

2025

Report on Road and Automotive

User Needs and Requirements

#EUSpace 



EXECUTIVE SUMMARY

The Road and Automotive segment is undergoing a profound transformation, driven by the convergence of digitalization, automation, and the push for sustainability. In this context, the integration of space-based technologies, particularly Global Navigation Satellite Systems (GNSS) and Satellite Communications (SATCOM), is becoming increasingly critical to support the evolving needs of the sector. The 2025 User Consultation Platform (UCP) has reaffirmed the strategic role of these technologies in enabling safer, more efficient, and more connected mobility across Europe.

GNSS, and in particular Galileo, remains an essential element in the automotive ecosystem. It supports a wide range of applications, from eCall and smart tachographs to advanced driver assistance systems (ADAS) and connected and automated mobility (CCAM). Galileo's High Accuracy Service (HAS) and Open Service Navigation Message Authentication (OSNMA) are seen as key enablers for improving positioning accuracy and signal trustworthiness. However, challenges remain in terms of convergence times, hardware readiness, and the need for robust integrity frameworks to support safety-critical applications.

SATCOM is emerging as a complementary connectivity layer, particularly in areas where terrestrial networks are insufficient or unavailable. The IRIS² programme will have the opportunity to play a pivotal role in delivering secure, high-speed, and resilient connectivity for commercial automotive use cases. The transition from proprietary mobile satellite services to integrated terrestrial-non-terrestrial networks is underway, supported by the adoption of 3GPP standards and the development of multi-orbit satellite constellations. While integration challenges persist, such as antenna size, cost, and chipset availability, commercial fleets and logistics operators are identified as early adopters, with strong interest in SATCOM for applications like teleoperation, over-the-air updates, and connected fleet management.

The adoption of satellite Earth observation (EO) in road infrastructure management is progressing but remains at a low level of maturity across most road authorities. EO is increasingly used in specialized applications such as ground deformation monitoring with InSAR, landslide and flood risk assessment, and environmental monitoring along road corridors. However, in many organizations it is still applied through pilot projects, research initiatives, or external service providers, rather than being fully embedded in routine asset management workflows. Wider adoption is gradually increasing as higher-resolution data, cloud processing platforms, and integration with GIS and asset management systems make EO-derived information more accessible and operational for infrastructure managers.

The report identifies several key user needs and drivers, including the demand for high-accuracy, signal authentication, low-latency and high-availability connectivity, and seamless integration of satellite services into vehicle architectures. Regulatory frameworks, such as the EU General Safety Regulation and the mandatory deployment of eCall and smart tachographs, continue to drive GNSS adoption. Meanwhile, the growing complexity of connected and automated vehicle functions is increasing the performance expectations placed on both GNSS and SATCOM systems.

Despite the progress made, several gaps and challenges remain. For GNSS, the lack of automotive-grade antennas supporting advanced Galileo signals and the need for faster convergence times are key barriers to adoption. For SATCOM, the integration of broadband services into passenger vehicles is constrained by hardware limitations and cost. Nonetheless, these challenges present opportunities for innovation, particularly in the development of hybrid connectivity solutions and the standardization of satellite-based services for the automotive sector.

Looking ahead, the EU Space Programme, is well-positioned to address these evolving needs. Continued investment in standardization, hardware development, and stakeholder engagement will be essential to unlocking the full potential of space technologies in the road and automotive domain. The path forward will require close collaboration between industry, regulators, and technology providers to ensure that space-enabled services deliver tangible benefits for mobility, safety, and sustainability.

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1 SCOPE AND METHODOLOGY

1.1 Scope

The User Consultation

The User Consultation Platform (UCP) is a process developed at the European Union Agency for the Space Programme (EUSPA) to collect user needs and requirements and take them as inputs for the provision of user driven space data-based services by the EU Space Programme.

The objective of this report is to provide a reference for the EU Space Programme and for the Road and Automotive segment community, reporting the most up-to-date user needs and requirements in the Road and Automotive market segment for the use of Position, Navigation and Timing (PNT), Earth Observation (EO) and secure telecommunications (SATCOM) technologies. Its scope is to cover needs and requirements from the user perspective, considering the market conditions, regulations, and standards that influence them. The report serves as a reference for end users, service providers and the whole EO community in planning and decision-making activities for those concerned. The report is also intended to serve as an input to more technical discussions on systems engineering and to shape the evolution of the European Union's satellite navigation systems, Galileo and EGNOS and the Earth Observation system, Copernicus, and in the future Space Situational Awareness, GOVSATCOM and IRIS2.

The UCP process contains a regular event, where users from different market segments meet to discuss their needs and application-level requirements relevant for PNT, EO and SATCOM and the conclusions are presented in this document. This report is a living and evolving document that is regularly updated by EUSPA. It served as a key input to the UCP, that is continuous process to reflect the evolution of the user needs, market and technology captured during the event. The report does not represent any commitment of the EU Space Programme to address or satisfy the listed needs and requirements in the current or future versions of the services and/or data delivered by its different components.

This report is organized as follows:

- Section 2.1 addresses the prospective use of EO/GNSS/SATCOM in the Road and Automotive segment, with identified trends, and innovations
- Section 2.2 presents the market evolution and key trends in the Road and Automotive segment, together with definitions of main user groups and actors in the value chain, followed by Section 2.3, that describes the market drivers (regulations, standards etc.)
- Section 2.4 describes applications and operational scenarios relevant for EO/GNSS/SATCOM, presenting main user needs and expectations towards services and data to serve operational scenarios, together with limitations and gaps identified by end users. Some applications are more detailed as they have been assessed specifically during the 2025 UCP.
- Section 2.5 summarizes the main User Requirements for the Road and Automotive segment in the applications domains analysed in this report.

1.2 Methodology

The UCP process follows systematic steps that are implemented in a continuous, repetitive manner. The logical steps allow transparency and continuous updates of the results, considering the new market developments and evolving user needs and requirements.

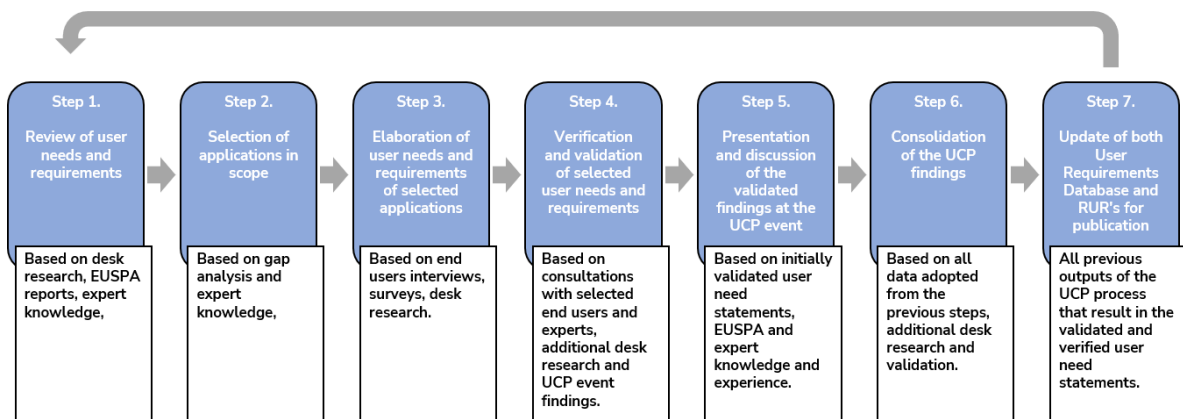


Figure 1: Road and Automotive segment user requirements analysis methodology

Each Market Segment has its peculiar evolution due to the changes in legislation, standards, technological trends and so forth, therefore the update of the Report on User Need and Requirements can occur with a time distance of at least two years.

UCP user needs and requirements collection and analysis is based on one hand side on desk research and on the other, on stakeholders' consultations and experts' knowledge.

The UCP process starts with review and analysis of the most up-to-date sources related to the user needs and requirements in selected market segments. This step leverages on the previous UCP Reports on User Requirements, latest EUSPA EO and GNSS Market Report [RD1], Technology Reports and other expert publications and knowledge. The selection of relevant applications in each market segment is made based on the market analysis, the gap analysis from the earlier editions of the UCP and EUSPA, as well as external experts' know-how.

After the initial desk research, the stakeholders' consultations are carried out, both representing end users and intermediate users (service providers), in order to validate the findings and collect missing information (Step 3). Validation of user needs requires additional feedback from relevant users' representatives that review the draft version of the Report on User Needs and Requirements, prepared in advance of the UCP event.

The UCP event is organized by EUSPA on an annual basis and offers a forum to present and discuss the finding, being additional layer of updates and gaps filling in the process. All the information and data gathered during the previous steps are consolidated in the segment-specific, presented here Report on User Needs and Requirements (RUR) and later on in the EUSPA User Requirements Database (Step 7).

2 ROAD AND AUTOMOTIVE

2.1 The role of the European Space Programme to meet the evolving user needs

The role of EUSPA

EUSPA (European Union Agency for the Space Programme) plays a pivotal role in the context of the EU Space Programme, acting as a key operational agency that is user-oriented and focused on promoting and maximizing the uptake of satellite-based services across various sectors, through the following activities:

1. User-Centric Approach

- EUSPA adopts strategies that prioritize the needs and requirements of users. It aims to enhance the accessibility and integration of satellite services, ensuring that a broad spectrum of users, including governmental bodies, businesses, and citizens, can benefit from services related to Earth Observation, Satellite Navigation, and Connectivity.

2. Service Provisioning

EUSPA is responsible for providing state-of-the-art services in areas such as:

- Positioning, Navigation, and Timing: Through the Galileo and EGNOS systems.
- Satellite Communications: It facilitates communication services for governmental applications through GOVSATCOM and is working on the new IRIS2 initiative.
- Space Surveillance: EUSPA manages Front Desk services for the EU Space Surveillance and Tracking program, ensuring safety and security in space operations.

3. Enhancing the European Space Ecosystem

EUSPA works to foster a robust European space ecosystem by:

- Providing market intelligence and technical expertise to innovators, SMEs, and academia.
- Leveraging EU funding programs such as Horizon Europe to stimulate innovation and research in space-related technologies.
- Supporting startups and developing partnerships that enhance technological advancements.

