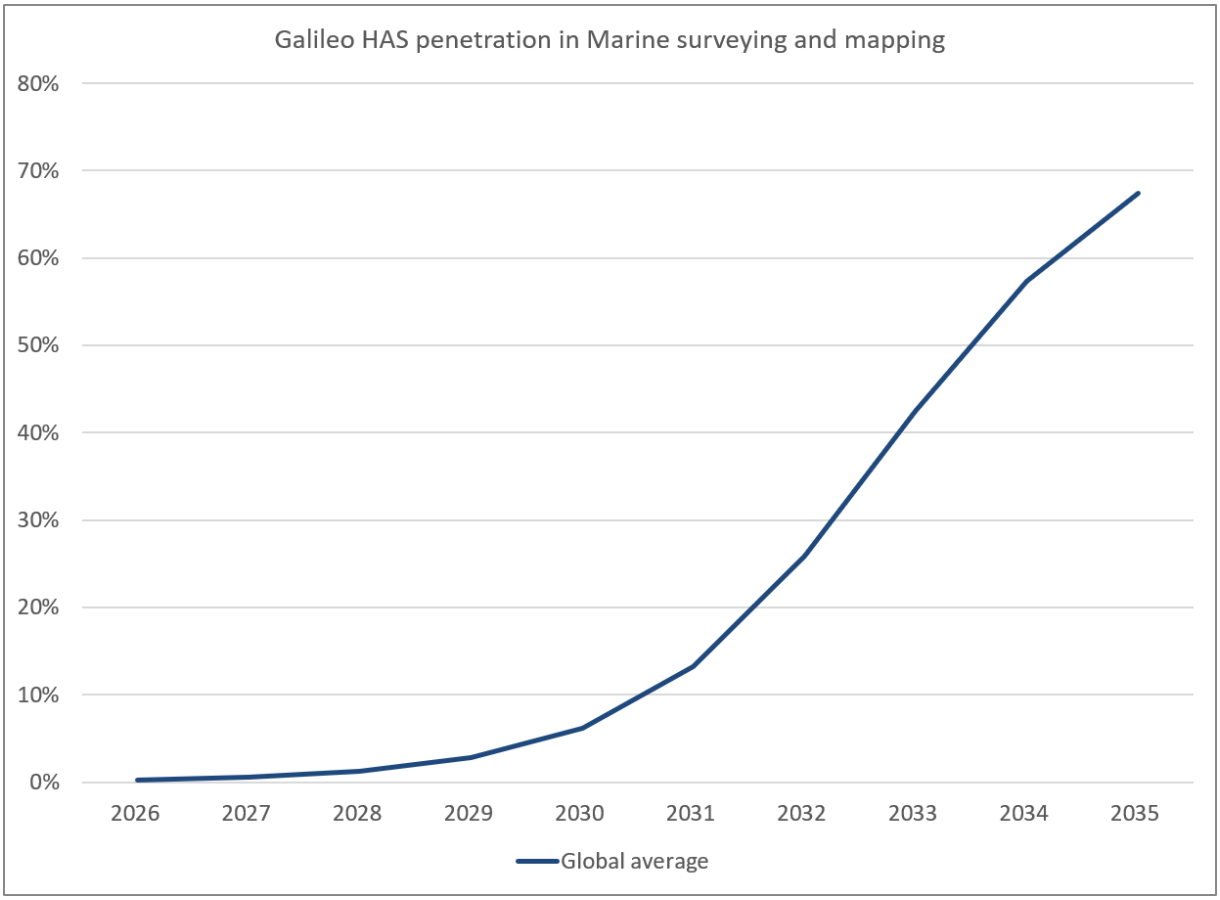


Figure 1 - Galileo HAS penetration in Marine surveying and mapping

As can be seen from the Figure 1 above, the global uptake of Galileo HAS within dedicated GNSS receivers for surveying and mapping purposes is expected to see a rather slow start. By 2030, it is foreseen that

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roughly 10% of the new receivers sold will be HAS-enabled. However, this is forecasted to ramp up and reach almost 65% by 2035.

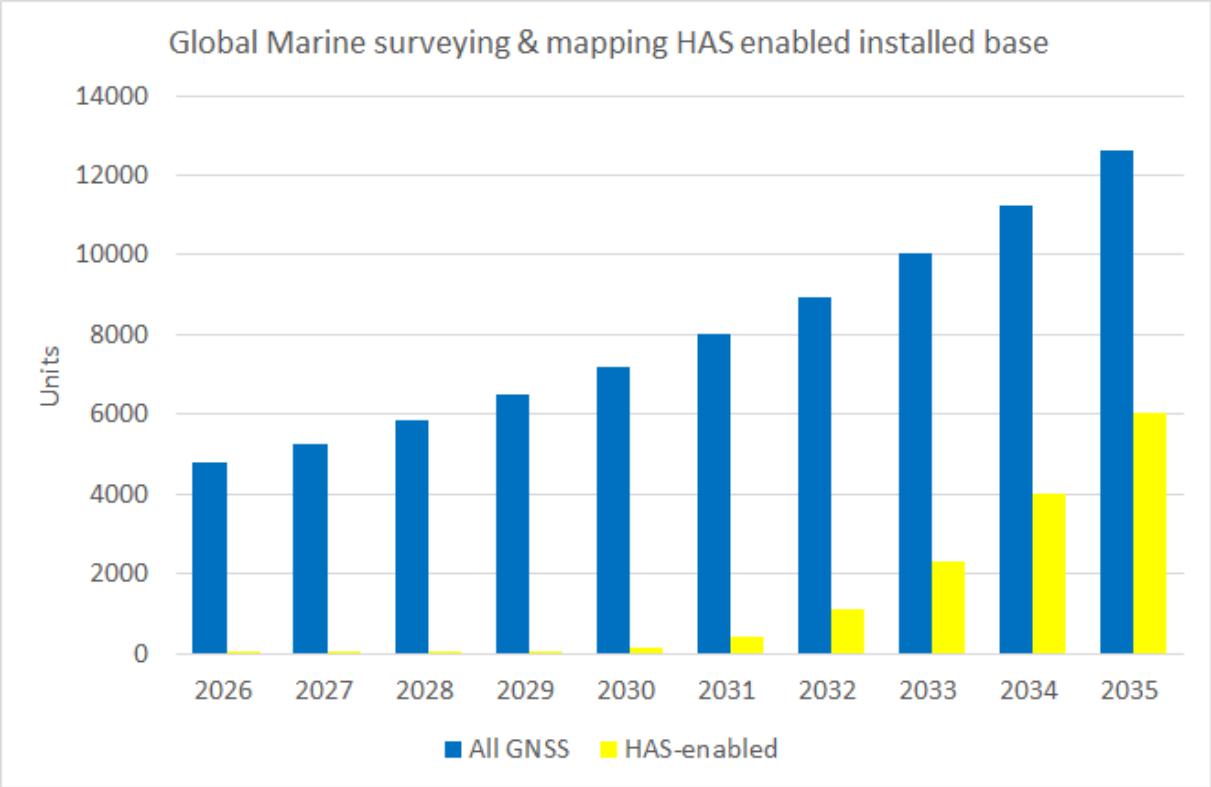


Figure 2 - Global Marine surveying & mapping HAS enabled installed base

Figure 2 shows us the global installed base of maritime receivers for the surveying and mapping applications. Based on the latest EUSPA forecasts, this global market (blue bars) is expected to grow from roughly 4,000 receivers in 2025 to almost 13,000 receivers by 2035. Combining the information derived from Figure 1 and combining it with the blue bars allows us to estimate the build-up of HAS-enabled receivers within this global installed base. As visible on the chart, by 2035 it is expected that there will be a total of 6,000 HAS-enabled receivers in use.

4.4.3 Future outlook

The potential of Galileo **HAS in the maritime domain** has been tested by the scientific community [1] and by public institutions and the industry [2], showing that the promised performance and related **benefits are real**. The advantages HAS offers can be applied to a variety of maritime use cases beyond hydrographic surveying, including but not limited to **auto-docking, dynamic positioning and autonomous vessels**.

Currently, several HAS-projects are being run to showcase the added value of HAS for autonomous navigation, inland waterway navigation, etc. where a horizontal accuracy of 20cm could improve the navigation in restricted environments. Outside of these navigation applications, it is believed that the use of HAS could also benefit the European-wide water level measurement in inland waterways, by integrating HAS alongside physical standard gauges and in smart buoys.

European institutions will continue to offer support to the industry in this direction, with the ultimate objective of making the industry more innovative and competitive.

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KONGSBERG

KONGSBERG

KONGSBERG is a global leader in **hydroacoustic systems, inertial navigation**, and **high-precision positioning**, supporting applications such as hydrographic surveying, offshore energy, maritime autonomy, and dynamic positioning (DP). Its strategy integrates advanced navigation technologies, including the Galileo High Accuracy Service (HAS), to enhance reliability and performance across demanding maritime operations.

The Seapath 385 system combines **multi-constellation GNSS** receivers, **inertial measurement units**, and sophisticated data-fusion algorithms to deliver precise heading, position, velocity, roll, pitch, and heave, making it a core reference system for **hydrographic surveying**. Shallow-water survey operations typically require **RTK** corrections or commercial satellite augmentation for centimetric accuracy, particularly vertically. However, in **deeper waters**, where vertical precision is less critical, **Galileo HAS** becomes a strong alternative by providing **~10 cm** accuracy without subscription fees. Industry feedback shows that HAS is already **operationally stable**, with benefits such as improved availability in northern latitudes, with respect to alternative solutions, but uptake is still modest because HAS is currently an **optional feature** that users must enable.

While the survey segment is specialized and relatively small, the **Dynamic Positioning (DP)** market is significantly larger. KONGSBERG serves this segment with navigation reference systems used on offshore support vessels, construction ships, and research platforms. DP applications prioritize **robust, drift-free horizontal positioning**, creating a strong fit for Galileo HAS, particularly for vessels operating in offshore zones where terrestrial correction networks are unavailable.

DP systems rely on **stable, resilient GNSS corrections** rather than centimetric vertical accuracy. Galileo HAS aligns well with DP operational needs because:

- **Global satellite broadcast** ensures accuracy even in remote offshore regions.
- **Multiple transmitting Galileo satellites** improve robustness in **high latitudes**, where geostationary correction systems are less effective.
- **Free access** reduces operating costs for fleet operators
- **Compatibility with DPS i-series' inertial sensors** ensures smooth vessel control even during convergence periods.
- **Availability via NTRIP** (Networked Transport of RTCM via Internet Protocol) provides an additional delivery channel when internet connectivity is present.

For DP vessels operating in **deep water**, where vertical accuracy is not a limiting factor, HAS provides a reliable and economical augmentation source.

KONGSBERG's **DPS ix-series** provides integrated GNSS/INS positioning tailored to DP needs, offering stable, drift-free horizontal positioning even under masking, scintillation, or interference. The **DPS ix3**, **ix4**, and **ix6** receiver models are all designed for robust multi-GNSS/INS fusion and are fully prepared to utilize **Galileo HAS** when required.

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KONGSBERG

Industry feedback indicate that the **DP equipment market** is of considerable size, with an estimated **several hundred DP-capable GNSS receivers sold per month** worldwide, HAS is already seen as a clear added value due to its global coverage and zero subscription cost.

KONGSBERG's trajectory reflects a strong and growing alignment with **Galileo's differentiating services**. Rather than treating HAS as a niche feature for specific applications, KONGSBERG increasingly considers it part of the default technological foundation of its receivers. In practical terms, this means **HAS will be** included, to ensure future readiness.

On **OSNMA**, KONGSBERG adopts an even more forward-leaning stance. Authentication is viewed as central to the next generation of maritime navigation integrity, especially for DP operations exposed to spoofing risks. As a result, KONGSBERG envisions **embedding OSNMA capability into all new receiver models**, making authenticated Galileo signals part of the standard trust framework for maritime positioning.

Bringing together, the DPS ix-series, Seapath, HAS readiness, and future OSNMA integration, KONGSBERG is positioning its portfolio to deliver reliable, resilient, and globally accessible high-accuracy GNSS to both survey and DP customers, supporting safer operations, reduced costs, and continued leadership in the evolution of maritime navigation.

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4.5 HAS for Agriculture

Galileo HAS offers significant potential for agriculture. Although its early role will mainly be as a complementary/backup or entry-level solution, its free availability, global coverage, promising accuracy, and ability to operate even in areas without connectivity position it as a powerful catalyst for the sector's shift toward more automated, efficient, and data-driven farming.

4.5.1 Service applicability

The **agriculture sector**, shaped by major **vertically integrated** players like CLAAS, CNH Industrial, Trimble, Hexagon, John Deere and Topcon, has long relied on high-accuracy positioning, making it a fertile ground for new GNSS innovations such as Galileo HAS.

Although only commercial augmentation services can meet the demanding requirements for centimetre accuracy needed in applications such as high-precision variable rate applications, **HAS** still offers a very attractive value proposition: free, globally available, high-accuracy corrections with < 20cm horizontal positioning accuracy (cm-level for pass-to-pass accuracy) that **meets the needs** for applications such as **automated guidance systems, precision irrigation or low precision variable rate applications**. Various integrators also consider HAS inclusion as a back-up positioning service for agriculture **autonomous machinery or robots**.

Field delineation and surveying-related tasks are dominating early HAS deployments, mirroring trends in mapping and surveying where HAS adoption is already progressing. Manufacturers like Hemisphere, Trimble and EOS have **already introduced compatible receivers**, demonstrating that integration is technically straightforward and commercially viable.

In addition, HAS can **expand precision agriculture into areas where RTK coverage and internet connection are limited or unavailable**. This opens new potential for farmers who currently lack access to RTK infrastructure or cannot afford high end subscription-based services. This is particularly strong **in rural and connectivity-limited regions**, where farmers often face barriers to adopting advanced positioning technologies. HAS directly addresses this gap by delivering high accuracy without requiring terrestrial networks or paid subscriptions. This positions it as an enabling technology for farmers not yet engaged in precision agriculture, offering an accessible entry point that can introduce digital practices at low cost. And because HAS can operate as a reliable fallback to RTK, farmers adopting it today could gradually scale up toward higher-precision systems as their needs evolve.

The potential for HAS to reduce operational costs across the value chain is also attracting interest, as hardware prices fall and HAS-enabled chipsets become more widespread, adoption is expected to become increasingly feasible. Even manufacturers initially cautious about integrating HAS recognise that its zero-cost model could make it a compelling complement to existing services without undermining higher accuracy offerings. Positive momentum is already visible. European system integrators such as AGC Technologies already begun integrating HAS into precision agriculture receivers, and so are doing non-EU manufacturers such as Quectel and Unicore, demonstrating the technology's high potential and viability, while accelerating **innovation cycles even beyond EU borders**. System integrators and agricultural machinery manufacturers, such as CLAAS, are exploring HAS implementation and view it as a valuable addition to their portfolios.

Overall, **Galileo HAS holds strong potential in agriculture**. While it will initially serve as a complementary/backup or entry-level technology or for applications with less stringent accuracy needs, its advantages such as free access, global coverage, strong accuracy potential, and suitability for regions lacking connectivity, make it a powerful enabler for the sector's transition toward more automated and data-driven

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farming. As performance improves and hardware costs fall, HAS is well positioned to become an integral component of the agricultural navigation ecosystem, expanding precision agriculture to new users and use cases worldwide.

4.5.2 HAS for automated farming guidance system

4.5.2.1 Overview

Precision agriculture increasingly depends on **robust guidance systems**, and this is where Galileo HAS can bring meaningful, practical value. Modern farm machinery already uses multi constellation, multi frequency GNSS receivers, together with augmentation techniques such as RTK, PPP and PPP-RTK, to improve resistance to multipath and maintain stable steering performance, but the sector still faces recurring obstacles linked to the reliance on RTK networks: subscription fees, coverage gaps, and the need for continuous connectivity. Even the most advanced auto steer systems can lose centimetre level accuracy within seconds when RTK corrections drop out, forcing operators to slow down, realign, or switch to manual driving, especially in rural areas with patchy mobile coverage or challenging terrain.

In this context, **Galileo HAS** introduces a welcomed **layer of resilience**. By providing **free, globally available below 20cm (cm-level for pass-to-pass) accuracy**, HAS can significantly improve the baseline accuracy of standalone GNSS and GNSS+SBAS guidance systems without requiring cellular or radio links. For many farming operations, such as manual guidance, auto guidance in broadacre fields, and general machinery navigation, this accuracy is more than sufficient to maintain clean passes and reduce overlap. The ability to receive corrections directly via satellite or internet means HAS-equipped devices can continue functioning smoothly when RTK links fail, allowing operators to keep working instead of waiting for reconvergence or troubleshooting connectivity issues.

This infrastructure-free reliability is particularly valuable when machinery moves through valleys, remote plots, or wooded headlands where cellular data drops out. While RTK remains essential for the most precision critical tasks, **HAS** offers farmers a **powerful safety net**: a seamless transition from centimetre accuracy to high decimetric accuracy that preserves operational continuity. It also simplifies system architecture for solution providers, freeing them to focus on agronomic intelligence and automation rather than deploying correction networks.

