EARTH OBSERVATION AND GLOBAL NAVIGATION SATELLITE SYSTEMS

ANALITICAL REPORT PART II (TIMING & SYNCHRONISATION OF TELECOMMUNICATION NETWORKS, MARITIME AND INLAND WATERWAYS, RAIL AND AUTOMOTIVE TRANSPORT)

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ABSTRACT

The EU Space Programme is a business growth enabler that stimulates the econo my and pushes the bar of innovation. The EUSPA EO & GNSS Market Report is the ultimate guide to anyone who seeks to make the EU Satellite Navigation and Earth Observation technologies part of their business plan and develop new space downstream applications. More than ever society relies on innovative solutions to deal with the big data paradigm. Earth Observation (EO) and Global Navigation Satellite System (GNSS) data is becoming increasingly important to these innova tive solutions through dozens of applications that are emerging or already in use by citizens, businesses, governments, industry, international organisations, NGOs and researchers around the world. The study provides analytical information on the dynamic GNSS and EO markets, along with indepth analyses of the latest global trends and developments through illustrated examples and use cases. Using advanced econometric models, it also offers market evolution forecasts of GNSS shipments or EO revenues spanning to 2031. This article represent the brief overview essential role of space data across market segments including, timing & synchronisation of telecommunication networks, maritime and inland waterways, rail and automotive transport.

KEYWORDS: EUSPA, *GNSS, rail and automotive transport, synchronisation, telecommunication networks.*

Brief description based on the Copernicus Programme report, which is coordinated and managed by the European Commission and is the European Union's Earth Observation and Monitoring Programme (www.euspa.europa.eu).

I. INTRODUCTION

Coordinated and managed by the European Commission, Copernicus is the European Union's Earth Observation (EO) and Monitoring programme. Most data generated by Copernicus are made available to anyone globally based on a Full, Free and Open (FFO) data policy. They are accessible through various services, including a set of cloud-based platforms called Data and Information Access Services (DIAS).

European Union Agency for the Space Programme (EUSPA) with the support of VVA, Egis, Evenflow, FDC, Université Gustave Eiffel and LE Europe, to introduce the first published EUSPA Earth Observation (EO) and Global Navigation Satellite System (GNSS) Market Report [5].

The European Association of Remote Sensing Companies (EARSC) is a not-for-profit organisation which coordinates and promotes the activities of European companies engaged in delivering Earth Observation-derived geo-information services. Acting as a bridge between industry, decision makers and users and covering the full EO value chain, the organisation's members span across 25 countries and include over 130 companies (including SMEs and start-ups) [1].

The objective of the EU GOVernmental SATellite COMmunication (GOVSATCOM) initiative is to ensure the availability of reliable, secure and cost-effective satellite communication services for EU and national public authorities managing emergency and security-critical missions, operations and infrastructures.

II.TIMING & SYNCHRONISATION OF TELECOMMUNICATION NETWORKS

In July 2020, the International Telecommunication Union (ITU) released a technical report on the use of GNSS as the main time reference in telecommunications. The report contains information related to optimal GNSS reception in telecom applications where highly accurate time recovery is critical. In particular, it provides guidelines for the design and operation of GNSS-based telecommunications clocks for applications with accurate time recovery. In addition, the report mentions several relevant GNSS vulnerability reports prepared by the Telecommunications Industry Solutions Alliance. (ATIS) [2].

5G networks will enable new applications across a wealth of sectors. The expected high data rates, low latency and massive type communications on the same mobile infrastructure leads to stringent time and phase accuracy requirements, but also tight security and robustness requirements. The need for synchronisation in the radio access network has grown as new radio technologies and network architectures emerge to boost efficiency and support demanding 5G use cases [8-13]. GNSS is instrumental in the global distribution of a UTC-traceable reference. A GNSS-based solution installed directly at base station sites can provide cost-efficient, accurate and predictable time synchronisation of the radio network without any support from the transport network. 5G efficiency relies, among other things, on signal strength and coverage to reach remote areas and enable the high-speed transmission of large amounts of data. On the EO side, Sentinel-2-derived land cover maps are being used for 5G infrastructure planning. Other means of EO such as Radio Frequency (RF) sensing can be applied to map wireless spectrum and available infrastructure to optimise wireless networks at planning stage or in monitoring (e.g. to detect and localise interference) [14, 15].

5G may be a crucial enabler in the uptake of EO usage. In smart farming for instance, it would enable (two-way) transmission of EO data and integrate it into agricultural applications in real-time [23-28]. At the same time, concerns around interference created by 5G networks impacting satellite-based weather forecasts need to be addressed by regulators and standardization [55-56].

The GNSS Infrastructure Timing and Synchronisation market witnessed solid growth over the last decade favoured by the deployment of modern communication infrastructure such as 4G, small cells and, more recently, data centres. In particular, DCN operators, which benefited from the 4G base stations rollout, have driven the growth of the GNSS T&S market with more than 40% of the TSCI revenues in 2020 (and 28% of shipments). More recently, shipment growth was observed during the pandemic as the demand for high data transfer rate, high reliability and low latency connectivity positively affected the market.