4. Ensuring Security

- EUSPA plays a critical role in the security of the EU Space Programme. By operating the Galileo Security Monitoring Centre (GSMC), it implements and monitors the security of satellite services, thereby bolstering the overall security framework for EU Member States.

5. Stakeholder Engagement

- EUSPA actively engages stakeholders from the entire space value chain, including industry leaders, academic institutions, and end-users. It facilitates feedback mechanisms where users can express their needs and satisfaction levels regarding EU satellite services. This engagement is crucial for the continuous evolution of the EU Space Programme.

EUSPA conducts various essential activities which include:

- User Consultation Processes: These are designed to gather insights and perceptions from users to improve service delivery.

- **Market and Technology Monitoring:** EUSPA analyses trends and forecasts in the space industry to inform strategic decisions.
- **Research and Development Funding:** The agency identifies funding needs for R&D initiatives and ensures their implementation.
- **Pilot Programs:** EUSPA supports the testing and piloting of innovative applications to explore new possibilities in space services.
- **Commercial Acceleration Programs:** Through the CASSINI Programme, EUSPA promotes innovative commercial ideas and facilitates their growth in the marketplace.

In summary, EUSPA serves as a cornerstone of the EU Space Programme, bridging the gap between technological advancements and user needs. By providing innovative satellite services, fostering a collaborative space ecosystem, ensuring security, and engaging with a wide array of stakeholders, EUSPA is crucial in advancing the EU's strategic interests in space and enhancing the overall benefit of space technologies for society.

The role of COPERNICUS

Copernicus is the Earth Observation component of the European Union's space programme, looking at our planet to support the management of the environment, mitigate the effects of climate change and ensure safety and civil security across Europe. Copernicus delivers its data and services with a free and open policy. It consists of three main components:

Space Component, which delivers data from a fleet of dedicated observation satellites (the 'Sentinels') and other Copernicus Contribution Missions (CCM). Six Sentinel satellites families are designed to serve a wide range of users and are provided with a free and open access globally. They ensure an independent and autonomous Earth Observation capacity for Europe with global coverage. The satellites provide observations which serve a wide range of users for a multitude of applications in the areas of climate, land and ocean services, emergency management, atmosphere and air quality, among others.

- Sentinel-1A provides all-weather, day and night radar imagery for land and ocean services. Sentinel 1-B was retired in December 2021. The Sentinel-1C satellite was launched on 5 December 2024 and Sentinel-1D launch is planned in 2025.
- Sentinel-2A & -2B provide optical imagery for land and emergency services.
- Sentinel-3A & -3B provide optical, radar and altimetry data for marine and land services.
- Sentinel-5P provides atmospheric data, bridging the gap between ENVISAT and future Sentinel-5 data.
- Sentinel-4 & Sentinel-5 will fly aboard EUMETSAT MTG-S and Metop-SG satellites. They will monitor air quality, trace gases and aerosols over Europe at high spatial resolution and very high frequency.
- Sentinel-6 provides radar data to measure global sea surface height observations for climate monitoring and ocean and seasonal forecasts. It continues a time series of mean sea level rise measurements dating back to 1992.

CCMs complement the data portfolio in the Sentinel satellites missions with another layer of value to meet user needs, providing data from commercial data providers. There are around 30 existing or planned to contribute missions, encompassing various technologies like SAR, optical sensors, spectrometers and altimetry systems.

In-Situ Component collects data acquired by a multitude of sensors at air-, sea- and ground-level, and includes geospatial reference data.

Service Component of Copernicus programme transforms the various data into timely and actionable information products. The Copernicus Services deliver value-added information products in six thematic areas:



Figure 2: Copernicus services

The role of European Global Navigation Satellite System (EGNSS)

EGNSS is the European satellite navigation program designed to provide highly accurate and reliable positioning, navigation, and timing services on a global scale and ensuring Europe’s technological autonomy. EGNSS offers high-precision and multi-constellation capability. There is a free positioning service available to the public, as well as encrypted services for government and commercial use, like the Public Regulated Service (PRS) for government-authorized users. EGNSS includes two main systems:

- **Galileo** is the European satellite navigation system that provides highly accurate global positioning and timing information. It offers several unique features, including higher accuracy (especially in urban areas), improved availability, and an authentication service to prevent signal spoofing. Numerous EU economic sectors rely on Galileo, from transport and agriculture to border management and search and rescue. Its 20cm accuracy makes Galileo a game changer for autonomous driving and commercial drones. Already more than 3.5 billion smartphones are Galileo-enabled.
- **EGNOS** (European Geostationary Navigation Overlay Service) is a satellite-based augmentation system (SBAS) that improves the accuracy, integrity, and reliability of the navigation services to aviation, maritime and land-based users in over 30+ countries.

For the Road and Automotive segment, Galileo provides highly accurate positioning, navigation, and timing (PNT) information that is essential for safe and efficient road transport operations. This includes applications such as lane-level navigation, advanced driver assistance systems (ADAS), and connected, cooperative, and automated mobility (CCAM). Galileo’s unique features, such as enhanced accuracy, signal authentication, and improved availability, make it a valuable asset for enabling reliable and resilient vehicle positioning across diverse driving environments.

Major outcomes and key insights Road and Automotive GNSS session UCP 2025

- **Absolute Positioning and Integrity:** Reliable, lane-level absolute positioning is essential for ADAS and CCAM applications. Galileo’s HAS and OSNMA offer strategic advantages in improving accuracy and robustness, but high integrity remains a critical requirement.
- **Market Adoption and Receiver Capabilities:** Automotive-grade antennas supporting Galileo’s E6B signal are not yet available, prompting OEMs to invest in R&D for compatible hardware. Adoption of OSNMA and HAS is increasing, driven by regulatory requirements and industry pilots, but further market penetration is needed.

- **Resilience and Redundancy:** GNSS faces inherent limitations, including vulnerability to jamming and spoofing. OSNMA helps counteract spoofing, and redundancy through sensor fusion and dead reckoning remains essential.
- **Accuracy and Convergence Times:** Sub-meter accuracy is becoming necessary for higher levels of automation, with HAS offering globally available, decimetre-level accuracy. However, convergence times is also important, as solutions must manage delays without compromising user experience.
- **Data Integrity and Security:** Systems such as smart tachographs rely on GNSS for authentic and secure Position, Velocity, and Time (PVT) data. Environmental challenges, interference, and time drift impact performance, highlighting the need for robust security frameworks.

Table 1: Takeaways for GNSS from the 2025 UCP

European Secure SATCOM

The EU Secure Satellite Communication System, known as **GOVSATCOM** is an investment made by the EU, which aims to provide secure and cost-efficient communication capabilities to security and safety-critical missions and operations. **IRIS²**, the new multi-orbital constellation of 290 satellites will provide secure connectivity services to the EU and its Member States as well as broadband connectivity for governmental authorities, private companies and European citizens, while ensuring high-speed internet broadband to cope with connectivity dead zones. The program is part of the EU's broader strategy to strengthen its autonomy, security, and defence capabilities, especially in response to increasing geopolitical challenges and cybersecurity threats.

Major outcomes and key insights Road and Automotive SATCOM session UCP 2025

- **IRIS² Programme:** Positioned as a strategic enabler for secure, resilient, and interoperable connectivity, supporting both government and commercial automotive use cases. The constellation will deliver services via a multi-layer satellite network, with a focus on open standards and dual-use capabilities.
- **Market Evolution:** The automotive sector is expected to be moving towards ubiquitous, seamless connectivity, with satellite communications filling coverage gaps and supporting disaster recovery. Adoption of 3GPP standards is critical for interoperability and mass-market integration.
- **Technical Challenges:** Integration of broadband SATCOM terminals remains a niche due to size, cost, and manufacturing scale. Advances in antenna technology and chipset development are needed for widespread adoption. Hybrid solutions are essential for meeting low-latency, safety-critical requirements.
- **Business Models:** The ecosystem is exploring new models for value and cost sharing, with OEMs and satellite providers considering direct contracts and differentiated offerings. Consumer willingness to pay is highest for essential services in areas with poor terrestrial coverage.
- **Standardization and Interoperability:** Industry consensus is that open standards (3GPP) are vital to avoid vendor lock-in and enable scalable, interoperable solutions. The shift from proprietary technologies to standard-based approaches is underway.

Table 2: Takeaways for SATCOM from the 2025 UCP

2.2 Market overview & trends

2.2.1 Market Evolution and Key Trends

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 becoming even more critical in the sector as vehicles transition toward connected, software-defined, and increasingly automated operations. GNSS underpins a wide range of safety-critical, regulatory and operational functions, providing position, navigation, and time information (PNT) that is reused across vehicle systems and mobility services. Trends are shifting the GNSS automotive market from a focus on basic reception toward higher-value capabilities, including high-accuracy positioning, resilience against interference and authenticated data for safety and compliance. As a result, GNSS is increasingly positioned as a core element of the automotive sensor and connectivity stack,

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 (Earth Observation).

EO supports every phase of road infrastructure management, including site selection, planning, design, construction, operations, maintenance, disaster response, and risk assessment. Road infrastructure elements like surfaces, sub-structures, bridges, and tunnels face risks from natural phenomena (such as ground deformation, extreme weather, vegetation encroachment), human activities nearby, and ageing or increasing traffic volumes. Compared to traditional inspections, EO enables efficient large-scale monitoring, saving time and labour costs while reducing logistical challenges. The widespread availability of free satellite imagery allows for historical comparisons, further improving cost-effectiveness.

SATCOM is emerging as a complementary connectivity layer for road and automotive applications, as the sector moves towards ubiquitous, resilient and globally available communication. Once limited to niche, proprietary mobile satellite services, automotive SATCOM is now evolving toward a converged terrestrial–non-terrestrial network ecosystem. This transition positions SATCOM as a key enabler for advanced automotive functions, including over-the-air updates, connected safety services and future automated driving, particularly in areas where terrestrial coverage is limited or unavailable.

2.2.1.1 GNSS Key Market Trends

The global GNSS market for road and automotive continues to expand as the automotive sector moves through a phase of structural transformation driven by electrification, digitalisation, regulatory pressure and the gradual deployment of cooperative, connected and automated mobility (CCAM). Following the recovery from semiconductor shortages, European vehicle manufacturing has largely stabilised, with OEMs reporting renewed growth in battery-electric and hybrid vehicles, supported by the EU's long-term zero-emission objectives and parallel investments in resilient supply chains and domestic battery production. Within this context, GNSS is becoming more deeply embedded in vehicle platforms, not only as a navigation tool but as a foundational enabler of connected and software-driven functions across passenger and commercial vehicles.