By strengthening the accuracy, reach, and robustness of guidance systems, Galileo HAS lowers barriers to entry for farmers who have not yet adopted precision farming and enhances the reliability of systems for those who already have. It broadens access to advanced guidance technology while reducing dependencies, costs, and complexity, helping the agricultural sector move toward more automated, efficient, and resilient operations. In addition to being free to use, HAS also offers truly **global coverage**, making it an attractive option where RTK cannot be deployed due to lack of internet access or the impracticality of portable radio stations, and it provides accuracy that is adequate for a wide range of applications while serving as a **secondary source of accuracy when RTK fails**.

4.5.2.2 Expected uptake

As the technology matures and HAS **performance improves with SL2 introduction, integration in farming guidance and autosteering systems** will be accelerated. The following charts offer an overview of the expected uptake in these applications.

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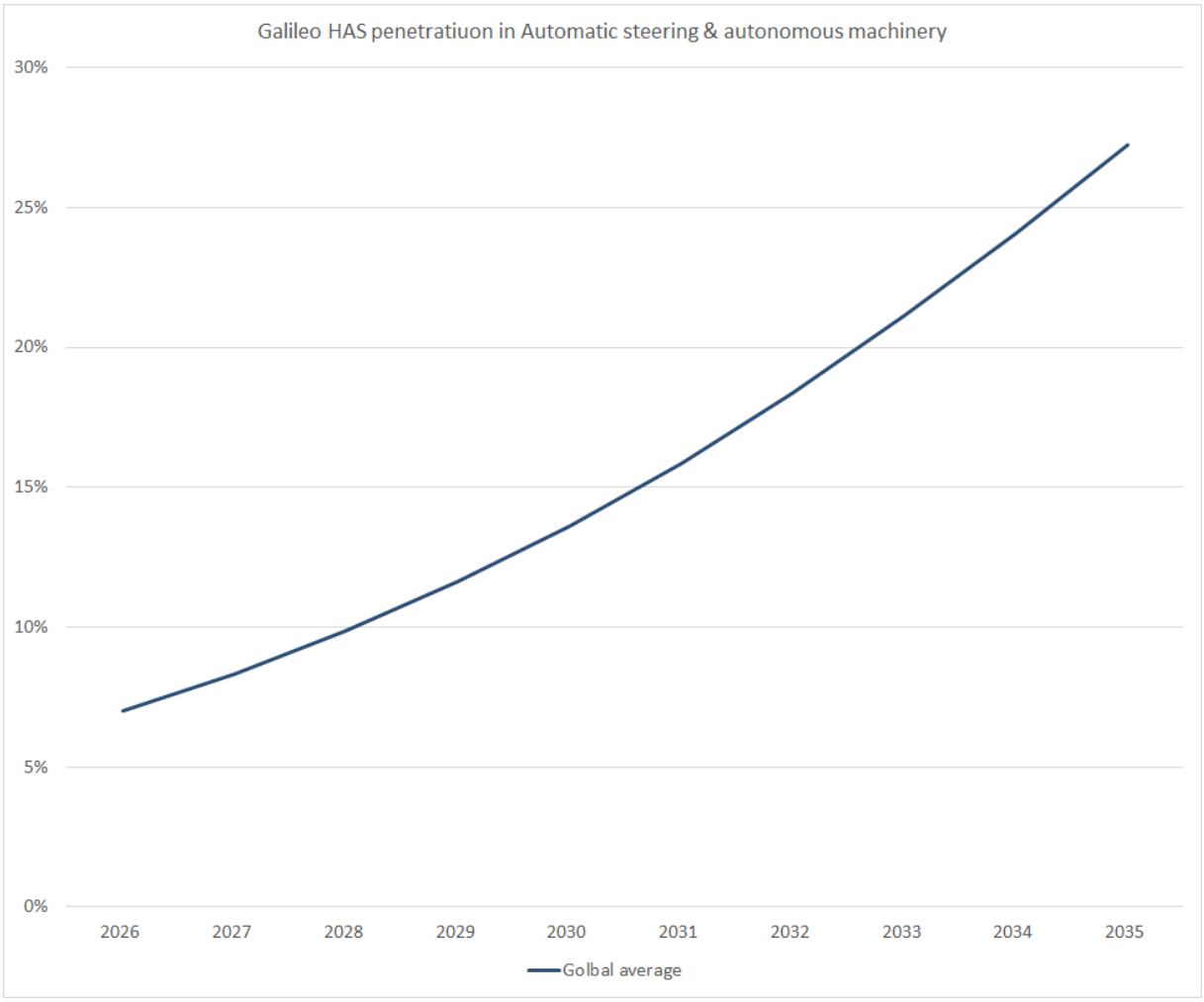


Figure 3 - Galileo HAS penetration in Automatic steering & autonomous machinery

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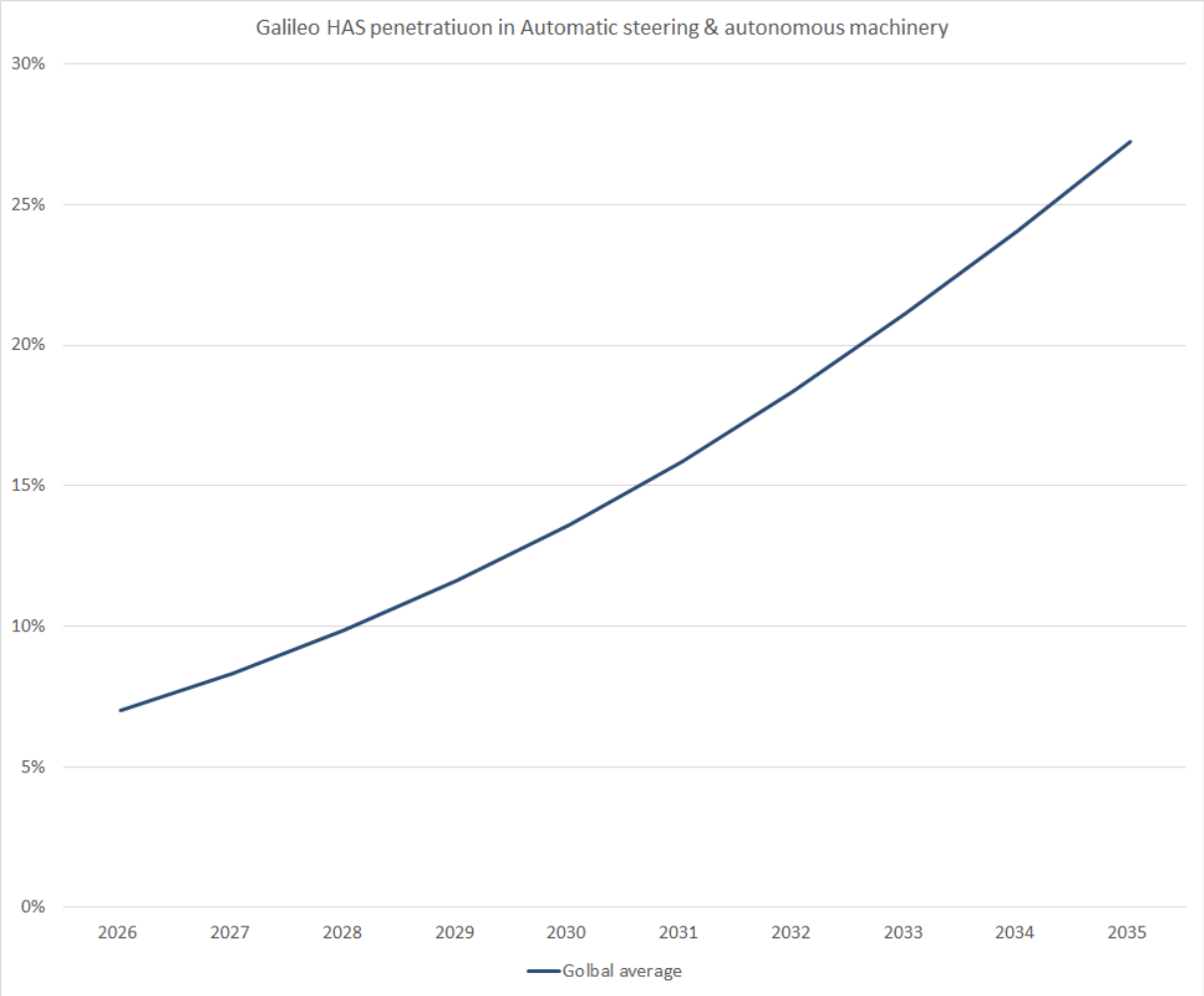


Figure 3 illustrates the

expected global uptake of Galileo HAS in automatic steering and autonomous agricultural machinery. The forecast shows a gradual increase in penetration from the current early stage of adoption, supported by the growing availability of HAS-capable receivers and increasing integration of the technology into agricultural applications. Uptake is expected to accelerate over the coming years as HAS is progressively incorporated into new generations of receivers and agricultural machinery, while continuing to complement established high-precision solutions such as RTK. The European market is expected to lead this transition, with adoption progressing more gradually in other regions.

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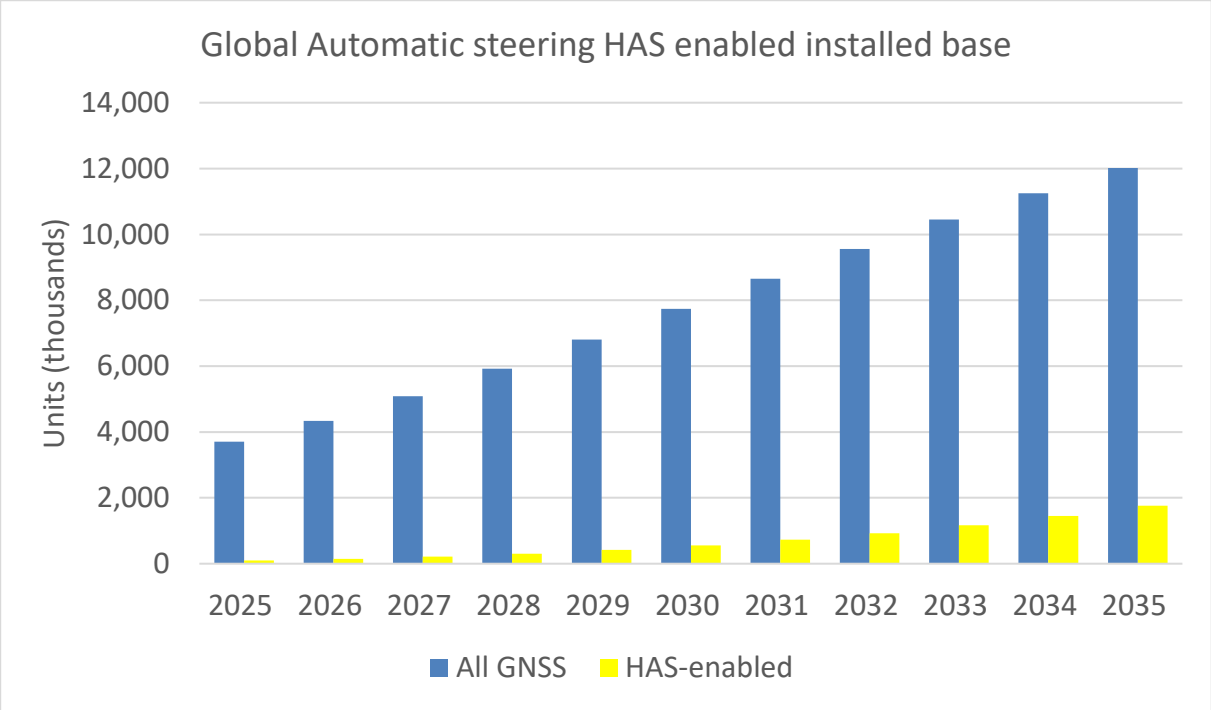


Figure 4 - Global Automatic steering HAS enabled installed base

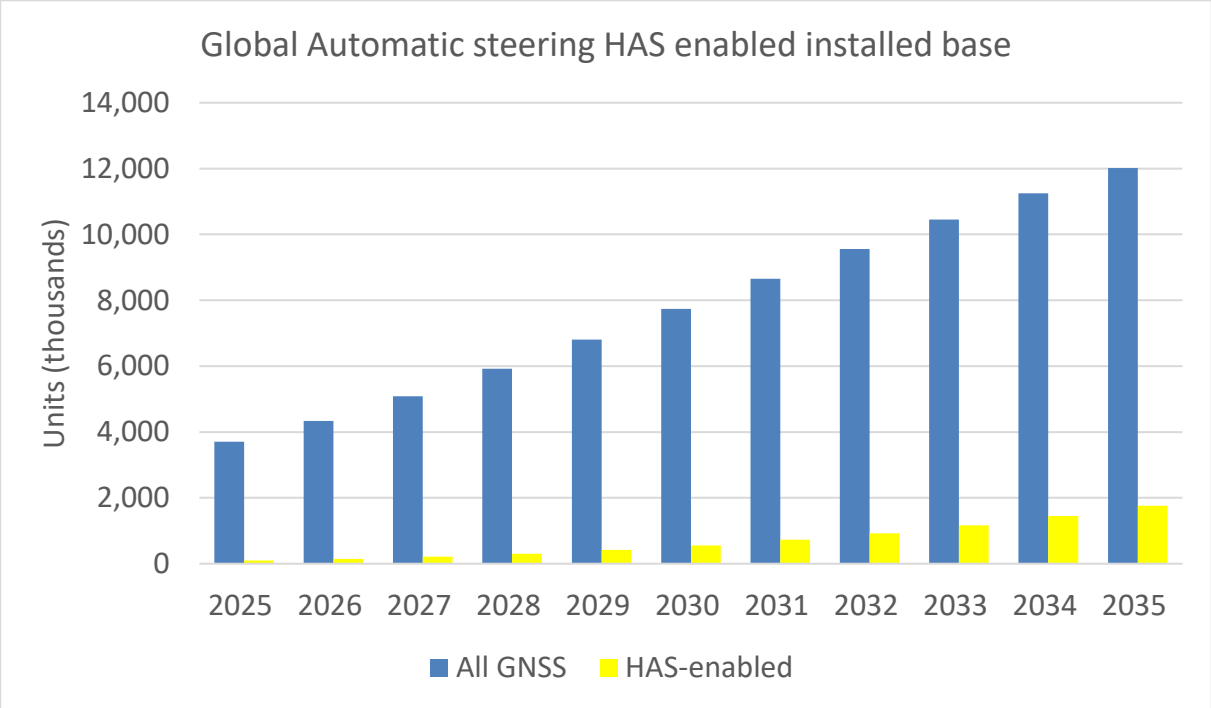


Figure 4 presents the forecast of the global installed base of GNSS receivers for Automatic steering (blue bars) which is expected to grow steadily from approximately 4.3 million units in 2026 to around 12 million by 2035. Within this expanding market, the installed base of HAS-enabled receivers is also expected to increase progressively, with growth accelerating after 2030 as HAS integration expands and new

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generations of agricultural equipment enter the market. By 2035, the global installed base of HAS-enabled receivers is expected to reach approximately 1.8 million units, reflecting the gradual integration of Galileo HAS into automatic steering solutions.

4.5.3 Future outlook

Galileo HAS shows strong potential across several agricultural applications where decimetric accuracy is sufficient. In **manual and assisted guidance and field delineation and mapping applications**, for example, the precision offered by HAS is already more than adequate as the service comfortably meets real-world performance needs.

A similar situation can be seen for **spraying and spreading**. Sprayers typically cover working widths of 20 to 30 metres, so the slight deviation introduced by decimetric accuracy has no meaningful impact on field performance. The same applies to spreading, where machine-level accuracy tolerances are significantly broader than centimetric standards. In these cases, HAS provides a reliable and cost-effective positioning source without requiring the infrastructure or subscription-based services associated with RTK.

For **seeding**, in pneumatic planting for cereals such as wheat or barley, Galileo HAS delivers **sufficient accuracy to guide machinery** effectively across the field. Its precision aligns well with the agronomic tolerances of broadacre seeding operations.

While some integrators, receiver manufacturers, and precision farming service providers are already pioneering above mentioned applications, adoption of HAS is expected to grow gradually, accelerated by the introduction of Service Level 2 that brings further service performance improvements and as the technology matures. However, **row-crop planting is far more demanding**. Here, centimetric alignment is essential to ensure uniform spacing, maximise yield, and avoid damage during subsequent mechanical operations. For these more advanced, precision-dependent tasks, RTK remains indispensable, which is why HAS is not recommended as the primary solution.

Overall, Galileo HAS offers a highly viable option for a wide range of agricultural applications, particularly those with decimetric accuracy requirements, while RTK continues to serve the most demanding, centimetre-level use cases.