This trend is expected to sustain market growth in the future. This is also the case of the newly analyzed GNSS T&S data centre market that has gained importance thanks to an increased level of required timing accuracy and the need to comply with regulation. Consolidation is increasingly taking place in the data centre market towards hyperscale data centres; this growth should remain robust after 2020.

Online video gaming has steadily progressed over the last decade in terms of audience and volume of data broadcast. According to Mordor Intelligence, the global gaming market was valued at €135 billion in 2020 and is expected to reach a value of €245 billion by 2026, registering a CAGR of 10.5% over that period. In particular, the emergence of cloud gaming is driving the market with a strong recent boost of video game live streaming that has gained further traction during the COVID-19 pandemic.

To ensure an engaging user and spectator experience, voice and video must be precisely synchronised in streaming applications and online gaming. Maintaining precise time synchronisation across the network is paramount to support seamless operations of digital infrastructure used in online gaming, such as ensuring the chronological order of play in multiplayer games. GNSS is expected to be among the most relevant solutions to ensure this T&S function, and is therefore expected to benefit from this market development.

GNSS is used in several forms of transport infrastructure (e.g. Airport, Railway and Maritime), in particular for Timing and Synchronisation, which are both critical

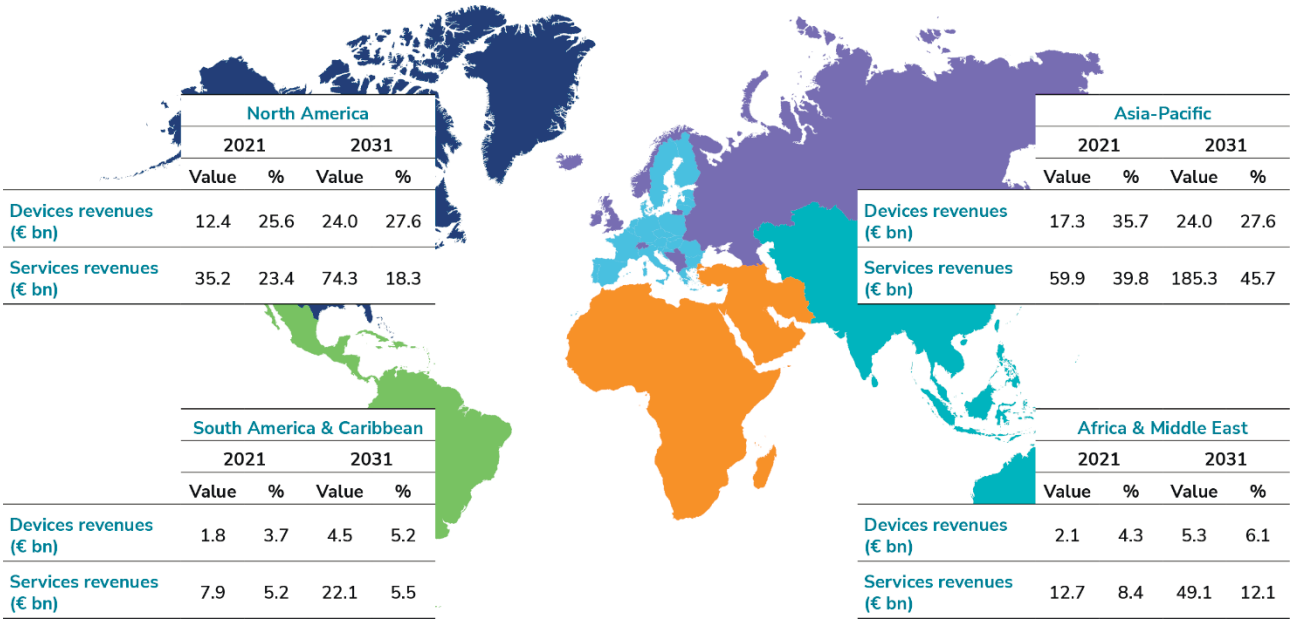
components for this infrastructure to operate [16-18].

However, the GNSS interference threat is rising, as pinpointed by US Coast Guards or by several pilots in NASA's Aviation Safety Reporting System. Several technology providers have therefore developed solutions to increase situational awareness at the level of local infrastructure (e.g. ports, airports, etc.) to ensure that the 'Timing' service is provided safely.

This technology consists of monitoring GNSS observables and comparing the expected GNSS signal characteristics with observed characteristics in order to detect anomalies. Some systems can identify the type of interference as well as pinpointing the location of the devices causing the interference, allowing authorities to take immediate remedial action. These time monitoring systems can be combined with atomic clocks and trusted time distribution to secure the communications network. Although they are not quantified in this report, new business opportunities and services are appearing that ensure protection and greater resilience of the transport infrastructure that relies on GNSS.