The electrification of the automotive fleet is reinforcing the role of connectivity and data in vehicle operation. Battery-electric and plug-in hybrid vehicles rely on continuous digital interaction for functions such as energy management, over-the-air software updates, fleet optimisation and integration with charging and mobility services. GNSS underpins many of these capabilities by providing reliable

positioning and timing, enabling geofencing, route optimisation and real-time coordination with infrastructure and other road users. As vehicles evolve into software-defined platforms, positioning quality becomes increasingly important, as GNSS outputs are reused across multiple vehicle functions and services rather than confined to standalone navigation systems.

Regulation remains one of the strongest drivers of GNSS adoption in the automotive sector, particularly in Europe. The EU General Safety Regulation and related implementing acts mandate or define test procedures for a growing set of advanced driver-assistance systems, including intelligent speed assistance and emergency lane-keeping. eCall, mandatory for new passenger cars and light commercial vehicles, continues to anchor baseline GNSS requirements by obliging vehicles to transmit accurate location information to emergency services in the event of a crash. In the commercial vehicle segment, smart tachographs represent a large-scale, compliance-driven use of GNSS, with EU legislation requiring GNSS-enabled devices for cross-border freight operations and setting tight deadlines for new vehicles and fleet retrofits. These regulatory use cases elevate GNSS from a convenience technology to an element directly linked to enforcement, liability and safety outcomes.

At the same time, the acceleration of CCAM is pushing GNSS performance requirements well beyond traditional navigation grades. Mandatory safety systems, combined with pilot deployments of conditional automation on highways, are creating demand for lane-level absolute positioning, high integrity and predictable performance in challenging environments. Industry consultations highlight that sub-meter accuracy is increasingly expected for higher levels of automation, while robustness against interference and continuity of service are critical for maintaining safe operation when GNSS signals are degraded. As a result, GNSS is almost universally deployed as part of a broader sensor-fusion stack, complemented by inertial sensors, wheel odometry, cameras and maps, but it remains the primary source of global absolute position and trusted time.

Security and resilience have emerged as central themes shaping the GNSS automotive market. Jamming and spoofing are no longer considered theoretical risks but practical threats with implications for safety, compliance and public trust. This is particularly visible in regulated applications such as smart tachographs, tolling and enforcement, where authentic and tamper-resistant position, velocity and time data are required. Authentication mechanisms and integrity monitoring are therefore gaining attention, although adoption is influenced by vehicle architecture constraints, competing cybersecurity priorities and the maturity of automotive-grade receivers and antennas capable of supporting advanced GNSS features. These factors contribute to a gradual, uneven uptake of more sophisticated GNSS capabilities, even where their long-term value is recognised.

Commercial vehicles and logistics stand out as one of the strongest near-term opportunities for GNSS in automotive. Hub-to-hub freight operations, platooning concepts and increasingly automated logistics chains rely on precise routing, trusted tracking and regulatory compliance, all of which depend heavily on GNSS. Shared mobility fleets and professional transport operators are also scaling rapidly in response to decarbonisation targets, reinforcing demand for robust, secure and interoperable positioning solutions that can operate reliably across borders and jurisdictions. Beyond the vehicle itself, GNSS is increasingly linked with intelligent transport systems and smart infrastructure, supporting synchronisation, traffic management and emerging vehicle-to-everything use cases that connect vehicles with roadside units and urban mobility platforms.

Looking ahead, the automotive GNSS market is expected to grow less through sheer increases in unit volumes and more through rising performance expectations and functional criticality. While overall vehicle production may face cyclical slowdowns and regional disparities, demand for Battery-Electric Vehicles (BEVs) platforms, ADAS (Advanced Driver Assistance Systems) and automation-related components is projected to continue increasing. In this environment, GNSS solutions that combine high accuracy, integrity, resilience and security are likely to capture a growing share of value, particularly in commercial and safety-critical applications. However, adoption will remain uneven, constrained by cost pressures, technology readiness and the mismatch between fast-moving digital innovation cycles and slower-evolving vehicle and infrastructure lifecycles. Suppliers that can align GNSS capabilities with regulatory needs, integrate them effectively into software-defined vehicle architectures and demonstrate robustness in real-world conditions are best positioned to benefit from the next phase of transformation in automotive mobility.

The chart below presents the estimations made in the EO & GNSS market report [Error! Reference source not found.], regarding the revenues for GNSS device sales and services by application at a global level.¹

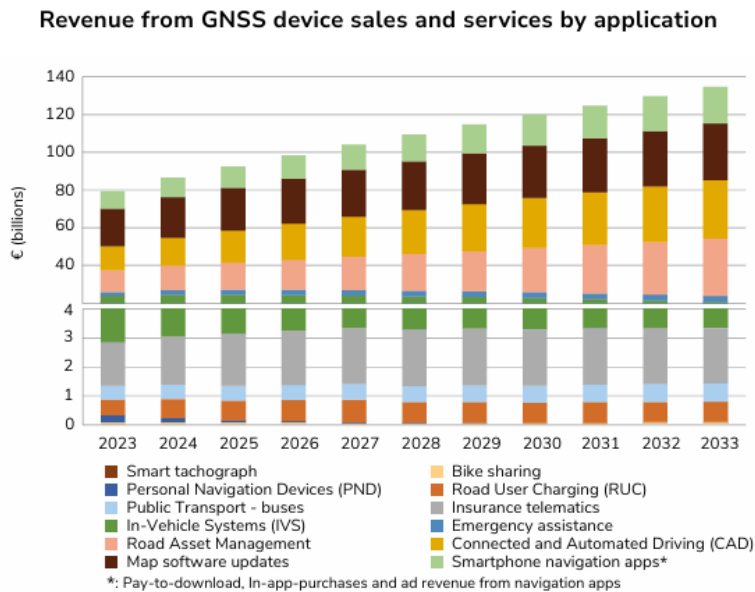


Figure 3: Road and Automotive GNSS market evolution

2.2.1.2 EO Key Market Trends

The EU's willingness to become the first continent to reach carbon neutrality by 2050 drives the need for reducing the environmental footprint of infrastructures and strengthening their resilience to climate change. In this general context, the EO and GNSS EUSPA Market Report and the previous Reports on User Needs and Requirements on surveying have identified several key trends in the infrastructure market, which are relevant for the monitoring of Road infrastructure [Error! Reference source not found.].

These key trends are the uptake of services based on InSAR for the identification of risks related to ground deformation, the increasing use of EO to better understand the impacts of climate change and support the design and construction of more resilient infrastructures.

¹ European Union Agency for the Space Programme. (2024). *EUSPA market report 2024*. https://www.euspa.europa.eu/sites/default/files/euspa_market_report_2024.pdf

In addition to the above-mentioned trends, the multiplication of commercial constellations of EO satellites and the increasing use of Artificial Intelligence are expected to have a significant impact on satellite-based applications. One of the most important trends will be the decrease of the cost of satellite imagery because currently, the high cost represents the most important reason that hinders the full adoption of the EO. An overview of these profound evolutions expected in the next years is provided hereafter:

- Emergence of low-cost satellite technology that leads a multiplication of large constellations of small satellites (often referred to as “smallsats”).
- Lower launch and payload development costs that have opened the door to a commercial offer, even in domains like Synthetic Aperture Radars (SARs) which were previously limited to institutional missions. This leads to a decrease of the price of SAR imagery as well improvements in performance.
- Increase of performance in terms of revisiting time, spatial and spectral resolution. In the domain of SAR, the revisit frequency being in the range of 1-3 hours because each constellation, has different satellites that observe a location at different times of the day rather than the more conventional dawn-dusk sun-synchronous orbit. SAR commercial constellations such as Iceye, Umbra, Capella Space adopted very-high resolution (VHR) SAR sensors that provide a ground plane resolution until of 25 cm. The trend is similar for optical imagery, where commercial operators such as WorldView-3 provide revisiting time of one day, a spatial resolution until 30 cm in the panchromatic band (450 - 800 nm) and a spatial resolution of 1.3 m in the multispectral Visible Near Infrared (VNIR) band (860 to 1040 nm). Other operators such as Planet, Satellogic are deploying constellations on the Low Earth Orbit (LEO) aiming to offer sub-meter resolution optical imagery with revisit times inferior to 1 hour. Some companies are envisaging to deploy EO smallsats on the Very Low Earth Orbit (VLEO).
- Recent launch of additional longer wavelength L-band SAR satellites - ALOS-4 by JAXA and L and S-band NISAR mission by NASA and ISRO will improve ground motion observation capabilities for road and other linear infrastructure. These will increase measurement point density in vegetated areas as well as soil moisture retrieval at finer scales. Upcoming Copernicus L-band LSTM will contribute with free and open L-band data akin to the Sentinel 1.
- Road infrastructure managers are slowly adopting the satellite EO data into their workflows - sometimes directly or through intermediary products such as national landslide or flooding risk maps, climate and extreme weather forecasts.
- Development of new applications based on the increased performance of the new constellation such as the near real time monitoring and tracking of rapid ground deformation that can happen during and after the construction of the infrastructures or the applications of change detection provided in the near real time.

The increasing use of Artificial Intelligence and Machine Learning is also part of the trends which are changing the Earth Observation market and have direct impacts on applications relevant to the infrastructure market. These technologies enable the automation of processes which are usually costly and time-consuming and bring Earth Observation applications a step forward by enabling the identification of patterns, trends or correlations which would have remained invisible and unexploited with more traditional processing techniques. They are also facilitating the fusion of data from multiple sources and the integration with the Internet-of-Things (IoT). Moreover, the use of Artificial Intelligence and Machine learning will increase the service providers' ability to deliver solutions for even for non-technical users.

EO market evolution

The benefits and the interests of the use of EO in the infrastructures sector is shown by the growing volume of the market. When looking at the use of EO for monitoring infrastructure in general, the total revenue generated by the sales of EO data and EO-based services is expected to increase at a regular pace in the years to come.

The chart below presents the estimations made in the EO & GNSS market report 2024² regarding the revenues for EO data & services at a global level. It should be noted that the values represent the general EO market for infrastructure and that EO for Road infrastructure is a subset of this. In the current version of the report, it is not possible to subtract the values for Road infrastructure. Based on the consultation of road network operators conducted in the UCP process, the operational use of satellite EO products and services in the infrastructure market remains relatively low.