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Modern precision farming relies on satellites for machines guidance, to reduce overlaps, and maintain repeatability across large and heterogeneous fields. While Real-Time Kinematic (RTK) corrections deliver centimetric performance where reference networks and connectivity are robust, many farms still face gaps linked to uneven coverage, the need for continuous cellular or radio links, especially in rural or remote areas, on top of subscription costs and related budget constraints. In this context, a free and globally available high-accuracy layer can extend precision workflows to places where RTK is impractical or intermittent.

AGC Technologies, a Spanish innovative company active in agricultural, construction, and maritime sectors, integrates the Galileo High Accuracy Service (HAS) to deliver a new generation of precise, reliable, and cost-effective positioning for agricultural machinery.



By integrating HAS, AGC Technologies' guidance consoles can operate with high accuracy without requiring RTK networks, base stations, or paid subscriptions. The system receives **HAS corrections directly from satellites when cellular connectivity is weak, and via the internet when coverage is available**, ensuring **continuous performance** in fields where infrastructure is limited. This dual delivery path aligns with the official HAS architecture, which supports both the E6-B broadcast and internet-based correction streams to maintain operational robustness.



AGC Technologies uses **multi-constellation, multi-frequency** GNSS-including Galileo E1/E5/E6 and GPS L1/L5-to enhance **reliability** in real-world agricultural environments. This increases **resistance to multipath** and **improves accuracy** around tree lines, rolling terrain, or tall crops. HAS-corrected GNSS is combined with inertial sensors (IMUs) inside AGC Technologies units, so short GNSS interruptions caused by canopy or terrain are bridged smoothly using GNSS/INS fusion, a method widely deployed for autonomous and precision agriculture navigation. For farmers, this integration means **more accurate guidance lines, improved section control, and better repeatability** than SBAS solutions, but **at just a fraction of the cost** and complexity of RTK systems. HAS effectively complements RTK for applications such as spraying and spreading, and often harvesting, for which decimetric accuracy is adequate, while row-crop planting remains a centimetric task.



AGC Technologies is currently testing algorithms to raise pass-to-pass performance when ingesting HAS corrections.

On top of technical advancements, **spreading awareness** across OEMs, dealers, and farmers on the benefits offered by HAS is important to support the market growth.

HAS effectively positions **AGC Technologies** as an **accessible high-accuracy platform**, offering consistent, infrastructure-independent precision for tasks such as spraying, fertilizing, mowing, and harvesting, bringing high-performance guidance technology to a broader range of operations.

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5 GALILEO OSNMA

5.1 Definition and purpose

The Galileo Open Service Message Authentication (OSNMA) is a free data authentication feature for Galileo's **Open Service**, accessible to users worldwide. By offering assurance that the Galileo navigation message is authentic, OSNMA aims at strengthening the robustness of the positioning by increasing the capability of **detecting spoofing events** [4], which can disrupt critical applications across various sectors.

The Galileo OSNMA is operational since **July 24th, 2025**, and current evolution plans already include the cross-authentication of GPS, which would incorporate the U.S. constellation into the OSNMA service.

A high-level, introductory description of OSNMA, including its up-to-date planned implementation roadmap and an overview of the addressable markets, is available in its Information Note.

A full description of the service is available in its Service Definition Document (SDD).

Lower level technical details are available in its SIS Interface Control Document (ICD), Internet Data Distribution (IDD) ICD and Receiver Guidelines.

5.2 Key benefits

OSNMA implementation can be beneficial both for safety-critical and compliance authentication applications:

- **Safety-critical applications**: these include sectors such as aviation, maritime navigation, autonomous vehicles or rail, where spoofed signals could lead to hazardous outcomes. In these contexts, OSNMA serves as a safeguard, ensuring that the navigation data originates from a trusted source (i.e., Galileo) and has not been tampered with during transmission.
- **Provision of compliance authentication**: refers to use cases where GNSS data is employed as verifiable evidence in administrative, legal, or commercial processes. Examples include the use of satellite positioning to validate eligibility for agricultural subsidies under the Common Agricultural Policy (CAP), logistics tracking for customs compliance, or geolocation data in insurance claims. Here, OSNMA helps prevent fraud by providing cryptographic assurance that the navigation data used to generate the reported position information is genuine and unaltered. The main benefits include:
    - **Simplified checks, better fraud detection and deterrence for authorities**.
    - **Easier compliance for users, namely simplified audit and reduced administrative burden**.

5.3 Market potential

As security threats evolve and industries become increasingly dependent on positioning and timing, the market is searching for reliable ways to protect GNSS-based operations. In this landscape, Galileo's OSNMA emerges as a timely and high-value solution, capable of providing an additional layer of security across a wide range of sectors. Indeed, a significant number of OSNMA-enabled receiver models are already on the market.

Sectors such as **critical infrastructure** (energy grids, transport systems and telecommunications networks) have in the last years deepen their reliance on accurate PNT data, and GNSS in particular.

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Automation also reinforces the demand for robustness. From **autonomous vehicles to remote industrial systems**, automation is expanding faster than ever, and with it the threat of cyberattacks. The market is therefore actively looking for authentication solutions like OSNMA, ensuring machines act on genuine data.

What makes OSNMA particularly compelling is its **wide applicability**, OSNMA can indeed serve virtually any segment that depends on GNSS, whether in highly regulated environments or in mass-market applications seeking an additional layer of security.

From the data authentication viewpoint, OSNMA provides a foundational layer to implement robust PNT solutions. Actually, while OSNMA alone cannot secure the full data chain, it offers a critical first defence against spoofing and can be combined with data-signing and security solutions to build full end-to-end integrity. This capacity resonates strongly with **insurers, auditors, and public authorities** that rely on trustworthy location data. It has applications in, for example, **agricultural monitoring or fisheries control**.

In summary, the overarching narrative is clear: OSNMA sits at the intersection of rising security demands, expanding automation, regulatory pressure for integrity, and a strong push toward GNSS authenticity worldwide. Its free availability and broad compatibility give it a unique market advantage, and as awareness grows, OSNMA is positioned to play a central role in securing the next generation of GNSS-enabled services.

The following table provides an overview of the applications expected to mostly benefit from the Galileo OSNMA.

Table 3 – Market segments mostly benefitted from OSNMA

Markets	Applications
Agriculture	OSNMA is recommended for the geo-tagging of pictures as part of the EU's Common Agriculture Policy (CAP). In the longer term, it may also become relevant for the operation of autonomous machinery.
Aviation and Drones	As one of the industries most concerned by RFI threats, OSNMA will contribute to mitigate spoofing events. The first steps to set-up the regulatory enablers have already taken place.
Emergency Management & Humanitarian Aid	OSNMA is expected to increase the resilience and security of emergency operations, assisting Civil Protection bodies in their duties and supporting applications like personnel and vehicle-tracking.
EU Border Security and Customs operations	There is an increasing number of RFI events affecting, for example, the operation of border patrolling and customs agencies. The potential for OSNMA implementation has been demonstrated by means of pilot projects and the user community is interested.
Fisheries & Aquaculture	It is expected that OSNMA will be integrated into the position reporting implemented in VMS (Vessel Monitoring System) equipment.
Energy & Infrastructure	The authentication provided by OSNMA will increase the robustness and resilience of Timing and Synchronization (T&S) in applications like energy grid operations and telecommunications networks.
Insurance and Finance	Authentication is considered a key aspect to enhance the robustness in timing applications. In this context, receiver manufacturers have already deployed OSNMA-capable solutions
Maritime and Inland Waterways	The maritime user community is very interested in solutions able to mitigate the consequences of increasing RFI threats. Concerns exist in operations like the transport of dangerous goods. In this context, some manufacturers have already started to roll-out OSNMA enabled equipment to support non-SOLAS applications.
Road & Automotive	Adoption in this segment is already a reality, mainly favoured by the regulatory context that has mandated OSNMA implementation in smart tachographs. There

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	is, besides, a huge opportunity in Cooperative and Automated Driving (CAD) applications.
Space	GNSS RFI events are also increasing at LEO altitudes. In this context, the demand for increased resilience is expected to grow over the next years. Some manufacturers are already commercialising spaceborne receivers implementing OSNMA along with advanced jamming mitigation techniques.

5.4 OSNMA for Road and Automotive

OSNMA is already an established technology in the EU for smart tachographs, since it increases the trustworthiness of recorded logs, and is expected to contribute to automated driving by increasing the robustness of the PVT solution.

5.4.1 Service Applicability

The **Road and Automotive** sector represents a very important application segment for OSNMA, as it relies heavily on satellite-based positioning **for both safety-critical and compliance-driven functions**. Actually, this relevance was reinforced at the User Consultation Platform (UCP) 2025 Road & Automotive session, where Original Equipment Manufacturers (OEMs), Tier 1 suppliers, GNSS specialists, and regulatory experts highlighted the importance of authenticated, robust navigation for the future of Cooperative, Connected and Automated Mobility (CCAM). Stakeholders emphasised persistent vulnerabilities to jamming and spoofing, as well as the growing need for **absolute positioning**, **integrity**, and **resilience** as automation advances.

Hence, as vehicles sold in the EU are increasingly required to comply with regulations aimed at Advanced Driver Assistance Systems (ADAS) implementation, they become more connected and more automated. Here, OSNMA stands out as a valuable enabler of trustworthy and robust GNSS positioning.

As said, its role is particularly relevant for the next generation of safety-critical automotive systems and regulated applications where data integrity is essential.

(1) In **Security-critical authentication applications** like **Cooperative and Automated Driving (CAD)** spoofing is one type of challenge faced by GNSS-based vehicle positioning systems where OSNMA is perceived as a potential mitigation by the industry.
(2) In **compliance-driven authentication applications**, such as **smart tachographs** (nowadays with the strongest regulatory driver for OSNMA uptake), or eventually **Road User Charging (RUC)** or insurance telematics, OSNMA provides a means to ensure trustworthiness of the PVT.

Actually, **smart tachographs** emerged at UCP 2025 as **the single most significant, near-term driver** for widespread OSNMA adoption in road transport. This case is therefore presented in the next sub-chapter.

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5.4.2 OSNMA for Smart tachographs

5.4.2.1 Overview

Smart tachographs are regulatory devices mandated in the European Union under **Regulation (EU) No 165/2014**[3], designed to monitor driving times, rest periods, and vehicle movement to ensure road safety and fair competition.

Second-generation smart tachographs version 2 (G2V2), required in newly registered vehicles since 21 August 2023 and mandatory for all vehicles engaged in international transport from August 2025, include a dedicated GNSS OSNMA-capable receiver and are structured around the need for trustworthy Position, Velocity, and Time (PVT) data. This mandate ensures that smart tachographs will experience **the fastest and most complete adoption** of OSNMA across all automotive applications.

During the UCP 2025 session, on the other hand, stakeholders underlined that smart tachographs rely on **high-integrity, authenticated PVT data**, and thus benefit directly from what OSNMA provides.

Aumovio, for example, provided key insights into the practical deployment of OSNMA in smart tachographs. **Implementation challenges** emerged from real-world testing:

- The number of visible satellites broadcasting OSNMA can vary, and the reliability of data streams is a critical factor.
- Environmental conditions (obstacles, interference, unintentional jamming) significantly affect OSNMA performance.
- OSNMA's **time to authenticated fix** is far longer than standard Time to First Fix (TTFF). Importantly, if the real-time clock drifts more than **163 seconds**, OSNMA authentication becomes invalid, adding pressure on timing stability in tachographs.
- Lack of over-the-air (OTA) update capabilities complicates deployment in existing units, although transitional measures allow devices to ignore OSNMA until updates are available.

Stoneridge, meanwhile, stood out as an early mover during 2025: by mid-year they had already begun releasing **OSNMA-capable second-generation smart tachographs**, positioning themselves ahead of regulatory deadlines.

5.4.2.2 Expected uptake

In Europe, OSNMA uptake in 2026 starts beyond 90% because of the abovementioned regulation. Hence, as tachographs are replaced with OSNMA-capable G2V2 units, it is expected to reach almost **100% penetration by 2028** across heavy goods vehicles, buses, and light commercial vehicles. Aumovio and Stoneridge, dominants in the EU market, have released OSNMA-integrated tachographs with rapid deployment following the mandatory requirements. Outside Europe, adoption remains more limited, with North America projected to reach approximately 10% penetration in the absence of mandates, and negligible uptake in the rest of the world.

This uptake forecast is presented in the next chart.

[3] Subsequently amended by Commission Implementing Regulations (EU) 2019/799, 2018/502 and 2021/1228.

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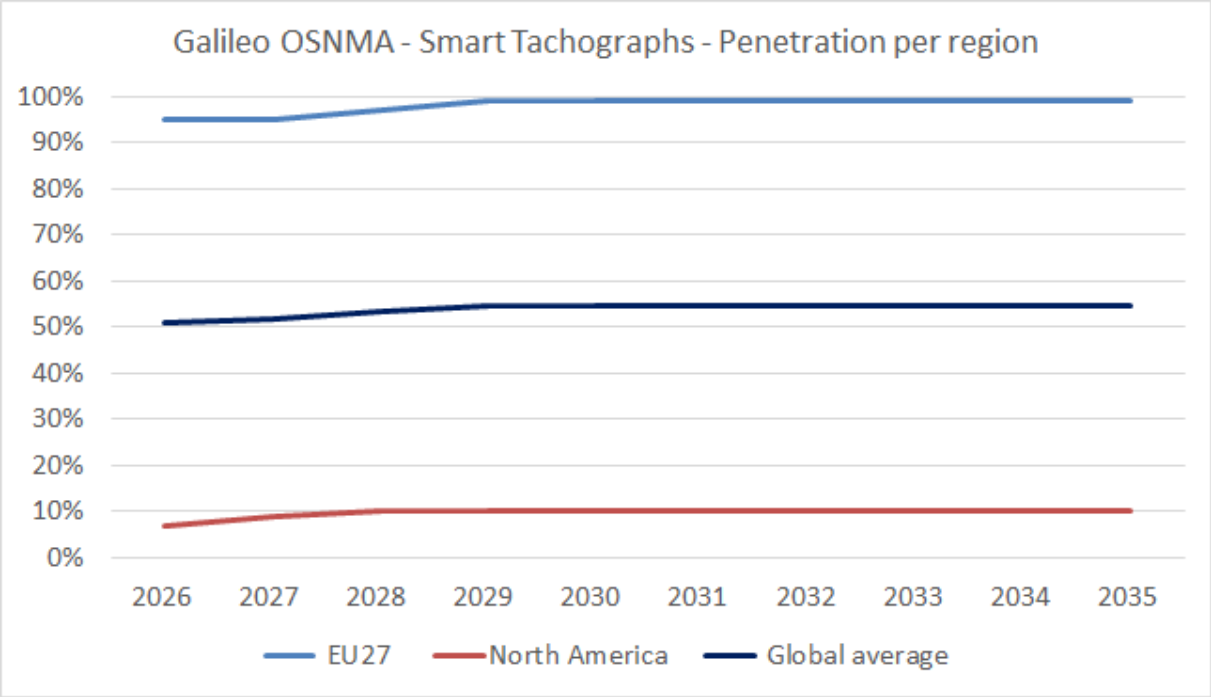


Figure 5 - Galileo OSNMA - Smart Tachographs - Penetration per region

Please note that the uptake of smart tachographs is primarily assessed in the EU-27 and North America, as adoption remains very limited in other regions.

At global level, the presence of OSNMA in the overall smart tachograph picture will significantly grow over next years as an increasing number of devices are rolled-out in the EU as illustrated by Fig 5. The use of smart tachographs, however, is not a global practice, and this will prevent OSNMA from growing in this segment in other markets.