Wide-scale 5G deployment is still at its early stage in several regions, with EU27, Asia Pacific and North America leading the telecommunication infrastructure modernisation (with over 60% of global shipments combined). The peak of GNSS T&S sales is expected around 2024, coinciding with the most intense period of 5G rollout. Regarding the newly analyzed GNSS T&S data centre market, Asia Pacific (22% of shipments in 2021 and 29% in 2031) is expected to close in on North America (39% of shipment in both 2021 and 2031) within the next decade, at the expense of EU27 (22% of shipments in 2021 and 17% in 2031). Overall, the demand for more sophisticated devices should only impact the Telecom market marginally. Price stability or limited growth is expected in the coming years with new functionalities appearing (e.g. anti jamming, anti spoofing, integrity, multi bands and multi constellations).

At the same time, construction activities are expected to show significant growth again (after a drop in 2020 due to COVID-19), with this effect spilling over to a steady growth of related GNSS shipments. This covers handheld devices and those used in heavy machinery, both powering geomatics applications where the use of GNSS has undoubted value (Fig. 1).



European Union (EU27)	2021		2031	
	Value	%	Value	%
Devices revenues (€ bn)	12.1	25.0	21.6	24.8
Services revenues (€ bn)	27.4	18.2	53.7	13.3

Global	2021	2031
	Value	Value
Devices revenues (€ bn)	48.4	87.0
Services revenues (€ bn)	150.5	405.2

Russia & Non-EU27 Europe (Non-EU27 Europe)	2021		2031	
	Value	%	Value	%
Devices revenues (€ bn)	2.7	5.6	7.6	8.7
Services revenues (€ bn)	7.4	4.9	20.7	5.1

North America	2021		2031	
	Value	%	Value	%
Devices revenues (€ bn)	12.4	25.6	24.0	27.6
Services revenues (€ bn)	35.2	23.4	74.3	18.3

Asia-Pacific	2021		2031	
	Value	%	Value	%
Devices revenues (€ bn)	17.3	35.7	24.0	27.6
Services revenues (€ bn)	59.9	39.8	185.3	45.7

South America & Caribbean	2021		2031	
	Value	%	Value	%
Devices revenues (€ bn)	1.8	3.7	4.5	5.2
Services revenues (€ bn)	7.9	5.2	22.1	5.5

Africa & Middle East	2021		2031	
	Value	%	Value	%
Devices revenues (€ bn)	2.1	4.3	5.3	6.1
Services revenues (€ bn)	12.7	8.4	49.1	12.1

Figure 1. GNSS demand world map

III. MARITIME AND INLAND WATERWAYS

GNSS and EO contribute substantially to the maritime and inland waterways sector, assisting a diverse pool of stakeholders ranging from vessel operators and recreational boaters to port authorities in their day-to-day operations and activities.

In addition to safe and efficient navigation, GNSS devices provide a multitude of applications for inland waterways and port operations, while High Accuracy Services enable automation. Combined with EO, navigation efficiency can be optimised, and further explored in areas previously considered too dangerous or inaccessible such as new maritime routes or shallow inland waters.

Besides supporting different synergetic applications with GNSS, EO data itself provides precious insights for ocean services such as ocean monitoring, forecasting and ocean climate records, generating many coastal and marine environment applications.

Maritime sector is sailing towards a more green, autonomous and digital future. Maritime has been profoundly impacted by COVID-19, with global changes to trade and a highlighting of the fundamental importance of uninterrupted supply chains. Maritime tracking insights obtainemeasuringd via GNSS data from Automatic Identification System (AIS) are a great method for the impact of the the pandemic on trade. GNSS has allowed various bodies to track global changes to shipping patterns and frequency and provide important information. Data from Marine Traffic and other providers has offered an overview of the decline in port calls in 2020 relative to the same period in 2019, while companies such as the Maritime intelligence specialist VesselsValue are using AIS data to map cruise ship activity throughout the pandemic [33-34].

In addition, the COVID-19 pandemic has shown that digitalisation has become more important than ever, as has reducing staff onboard while ensuring safety, thus paving the way for automated solutions.

5G is accelerating the path towards automation, enabling vessels, port vehicles and port equipment such as gantries to operate more autonomously (due to its high bandwidth and low latency capabilities), and in larger quantities (given its ability to support a massive amount of connected devices) [51-54]. 5G trials are ongoing at ports around the world, including Hamburg, Rotterdam, Singapore, Shanghai and Antwerp.

The port of Antwerp, in particular, created a 5G-connected tugboat to relay images and radar data of the port's conditions in real-time, with a view to employ autonomous ships and trucks in the near future. The trend towards 5G in ports in turn is increasing the adoption of GNSS-based navigation tools, as equipment that was previously manually operated becomes auto-mated.

In addition to automation, 5G has the potential to impact a wide range applications within ship-to- ship, ship-to-shore, and onboard communication. As part of the H2H Project, SINTEF has looked into the potential applications of 5G communication within the context of maritime operations in various waters.

The IMO has issued Resolution MSC.428(98) for maritime cyber-risk management, effective from January 2021. The resolution focuses on cyber threats against the integrity and availability of technology systems.