Reasons for low adoption vary by use-case and product – from unfavourable cost to benefit ratio, competitive alternative platforms (e.g. aerial/drone), mismatch with established workflows (e.g. MTinSAR vs traditional geodetic and geotechnical monitoring), lack of fundamental observation capabilities (e.g. north-south lateral ground motion, observation under vegetation), general lack of awareness and trust. Most of these challenges are being addressed by the EO and infrastructure managers. Best practices on how to integrate satellite EO into operations are proliferating.

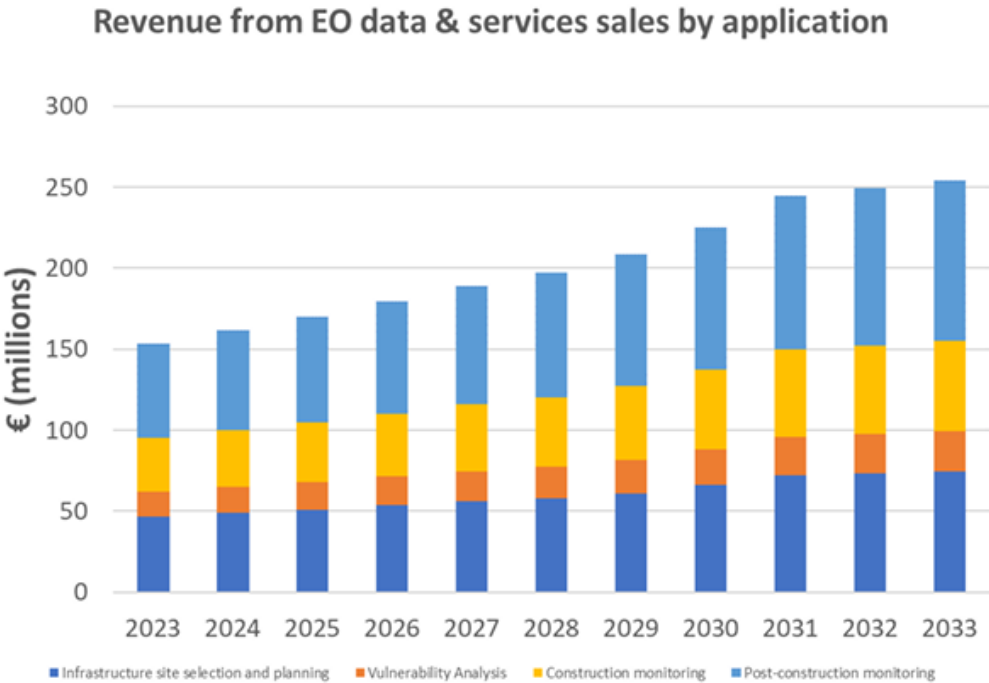


Figure 4: Revenue from EO data sales by automotive application. Global

2.2.1.3 SATCOM Key Market Trends

The SATCOM market for Road and Automotive has undergone a significant transformation over the past decades. Initially considered a niche solution, SATCOM was primarily associated with proprietary Mobile Satellite Services (MSS) connectivity, relying on specialised antennas to deliver basic telematics functions. Today, the industry is moving towards a converged ecosystem that will integrate Terrestrial Networks (TN) and Non-Terrestrial Networks (NTN), leveraging standardised 3GPP protocols, multi-orbit satellite capabilities, and embedded vehicle antennas to enable seamless global connectivity.

In early stages, automotive SATCOM was dominated by proprietary MSS solutions offered like providers such as Inmarsat or Iridium. These services were largely narrowband, supporting low-data-rate applications like fleet tracking, emergency call systems, and remote diagnostics. Connectivity speeds were limited, which constrained the scope of use cases. In addition, vehicles required dedicated, bulky antennas (typically patch or helical designs) mounted externally. This hardware complexity, combined

² Ibid

with high service costs, restricted adoption primarily to commercial fleets operating in remote or underserved regions where terrestrial coverage was unreliable.

In recent years, the SATCOM market has entered a transition phase, evidenced by the efforts to bridge legacy MSS systems with emerging terrestrial technologies. This integration is being driven by several strategic objectives. First, it aims to improve user experience by creating seamless connectivity between satellite and cellular networks, reducing complexity for the automotive sector. Second, it ensures service continuity by combining terrestrial coverage in urban areas with satellite coverage in remote regions. Third, it is looking toward enabling advanced use cases, such as over-the-air (OTA) updates, HD mapping, and autonomous driving, which require higher bandwidth and lower latency than traditional MSS could provide.

In line with this transition, MSS operators introduced adaptations (such as LTE-MSS) to improve integration with cellular networks. A major milestone was the introduction of 3GPP release 17, which defined NTN standards and enabled 5G New Radio (NR) over satellite. Concurrently, antenna technology advanced significantly, with the development of flat-panel electronically steered arrays (ESAs) capable of supporting multi-orbit connectivity across GEO, MEO, and LEO constellations. While these ESAs are primarily aftermarket solutions, they expanded SATCOM use cases beyond basic telematics to include backup connectivity for emergency calls (eCall), vehicle-to-everything (V2X) communications and Advanced Driver Assistance Systems (ADAS).

Nowadays, the automotive SATCOM landscape is characterised by full TN-NTN convergence. Building on 3GPP Releases 18 and 19, NTN now complements terrestrial 5G and emerging 6G networks, enabling direct-to-device (D2D) connectivity in FR1 and FR2 frequency bands. This evolution supports wideband services and seamless handover between terrestrial and satellite networks, ensuring ubiquitous coverage.

The transition towards a fully integrated SATCOM ecosystem for road and automotive applications is still underway. Manufacturers and technology providers are actively developing next-generation systems and antenna solutions to unlock the full potential of SATCOM, aiming to make seamless, high-speed connectivity accessible for all vehicle types. This ongoing innovation will enable the sector to take full advantage of improved coverage, reliability, and advanced services offered by emerging satellite networks.

2.2.2 Main User Communities

The integration of space-based technologies, GNSS, EO, and SATCOM, is reshaping the Road and Automotive ecosystem. These technologies serve a broad range of users whose needs vary significantly depending on their operational environment, business models, and the role they play within the mobility value chain. Understanding these user communities is essential to identify how space assets can best support safer, more efficient, and increasingly connected mobility systems.

The users of space-enabled applications extend far beyond vehicle owners and drivers, although these remain core beneficiaries, relying on accurate positioning, reliable connectivity, and contextual information to improve safety, comfort, and travel efficiency. The broader community encompasses actors involved in the manufacturing of vehicles, the operation and maintenance of road networks, the delivery of mobility services, and the governance and financing of critical transport infrastructure.

- **Vehicle manufacturers and associated service providers**

The automotive industry features a complex and deeply interconnected value chain. **Vehicle manufacturers** work with **tier-1 suppliers, component manufacturers, and specialised device vendors**, both during original vehicle production and in the aftermarket. They rely on GNSS for high-accuracy positioning and timing, on EO for environmental and infrastructure insights, and increasingly on SATCOM for resilient communication.

Service providers leverage hardware and connectivity embedded in vehicles to deliver value-added services such as telematics, navigation services, usage-based insurance, remote diagnostics, and fleet management.

Multiple industry-driven working groups and alliances support the harmonisation of technical requirements for positioning, timing, communication, and data sharing, ensuring consistent integration of space technologies across manufacturers and platforms.

- **Mobility operators, logistics and insurance**

Fleet operators, logistics companies, shippers and mobility service providers depend heavily on GNSS to manage daily operations. High-accuracy positioning enables efficient routing, real-time vehicle monitoring and optimisation of delivery schedules. EO adds value by providing environmental and infrastructural insights that support planning and risk management. Regarding SATCOM, future implementation offers the possibility of robust communication links that can prove of high-value in remote or underserved regions where terrestrial networks may be insufficient.

Insurance companies represent another important user group. For GNSS, insurers leverage telematics data to design usage-based or behaviour-based policies, improve risk assessment and support claims verification. For EO, insurers use EO data to evaluate exposure of road infrastructure to geohazards, monitor changes over time, and understand risk factors affecting insured assets.

- **Road infrastructure owners, operators and construction sector**

The design, **construction, operation and maintenance** of road infrastructure involve a wide range of actors whose activities are supported by GNSS, EO and SATCOM. **Construction and civil engineering companies** use GNSS for precise positioning in surveying, machine guidance and project execution. EO is used to monitor terrain conditions, detect ground movements and analyse environmental impacts before and during construction. **Public or private infrastructure owners and operators** rely on space-based data to assess road condition, plan maintenance, manage traffic flows and identify structural issues. SATCOM could play a key role in ensuring connectivity for remote monitoring systems, especially along long-distance or sparsely populated road networks.

In **large infrastructure projects**, EO-based multi-temporal analyses such as InSAR are used to detect subsidence, slope instability or gradual ground deformation. These capabilities enhance the resilience of road networks, support the planning of mitigation measures and reduce long-term maintenance costs.

- **Public authorities and regulators**

Public authorities at municipal, regional, national and European levels use GNSS and EO to support a wide range of planning and oversight activities. GNSS enables accurate traffic management, efficient road enforcement and improved emergency response. EO supports spatial planning, environmental impact assessments, verification of land-use regulations and compliance monitoring. **Regulatory authorities** depend on space-based data to ensure that infrastructures comply with technical standards, safety rules and environmental requirements. For emergency and civil protection services, EO and SATCOM offer crucial situational awareness during natural disasters, large-scale incidents or crises affecting transport networks.

- **International development organisations and financial institutions**

International development organisations, such as the **World Bank** and other development banks, often fund large road and transport infrastructure projects in emerging regions. They rely on GNSS and EO to monitor construction progress, evaluate environmental and social impacts, and identify risks that may affect long-term project viability. EO provides objective evidence of land use, ground movements, vegetation changes and other environmental factors, while GNSS supports the verification of construction accuracy and compliance with engineering specifications. Financial institutions similarly use EO-derived information to evaluate exposure to risk, monitor insured infrastructure assets, and obtain independent assessments of infrastructure condition throughout their lifecycle.