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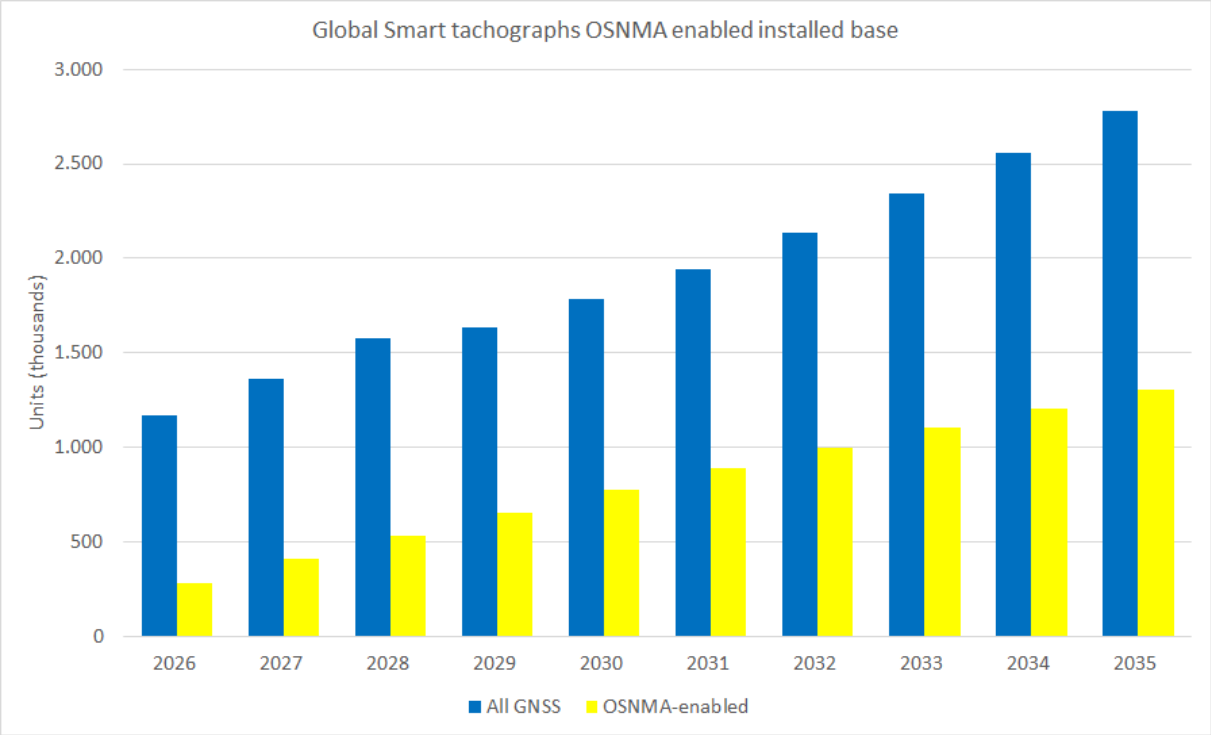


Figure 6 - Global Smart tachographs OSNMA enabled installed base

In Figure 6, it can be observed that the global installed base of smart tachographs is expected to nearly triple during the next 10 years (from over 1 to 2.8 million). In this context, the number of OSNMA-capable ones will not triple but grow by a factor of 12 (from 100.000 units to 1.2 million), representing nearly half of the devices installed globally.

5.4.3 Future outlook

As depicted in previous paragraphs, the growth of OSNMA in the smart tachograph market is strongly backed-up by the existence of a regulation mandating its implementation in heavy vehicles operating internationally as well in light commercial vehicles (2.5-3.5 tonnes) operating internationally.

OSNMA implementation is expected to also occur in other areas, in particular **In-Vehicle Systems (IVS) and Emergency Services**, **Road Asset Management**, **Insurance Telematics**, **CAD**, **Public Transport and Road-User Charging**.

In the Road and Automotive segment, IVS represents the largest market in terms of GNSS shipments. Here, for some chipset manufacturers, OSNMA will be a standard offer in their automotive products and hence this will have a positive impact on the integration of OSNMA in IVS receivers.

Based on the availability of these chipsets, system integrators and OEMs will require time and service maturity to gain confidence and fully exploit OSNMA capabilities.

Therefore, overall, maximum adoption rates are expected to occur post-2035, concentrated along EU27, non-EU27 Europe and North America.

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5.5 OSNMA for Maritime

Growing GNSS interference is driving the maritime sector toward authenticated navigation, with Galileo OSNMA increasingly viewed as a critical security layer for trusted PNT and resilient VDES-based services.

5.5.1 Service Applicability

The maritime sector, just as most sectors extensively relying on GNSS such as aviation, emergency management and road, to mention a few, is facing a growing threat landscape driven by increasingly frequent and sophisticated **cyberattacks**, particularly **GNSS spoofing** and **jamming**. These attacks can mislead vessels by feeding counterfeit navigation signals or degrading GNSS reception, creating significant navigational, operational, and safety risks. Multiple regions have already reported thousands of such incidents monthly, particularly in the Baltic and Black Sea areas, as highlighted by the European Commission and other monitoring bodies [5].

In the maritime sector the need for trusted, authenticated data is especially critical. Applications such as **vessel tracking and tracing, traffic management, port call reporting**, and **marine surveying** rely extensively on GNSS-derived PNT information. OSNMA-authenticated data can not only improve resilience against spoofing [6]. but also strengthen **regulatory compliance**, providing robust evidence for legal or administrative proceedings.

Studies, including the ASGARD maritime receiver project show that OSNMA can significantly enhance resilience by detecting spoofed signals across a variety of attack types (e.g., replicated SIS attacks, partial-satellite spoofing) [7].

5.5.2 OSNMA for VDES

5.5.2.1 Overview

As highlighted during the UCP2024, spoofing and other GNSS RFI were identified as main concerns by the maritime industry across several applications, including traffic management. Whilst mariners and maritime authorities currently rely on AIS for traffic management and positioning reporting, AIS is expected to evolve into VDES as it will address current bandwidth and security limitations of AIS.

Integration with Galileo OSNMA can add authentication to increase the robustness of vessel navigation and position reporting, underpinning smarter and more secure traffic management. This would also make navigation routes safer, improve situational awareness, and facilitate the activities by relevant authorities when it comes to vessel monitoring.

5.5.2.2 Expected uptake

The following charts offer an overview of the expected uptake.

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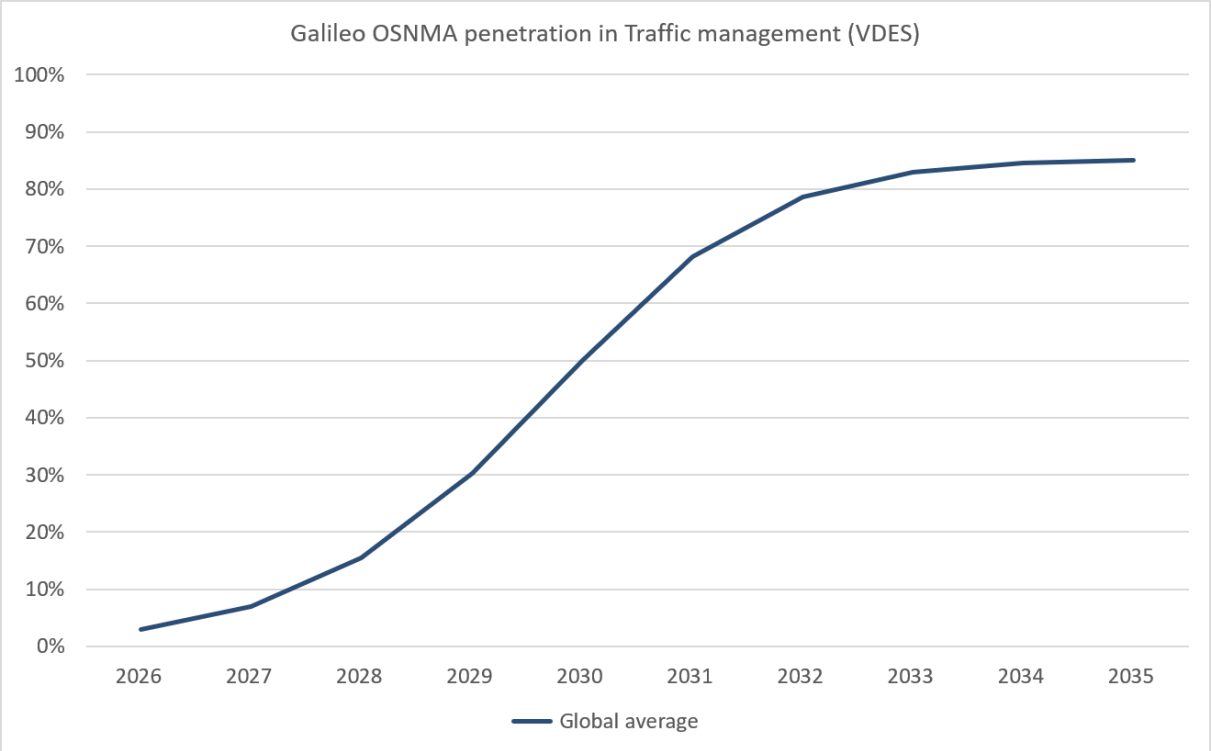


Figure 7 - Galileo OSNMA penetration in Traffic management (VDES)

Based on stakeholder interviews, Figure 7 presents the estimated penetration of OSNMA amongst receiver shipments for traffic management purposes. It is currently believed that roughly 7% of the annual sales in 2028 (year of VDES integration into the SOLAS regulatory framework) include OSNMA support, an uptake that is forecasted to reach 90% by 2035.

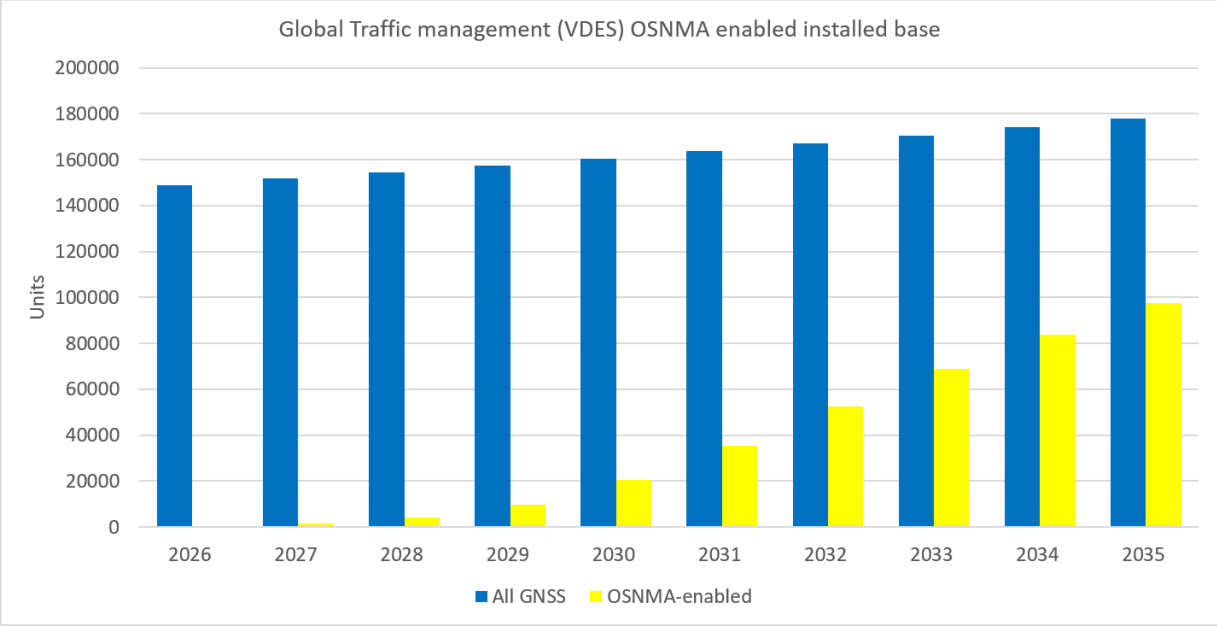


Figure 8 - Global Traffic management (VDES) OSNMA enabled installed base

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As evident from the figure above, the global installed base of maritime receivers for traffic management (blue bars) shows a steady increase from roughly 150,000 receivers in 2026 towards almost 180,000 receivers by 2035. When using the penetration of OSNMA over annual shipments, it is possible to estimate the build-up of OSNMA-enabled receivers in use over the same timeframe. In 2035, this estimate number would reach roughly 95,000 OSNMA-enabled receivers in use.

5.5.3 Future outlook

The **future uptake** of OSNMA in the maritime ecosystem will largely depend on **regulatory frameworks**. Applications governed by **IMO SOLAS** and EU's Maritime Equipment Directive (MED) strict rules, such as **AIS evolving into VDES**, will adopt OSNMA more slowly due to required conformity assessments and approval cycles. This mirrors ongoing integration efforts in aviation and road transport, where OSNMA is already being incorporated into international standards and EU-mandated systems.

Despite industry enthusiasm, end-user adoption may lag without regulatory mandates. Maritime operators often take a conservative approach to technology change, and many remain unaware of authentication benefits offered by OSNMA. The entire maritime value chain, from **chipset manufacturers, OEMs, system integrators** and also **end-users**, is in need of a reliable authentication solution that OSNMA can satisfy. Initiatives to spread awareness on its value proposition, including but not limited to EUSPA's OSMNA info day, will support the uptake.

Looking ahead, the broader European strategy to counter GNSS interference, including spoofing and jamming, continues to evolve. The maritime sector will benefit from these resilience layers, especially as incidents of GNSS interference continue to rise across Europe [9].

As discussed during the EUSPA User Consultation Platform in 2024, the role of authentication will become increasingly important for **autonomous vessels (MASS)**, where reliable and authenticated PNT is considered essential. As autonomy increases, so does the need for robust trust frameworks, of which OSNMA can be a foundational component.

Overall, as spoofing becomes a persistent operational hazard and authenticated navigation transitions from "nice to have" to **mandatory for safety and governance**, OSNMA is expected to become a key enabler of trusted maritime PNT over the coming decade

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Ship VHF Data Exchange System (VDES)

The **VHF Data Exchange System (VDES)** is emerging as the successor to the **Automatic Identification System (AIS)**, whose channels, introduced in the late 1990s and mandated for SOLAS-class ships since 2002, are now reaching its capacity in high-traffic waters. Developed over several years by the International Association of Marine Aids to Navigation and Lighthouse Authorities (IALA) as a new global standard, VDES offers expanded bandwidth, structured digital messaging, and support for authenticated maritime services. During **UCP 2024**, stakeholders highlighted that VDES will provide greater capacity, global coverage, and improved authentication frameworks through the **Maritime Connectivity Platform**, paving the way for enhanced safety-of-navigation services, potential future Global Maritime Distress and Safety System (**GMDSS)** integration, and secure operational exchanges such as Arctic search patterns.

However, VDES's performance is increasingly challenged by the sharp rise in **GNSS interference**, including spoofing and jamming, reported across the Baltic Sea, Black Sea, Strait of Hormuz and Western Pacific. Such interference undermines the accuracy of shipboard **PNT** solutions and disrupts the strict timing structure needed for VDES transmissions. Maritime authorities note that because VDES depends on GNSS-derived timing and position data, interference can degrade position reporting reliability and impair VDES service integrity.

In this context, **IALA** has identified **Galileo OSNMA** as a key enabler to strengthen GNSS resilience and has accordingly updated its guidance, including **G1117 (VDES Overview)** and **G1181/G1180 resilience and integrity documents**, to recommend authenticated GNSS as part of resilient maritime PNT, reflecting the rising threat landscape and the need for integrity-protected timing and position data.

Therefore, within the VDES architecture, OSNMA will provide a **trusted foundation** by ensuring the embedded GNSS position in VDES messages has not been manipulated. But the guidelines also highlight the value of **dual authentication**: first verifying the GNSS-derived position using OSNMA, then authenticating the VDES message through VDES's own cryptographic mechanisms, preventing cases where a falsified position is wrapped inside an otherwise valid VDES transmission.

Recent international discussions within **IMO** and the **United Nations** underscore the urgency of addressing widespread GNSS interference, while several EU Member States have requested coordinated European countermeasures due to thousands of monthly incidents. Maritime users participating in the **EUSPA User Consultation Platform** reaffirmed that secure, robust positioning and authenticated VDES links are essential for future maritime operations. This becomes even more critical for **MASS (Maritime Autonomous Surface Ships)**, where authenticated PNT and resilient communications form mandatory safety prerequisites.

Looking ahead, OSNMA is expected to become a **core element** of VDES-based services. Both shipborne receivers and shore infrastructure are preparing for integration, and forthcoming IALA guideline updates (expected in 2026) will formalise OSNMA requirements within VDES system design. Manufacturers are already aligning with these developments, positioning OSNMA as a foundational enabler of **resilient maritime navigation, secure digital services, and trustworthy position reporting** across Europe and globally.

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5.6 OSNMA for Aviation and Drones

OSNMA has strong potential for securing air navigation, providing trusted and spoof-resilient positioning. It has already been identified by the Aviation community as a technology for future implementation, and its adoption is expected to rise over the coming decade for high value Drone missions.

5.6.1 Service Applicability

GNSS is indispensable within aviation, underpinning all facets of the industry – from Performance Based Navigation and flight planning to operations, airspace design, and the provision of services to airlines, pilots, airports, and Air Navigation Service Providers (ANSPs). However, the **recent sharp increase of radio-frequency interference (RFI) of malicious origin** presents a significant challenge to the safe and reliable use of GNSS.

Improving GNSS resilience has therefore become a key priority in response to increasing RFI and so the operationalisation of **OSNMA is expected to support it.** International bodies including ICAO, in coordination with industry groups, such as EUROCAE and RTCA, are leading the **development and harmonisation of new standards**, **with a particular focus on OSNMA**, DFMC and SBAS authentication. However given the stringent regulatory context and the long times needed to bring new technologies into operation, this will take years to happen.

On the other hand, the drones market is expected to be more flexible towards OSNMA adoption considering that GNSS is an essential embarked technology and that their receivers are equally vulnerable to spoofing. Feedback gathered during UCP 2024 shows that **demand for authenticated signals is strong**. Drone users repeatedly highlighted the rising threat of GNSS jamming and spoofing, with many reporting interferences during operations. OSNMA was consistently cited as a key mitigation measure, particularly valuable for detecting spoofed navigation data before it triggers unsafe behaviour.