An increase in shipping cyberattacks has been seen during the COVID-19 pandemic, as hackers attempt to exploit the vulnerabilities of maritime systems during a period of reduced staffing. The long-term focus for maritime users will be on ensuring continuity of service and protection against cyber-threats.

With low-cost spoofing devices being easily available and such cyber attacks becoming a recurring issue, a key role for authenticated GNSS is envisioned as a response to the growing threat of spoofing at sea or at ports. EU projects such as Prepare Ships and Bluebox Porbeagle are addressing this issue by creating secure devices equipped with authentication services [4].

Increasing cybersecurity risks, ship traffi and volume, in combination with the advanced automated function of vessels and future autonomous capabilities, together make the integrity concept for maritime positioning of utmost importance. Maritime positioning requirements for integrity services are assessed by organisations such as the Resilient Navigation and Timing Foundation (RNTF) and the Royal Institute of Navigation (RIN), stressing the needs of users.

To tackle this challenge, the R-MODE BALTIC project is developing and demonstrating a new maritime backup system for position, navigation and time purposes. It provides a safe ship navigation solution when

the established GNSS fail due to interference or jamming. In fact, the project promotes the fi st worldwide operational test area for a new maritime system for PNT as a backup for GNSS in the Baltic Sea.

Another project (MarRINav) has explored the vulnerabilities of the GNSS PNT solutions to complement current GNSS performance by adding layers of integrity and resilience

Once only available to military and professional users, Augmented Reality as a navigational aid is now becoming a reality for any ship-owner. Systems such as Raymarine's ClearCruise AR integrated with its Axiom chart plotters use real-time video to overlay a view of the horizon with AR markers, which highlight ships or buoys and display information such as their distance, identity and heading. AR eases the navigation by helping understand complex navigational situations and increase safety, especially in difficult meteorological conditions.

On top of this, AR provides real situational awareness, thus improving decision making via maintenance assistance for machinery and remote assistance from land offices. AR can also be used for training with real-world videos, when advanced technology equipment are introduced to the crew.

In future, AR technology could be improved with AI-based object recognition features to tag ships which do not

have AIS identification. By combining natural and digital experience, AR technology can revolutionise many maritime operational tasks.

GNSS authentication, both at data level and at range level, is important for the overall trustworthiness of the service. OSNMA, as an integral part of Galileo OS, will be a data authentication function available worldwide for free, which will protect from service disruption (jamming and spoofing) and incidents.

Galileo High Accuracy Service (HAS) will be gradually rolled out for the benefit of the Maritime sector. This will be useful specifically for Merchant Navigation and Pilotage operations in Ports, Inland Waterways, Offshore supply vessels with dynamic positioning, Autonomous Surface Vessels and others (Fig. 2).

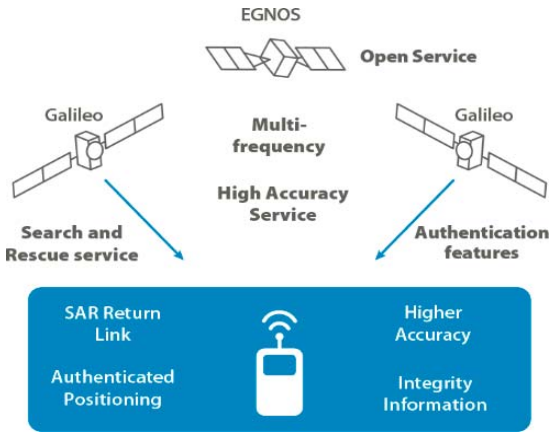


Figure 2. Enhanced devices and advanced data for better performance in maritime activities

The ASGARD project was launched under the Fundamental Elements R&D funding mechanism supporting the development of EGNSS-enabled chipsets, receivers and antennas. It is a research project targeting de-development of shipborne double-frequency receivers [3]. ASGARD focused on developing a multi-constellation and double frequency (E1/E5) maritime receiver that uses Galileo and that complies with European and International specifications. This receiver must implement the required algorithms to process OSNMA encrypted GNSS signals.

ASGARD shipborne receiver will take benefit of all Galileo OS features (improved performance and robustness thanks to dual-frequency and OSNMA capabilities), which in turn will ease the use of the Resilient PNT concept in maritime navigation [3].

The 'PREParE SHIPS' project develops a collaborative resilience navigation solution. It aims to develop and enhance existing software solutions by exploiting the distinguished features of the Galileo signals as well as combining it with other nautical information and sensor technologies [38-44]. The accurate position of the solution is based on EGNSS, data and machine learning. The project is also using the Copernicus Marine Service Analysis and Forecast model products for wind, current and waves. The project is using eight EO products (one example being analysis-forecast outputs).

The benefits generated by this smart positioning solution are: reduction of the environmental impact (in line with IMO targets); prediction behaviour of vessels; decreased risk for collisions; and more energy-effective manoeuvring. Those potential benefits are of critical importance, taking into consideration the current challenges the industry is facing, including vulnerability of safety critical applications, increased automation and increased traffic.

To address these challenges, 'PREParE SHIPS' is focusing on a support system covering EGNSS resilience positioning, Real time dynamic predictor, Ship-to-ship/ship-to-shore interaction and geo-fencing [4].