- **Standardisation bodies**

Standardisation bodies play an essential role in defining the technical frameworks that enable the adoption of space-based technologies in the automotive and road sectors. Organisations such as **ISO**, **ETSI** and **CEN/CENELEC** work on performance criteria for GNSS-based positioning and timing, ensuring that these parameters meet the needs of safety-critical automotive applications. In the field of EO, **ISO** and the **Geoscience and Remote Sensing Society** support the development of standards for remote sensing data generation, processing and interoperability. The **IEEE Standards Association** works closely with the **GRSS Standards Committee** to develop new standards for data products derived from remote sensing systems. These activities help establish common expectations and enable consistent deployment of space-enabled services across markets.

In addition to these traditional standardisation bodies, **3GPP** obtained a predominant role in the Road and Automotive segment as it is essential in defining communication standards for the automotive and mobility ecosystem. By standardising both NTN and Terrestrial Networks (TN), 3GPP ensures that satellite and terrestrial communication systems can interoperate seamlessly. This harmonisation is fundamental for connected and automated mobility.

- **Research and academic community**

Research institutes and universities are key contributors to technological innovation in the mobility sector. In GNSS, academic groups focus on signal processing techniques that enhance positioning performance in challenging environments, such as urban canyons, where multipath and signal blockage are common. Their work includes the development of augmented multi-frequency solutions that meet the accuracy requirements of autonomous driving. In EO, research centres advance new methods for InSAR processing, atmospheric correction, and multi-temporal analysis to improve the detection of subtle ground movements. They also explore the use of machine learning for change detection, land classification and predictive modelling. Some institutes specialising in legal metrology further support the evaluation and certification of measurement systems used in the transport sector.

- **Professional associations and stakeholder communities**

Professional associations and stakeholder communities play an important role in bridging industry needs, technological innovation and policy development. Organisations such as the **European Association of Remote Sensing (EARSC)**, **Construction Industry Research and Information Association (CIRIA)**, **World Road Association (PIARC)**, **Conference of European Directors of Roads (CEDR)**, **Forum of European National Highway Research Laboratories (FEHRL)** and others facilitate the exchange of knowledge, promote best practices and support the dissemination of insights relevant to the use of GNSS, EO and SATCOM within the road and automotive domains. The **5G Automotive Association (5GAA)** is a key actor bringing together the automotive, telecommunications and technology sectors to advance connected, cooperative and automated mobility, with particular emphasis on cellular V2X technologies and the integration of satellite communication within multi-access connectivity frameworks.

The **Car2Car Communication Consortium (C2C-CC)** complements these efforts by uniting vehicle manufacturers, equipment suppliers, research organisations and road operators to promote interoperable vehicle-to-vehicle and vehicle-to-infrastructure communication based on cooperative ITS standards [RD2].

More broadly, stakeholder engagement with local communities, environmental groups and government bodies ensures that transport and infrastructure developments take into account societal expectations, environmental constraints and long-term sustainability objectives. Their involvement contributes to more inclusive decision-making processes and supports the responsible deployment of space-enabled solutions across the mobility ecosystem.

Building on the distinct roles of the stakeholders outlined above, it is important to recognise that the value chains underpinning GNSS-based applications, EO-based applications, and SATCOM implementation differ from one another. This divergence primarily stems from the nature of each technology: while the GNSS value chain is centred around the production, integration, and utilisation of physical devices such

as receivers, the EO value chain is focused on the provision of processed data products, such as maps and actionable insights, and does not involve dedicated “EO devices” as part of its operational flow. SATCOM, similarly, follows its own implementation pathway tailored to connectivity solutions and infrastructure.

The different value chains are portrayed and analysed in the sections below.

2.2.2.1 GNSS Key Users

As presented in the EO and GNSS EUSPA Market Report (See [RDError! Reference source not found.]), the main market players in the GNSS value chain are:

- Component and receiver manufacturers
- System integrators: Tier 1 suppliers and vehicle manufacturers
- Aftermarket device vendors
- Service providers
- (End) users

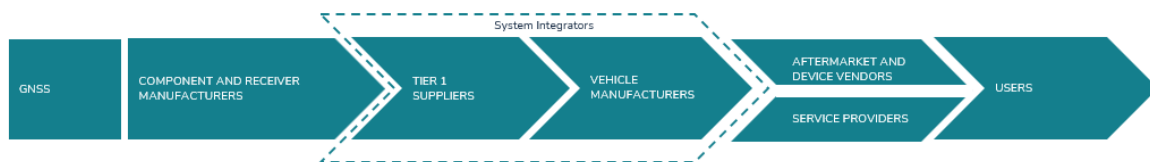


Figure 5: GNSS Road & Automotive value chain

Vehicle manufacturers, also referred to as Original Equipment Manufacturers (OEMs), are central to the GNSS Road and Automotive value chain. In this market segment, OEMs generally drive demand by setting precise needs and requirements, which are then passed on to system integrators and chipset manufacturers. Instead of technology providers pushing new features, innovation rises from below, with advancements introduced only after OEMs carefully weigh costs and benefits. Because the automotive sector is highly cost-conscious, every expense is examined closely. As a result, new technologies are adopted thoughtfully, ensuring each feature offers tangible benefits.

As shown above, the main players in the GNSS Road and automotive segment value chain are:

- **Components and receiver manufacturers:** Companies that produce chips, antennas, and other inputs for GNSS receivers, adding value to devices. Examples include Hexagon, TE connectivity and U-blox.
- **System integrators:** They implement GNSS equipment within complex systems. In automotive, Tier 1 suppliers (e.g., Aumovio, Bosch or Valeo) assemble components into systems like navigation units, while automakers (e.g., BMW, Renault, General Motors or Volkswagen) integrate these into their vehicles.
- **Aftermarket device vendors:** These companies sell products that enhance existing equipment, such as TomTom, Trakm8, and Octo Telematics.
- **Service providers:** Organizations offer services related to GNSS, including mobile network operators (Telefonica, Vodafone), traffic info providers (TomTom), road tolling (Kapsch, Sky Toll), and car-sharing operators (Share Now or Free2Move).
- **End Users:** Include vehicle owners, drivers, insurance firms, fleet and road operators, shippers, and logistics companies.

2.2.2.2 EO Key Users

As far as the EO-related value chain is concerned, the main market players identified in the EO and GNSS EUSPA Market Report³ are:

³ <https://www.euspa.europa.eu/newsroom/news/new-euspa-eo-and-gnss-market-report>

- **Data providers:** Providers of unprocessed or pre-processed EO data from multiple sources (i.e. satellites and in-situ (non-space) measurements). Typically operating a data-as-a-service business model.
- **Infrastructure providers:** Providers of various types of computing infrastructure upon which EO data can be accessed, stored, distributed or manipulated. Typically operating an infrastructure-as-a-service business model.
- **Platform providers:** Providers of online platforms and/or digital services, through which users can utilise tools and capabilities to analyse EO data, develop algorithms and build applications. Typically, operating platform-as-a-service and/or software-as-a-service business models.
- **EO products and service providers:** Providers of products (e.g. land cover classifications) or services (e.g. ground motion monitoring) that make full use of EO data and processing capabilities offered by data and platform providers. Typically operating an analytics-as-a-service business model.
- **Information providers:** Providers of sector-specific information that incorporates EO data along with non-EO data. Typically operating an insights-as-a-service business model.
- **End Users:** Final users benefitting in their decision making or operations from the solutions offered by EO services and/or information providers.



Figure 6: EO Infrastructure value chain

European companies account for half of the global Analysis, Insights & Decision Support market. Companies in this market make use of EO data to provide information and intelligence to their clients seeking to solve complex geospatial challenges. The main players in the EO Road and automotive segment value chain are:^{4 5}

- **Data providers:** includes providers of unprocessed or pre-processed EO data. Of all the types of data that EO encompasses, one of the most relevant for the Road and Automotive sector is Interferometric Synthetic Aperture Radar (InSAR) data. Some of the main satellite constellations and missions known for providing InSAR data include:
 - Sentinel-1 (Copernicus Programme, EU): Sentinel-1A and Sentinel-1B provide free and open SAR data, including InSAR data globally with archives back to 2015.
 - NISAR (NASA and ISRO) – L and S band SAR observations with free and open data policy for ground motion and soil moisture monitoring
 - TerraSAR-X (German Aerospace Center, DLR) and TanDEM-X: radar satellites provide high-resolution SAR data TanDEM-X, in particular, was used in a ground-breaking mission to create a global digital elevation model (DEM) through interferometry.
 - Cosmo-SkyMed (ASI, Italy): The Cosmo-SkyMed constellation consists of four radar satellites (CSK-1, CSK-2, CSK-3, and CSK-4) that offer SAR data suitable for InSAR applications.
 - X-band constellations from ICEYE, Umbra and Capella Space
 - ALOS PALSAR L-band used for soil moisture and SAR interferometry in lightly vegetated areas

⁴ Report on Infrastructure User Needs and Requirements. Available at: [Report on Infrastructure User Needs and Requirements \(europa.eu\)](https://ec.europa.eu/euspa/euspa_ruc_brochure.pdf)

⁵ GNSS adoption for Road User Charging. Available at: [euspa_ruc_brochure.pdf \(europa.eu\)](https://ec.europa.eu/euspa/euspa_ruc_brochure.pdf)

- **Infrastructure providers:** refers to organisations offering various types of computing infrastructure and cloud storage upon which EO data can be accessed, stored, distributed, or manipulated. These organizations often collaborate with space agencies, research institutions, and private companies to support EO missions and data dissemination. Some key European infrastructure providers are Cloudferro, T-Systems, OVH Cloud.
- **Platform providers:** refers to those companies that offer online platforms and/or digital services, through which users can utilise tools and capabilities to analyse EO data, develop algorithms and build applications. Some of the main platform providers include Google Earth Engine and Copernicus Data Space Ecosystem.
- **EO products and service providers:** these are companies that provide products or services that make full use of EO data and processing capabilities offered by data and platform providers. European EO products and service providers relevant to the road and automotive sector generally address several market segments and are not sector oriented. In Europe, the Entrusted Entities delivering the Copernicus core services are also part of “EO Products and Service Providers”. Some examples are: eGeos, GAF, Planetek, SkyGeo, TreAltamira, Spotlite, Terrasigna, Sixense, Geofem, Detektia and dozens of others.
- **End Users:** the final users who benefit from the applications and services offered by information providers. They belong to the various user communities described in section 3.2. and are:
 - Public authorities, including regulatory authorities, at local (e.g. municipalities), regional, national, or European level in charge of the planning and deployment of road infrastructures;
 - Construction and public works companies including civil engineering companies;
 - Infrastructure owners and/or operators in charge of the maintenance;
 - International development organisations;
 - Financial institutions;
 - Insurance companies.