In the following sub-chapters, the paper will explore the use of OSNMA for drones' navigation.

5.6.2 OSNMA for drones navigation

5.6.2.1 Overview

Over next years and decades, drones will be increasingly deployed in **dense, regulated and safety-critical airspaces**, particularly with the growth of **e-identification systems** and **urban air mobility**. Here, OSNMA will add a trusted authentication layer, enabling both security-critical validation and compliance-related assurance for the positioning data that underpins all drone operations.

As emerged already during the UCP 2024 discussions, drone operators, manufacturers, regulators and technical experts converge on a shared conclusion: as drone operations expand in scale, density and complexity**, authenticated GNSS is becoming indispensable, and Galileo OSNMA** is emerging as one of the most relevant tools to deliver this resilience. In other words, OSNMA aligns closely with user needs for integrity, spoofing detection and trustworthy tracking.

Stakeholders such as Dronetag and TopView emphasised that authenticated GNSS is becoming vital for **electronic conspicuity**, **remote ID**, and **legal-value flight records**, all key requirements for the future of U-space. Yet they also flagged a current market gap: **too few low-cost, OSNMA-capable GNSS chipsets** exist today, limiting rapid industry uptake.

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From the technological perspective, some chipset and receiver manufacturers already started implementation in 2025, although **large-scale integration is expected from 2026**. Implementation will affect high-end receivers or even broader integration across product lines, depending on the manufacturer.

5.6.2.2 Expected uptake

Adoption of OSNMA-capable receivers among drone manufacturers and operators is expected to scale more slowly than the availability of compatible hardware. Uptake will likely unfold over the next five to ten years, driven by increasing security needs and anticipated regulatory requirements for urban air mobility. Full market integration is not expected before 2035 due to potential battery consumptions concerns.

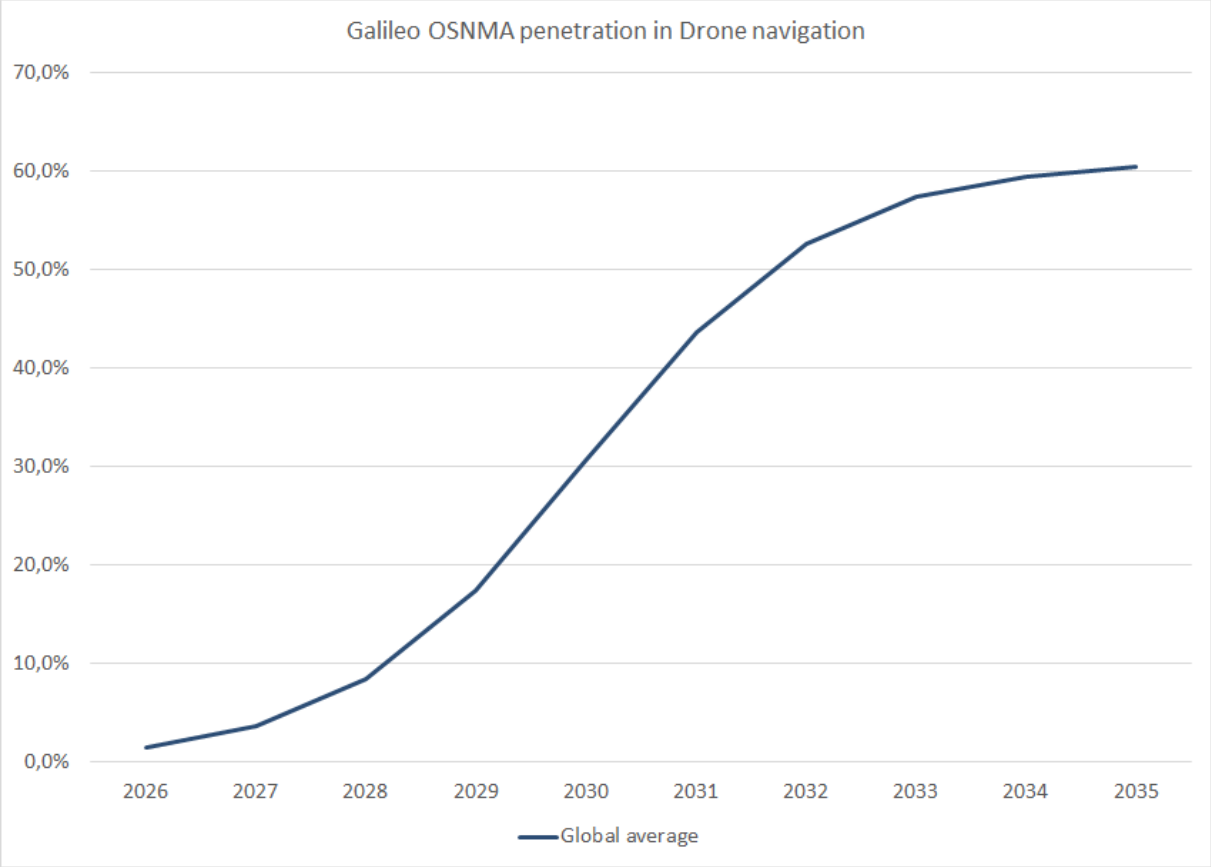


Figure 9 - Galileo OSNMA penetration in Drone navigation

Figure 9 presents the global forecast, suggesting that, **at peak, OSNMA could reach around 60% of the drone GNSS receiver market**, constrained primarily by its energy demands. However, the relatively short four-year drone replacement cycle will support faster turnover once adoption accelerates.

With DJI dominating roughly 70% of global drone production and widely deploying multi-constellation receivers, OSNMA-capable technology should disseminate consistently across the globe, though adoption of advanced features, such as authentication protection, may remain slower in less developed markets.

Figure 10 shows how the installed-based of OSNMA-capable devices (yellow columns) will grow with respect to the total number (blue columns) over the years. This is an effect of the estimated average drone lifetime of 4 years.

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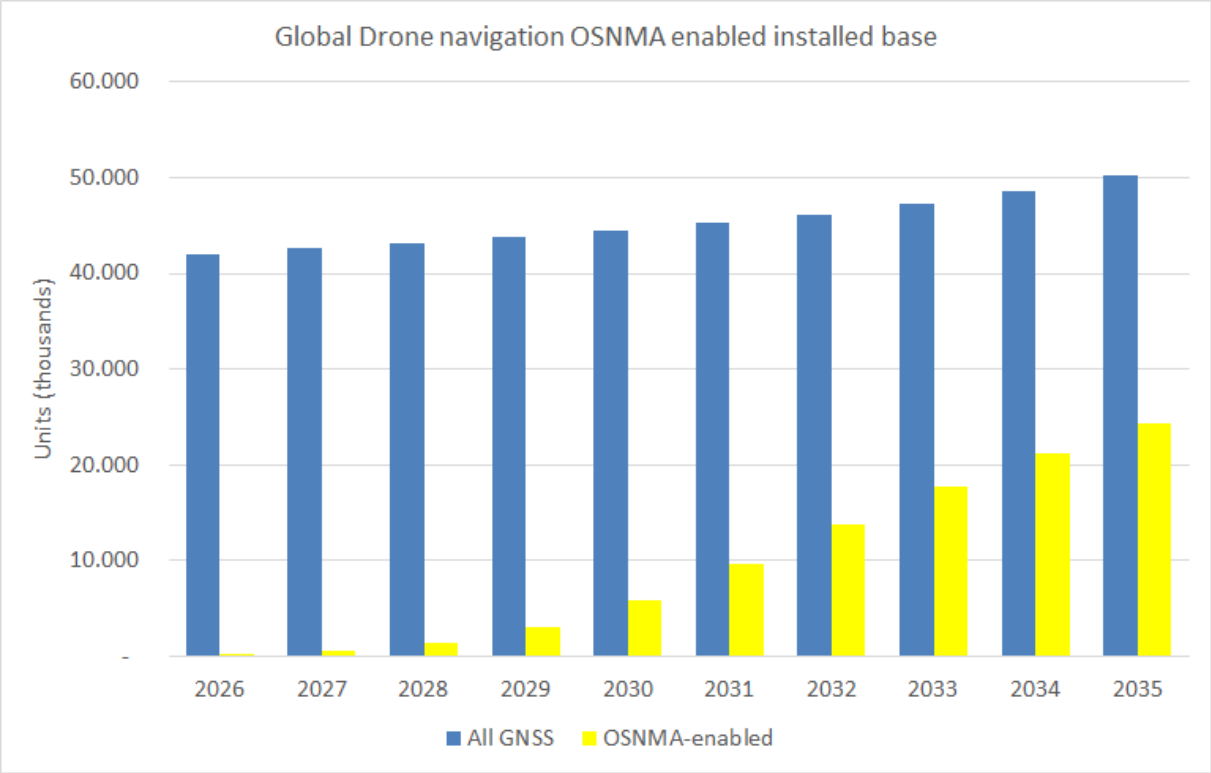


Figure 10 - Global Drone navigation OSNMA enabled installed base

5.6.3 Future outlook

As already presented, for drone navigation OSNMA is expected to become an important security enhancement.

For *certified* aerial vehicles, like manned aviation or air taxis, adoption will be slower, but the first steps are already taking place. **ICAO has recently recognised OSNMA as an authentication solution** to strengthen GNSS system resilience **and has endorsed Standards and Recommended Practices (SARPs)** for GNSS navigation data authentication, with Galileo OSNMA SARPs expected to be applicable by 2029.

Another essential regulator steps will consist of the development of **receiver standards** by bodies like EUROCAE and RTCA. And besides these, the community will have to define how to operationally integrate OSNMA in daily aircraft operations.

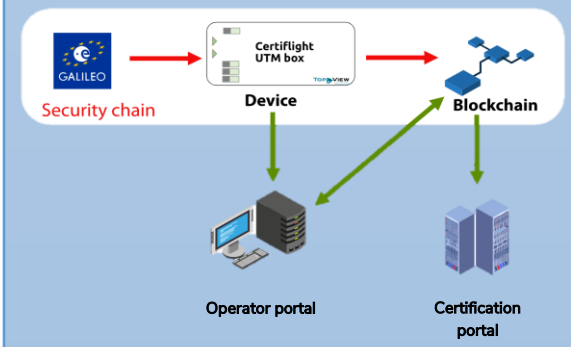
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Funded by the European Union

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Certiflight

Certiflight is a European initiative funded by EUSPA, designed to create a new U-space service that provides legally reliable certification of flight tracks for drones (UAS) and ultralight aircraft. The project leverages three technological pillars to ensure trust, authenticity, and legal validity of aerial navigation data: **Galileo OSNMA, e-conspicuity, and blockchain-based data integrity**. Through these combined capabilities, Certiflight establishes a "chain of trust" for flight information inside low-altitude Very Low Level (VLL) airspace, where drones and small aircraft increasingly share the environment.



At the heart of the system is the UTM Box, a compact onboard device used by drone and general aviation pilots to collect authenticated GNSS data, transmit regulatory remote identification information, and synchronise payload data such as images or sensor outputs. This data is linked to a secure blockchain infrastructure, ensuring that flight logs, mission data, and sensor recordings remain unalterable and traceable. The service supports a broad set of functions, including tracking, authenticated tracking, remote ID, legal recording, digital logbooks, smart automation, and accident/incident reporting, making it applicable to commercial services, safety oversight, and legal investigations.

The project also responds to emerging regulatory needs. Current **EU U-space regulations** demand reliable tracking and identification as drone operations expand, especially for BVLOS missions and operations shared with ultralight aviation. Certiflight addresses the **absence of an aeronautical-grade certified component capable of providing legally valid position information**. Its **OSNMA-authenticated data and blockchain security model** aim to **fill this gap**, enabling flight evidence that can withstand procedural and legal scrutiny.

To validate its technology, Certiflight has conducted extensive **flight testing** across multiple scenarios: airport inspections, powerline monitoring, volume calculation, agricultural assessments, canal inspection missions, and airspace conflict-resolution trials. These tests **confirm the robustness of the UTM Box, its remote-ID capabilities, and its compatibility with operational safety requirements**. In one study involving general aviation aircraft, the system successfully provided **conflict-resolution advisories**, demonstrating its relevance for integrated U-space environments.

Throughout its first development phase, the project achieved all strategic objectives, including building a liability chain for drone operations, developing mission data certification tools, and enhancing safety mechanisms for UAS and general aviation users. Over 100 experts, including pilots, operators, and authorities, have already evaluated the system and confirmed the legal credibility of its certified flight reports.

As Certiflight progresses toward potential commercialisation, it aims to further refine its conflict-resolution support, enhance sensor-noise filtering, and improve pilot interfaces. Ultimately, the project positions itself as a key enabler for safe, transparent, and legally verifiable drone operations, supporting the future of U-space services across Europe.

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5.7 OSNMA for Timing and Synchronisation

OSNMA gives critical industries a trusted, spoof-resilient timing source, reducing the risk of timing-related failures across power grids, telecom networks, and financial systems. It strengthens operational safety and regulatory compliance by ensuring timing data is authentic and reliable, making it an increasingly essential component of secure synchronization architectures.

5.7.1 Service applicability

Timing and synchronization underpin the reliable functioning of critical operations across energy, telecommunications, finance, and other infrastructure-dependent sectors:

- Power grids rely on tightly synchronized **Phasor Measurement Units (PMUs)** using GNSS-derived timestamps to obtain microsecond-accurate measurements across vast networks, enabling stable grid operations.
- Financial institutions require secure, traceable timing to **timestamp transactions**, meet regulatory requirements, prevent fraud, and ensure market integrity.
- **Telecommunications networks** depend on precise timing to align data transmissions, manage handovers, and sustain the performance of 4G/5G systems.

As **the dependence on accurate and distributed timing increases, so does the urgency of securing the underlying GNSS time source** that synchronizes these systems.

During the UCP 2024 Timing & Synchronization session, where stakeholders from telecom, energy, finance, or rail met, shared needs were emphasized: while GNSS already provides the backbone for timing distribution across sectors, its integrity, resilience and robustness must be guaranteed.

In this context, participants identified Galileo OSNMA as one of the means to answer to these needs.

In addition, users highlighted that delays inherent in OSNMA's spoofing-detection process can introduce timing errors during an attack, making **high-quality oscillators and resilient fallback architectures essential**. Despite these constraints, industry sentiment remains cautiously optimistic: OSNMA is still maturing but its value proposition is strong, and early adopters are already integrating it into next-generation receivers.

UCP 2024 also underscored OSNMA's alignment with Europe's emerging timing ecosystem. In this context, the published **CEN/CENELEC standard for Galileo Timing Receivers**, which includes requirements for OSNMA processing, was recognized as a major milestone in mainstreaming secure GNSS timing. This creates a path toward consistent, verifiable GNSS-based timing across telecom networks, energy grids, railways, and financial infrastructures. By embedding OSNMA support into the standards that future timing receivers must follow, **Europe is formalizing authenticated GNSS as part of the continent's long-term timing resilience strategy**.

Across sectors, OSNMA's relevance varies by operational demands. Telecom operators highlighted that OSNMA can significantly bolster the synchronization resilience of advanced networks, especially as 5G and emerging 6G systems require extremely tight time budgets. For power grids and financing applications, the next sub-chapters provide deeper insights.

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5.7.2 OSNMA for PMUs

5.7.2.1 Overview

GNSS-based timing is often a single point of failure in many architectures: network clocks, data centres, power grid controllers, railway signalling systems, and distributed computing environments. Here, a manipulated GNSS signal can compromise the integrity of entire infrastructures.

Trusted/verified GNSS time such as that provided by **OSNMA** can materially **improve critical-infrastructure robustness**, offering operators the ability to detect falsified timing data and trigger internal alerting or holdover mechanisms before cascading failures occur.

In energy systems, authenticated timing helps ensure that PMUs and grid monitoring tools maintain trustworthy, coordinated measurements. The industry's resilient timing architectures will increasingly adopt **multi-layer approaches**: authenticated GNSS (OSNMA), terrestrial timing networks, atomic clocks, LEO-based timing signals, and network-derived cross-checks. Within these hybrid architectures, OSNMA serves as the trusted anchor, enabling the detection of inconsistencies across different timing sources, protecting against spoofing, and supporting continuity during GNSS disruptions.

5.7.2.2 Expected uptake

The path toward widespread OSNMA adoption is expected to be gradual and shaped largely by application needs, regulatory influences, and industry readiness. Although some manufacturers rolled out OSNMA enabled receivers as early as 2025, many others preferred to wait for the service to fully mature before committing to large scale integration. This staged uptake reflects ongoing challenges around key management, firmware updates, and coordination across diverse technological ecosystems. Some manufacturers have even implemented OSNMA capable hardware but temporarily disabled the feature due to key distribution issues.

The **energy** industry, known for **long technology cycles**, is expected to migrate slowly, replacing receivers over 10–15-year intervals. The following charts offer an overview of the expected uptake of OSNMA within PMUs.