IV. RAIL TRANSPORT

GNSS and EO serve the rail sector in many ways. First, GNSS plays a role in rail digitalization; from asset management to infrastructure monitoring and enhanced passenger information, GNSS is already largely deployed in non-safety critical applications [45-50]. Moreover, a large number of initiatives are preparing for the introduction of GNSS in High- and Low-Density Command & Control Systems, paving the way for new train operations.

Furthermore, satellite-based imagery offers solutions around track deformation monitoring, vegetation encroachment detection and natural hazard risk assessments, leading to reduced needs for on-site inspections.

GNSS and EO therefore both increase safety and reduce the cost of infrastructure management and operations compared to legacy solutions. The number of global initiatives demonstrates the consideration given to GNSS and EO-based developments in Rail.

In order to increase rail efficiency and attractiveness, railway stakeholders are taking advantage of new digital and computer- based technologies to become increasingly user-centred and to improve passenger and freight management services.

GNSS is part of the digitalisation that is reflected in the development of new applications, allowing passengers to get real-time journey information and to reserve and to purchase tickets. These also aim to drive shipping back towards rail freight by proposing means to facilitate freight tracking.

Railway operators and infrastructure managers benefit from digitalisation because it improves asset management and maintenance, thereby reducing the operational costs. A growing number of operators are deploying real-time remote diagnostics monitoring systems (e.g. SNCF Logistics with Traxens, DB Cargo, etc.). They collect various pieces of data such as the loading of wagons, within-wagon temperature and humidity, and the position and condition of cargo and rolling stock (which can subsequently be remotely controlled). Such data and its analysis will increase rail freight efficiency, allowing the planning of preventive maintenance actions with greater efficiency.

Digital transformation is also driven by the development of digital twins, particularly for the predictive maintenance of railway infrastructure and rolling stock and for predicting future incidents. These models are based on the collection of real data, some of which is provided by GNSS and EO services [19-22].

Whereas classical infrastructure monitoring procedures rely on the use of measurement vehicles with dedicated runs, new methods based on EO data provided by satellites or drones are being introduced. The use of these technologies meets railway exploitation challenges and allows a global high-frequency monitoring capacity at lower costs [29-32].

Among the potential railway applications of EO, vegetation supervision is currently the most industrialised. For the last two years, some railway operators, such as SNCF or Deutsche Bahn, have been using very high-resolution optical Earth-imaging satellites to get large amounts of information on vegetation development along tracks. This data is used to assist vegetation management teams to operate more efficiently.

Moreover, industrial R&D projects are carried out to study the potential wide operational deployment of satellite-based synthetic aperture radar interferometry (InSAR) or LiDAR acquisition by drones.

Train location is a key element in enhancing railway capacity and fostering new concepts within the sector. Use of GNSS to compute train location may improve position accuracy and integrity at the same time as decreasing operational costs by reducing the need for trackside equipment. However, in a railway environment with tranches, vegetation and urban buildings, GNSS may suffer from performance degradation regarding accuracy or availability. In order to improve train positioning performances, multi-sensor architectures and data fusion algorithms are essential, and have been investigated in several R&D projects (see projects in section on European GNSS).

In June 2020, Alstom was certified to implement its data fusion algorithms using both GNSS and inertial movement in a new odometry system to accurately and safely measure the location and speed of trains. It is one of the first safety-related GNSS applications within railway signalling.

The development of fail-safe location systems must be accompanied by the development of validation tools. Due to safety needs and the complexity of the railway environment, stakeholders require highly controllable laboratory tools. Some developments are supported by the Shift2Rail programme (Gate4rail project) and ESA (Sim4Rail project). The testbeds developed intend to simulate the behaviour of these future solutions under both nominal and extreme conditions [5].

With the development of drones, new railway applications can be envisioned. First of all, projects such as RADIUS (EUSPA) or In2Smart (Shift2Rail) study the potential of drones being used to inspect railway catenary lines and other vital aspects of railway infrastructure, such as the alignment of tracks and switching points. These activities are currently performed by humans and are highly demanding in terms of personnel labour costs and operational constraints. The use of drones will allow these inspections to be performed more regularly with improved safety, reliability and punctuality of the service, all while reducing operational costs.

Galileo-enabled receivers already serve millions of passengers using SNCF high-speed trains (TGV) with the provision of enhanced services (e.g. real-time, precise train location information in stations). Furthermore, GNSS receivers are currently used to track rolling stock (more than 50,000 freight wagons of multiple EU railway undertakings are already equipped with GNSS-based telematic solutions).

The on-going development of fail-safe applications involves the investigation of the multi-frequency potential of EGNSS for more availability, accuracy and integrity.

Although the refinement of the railway users' specific needs and requirements is progressing, there is some concern on how an EGNSS-based safety service must be tailored to answer these requirements.

The High Accuracy Service (HAS) and authentication features could support an attractive and robust localization solution for the future digital rail agenda (Fig. 3).