2.2.2.3 SATCOM Key Users

The main market players in the value chain are:

- Satellite manufacturers
- Satellite operators
- Ground Segment Manufacturers
- Service Providers
- Terminal providers
- End users

Figure 7 below illustrated the SATCOM value chain adapted for Road and Automotive.

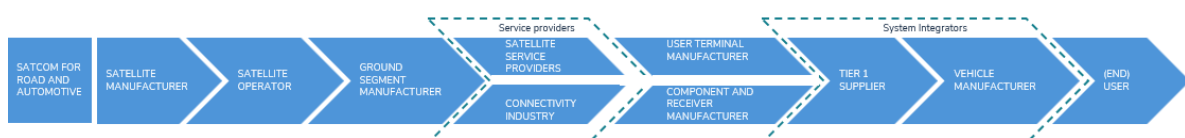


Figure 7: SATCOM Road & Automotive value chain

The value chain must be carefully adapted to address the requirements of specific market segments, such as Road and Automotive, in order to reflect the distinct needs and characteristics of these sectors regarding satellite connectivity.

Service providers, including both satellite and traditional connectivity industries, fulfil a critical function, which will be examined in greater detail in subsequent sections. In the context of SATCOM implementation, satellite and connectivity providers collaborate closely throughout the deployment process.

In addition to satellite service providers, it is necessary to recognise the crucial role of connectivity providers within the road and automotive SATCOM value chain. Both satellite and traditional connectivity industries, including Mobile Network Operators (MNOs) and companies facilitating vehicle-to-everything (V2X) communication, must be actively integrated into this ecosystem. The successful future deployment of SATCOM technology in the automotive sector hinges upon the close cooperation between these two groups, as they collectively provide the infrastructure and services necessary to achieve seamless, reliable, and resilient vehicle connectivity.

The main users identified are:

- **Satellite (space segment) manufacturers:** companies having capability of designing, manufacturing, assembling, testing (MAIT) and qualifying satellites that can operate in different orbits and be part of different constellation concepts. Satellites are composed of a platform (also called bus) and one or several payloads. The payload(s) is/are really tailored to the mission(s) of the system.
- **Satellite operators:** companies that purchase and operate satellites. They usually have also their own ground segment infrastructure. Satellite operators might lease/manage capacity or network solutions (including equipment) either directly to the end consumer or through a service provider. It is noteworthy that equipment can be located in a proprietary site or hosted in third-party owned site.
- **Ground segment manufacturers:** companies having capability of designing, manufacturing, assembling, testing (MAIT) and qualifying ground segment. The ground segment is composed of all the ground-based elements of a space-based system required to operate the satellite(s) and distribute the payload(s) data among interested parties on the ground, via a dedicated network.
- **Service providers**
 - **Satellite service providers:** organisations that deliver satellite-based communication services to end-users and enterprises. They own, operate, or lease satellite infrastructure, managing the transmission of data, voice, and video signals via satellite networks.
 - **Connectivity industry:** provide the necessary communication technologies that allow for information exchange between vehicles (V2V), infrastructure (V2I), and networks (V2N). It is the backbone that enables Intelligent Transport Systems (ITS) to function by allowing real-time data sharing and communication.
 - **Mobile Network Operators (MNOs):** own and operate the full physical cellular infrastructure; towers, spectrum licenses, core networks etc. They provide end-to-end connectivity services like voice, data and 5G directly to customers.
 - **Mobile Virtual Network Operators (MVNOs):** do not own infrastructure, but lease wholesale capacity from MNOs, then resell customized plans to consumers.
- **User terminal manufacturers:** traditionally, user terminal manufacturers developed proprietary antennas compatible with one or several satellite constellations. However, with 3GPP Release 17 and the standardisation of NT-TNT (Non-Terrestrial-Terrestrial Network) connectivity, the design and production of user terminals and antennas are increasingly opening

to traditional automotive component suppliers and receiver manufacturers, bridging the SATCOM and automotive value chains as the market evolves toward integrated connectivity technologies.

- **Component and receiver manufacturers:** design, produce, and supply individual parts or assemblies used in vehicles. This includes SATCOM receivers and other telematics hardware essential for enabling vehicles to connect with satellite networks, terrestrial infrastructure, and other vehicles.
- **Tier 1 and technology suppliers:** These are key technology providers and system integrators that work with OEMs to develop and integrate satellite-enabled components, such as antennas, onboard telematics, and SATCOM devices, into vehicles and infrastructure. They work with Connected, Cooperative, and Automated Mobility (CCAM) initiatives, which focus on enabling vehicles to communicate with each other, infrastructure, and road users.
- **OEMs:** Due to the growing demand for connected and autonomous mobility, OEMs are looking at incorporating SATCOM technology to address the limitations posed by terrestrial networks, especially in rural or remote areas.
- **(End) users**
 - **Vehicle owners:** Could benefit from SATCOM indirectly through embedded telematics systems that fall back to satellite when cellular coverage falls.
 - **Commercial fleet operators:** These are companies that manage fleets of vehicles used for various commercial purposes, including transportation and logistics. These operators typically oversee many vehicles, ranging from small delivery vans to heavy-duty trucks. They have interest in SATCOM for real-time tracking, remote vehicle monitoring, and route optimisation.
 - **Logistics and transportation companies:** These companies facilitate the movement of goods, often operating at a global scale. Their fleets often consist of large vehicles such as cargo trucks, and they rely on efficient operations and safety to manage deliveries on time. SATCOM can provide reliable communication for tracking and managing these fleets
 - **Long-haul trucking firms:** These companies specialise in transporting goods over long distances, often crossing state and national borders. Their fleets may include heavy-duty trucks designed for long hauls. SATCOM can make sure it complements the terrestrial networks and provide uninterrupted connectivity for navigation, communication, and safety monitoring.
 - **Road operators:** These public and private entities (e.g., road constructors, toll road operators, national authorities) manage and maintain road infrastructure such as highways, toll systems, bridges, and tunnels. SATCOM has the potential to enhance infrastructure management and monitoring, promoting more efficient operations and maintenance. While there is a growing interest among these stakeholders in leveraging SATCOM technology, its current application remains limited. However, as the technology continues to evolve, it is anticipated that their adoption of SATCOM will increase significantly.

IRIS² and the SpaceRISE Consortium

IRIS² (Infrastructure for Resilience, Interconnectivity and Security by Satellite) is the European Union's third flagship space programme, designed to provide secure, resilient and high-performance satellite connectivity across Europe and beyond. Implemented as a public-private partnership between the European Union, the

European Space Agency (ESA) and industry, IRIS² aims to strengthen Europe's strategic autonomy, digital sovereignty and resilience by ensuring trusted connectivity for governmental users while enabling commercial services for businesses and citizens. The system will rely on a multi-orbit architecture, combining Low – Low Earth Orbit (LEO), High – LEO, and Medium Earth Orbit (MEO) satellites, together with a dedicated ground segment, and is expected to start providing services from the early 2030s [RD3][RD4].

The SpaceRISE consortium was awarded the concession contract to design, deploy and operate IRIS² for a period of 12 years. SpaceRISE brings together three major European satellite operators; SES, Eutelsat and Hispasat, and is supported by a core industrial team. SpaceRISE is responsible for delivering the full end-to-end system, covering the space segment, ground infrastructure and operational services, while ensuring security, resilience and long-term service continuity.

IRIS² is conceived as a multi-mission connectivity system, capable of supporting a wide range of use cases that require secure, reliable and low-latency communications. While IRIS² is not an automotive-specific programme, its architecture is designed to enable services that are relevant to mobility, such as ubiquitous coverage, service continuity across borders, enhanced resilience, and secure data links in areas where terrestrial infrastructure may be limited or disrupted. The multi-orbit design, combining the low-latency characteristics of LEO with the coverage and robustness of MEO, is intended to support applications requiring high availability, continuity of service and resilience, including those relevant to connected and automated transport. The constellation will deliver services via a multi-layer satellite network, with a focus on open standards and dual-use capabilities. Within this framework, automotive use cases are viewed as part of the broader commercial services domain.

Each SpaceRISE member contributes complementary capabilities that are relevant to automotive-grade connectivity:

- SES brings extensive experience in MEO systems and low-latency broadband connectivity, contributing 18 MEO satellites to IRIS² and operational expertise in managed, carrier-grade services, which are key enablers for latency-sensitive and mission-critical applications.
- Eutelsat acts as the system development prime for IRIS² and provides deep expertise in LEO constellations and spectrum management, including Ku-band assets that are relevant for high-throughput connectivity and future mobility services.
- Hispasat contributes strong capabilities in secure satellite communications, governmental services and European coverage, reinforcing the resilience and security dimensions that are increasingly relevant for connected transport applications.

[RD5]

2.3 Key market drivers – Policies, Regulations, Standards

The following policies and regulations drive users' needs and requirements in the Road and Automotive sector.

2.3.1 Relevant organizations

International regulators

UNECE: The United Nations Economic Commission for Europe's main aim is to promote pan-European economic integration. Within this organization, as selected examples of Working Parties relevant for GNSS adoption, it is worth highlighting the UNECE World Forum for Harmonization of Vehicle regulation, also referred to as Working Party 29, which establishes regulatory instruments concerning motor vehicles and motor vehicle equipment, as well as the Working Party on the Transport of Dangerous Goods (WP.15), responsible for update of the Agreement concerning the International Carriage of Dangerous Goods by Road.

Standardisation bodies

ISO (International Organisation for Standardisation): Provides many of the functional safety, management and ITS standards regulators either reference or expect industry to follow. ISO 26262 (functional safety), ISO 21448 (SOTIF) and ITS-GNSS performance standards define how GNSS-based localization and sensor fusion (including GNSS, EO maps, inertial, etc.) must be engineered, validated and argued in safety cases for ADAS/ADS.

IEC (International Electrotechnical Commission): Provides electrical/electronic standards underlying vehicle E/E architecture. Defines EMC, power and interface requirements that GNSS receivers, satcom terminals and EO-downlink equipment in vehicles must satisfy to gain approval or meet OEM specifications.