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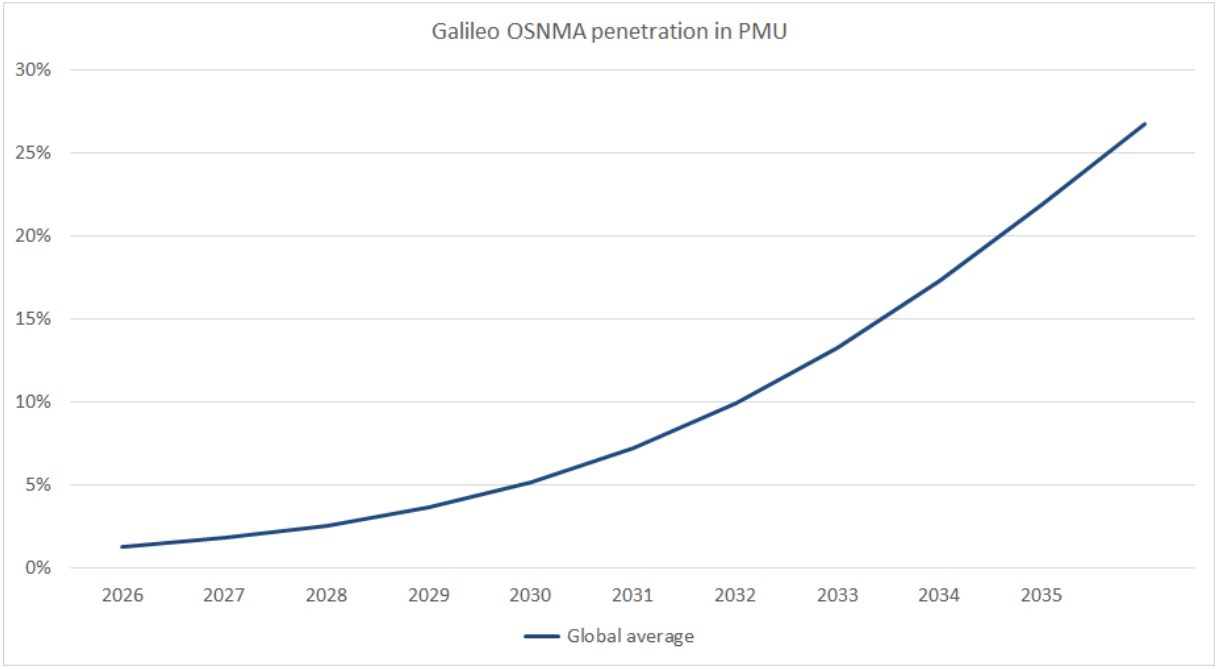


Figure 11 - Galileo OSNMA penetraton in PMU

It is noteworthy that the global average OSNMA penetration in PMU depicted in Figure 11 derives from regional penetration of Galileo for timing & synchronisation and the companies' business distribution information identified by EUSPA. Within the time horizon of the forecast presented, the uptake is expected to reach 35% in Europe by 2035. It is worth mentioning, however, that beyond the chart limits, the maximum addressable market is 100% of PMU receivers.

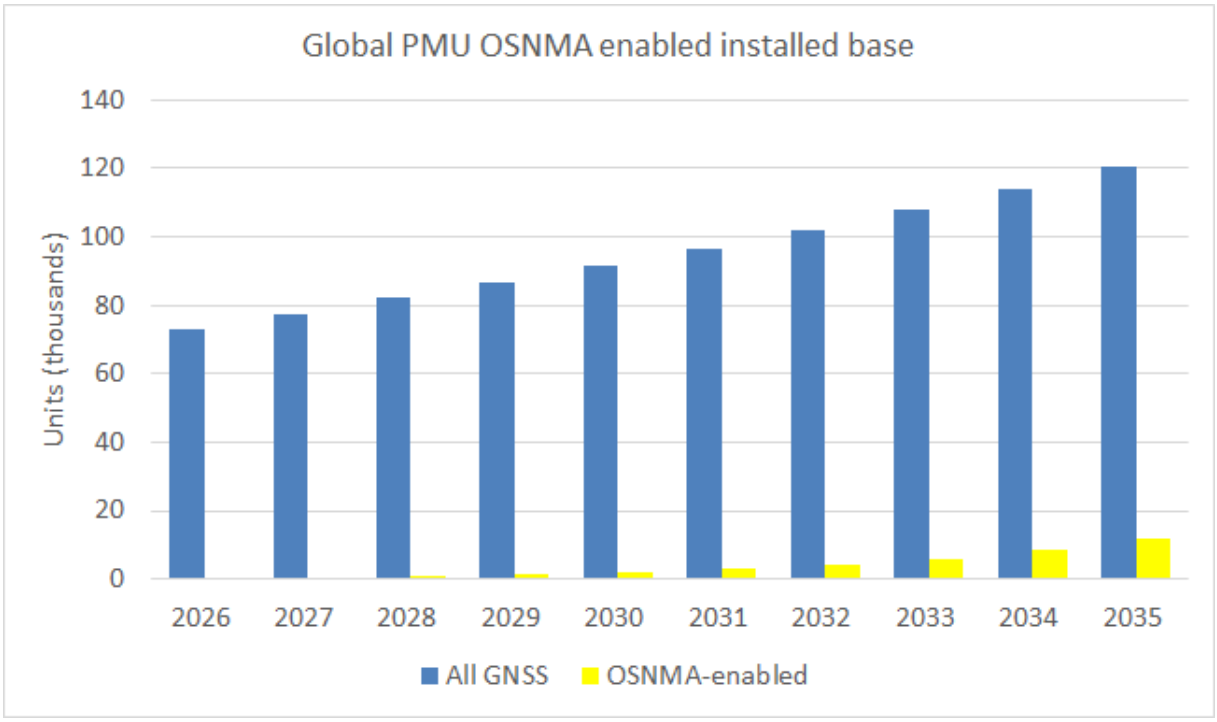


Figure 12 - Global PMU OSNMA enabled installed base

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With regards to the global installed base of OSNMA capable devices, the numbers in Figure 12 reflect the previously mentioned long technology cycles of this industry, with OSNMA's presence still low with respect to the global totals.

5.7.3 OSNMA for Financing

5.7.3.1 Overview

As timing becomes ever more central to high-performance networks in financial systems, authenticated GNSS is expected to shift from a desirable innovation to an operational necessity.

Indeed, in finance three independent timing sources are often required for compliance and auditability. Here, OSNMA can strengthen GNSS's role by adding authentication to what is otherwise a blind trust in signal origin. High-precision applications—such as high-frequency trading—operate at nanosecond-level sensitivity, leaving almost no margin for deception or delay, further underscoring the importance of authenticated timing inputs.

OSNMA's adoption will not eliminate all timing risks, but will rapidly become a foundational building block in Europe's strategy to safeguard the integrity of such timing services.

5.7.3.2 Expected uptake

In contrast with the energy sector, the **finance sector is prepared for faster uptake** due to its stringent accuracy demands, regulatory mandates and the competitive advantage that precise and secure timing provides.

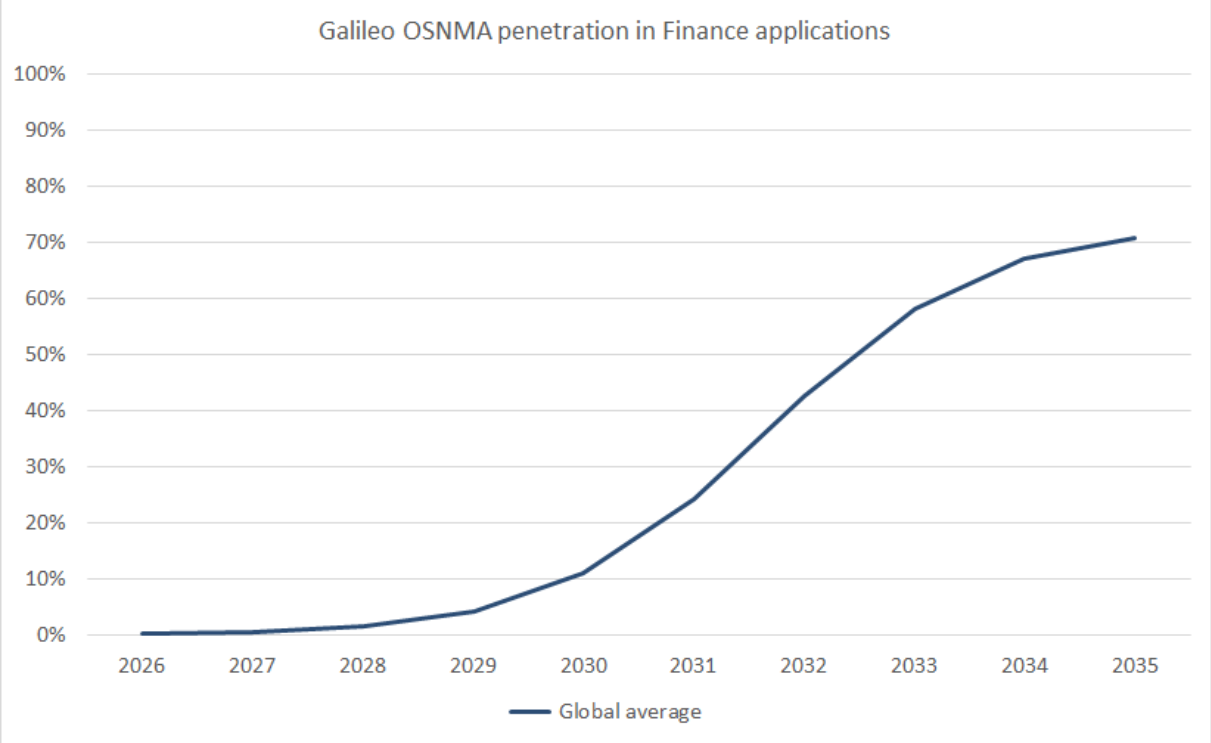


Figure 13 - Galileo OSNMA penetration in Finance applications

Figure 13 shows the preliminary implementation roadmaps indicating the expected uptake to start in less than 2 years, c.a. 2028, and the expected maximum addressable market will be 70% at global level on average.

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European manufacturers will be the strongest supporters of OSNMA, while competition in the Americas and dominance of Chinese manufacturers in Asia will influence how quickly the technology spreads globally.

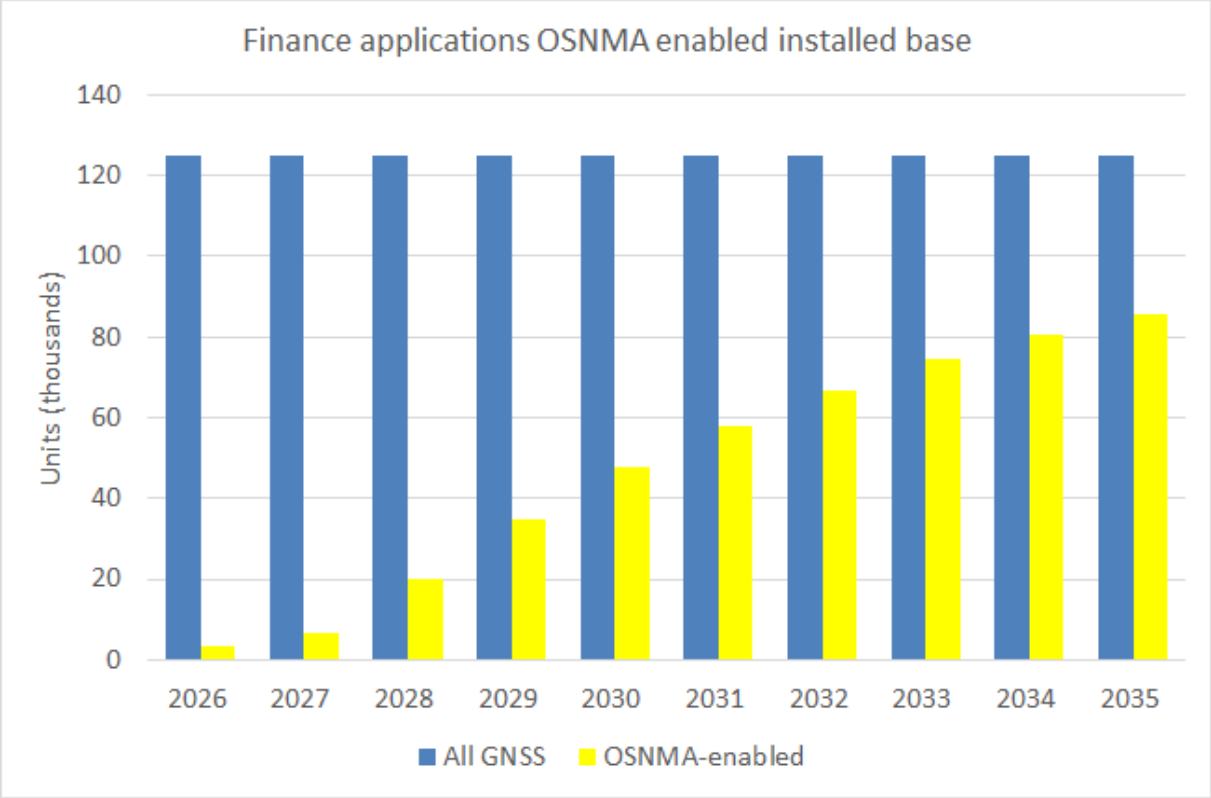


Figure 14 - Finance applications OSNMA enabled installed base

When it comes to the installed base of OSNMA receivers in finance applications, the faster uptake with respect to energy PMUs is also reflected in Figure 14. The forecast indicates that, by the end of the analysed period, OSNMA will be present in approximately two thirds of the operational devices.

5.7.4 Future outlook

Overall, while initial deployment will be cautious, OSNMA is positioned to become an increasingly important component of secure timing and synchronization ecosystems as industry expertise, standards, and supporting technologies mature.

As already introduced, adoption patterns will vary significantly across sectors. To illustrate, Figure 15 presents the forecasted shipments of OSNMA-enabled Timing & Synchronisation devices per application.

However, besides the distribution of shipments per application, it is even more interesting to note the overall growth expected for OSNMA-enabled **telecommunications** devices. Even if today this sector perceives lower spoofing risks and greater operational tolerance to minor synchronization losses, and thus is likely to adopt OSNMA only where performance requirements justify it, in total numbers it will be the sector in front. Telecommunications, indeed, represent 84% of the Timing & Synchronisation market, and so the forecasted shipments of OSNMA-enabled devices are projected beyond 350.000 units in 2035.

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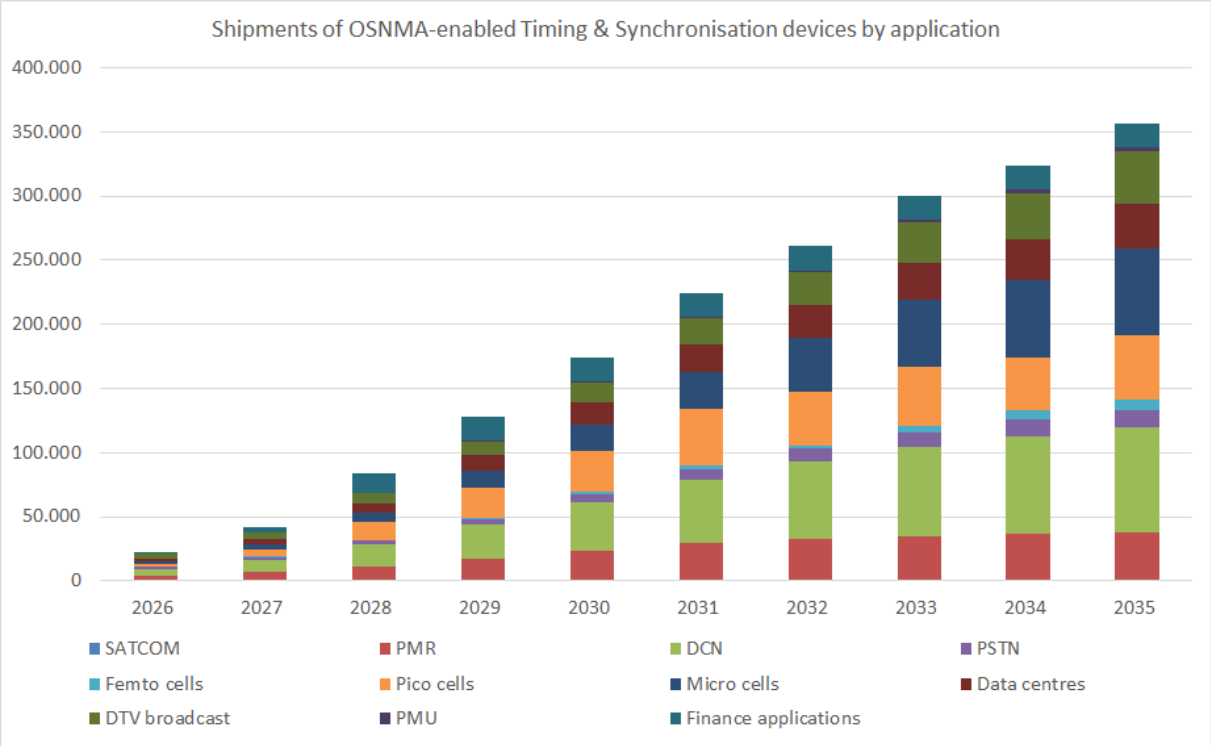


Figure 15 - Shipments of OSNMA-enabled Timing & Synchronisation devices per application[4]

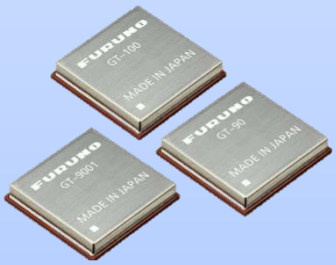
[4] PMR: Professional Mobile Radio
PMU: Phasor Measurement Units
DCN: Digital Cellular Network
PSTN: Public Switched Telephone Network

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FURUNO provides one of the clearest early commercial examples of how OSNMA can be successfully integrated into high-precision timing products. Their GNSS timing receivers implement OSNMA not as a standalone feature but as part of a multi-layer defence architecture combining:

- **OSNMA-based cryptographic authentication,**
- **proprietary spoofing-detection algorithms, and**
- **automatic satellite exclusion mechanisms.**

This dual-layer approach enables their receivers to detect spoofing attempts, including simulator-generated and replay-based attacks, and to automatically disregard compromised satellite signals before they affect timing outputs. In controlled tests, when a legitimate signal source was replaced with a recorded playback, the receiver's OSNMA status instantly flagged the spoofing condition, setting the affected satellite to an abnormal state and removing it from calculations.