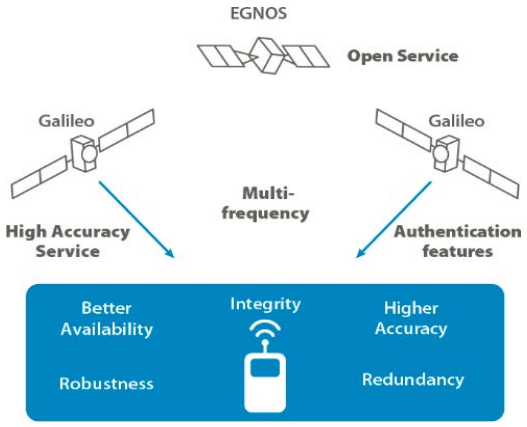


Figure 3. Integration all kinds of train location-based applications

To use EGNSS for rail safety applications such as signalling, sensor data fusion will be necessary to mitigate the known impact of local effects on GNSS performances. Two studies under H2020 have been launched to investigate this topic.

The CLUG project has developed a proof-of-concept of an on-board continuous and safe localisation unit providing information on the train's position, velocity and acceleration. This localisation unit may be useful in replacing or enhancing the existing on-board equipment, such as odometry and balise readers. The cost of trackside equipment should therefore decrease whilst new railway concepts are fostered, such as the moving block for ERTMS.

The HELMET project has developed an augmentation and integrity monitoring platform for rail and road, given that railways and highways are often close to each other

and share the same electromagnetic environment and similar requirements. A multimodal architecture has been designed, using Satellite-Based Augmentation Systems (SBAS) and Galileo services, to support a high integrity and high accuracy positioning service [6].

V. ROAD AND AUTOMOTIVE

Mobility is an important part of everyone's daily lives. The Road and Automotive market segment encompasses services and products offered to and consumed by the automotive industry. This includes road transport operators, road infrastructure operators and OEMs (Original Equipment Manufacturers, i.e. passenger and commercial vehicle makers and suppliers).

GNSS is used in safety-related applications in scenarios of potential harm to humans or damage to a system/environment (e.g. connected and autonomous cars, emergency assistance), liability applications (e.g. road user charging, smart tachographs) and fleet management systems including tracking of dangerous goods. Satellite navigation systems therefore significantly contribute to reducing congestion and associated emissions, improving the safety and efficiency of road transportation.

When it comes to smart mobility applications (e.g. distribution of traffic and real- time information to users and infrastructure managers), the contribution of GNSS is strengthened by fusion with satellite imagery.

EGNSS impact will be especially strengthened by important future developments including automated mobility and smart traffic management systems, smart applications and 'Mobility as a Service' where Galileo is expected to deliver new accuracy and reliability for location-dependant services to enhance urban mobility.

Robustness and availability are key GNSS requirements for forward-looking vehicle-to-everything (V2X) communication and automated driving technology. Continuous lane-accurate positioning is seen as an important milestone in the expansion of autonomous capability and situational awareness. The most important value added is safety achieved through redundancy (where GNSS-based lane determination acts as an independent source to supervise the vision-based systems) and alleviating tasks from the perception system (which can focus on changing surroundings). In such a way incorporating precision GNSS into LiDAR-based systems can unlock robustness and additional fallbacks for safety and utility, while high-integrity GNSS lane determination integrated into vision-based architectures can unlock lane-level manoeuvres and provide oversight to guarantee safety.

V2X is a communications technology for smart infrastructure, the exchange of information between vehicles helps avoid accidents, and information exchanges to road infrastructure in order to improve traffic efficiency. As autonomous vehicles will target operating beyond specific routes and cities, GNSS can emerge as a global standard to ensure interoperability across autonomous systems and act as a common reference for precise position and time information.

Autonomous driving is among the most demanding road applications as its high accuracy requirement must be coupled to a high level of integrity. Reaching accuracies and integrity performance metrics simultaneously is enabled by GNSS receivers that can utilise data received from a sufficient number of satellites and correction services. Various industry players are developing Autonomous Driving Systems (ADS), relying on a range of sensors including GNSS for absolute localisation, HD maps, LiDAR, radar and Internal Measurement Units (IMUs). With ongoing trials, the emerging approach is that GNSS is a key component of the sensor fusion system contributing to the safety of autonomous systems. This is the case for Navya, who reached a new milestone with its level 4 fully autonomous shuttle (tested without an operator on board) and VW who plan to roll out a first fleet of self-driving test cars in Hefei (China). Similarly, this combination of sensors in Sensible 4's autonomous driving software allows operation in various weather conditions and environments. Its performance will be tested in the north of Europe, together with Ruter and Holo, on Toyota vehicles to explore the integration of AVs into public transport service and new mobility services. In such a way GNSS continues to play a key role in the development of ADS with robustness (integrity) and availability as key requirements.

With 80% of the world's road network not paved, road networks tend to be particularly vulnerable to environmental, weather and vehicle-related damage with direct impact on its users.