SAE International (Society of Automotive Engineers): Influences regulators and OEMs via widely adopted engineering standards and definitions. SAE standards and technical reports on positioning for automated driving specify performance criteria (continuous, lane-level accuracy, availability, integrity) that GNSS and GNSS-augmentation services must satisfy for L2+ to L4 functions, shaping the service-level requirements for PPP, SBAS, NRTK and multi-sensor fusion.

European Commission

The European Commission places a strong emphasis on road and automotive as a core part of its transport and mobility agenda. By 2026, road and automotive policies and initiatives increasingly target safety, decarbonisation, digitalisation, and resilience of mobility across the Union, in line with the European Green Deal, the Sustainable and Smart Mobility Strategy, and the EU's 2030/2050 climate objectives. The overarching goal is to ensure safe, sustainable, and efficient road transport while fostering innovation, strategic autonomy and global competitiveness of the European automotive and mobility ecosystem.

Given the cross-cutting nature of this sector, policies, regulations, and funding instruments are designed and implemented across several Commission Directorates-General (notably DG MOVE, DG GROW, DG CLIMA, DG CNECT, DG ENV, DG RTD and DG DEFIS).

Key intervention areas relevant to the road and automotive segment include: the development and implementation of EU transport policy; the vehicle type-approval and certification framework (including safety, environmental and cybersecurity requirements); deployment of Intelligent Transport Systems (ITS) and Cooperative, Connected and Automated Mobility (CCAM); and the promotion of sustainable mobility through electrification and alternative fuels. In parallel, the Commission continues to enhance the industry's competitiveness through innovation, research and development programmes (such as Horizon Europe, CEF and partnerships on CCAM and batteries).

A particular focus is placed on the rollout of advanced digital infrastructure, including high-capacity fibre networks, 5G and emerging 6G systems, edge/cloud infrastructure and secure data spaces. These capabilities are essential enablers for connected and automated vehicles to communicate reliably with each other, with road infrastructure and with cloud/back-end services, and for integrating space-based services (e.g. Galileo/EGNOS positioning, satellite connectivity and Earth-observation data) into road transport and automotive applications.

European Parliament

The European Parliament's work in the road and automotive segment encompasses legislative, budgetary and political oversight functions. Its work covers road safety, vehicle regulation and type-approval, emission and CO₂ standards, alternative fuels, social and safety rules for professional drivers, infrastructure deployment, digitalisation and data governance, as well as broader industrial and trade policies affecting the automotive value chain. Members of the European Parliament (MEPs) contribute to designing and scrutinising EU laws and programmes aimed at achieving safer, more sustainable, connected and competitive road transport systems across the Union.

The European Parliament's work is largely channelled through key committees, in particular TRAN (Transport and Tourism), ENVI (Environment, Public Health and Food Safety), ITRE (Industry, Research

and Energy), IMCO (Internal Market and Consumer Protection) and LIBE (Civil Liberties, Justice and Home Affairs), often in co-decision with the Council. In recent years, the Parliament has been closely involved in revising CO₂ standards for cars and vans, strengthening General Safety Regulation measures, advancing the Alternative Fuels Infrastructure Regulation, and overseeing implementation of the Sustainable and Smart Mobility Strategy.

In 2026, two particularly relevant focus areas are the digitalisation of the transport sector and the regulation of Artificial Intelligence and data use in mobility. The Parliament is actively engaged in ensuring that connected and automated vehicles, mobility data spaces and transport platforms comply with EU rules on safety, cybersecurity, privacy, fundamental rights and fair competition, including through horizontal acts on AI, data, cybersecurity and chips.

Examples of relevant European associations

ACEA: The European Automobile Manufacturers' Association represents Europe's major car, truck, van, and bus manufacturers, advocating on policy, competitiveness, electrification, and market data. Focuses on EU regulatory alignment, zero-emission transitions, and industrial strategy to sustain the sector's global leadership.

AETIS: The Association of Electronic Toll and Interoperable Service groups nine European companies specialized in the payment of tolling and multimodal payment systems, focusing on full interoperability across the EU single market. The group advances dynamic pricing, real-time traffic management integration, and compliance with the revised Eurovignette Directive and AFIR for seamless adoption in electric and automated heavy-duty transport.

ASECAP: The Association of European Toll and Interoperable Service Operators represents the interests of toll road operators and other companies providing services related to toll collection and road infrastructure across Europe. The association advocates for interoperable electronic toll service (EETS 2.0), multimodal hubs, and V2I connectivity to enable CCAM and efficient cross-border freight in line with the Greening Mobility Package.

CEDR: The Conference of European Directors of Roads unites national road directors and administrations to benchmark practices, share knowledge, and advance road system improvements across Europe. Focuses on digital twins, AI-driven asset management, zero-fatality safe systems, and TEN-T freight corridors under the revised TEN-T Regulation. It leads EU-funded innovation on climate-adaptive pavements, 5G/6G-connected infrastructure, and GNSS-enabled traffic optimisation for CCAM pilots.

CLEPA: The European Association of Automotive Suppliers unites over 3.000 suppliers of automotive components, addressing supply chain innovation, sustainability, materials regulations, and digital transformation. Champions sovereignty in components like batteries, semiconductors, and software for connected/electric vehicles.

CORTE: The Confederation of Organisations in Road Transport Enforcement brings together enforcement authorities and organizations involved in road transport and traffic enforcement. One of the group's objectives is to optimise smart checks using digital tachographs 2.0, AI anomaly detection, and GNSS/smart tachograph data for cabotage/mass limits compliance. It promotes cross-border data sharing via EU Mobility Package tools and ECR collaboration to combat fraud in the greening freight sector.

EENA: The European Emergency Number Association aims to contribute to the improvement of the safety and security of people. The association is comprised of numerous emergency service representatives, solution providers, researchers, and Members of European Parliament. EENA pays specific attention to advanced mobile location services and e-call.

ECAVA: The European Connected and Autonomous Vehicle Alliance is an industry-led forum dedicated to enhancing Europe's competitiveness and digital sovereignty. The Alliance achieves this by coordinating advancements and innovation in software-defined vehicles (SDVs), AI-powered systems, as well as connected and autonomous driving technologies. It unites prominent automotive manufacturers, suppliers, and associations to facilitate collaboration on open-source software ecosystems, automotive

hardware, AI model development, and the extensive deployment of autonomous vehicles via cross-border testbeds and pilot initiatives.

ERF: The European Union Road Federation coordinates Europe's road infrastructure sector, acting as a platform for dialogue, research, and advocacy on road construction, maintenance, and asset management. Fosters dialogue on sustainable road assets, low-carbon materials, and smart infrastructure retrofits aligned with the Circular Economy Action Plan and Climate Adaptation Strategy.

ERTICO – ITS Europe: ERTICO works to boost the intelligent transport industry's competitiveness and improve user services. It represents stakeholders from connectivity, research, service provision, vehicle manufacturing, local governments, and users. ERTICO focuses on advancing CCAM and ITS for wider adoption of innovative transport solutions.

ETSC: The European Transport Safety Council is an independent organization promoting road safety through evidence-based policy recommendations and best practices. Influences EU regulations on vehicle safety, intelligent speed assistance, and post-crash technologies like eCall.

FIGIEFA: The International Federation of Automotive Aftermarket covers independent aftermarket repairers, parts distributors, and wholesalers across Europe. Addresses skills training, digital diagnostics, and access to vehicle data for non-OEM servicing.

TISPOL/ROADPOL: The European Roads Policing Network is an organization that brings together traffic police and law enforcement agencies from various European countries. In collaboration with Euro-Controlle-Route (ECR) they investigate the fraudulent use and manipulation of tachographs.

5GAA: The 5G Automotive Association brings together companies from the automotive, technology, and telecommunications industry to develop end-to-end solutions for future mobility and transportation services. 5GAA drives C-V2X, 5G-AA Red/Blue capabilities, and hybrid satcom-5G for non-terrestrial coverage. It advances edge-to-cloud platforms for platooning, remote driving, and immersive HMI in software-defined, highly automated vehicles.

R&I related platforms

ERTRAC: The European Road Transport Research Advisory Council (ERTRAC) is the European Technology Platform (ETP) for Road Transport. ERTRAC is recognized and supported by the European Commission. ERTRAC provides a strategic vision for road transport research and innovation in Europe and defines strategies and roadmaps to achieve this vision. It does so through the definition and updating of its Strategic Research and Innovation Agenda and implementation research roadmaps. Furthermore, it stimulates investment, coordinates R&D activities, enhances networking of Europe's research and innovation capacities, and promotes European commitment to R&D. Finally, it supports the implementation of Horizon Europe.

EUCAR: The European Council for Automotive R&D coordinates collaborative R&I among OEMs to advance greener, smarter mobility solutions like CCAM and zero-emission tech. Partners with the Commission on Horizon Europe priorities, shaping long-term competitiveness through pre-competitive research.

CCAM Partnership: The CCAM partnership is organised in order to align on the implementation of its Strategic Research and Innovation Agenda, a comprehensive roadmap for the implementation of the CCAM partnership and its objectives. It helps identify and define research and innovation activities to be included in the Horizon Europe Work Programmes. The box below offers an overview of the various clusters of the roadmap and the projects for each cluster.

2.3.2 Selection of applicable regulations, treaties and conventions

UN regulations

1958 Agreement: This agreement concerns the adaptation of harmonized technical UN regulations for wheeled vehicles, equipment, and parts which can be fitted and/or used on wheeled vehicles. Notably,

UN Regulations 155 and 156 amended the agreement covering cybersecurity, introducing the Cybersecurity Management System (CSMS), and software updates. They are designed to ensure the safe and secure updating of software in vehicles, which becomes increasingly important due to the development of ADAS systems and other technologies. Moreover, a further amendment to the agreement (UN Regulation 157) set uniform provisions concerning the approval of vehicles regarding Advanced Automated Lane Keeping Systems (2021). UN Regulation 157 was then amended to extend the automated driving speed up to 130 km/h in certain conditions (2022).

ADR (1958): The Agreement concerning the International Carriage of Dangerous Goods by Road (ADR). It lays out the compliance criteria for road vehicles carrying non-excessively dangerous goods internationally. In January 2023 a revised edition (ECE/TRANS/326) entered into force containing amendments adopted by the Working Party on the Transport of Dangerous Goods. GNSS is relevant to the ADR, as GNSS-based tracking systems can help monitor the movement of vehicles carrying hazardous materials.