FURUNO also addresses a key operational barrier in timing receivers: the management of OSNMA public keys, Merkle tree roots, and synchronisation conditions. Their products include a **flexible authentication mode** that automatically retrieves and handles cryptographic material, enabling OSNMA with no user intervention, making the technology accessible even for large-scale deployments in remote or unmanned installations. The receivers maintain stable timing even when temporary signal degradation interrupts OSNMA message acquisition, and seamlessly resume authentication once conditions recover.

Finally, FURUNO has commercialised this capability in a complete product line (GT-100, GT-9001, GT-90), demonstrating a market-ready implementation of authenticated GNSS timing. This positions their solution as one of the first real-world successes where OSNMA moves from a research feature into a robust, deployable technology for high-reliability synchronisation applications.

5.8 OSNMA for EU Border Management: asset tracking

OSNMA makes GNSS-based tracking far more resilient to spoofing, strengthening trust in critical operations. It is now set to become a key building block for Europe's future secure mobility systems.

5.8.1 Service applicability

As Europe advances toward increasingly digital, connected, and security-critical mobility systems, the need for trustworthy and interference-resilient satellite navigation continues to grow. **OSNMA** has emerged as

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one of the most important tools to meet this need. By embedding cryptographic authentication directly into Galileo navigation messages, OSNMA enables receivers to verify that Position, Navigation and Timing (PNT) information truly originates from Galileo satellites, providing a decisive defence against spoofing, manipulation, and other forms of GNSS interference.

A major step in demonstrating OSNMA's operational value has been the **Galileo-enabled Asset Tracking Demonstrator Pilot Project** [10], jointly organised by EUSPA and Frontex [11].

During the pilot, a demonstrator was developed and then deployed on **two operational vessels of the Romanian Border Police**, where it was subjected to realistic maritime conditions and controlled interference scenarios. These tests confirmed that integrating OSNMA into tracking devices significantly improves their resilience: receivers could not only detect when a navigation signal had been spoofed or jammed but also continue operating with higher confidence thanks to the authentication layer provided by Galileo. As Frontex reported, authenticated signals enhanced situational awareness, ensuring that crews maintained an accurate picture of their position even when traditional GNSS performance degraded.

The pilot also showed how OSNMA can be combined with other information sources to strengthen overall system robustness. This hybrid approach is particularly beneficial for maritime border operations, where environmental conditions, multipath reflections, and intentional interference can complicate navigation. Pilot participants highlighted that such resilience will be increasingly critical as Europe modernises its border-management capabilities and prepares for more technologically sophisticated threats.

Importantly, the pilot did not aim to validate OSNMA as a fully operational system, but rather to **assess its technology-readiness in realistic field conditions**, informing the next steps for potential deployment in future Frontex joint operations. It offered key lessons on interoperability, system robustness, and the environmental conditions under which OSNMA performs best, insights that will help shape procurement strategies and receiver requirements in coming years[5].

The final workshop of the project was conducted in Bucharest on November 25th 2025. This meeting brought together around 100 experts from border management, satellite navigation, cyber-security, and operational coordination. The meeting included an informative session setting out the strategic context of the joint EUSPA-Frontex pilot and also highlighted the importance of Galileo's robust services for the EU's long-term border-management security goals. Overall, the pilot served as a testing ground for next-generation tracking capabilities designed to operate reliably in hostile or interference-rich environments.

5.8.2 Future outlook

Beyond border management, this work signals a broader trend: OSNMA is becoming a strategic foundation for secure mobility in Europe. The authentication service is already being integrated into regulated systems such as **second-generation smart tachographs**, and its benefits extend to customs monitoring, tracking of sensitive or high-value goods, and other sectors where data integrity is mission-critical. Receiver manufacturers and system integrators increasingly see OSNMA as a standard feature for multi-frequency, multi-constellation positioning engines aimed at professional or safety-critical applications.

Looking forward, OSNMA is positioned to move from early adoption to mainstream use across Europe's mobility, security, and transport ecosystems. As the Galileo constellation expands, more satellites will broadcast OSNMA-enabled signals, increasing signal availability and improving authentication performance. Receiver manufacturers are progressing toward mass-market integration, and the experience gained through the demonstrator pilot is expected to accelerate operational uptake within border-management fleets, maritime authorities, land-based enforcement systems, and other public-sector operators.

Moreover, the introduction of the upcoming **Signal Authentication Service (SAS)** for the Galileo E6C frequency will extend authentication, eventually enabling **PVT authentication** for mission-critical applications [12].

[5] EU patrol vessels adopt Galileo OSNMA for secure positioning (https://www.euspa.europa.eu/newsroom-events/news/eu-patrol-vessels-adopt-galileo-osnma-secure-positioning)

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As cyber-physical threats grow more sophisticated, OSNMA is likely to play an increasingly central role in safeguarding the data foundations of automated mobility, law enforcement, logistics security, and critical infrastructure operations.

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6 GALILEO SAR RLS

6.1 Definition and purpose

The Search and Rescue (SAR) service of Galileo, referred as "SAR/Galileo", is Europe's contribution to the international distress beacon locating system COSPAS-SARSAT, a **free global satellite-based distress alerting system**. It is designed to detect and locate distress signals from compatible beacons used in **maritime, aviation, and personal contexts**. Galileo is the largest contributor to Cospas-Sarsat in terms of space and ground segments, significantly reducing the time needed to accurately locate a distress beacon when it is activated.

Galileo SAR also offers a unique capability called the **Return Link Service (RLS)**, that let users know that their distress signal has been received and the relevant SAR authorities have been notified of their position. This one-way technical acknowledgment to the user, an assurance not offered by any other GNSS, enhances situational awareness and user confidence during a distress situation.

The SAR/Galileo **Return Link Service** is operational since early 2020, building on the previous SAR capabilities already in operation since 2016.

A full description of the SAR/Galileo service is available in its Service Definition Document (SDD) [13].

Lower-level technical details of the Return Link Messages (RLM) that enable the RLS are included in the Open Service SIS Interface Control Document (ICD).

6.2 Key benefits

Galileo contributes to saving thousands of lives each year, and its RLS builds up on top of the SAR/Galileo providing:

- **Global coverage:** the SAR/Galileo operates worldwide through the Galileo constellation, independent of terrestrial networks.
- **High availability:** demonstrated extremely high operational availability (>99%), ensuring reliable delivery of acknowledgments.
- **Enhanced user assurance**: RLS–enabled distress beacon users receive direct confirmation that their alert has been detected and processed, improving confidence in SAR operations.

6.3 Market potential

Adoption of **SAR/Galileo RLS** is driven by the growing need for reliable emergency communication, providing users with assurance that their distress signal has been received. In addition, the system's performance is exceptionally reliable, consistently showing **availability and latency levels far surpassing the respective 95% and 99% official targets** [14].

The RLS, and SAR/Galileo in general, plays a crucial role in **aviation, maritime and personal safety**, where different types of beacons are used:

- Emergency Locator Transmitters (**ELTs**), which are beacons designed for use aboard aircraft. They are linked to the aircraft's registration;
- Emergency Position Indicating Radio Beacons (**EPIRBs**), designed for use aboard vessel to which they are registered;

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- Personal Locator Beacons (**PLBs**), which are designed to be carried by an individual. They are registered to a person, and are the most versatile type of beacon, as they can support all kind of outdoor leisure activities, like nautical (sailing, kayaking…), trekking, hiking, hobby flying, etc, but also and very importantly professional activities carried out at sea, with PLBs integrated in lifejackets or carried in small boats, or by small aircraft.

As for the RLS's current market adoption, recreational users often lack awareness of PLBs or rely on smartphones. Besides, the cost of dedicated beacons discourages broader uptake amongst this community. Next-generation features like RLS also require new, more advanced hardware, slowing transition until manufacturers fully support the technology.

The professional community, instead, is expected to be more keen to adopt RLS since they are already significant adopters of PLBs, with numerous application examples: workers in offshore oil, gas, wind energy, and commercial fishing, crew members on watch in vessels, or exposed to deck duties, with regulations and/or recommendations to wear a PLB at all times,

On the other hand, and even if the availability of RLS-capable ELTs is still today quite limited, it could be reasonable to believe that SAR/Galileo RLS will also see a strong adoption in regulated sectors (i.e. aviation and maritime). Indeed, the RLS feature can be accommodated in any of the beacon types and several products are already available on the market in the three categories.

The next sub-chapters, however, explore the use of SAR/Galileo RLS in PLBs.

6.4 SAR/Galileo RLS for Personal Locator Beacons

Personal Locator Beacons (PLBs) offer a global emergency lifeline, but the Galileo Return Link Service (RLS) is what makes them truly transformative. RLS sends a confirmation back to the beacon user that their distress alert has been received and processed, providing immediate reassurance in critical moments. This acknowledgment helps reduce panic and supports clearer decision-making while rescue teams are on their way.

6.4.1 Overview

Personal Locator Beacons (**PLBs**) provide a **direct, global link to emergency services**. They can transmit the user's exact location via satellite, enabling rapid response and significantly improving survival chances.

Indeed, in the absence of a reliable locator, rescue operations would only begin once someone notices the person (e.g. a hiker, a sailor or a pilot in distress) is missing:

- Engaging in **outdoor activities** such as hiking in remote areas, without an emergency location device, exposes individuals to severe risks. Injuries like fractures, hypothermia, dehydration, or medical conditions can worsen rapidly without timely assistance.
- In **maritime environments**, risks include drowning, exposure to storms, and lack of fresh water.
- For **aviation**, forced landings in rugged terrain or adverse weather can leave individuals vulnerable to harsh conditions and isolation.

Any delay to request help can stretch into hours or even days, drastically reducing survival chances. In all cases, sudden environmental changes, such as storms, extreme temperatures, or wildlife encounters, compound the danger.

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Communication limitations further escalate these risks. Mobile phones, with some exceptions[6], and standard radios often fail in harsh environments, remote mountains, open oceans, or sparsely populated regions. Without a satellite-based device, individuals have no reliable way to alert rescuers. This isolation can lead to **psychological stress, panic, and poor decision-making**, which worsen survival odds. Additionally, the **absence of precise location data** forces search-and-rescue teams to cover vast areas, **increasing operational complexity, costs, and even putting rescuers at risk**.

In summary, for anyone venturing into remote or high-risk environments, **on land, at sea, or in the air**, carrying an emergency beacons such as a PLB is not just recommended; it is a critical safety measure.

The SAR/Galileo RLS, introducing the groundbreaking feature of confirming to the user that their distress signal has been received and processed, provides psychological reassurance during critical situations, reducing panic and enabling better decision-making while waiting for rescue. Knowing that help is on the way allows individuals to conserve energy and focus on survival strategies. Technically, this closes the communication loop between the beacon and the rescue system, something previous SAR systems could not offer. By **improving user confidence and situational awareness**, RLS adds a vital human-centric dimension to emergency response.

6.4.2 Expected Uptake

Despite all the theoretical and practical strengths of RLS, the broad consumer uptake is constrained by the end-users lack of awareness and price sensitivity. The following charts offer an overview of the expected uptake.

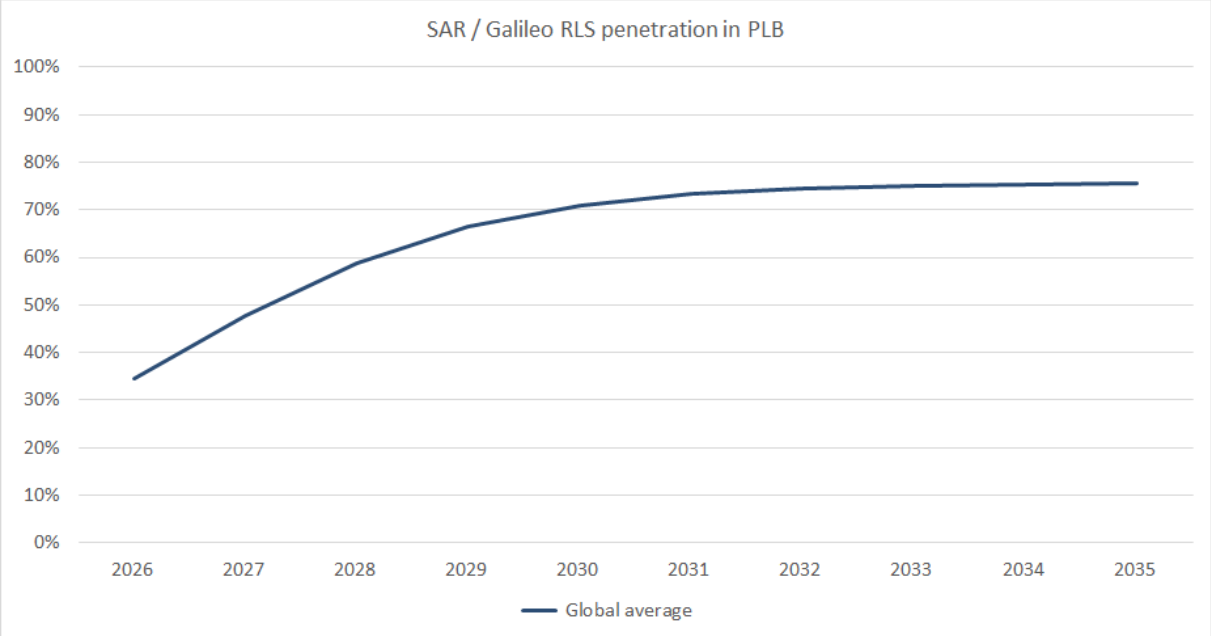


Figure 16 – SAR/Galileo RLS penetration in PLB

Figure 16 illustrates the expected evolution of RLS-enabled PLB adoption, based on the observed growth in RLS-enabled beacon production reported through Cospas-Sarsat manufacturer surveys. While recent survey data indicates that RLS-enabled beacon production already represents a substantial share of overall beacon manufacturing, adoption in the PLB segment is expected to remain below full market penetration due to the largely consumer-driven nature of the market, the absence of regulatory mandates comparable to those applying in aviation and maritime sectors, and the relatively long replacement cycles of existing devices. As

[6] In recent years, some smartphone manufacturers and telecom carriers have started to incorporate satellite-based SOS services.