The start-up Bareways combines different data sources (e.g. ground sensors, Sentinel data, historical data) in a mobility platform to give users a unified view of specific road conditions (thus helping avoid risks, delays and fatal incidents).

Current road condition information will be made available to the vehicle navigation system, together with other criteria for route planning and optimisation such as vehicle type, load fragility and driver safety needs. The platform is expected to boost e-mobility applications by suggesting routes depending on battery charge status and possibilities for regenerative braking.

The development of telematics services contributes to the persistent growth in the automotive sector as insurance telematics reached almost 18 million units in 2020, witnessing the highest historical CAGR of 35%, compared with other applications.

Another application substantiating market growth is emergency assistance, which is linked in the European market to the growing number of cars equipped with the mandatory eCall system since 2018.

Finally, during the pandemic, micro-mobility has once again emerged as a sustainable alternative to personal car usage. In particular urban bike sharing (along with e-scooter sharing) schemes account for about 7% of GNSS shipments in 2020 (Fig. 4).

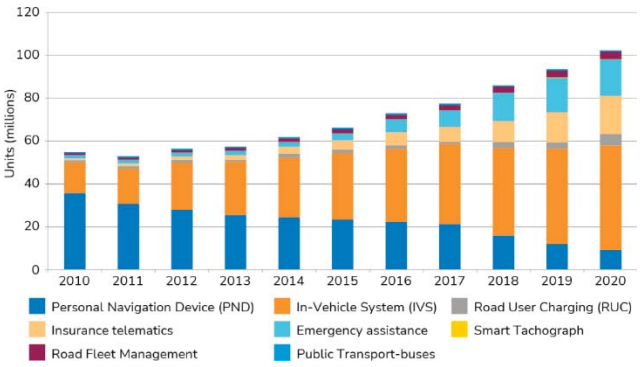


Figure 4. Shipments of GNSS devices by application

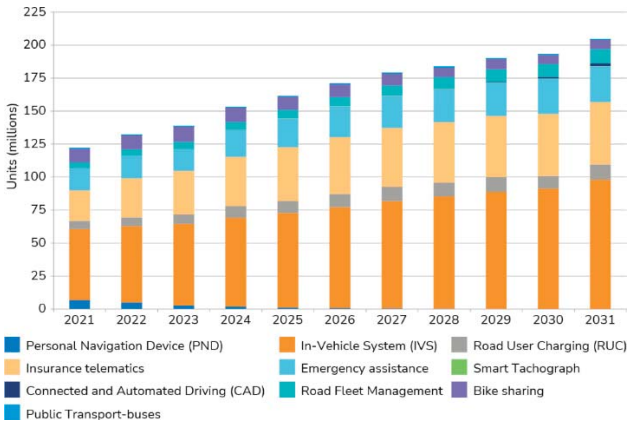


Figure 5. Reinforced trend of IVS becoming the primary PNT source

Geolocation technologies open up new opportunities to improve public mobility through various initiatives, such as demand-responsive transit services (on-demand buses) explored in the H2020 Galileo 4 Mobility project. The pilot was organised by Pildo Labs in collaboration with the Metropolitan Area of Barcelona (AMB), and aimed to tackle the low usage of bus services in the area. Taking advantage of the willingness of the local authorities to permanently implement an on-demand bus service for small villages in the area, Pildo launched a spin-off to commercialise developments performed within the project in the form of NEMI, a tool enabling flexible bus routes and making mobility in low-density areas feasible. A similar platform powered by satellite navigation, Shotl, supports the transition of companies with on-site employee movement to sustainable mobility.

After a significant slowdown of smart tachograph adoption in Europe with a 50% drop in annual shipments registered in 2020, the market is expected to pick up in the coming years due to regulatory developments. An extension of the tachograph's scope to light commercial vehicles, retrofitting provisions for vehicles with analogue and digital tachographs (expected by winter 2024), as well as introducing the first version of the smart tachograph by autumn 2025, will drive annual shipments up to 167,000 units by 2025.

Although globally new vehicle sales are unlikely to return to pre-pandemic levels until 2023, the penetration of GNSS-enabled applications is expected to grow substantially over the next decade (Fig. 5).

Comprehensive evaluation of performance and safety considerations is critical to successful deployment of autonomous systems. International organisations contributing to proving safety for autonomous vehicles include ISO (standards related to safety of execution, performance and intended functionality, as well as requirements for Electrical/Electronic/Programmable Electronic systems), Radio Technical Commission for Maritime Services (RTCM), standards related to Integrity for High Accuracy GNSS-based Applications, Third Generation Partnership Project (3GPP) standards linked to mobile GNSS assistance data and the emerging European standard EN16803.

Focusing on this latest development by CEN-CENELEC, EN16803 explores the use of GNSS positioning in the automotive framework and in particular the assessment of the basic performance of GNSS positioning terminals. In the ongoing phase, the main effort is concentrated on security performance including definition and validation of future testing scenarios.

Ongoing standardisation activities continue to unlock the benefits of autonomous features in cars and pave the way towards a driverless future, which is in turn associated with increased road safety.