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a result, the transition towards RLS-enabled PLBs is expected to continue throughout the forecast period, albeit at a gradually slowing pace as the market matures

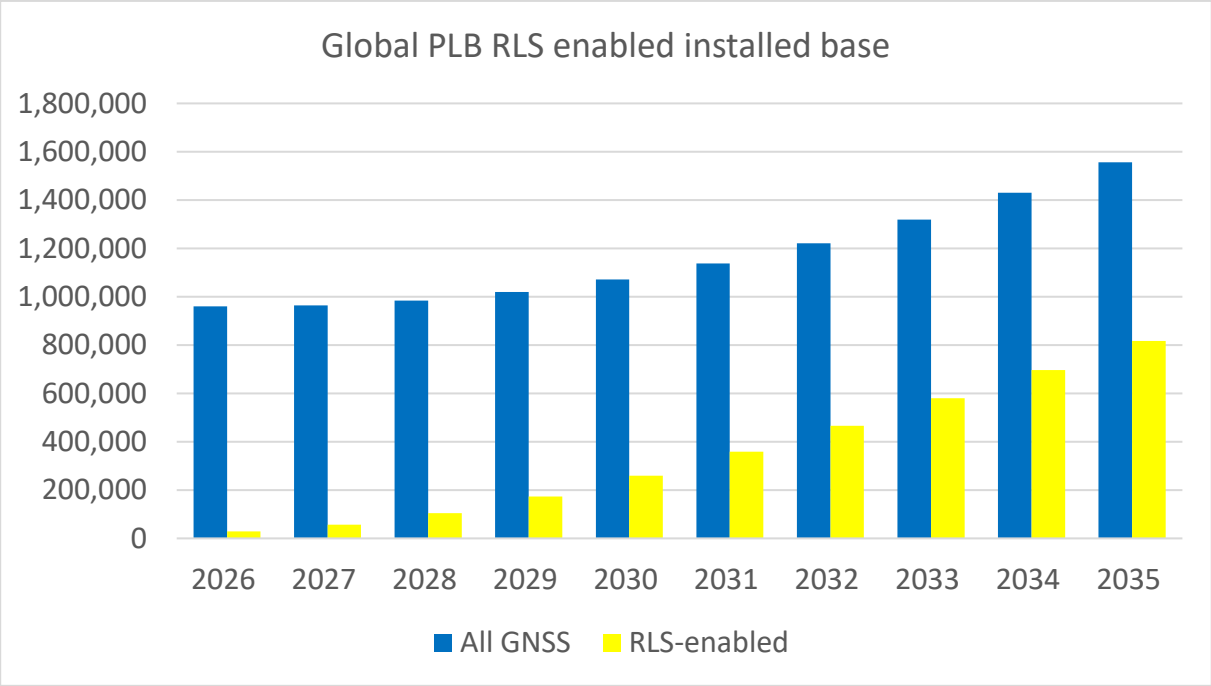


Figure 17 - Global PLB RLS enabled installed base

In Figure 17, it can be observed that the global installed base of PLBs is expected to grow steadily over the forecast period, increasing from just under 1 million devices in 2026 to around 1.6 million by 2035. In this context, the number of RLS-enabled PLBs grows significantly faster, rising from a relatively limited installed base in 2026 to approximately 800,000 units by 2035. This represents a substantial increase over the period, with RLS-enabled devices accounting for more than half of the total installed base by the end of the forecast period. This trend highlights a gradual but accelerating transition towards RLS-enabled and, increasingly, second-generation beacons, although the large installed base of legacy devices and their long replacement cycles continue to moderate the pace of adoption in the medium term.

6.5 Future outlook

SAR/Galileo is expanding its capabilities with **new services** designed to enhance how distress beacons, PLBs for individuals, ELTs for aviation, and EPIRBs for maritime users, support emergency situations. These **new functions build upon the Return Link Message (RLM)**, which within SAR/Galileo RLS already confirms to beacon users that their distress alert has been received.

One of the upcoming features, the **Remote Beacon Activation (RBA)**, could allow authorized users to remotely activate a beacon, for example in specific confirmed distress situations when aircraft are no longer tracked by air traffic control.

Another enhancement, the **Two-Way Communication (TWC)**, will introduce limited interaction between rescue centres and beacon users through predefined questions that help assess the nature of the emergency and the number of people involved.

Today, while SAR/Galileo **RLS** is already **operational**, **RBA and TWC** remain under development.

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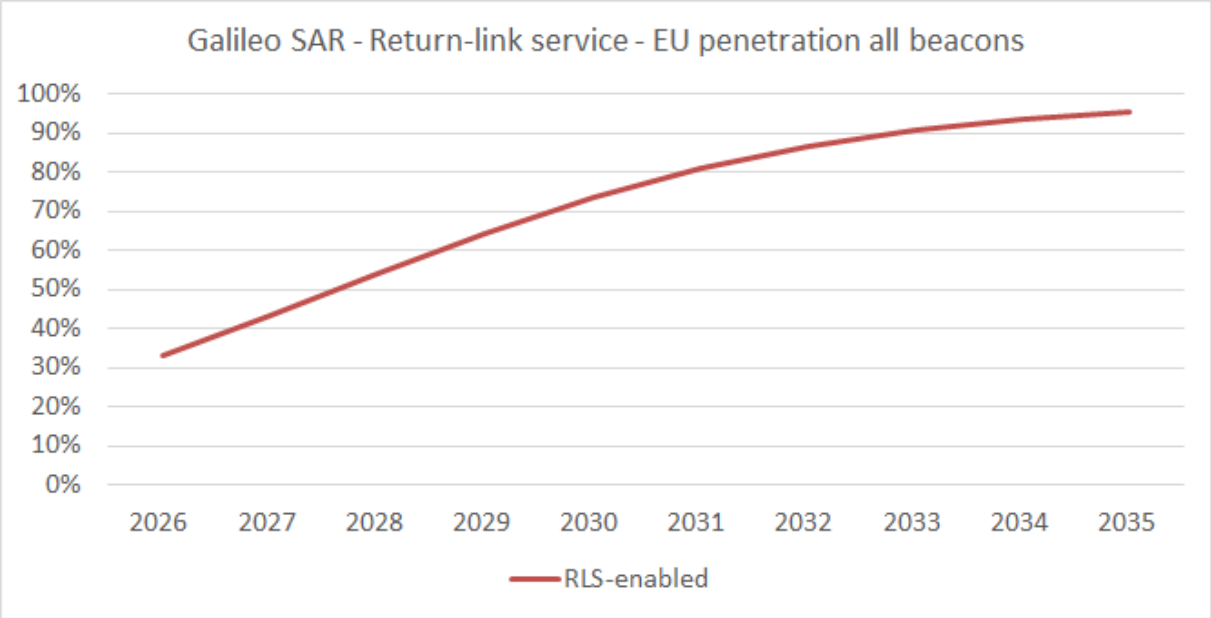


Figure 18 – SAR/Galileo - Return-Link Service- EU penetration all beacons

Figure 18 shows that the penetration of SAR/Galileo RLS across all beacon types in EU is expected to rapidly increase over the next decade. It rises from around 33% in 2026 to about 75% by 2030 and close to full adoption (around 95%) by 2035. Growth is strongest between 2026 and 2030, at roughly ten percentage points per year, as RLS is increasingly integrated into both first- and second-generation beacons across maritime, aviation and personal use segments, and as manufacturers expand their RLS-enabled portfolios. From 2031 onwards, growth gradually slows as the market approaches saturation. The remaining uptake will depend on replacing older non-RLS beacons at the end of their service life, and on addressing residual barriers such as cost considerations, regulatory fragmentation, and continued production of non-RLS-enabled devices. As a result, RLS will become the dominant standard in the European beacon market by the mid-2030s, despite a gradual transition period.

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Seas of Solutions - FastFind

Seas of Solutions, through its established brands McMurdo, Kannad Marine, and Netwave, develops the FastFind range of Personal Locator Beacons (PLBs). These compact, subscription-free devices are certified for global use on both land and sea through the Cospas-Sarsat satellite distress system. Funded by the European Union and led by Telespazio France, AWARE brings together eight partners from four countries. Each contributes key expertise: Telespazio and EENA in public safety systems, FDC in secure satellite navigation technologies, and CNES—France's national space agency—as the future operator of the Galileo EWSS service centre in Toulouse.



The flagship model, the **FastFind Return Link**, integrates **Galileo** and **GPS** satellite receivers with a **406 MHz distress beacon** and a **121.5 MHz homing transmitter**, achieving location **accuracy** of up to **62 metres**. Introduced in 2021 as the world's first PLB to offer **two-way satellite communication**, it builds on the proven FastFind 220 platform and incorporates Galileo's **Return Link Service (RLS)**, enabling the user to receive a confirmation message directly from the satellite system once their alert has been detected. Upon activation, the dual-GNSS receiver rapidly acquires a precise position, which is transmitted via the 406 MHz channel.



Galileo's **MEOSAR** satellites detect the signal almost instantaneously and relay it to ground facilities. RLS then returns a confirmation message to the beacon, which is communicated to the user through a clear visual indicator: a **blue LED** indicator flashes once every 50 seconds while the Return Link Message (RLM) is pending, and switches to rapid continuous flashing once the confirmation has been successfully received. This feature provides meaningful reassurance to individuals in distress, reducing stress levels and helping prevent impulsive decisions during emergencies. The LED-based interface is also accessible for users who may otherwise rely on reading glasses to interpret a screen. Typically, confirmation is received within **ten minutes**.

Operational testing has shown no degradation in performance under adverse or unusual environmental conditions. Nonetheless, some challenges remain, particularly regarding regulatory standardisation and certification processes required for broader market adoption.

The FastFind Return Link has been positively received by stakeholders across the maritime and safety sectors. However, continued efforts are required to improve **public awareness and understanding** of PLB technologies to maximise their life-saving potential.

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ACR Electronics, a leader in marine and outdoor safety gear, offers the ResQLink™ AIS Personal Locator Beacon, a compact, buoyant personal locator beacon (PLB) designed for use on land, sea, or air. It integrates GPS and Galileo GNSS plus Galileo SAR's RLS.



The all new ACR ResQLink AIS Personal Locator Beacon (PLB) is the most technologically advanced beacon in the world as it contains both satellite and local transponders. With the introduction of Automatic Identification System (AIS) functionality, Return Link Service (RLS) technology, and Near Field Communication (NFC) capability in one 406 MHz beacon, the ResQLink AIS represents a critical advancement in the evolution of PLB technology. Designed solely for marine use, the combination of 406 MHz and AIS distress messaging pairs both global and local rescue into one beacon for the first time, extending access to the Coast Guard and Search and Rescue as well as commercial and recreational boats in the area.

Alerting local AIS equipped boats in your vicinity allows for additional vessels to respond directly to the digital mayday with your precise location.

In addition, NFC capability provides users with the world's first smartphone connected Personal Locator Beacon, the new Return Link Service feature provides users with the peace of mind knowing that their distress message has been received and their location detected by Coast Guard.

RLS functionality works by sending a signal back through the Galileo satellite network to confirm to the beacon user that their distress message has been received and their location has been detected by the Coast Guard. A confirmation message is distinctly indicated by a flashing blue light on the PLB. Like other ACR beacons that include the important RLS feature, the ResQLink AIS provides the comfort of knowing that a distress message has been successfully delivered. Understanding that rescuers are aware of the beacon transmission and location reduces the stress often associated with Man Overboard incidents.

The ResQLink AIS is designed to install within a life jacket and activate upon inflation of the jacket (semi-automatic). Installation is made simple using the included oral inflation tube clip to attach the PLB to the life jacket with a ribbon connected around the bladder of the life jacket. Once correctly installed, the action of the life jacket inflating triggers deployment of the antenna and activation of the beacon.

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7 GALILEO DIFFERENTIATORS – WHAT TO LOOK OUT NEXT

As Galileo's service portfolio continues to mature, the expected evolution of its key differentiators—High Accuracy Service (HAS), Open Service Navigation Message Authentication (OSNMA), Emergency Warning Satellite Service (EWSS) and Search and Rescue Return Link Service (SAR RLS), signals a decisive shift toward a more resilient, secure and performance-driven European PNT ecosystem.

In maritime, **HAS** will increasingly support maritime applications like **auto-docking**, **dynamic positioning**, and **autonomous vessel operations**. In agriculture, HAS is expected to consolidate its role as a **decimetric-accuracy solution** for a wide range of tasks like guidance, spraying, spreading and broadacre seeding, becoming the standard accuracy layer for mass-market agricultural machinery, supporting increasingly automated workflows.

Beyond these, and from HAS capable chipsets already rolled-out, it is expected that HAS will be incorporated by vehicle manufacturers in the Road segment for **Connected and Automated Driving (CAD)** applications, in outdoor **Robotics** including drones, and by **NewSpace** stakeholders to enable real-time precise orbit determination solutions.

In parallel, **OSNMA** is set to become the backbone of secure civil space-based PNT in Europe, and plans for **GPS cross-authentication** suggest a multi-constellation authentication framework that could extend Galileo-grade protection even further.

In the **maritime and inland waterways** ecosystem, OSNMA adoption will progress at the pace of regulatory alignment, as systems governed by **SOLAS** must undergo formal conformity and approval processes. Nonetheless, OSNMA's importance will increase steadily as **GNSS interference** becomes a persistent operational hazard. It is expected to become integral also in **autonomous maritime systems (MASS)** that require assured, authenticated PNT as a foundational safety element.

On the other hand, OSNMA-capable hardware is expected to become more common among **drone manufacturers and operators**. With manufacturers such as DJI, responsible for most of the global drone production, continuing to deploy multi-constellation receivers, OSNMA-capable technology should diffuse internationally.

In **timing and synchronization (T&S)** applications, the **energy industry**, the **telecommunications** and the **financial sectors** are expected to become main users of OSNMA. European receiver manufacturers will act as early champions of OSNMA, while market trends in the Americas and Asia will determine how quickly authentication becomes a worldwide standard.

Additional markets and applications with potential for OSNMA adoption will include those where PNT may be employed as verifiable evidence in administrative, legal, or commercial processes, like law enforcement operations, logistics security and protection of critical infrastructure.

Eventually, OSNMA users may seek and obtain further security with the adoption of the upcoming **Signal Authentication Service (SAS)**, which will work as a complement to OSNMA.

Finally, the Galileo's Search and Rescue (**SAR)** will leverage the Return Link Message (RLM) to undergo a transformative expansion beyond the current **Return Link Service (RLS)**. The **Remote Beacon Activation (RBA)** will allow authorised users to remotely activate a beacon in specific confirmed distress situations. This capability will focus on the Aviation and Maritime sectors. Meanwhile, the **Two-Way Communication (TWC)** will enable structured exchanges between rescue centres and beacon users, facilitating more accurate assessment of emergency scenarios. PLB equipped users, also in Land, will benefit from it.

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8 CONCLUSIONS

As global dependence on reliable, resilient, and secure Positioning, Navigation and Timing (PNT) continues to deepen, Galileo's differentiators —**HAS**, **OSNMA**, and **SAR RLS**— are becoming increasingly central to the evolution of the GNSS ecosystem. Together, they represent a decisive advance beyond conventional satellite navigation, addressing emerging market needs that range from high-accuracy automation to cyber-secure mobility, autonomous operations, resilient warning systems, and next-generation emergency response. Their maturity and progressive integration into downstream applications confirm Galileo's capacity to shape the future of European and global PNT.

Galileo is therefore evolving into a **strategic enabler of Europe's competitiveness and resilience**.

First, it positions Galileo's space upstream and downstream industries at the forefront of GNSS technology and innovation, setting global benchmarks for performance, security and public value. European receiver manufacturers and application developers have embraced Galileo differentiators, which applicability is global, and rolled-out devices which are commercialised worldwide. In doing so, they have already fed the Galileo program with new evolution requirements which will help further tailor the services to the market.

Then, by offering high-accuracy positioning free of charge, satellite-level authentication, sovereign public warning capabilities and enhanced search-and-rescue functions, Galileo supports Europe's transition toward more automated, digital, and secure mobility systems, as demonstrated by the smart tachograph. It strengthens operational continuity across critical sectors (e.g. telecommunications), enables the development of safer services and provides a sovereign framework for protecting infrastructures and citizens against increasingly complex threats (e.g. critical infrastructures).

Key messages:

- **Galileo's differentiators directly address the next wave of user needs**, from automation and autonomy to data integrity, emergency resilience, and trusted services across transport, agriculture, maritime, aviation, energy, finance, border management, and emerging drone and U-space markets.
- **HAS, OSNMA and SAR collectively form a multilayered service ecosystem** that combines accuracy, authenticity, safety, and resilience, capabilities increasingly required for advanced applications and mission-critical operations.
- **Galileo is not simply an alternative GNSS, but a next-generation PNT infrastructure**, purpose-built to support Europe's strategic autonomy, security objectives, regulatory frameworks, and industrial innovation.
- **Future market evolution is already underway**, with manufacturers, service providers, and public authorities progressively integrating Galileo's differentiators into products, standards, and operational practices.
- **This trajectory confirms Galileo's long-term role as a cornerstone of Europe's digital, safe, and sustainable mobility landscape**, ensuring that European citizens, industries, and institutions benefit from world-leading space-based navigation services.

In sum, **Galileo's differentiators reflect a coherent strategic vision where performance, trust, security, and societal benefit converge**. As these services continue to evolve and expand, they will underpin the next decade of GNSS innovation, reinforcing Europe's position as a global leader in secure and resilient satellite navigation.

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- Promotes and maximises the use of data and services offered by Galileo, EGNOS, Copernicus, EU GOVSATCOM and soon IRIS ² across a broad range of domains.
- Fosters the development of a vibrant European space ecosystem by providing market intelligence, and technical know-how to innovators, academia, start-ups, and SMEs. The agency leverages Horizon Europe, other EU funding, and innovative procurement mechanisms.
- Implements and monitors the security of the EU Space Programme components in space and on the ground with the aim to enhance the security of the Union and its Member States. To do so, EUSPA operates the Galileo Security Monitoring Centre (GSMC).
- The EU Space Programme Security Accreditation Board is established within the Agency, representing the security accreditation authority for all of the EU Space Programme's components.

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