Road safety is one of the major elements of the European Union's transport policy; eCall continues to contribute to the reduction of road fatalities and alleviating the severity of road injuries. One of the ongoing initiatives that is looking to expanding eCall reach to L3 vehicle categories (2-wheeled powered vehicles or motorcycles) is H-Gear.

This project aims to develop a system composed of a device integrated into the motorcycle (provided by Honda), a software suite for the monitoring and control of the eCall and Anti-Theft services and a user mobile application for the interaction with the driver.

The H-Gear system will leverage on EGNSS features such as spoofing incident from the Galileo navigation message detection and mitigation using OSNMA, as well as the use of GNSS raw measurements (jointly with accelerometer data) during the alert/theft or accident mode, in order to verify the motorcycle's movement and position [7].

Present in all European new vehicle types equipped with eCall, Galileo is already contributing to improved safety and transport efficiency on European roads.

EGNOS improves GPS accuracy and provides information on the reliability of the positioning information. Together with Galileo and shortrange communications technologies implemented in smart tachographs, EGNOS contributes to enforce EU legislation (social regulation) on professional drivers' driving and resting times (Fig. 6).

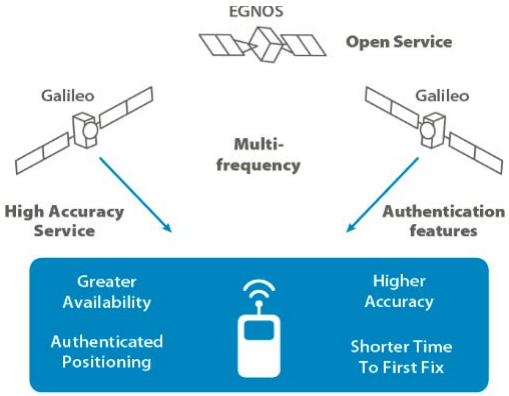


Figure 6. Smarter and more sustainable mobility

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

Galileo's Open Navigation Message Authentication (OSNMA) feature will contribute to addressing the security challenge faced by many applications as potential targets of spoofing attacks, including smart tachographs used in trucks, taxis and ride-sharing vehicles, and tracking devices used in commercial cargo.

The introduction of automated vehicles in cities represents a unique opportunity for a fundamental change in urban mobility. An effort lead by UITP, together with over 50 partners covering the whole urban mobility sector, aims to place public transport at the centre of automated vehicles revolution. SPACE will bring a high-level reference architecture to ensure a seamless integration of driverless vehicles with other IT systems in the mobility ecosystem. This will in turn help operators and cities make the right technical decisions when integrating AVs into the public transport network, speeding up the deployment of driverless mobility services.

An effective integration of AVs as shared vehicles in the public transport network (e.g. shuttle buses, car or ride-sharing schemes) is expected to drastically reduce car ownership, regain essential urban space, and result in better mobility for all.

MOLIERE is a joint initiative led by Factual to coordinate a consortium formed, among others, by SEAT. The study's main goal is to unlock much more precise, accurate and highly available location data enabled by Galileo through an open Mobility Data Marketplace underpinned by blockchain [35-37].

VI. CONCLUSION

Earth Observation (EO) refers to remote sensing and in-situ technologies used to capture the planet's physical, chemical, and biological systems and to monitor land, water (i.e. seas, rivers, lakes) and the atmosphere. Satellite-based EO by definition relies on the use of satellite-mounted payloads to gather data about Earth's characteristics. As a result, satellite-based platforms are suitable for monitoring and identifying changes and patterns for a range of physical, economic, and environmental applications globally. Once processed, EO data can be assimilated into complex models to produce information and intelligence (e.g. forecasts, behavioural analysis, climate projections, etc.), and complemented by in-situ measurements.

The Report applies utilises advanced forecasting techniques applied to a wide range of input data, assumptions, and scenarios to forecast the size of the GNSS and EO markets. The GNSS market is quantified according to shipments, revenues and installed base of GNSS devices.

Key input assumptions are collected from market reports and studies to help inform the penetration of GNSS, the average lifetime of a devices, device prices, EO data and services sales, and more. Input assumptions and outputs are subject to internal and external validation with consortium and industry experts to ensure emerging trends are captured as soon as they are identified.

Where possible historical values are anchored to actual data in order to ensure a high level of accuracy. Application-level model results are cross-checked against the most recent market research reports from independent sources before being validated through an iterative consultation process with European and international sector experts and stakeholders.

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

This Market Report considers the EO market to be defined as: activities where satellite EO-based data and value-added services enable a variety of applications across multiple segments.

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The 2023 event will take place February 13-15, 2023 in Denver, Colorado.

The Advisory Board will assist in developing conference programming comprised of both general sessions and breakout sessions that delve into the full spectrum of data needs, work processes, software integration and standards in both the geospatial and BIM worlds. Specific vertical industries include architecture, engineering, & construction; asset & facility management; disaster & emergency response; earth observation & satellite applications; energy & utilities; infrastructure & transportation; land & natural resource management; mining & aggregates; surveying & mapping; and urban planning / smart cities.

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