Vienna Convention on Road Traffic (1968): International treaty facilitating international road traffic, designed to increase safety by establishing standard traffic rules. In 2016 the convention was updated to allow automated driving vehicles in traffic.

EU legislation

EU type-approval: The European Community Whole Vehicle Type Approval (ECWVTA) ensures motor vehicles placed on the EU market comply with harmonised environmental, safety, security, and performance standards. This framework, governed by Regulation (EU) 2018/858, extensively references UNECE WP.29 UN Regulations and Global Technical Regulations under the 1958 Agreement, while introducing EU-specific requirements for cybersecurity (UN R155/R156), software updates, automated driving systems, and environmental performance.

Key updates:

- Regulation (EU) 2025/258 establishes updated harmonised approval procedures for vehicle components, systems, and functions – notably emissions/consumption measurement (including real-world WLTP+), cybersecurity architectures, and ITS/CCAM capabilities. From 1 January 2026, only approvals compliant with this regulation (and its delegated/implementing acts) remain valid EU-wide, enforcing unified certification for connected, automated, and zero-emission vehicles.

CCAM type-approval: Regulation (EU) 2019/2144 ("General Safety Regulation" – GSR2), establishes mandatory advanced safety systems for all new vehicles sold in the EU, targeting a 25–50% reduction in road fatalities through systems like intelligent speed assistance (ISA), emergency lane keeping (ELKS), driver drowsiness detection, and cybersecurity management.

Key implementing regulations (all supplementing GSR2 via delegated powers):

- Commission Implementing Regulation (EU) 2021/646: Defines type-approval procedures and technical specs for ELKS, explicitly recognising GNSS-based localisation as core to real-time lane positioning and orientation tracking.
- Commission Implementing Regulation (EU) 2021/1958: Sets detailed test procedures for ISA systems, designating GNSS/HD map fusion as the state-of-the-art reference for real-world speed limit recognition with highest performance/reliability.
- Commission Regulation (EU) 2022/1426: Establishes initial type-approval framework for Automated Driving Systems (ADS) in limited-series fully automated vehicles (L3+/L4), covering use cases like single-operator highway driving and hub-to-hub freight where GNSS/PPP provides essential continuous positioning.

GSR2 requirements are now fully mandatory for all new vehicle registrations, with extended transitional periods closed.

eCall: in the stream of EU type approval, Regulation (EU) 2015/758, fully mandatory since March 2018, requires type-approval of the eCall in-vehicle system (IVS) based on the EU-wide 112 emergency number for all new passenger cars (M1) and light commercial vehicles (N1). The system automatically or manually triggers a Minimum Set of Data (MSD) transmission including precise vehicle location to Public Safety Answering Points (PSAPs) in the event of a crash.

Commission Delegated Regulation (EU) 2017/79 sets the detailed technical requirements, test procedures, and conformity assessment for eCall type-approval, mandating:

- GNSS receiver performance meeting Annex VI specifications for EGNSS compatibility (Galileo + EGNOS preferred, GPS/GLONASS as fallback).
- Multi-constellation support, sub-10m Horizontal Position Error (HEP) at 95%, and <7s Time-To-First-Fix (TTFF).
- Secure MSD transmission via 4G/5G with backward compatibility to 3G (phased out by 2026).

Commission Delegated Regulation (EU) 2024/1180 and (EU) 2024/1084 update eCall technical standards to transition Europe's emergency call system from legacy circuit-switched (CS) voice networks (like 2G/3G) to modern packet-switched (PS) data networks (4G/5G), ensuring compatibility as CS networks phase out.

Smart Tachograph: Regulation (EU) 165/2014 introduced second-generation digital tachographs ('smart tachographs 2.0'), mandating GNSS connectivity for precise location recording. Technical requirements for construction, testing, installation, operation, repair, and GNSS functionality were set by Commission Implementing Regulation (EU) 2016/799, as amended by subsequent acts.

Key updates include:

- Regulation (EU) 2020/1054 added location data processing rules and enhanced smart tachograph features.
- Implementing Regulation (EU) 2021/1288 further amended 2016/799 to support the new tachograph version.
- Implementing Regulation (EU) 2023/980 introduced tachograph version 2.1, establishing a transitional GNSS authentication regime.

By 2026: Galileo Open Service Navigation Message Authentication (OSNMA) is now mandatory following successful completion of the trial phase mandated by Implementing Regulation (EU) 2021/1228, with 2023/980's transitional provisions fully phased out. All newly installed smart tachographs must use authenticated GNSS signals, ensuring location data integrity for enforcement under the EU Mobility Package.

Road user charging: Directive 2004/54/EC, fully implemented, mandates interoperability of EU electronic road toll systems through the European Electronic Toll Service (EETS), explicitly recognising GNSS-based satellite positioning coupled with mobile communications as a core technological solution alongside Dedicated Short-Range Communications (DSRC). This prevents fragmented national systems and enables seamless cross-border tolling for heavy-duty vehicles (>3.5t).

Key complementary legislation:

- Decision 2009/750/EC defines EETS technical specifications, essential requirements for On-Board Units (OBUs), and contractual frameworks for service providers.
- Directive (EU) 2019/520 establishes the European Electronic Toll Service Interoperability Platform (EETS-IP) for real-time cross-border enforcement data exchange on unpaid tolls.

Intelligent Transport systems (ITS): Directive (EU) 2023/2661 updated the ITS legal framework to improve data accessibility and interoperability with other transport modes. It mandates harmonised publication of key datasets for consistent ITS services across borders, strengthens interoperability

standards, and prepares digital infrastructure and traffic management for automated vehicles throughout the EU. Member States must fully implement by 21 December 2025.

Space: Regulation 2021/696/EU “establishing the Union Space Programme and the European Union Agency for the Space Programme” (EUSPA) is the main Space policy document for the European Union. Although the regulation highlights the role that Copernicus should play in supporting the Union’s capacity to achieve independent decision-making and actions in a certain number of fields, infrastructure monitoring them, it does not impose any regulatory obligations with regard to the use of space-based systems for infrastructure management.

Other EU level initiatives with an impact on CCAM:

The *2025 Industrial Action Plan for the European Automotive Sector* is a strategic EU initiative aimed at supporting the industry’s transition towards zero-emission and highly automated vehicles, while safeguarding supply-chain resilience and global competitiveness. The plan promotes fleet electrification, greater harmonisation of incentives across Member States, and increased investment in advanced R&D for connected and autonomous vehicle technologies. For the automotive ITS sector, it accelerates the uptake of intelligent transport systems by enabling large-scale deployment of autonomous driving solutions, strengthening digital connectivity, and fostering innovation in AI-driven mobility applications.

The *2025 Automotive Package* supports the automotive sector’s transition towards clean, competitive and resilient mobility. It prioritises flexibility in CO₂ emission targets, mandates corporate fleet electrification and promotes investment in battery supply chains. These measures indirectly support CCAM by easing regulatory pressures on vehicle manufacturers, allowing greater focus on automated and connected vehicle development, and accelerating electric vehicle deployment. The resulting market expansion creates favourable conditions for the scaling-up of CCAM solutions, including automated fleets and connected mobility services.

The *EU Digital Decade 2025 package* accelerates transport digitalisation through the rollout of gigabit connectivity, expanded 5G coverage, edge computing and artificial intelligence, with a strong emphasis on Connected, Cooperative and Automated Mobility. In this context, the proposed Digital Networks Act is particularly relevant for CCAM. By modernising telecom rules, harmonising spectrum use and strengthening network resilience, it enables the deployment of cross-border 5G corridors that are essential for cooperative and automated driving. These measures support reliable real-time vehicle-to-everything communications, which underpin automated driving functions, cooperative traffic management and cross-border CCAM services, while also reducing fragmentation and reinforcing cybersecurity obligations under NIS2.

The *2023 Communication establishing a common European Mobility Data Space (EMDS)* aims to facilitate access to, pooling and sharing of transport and mobility data across the EU. By addressing long-standing data silos between operators, public authorities and private mobility providers, the EMDS provides a key foundation for CCAM deployment. It enables cross-border data sharing, supports interoperability between systems, and enhances real-time situational awareness, which is critical for cooperative and automated mobility services.

2.3.3 Other standards, practices and guidelines

The following list gathers a non-exhaustive list of relevant standardization bodies working groups, and related standards and initiatives in the field of GNSS positioning that influence implementation of GNSS and required performance, in particular for safety-critical applications.

2.3.4 Relevant Standards for GNSS

ETSI TC SES/SCN

TS 103 246-1 to TS 103 246-5: Satellite Earth Stations and Systems, GNSS based location systems. Setting out functional requirements, reference architecture, performance requirements, requirements for location data exchange protocols, and performance test specifications.

CEN/CENELEC

EN 16803-1 to EN 16803-4: Suite of 4 standard documents about GNSS performance, relevant for road applications. The documents deal with basic metrics, field and “Record and Replay” testing procedures, and a focus on spoofing and interferences. EN 16803-1 was published in October 2016, the other two documents are ongoing work. EN 16803-4 is to be added in the future and will define the methods for carrying out / designing performance test scenarios intended to be replayed in lab.

ISO

ISO TC204: The ISO's Technical Committee 204 is developing a new project titled “TS 21176 – Intelligent Transport Systems – Cooperative ITS – Position, Velocity and Time functionality in the ITS station”. This is a collaboration between ISOTC204/WG18 (cooperative systems) and CEN TC5WG1.

ISO 26262 Road Vehicles-Functional Safety: On the functional safety of electrical and/or electronic systems in production automobiles defined by the ISO in 2011. Automotive Safety Integrity Levels (ASIL) derive from this standard.

ISO 5725 Accuracy of Measurements: On the accuracy (trueness and precision) of measurements methods and results, to establish practical estimations of the various measurements.

ISO/TC20/SC14 – WG8: Downstream space services and space-based applications: a dedicated WG established to cover downstream space services and space-based applications (land, maritime, aeronautical and near space domains).

Other relevant working groups

IAG – WG 4.1.4.: The International Association of Geodesy has a commission (4) focussing on positioning and applications. Within this commission, WG 4.1.4. (Robust Positioning for Urban Traffic) is concerned with the specification and characterization of GNSS requirements, and performance analysis for vehicles and pedestrians in urban areas.

TISA: The Traveller Information Services Association (TISA) follows the development of the TPEG protocol family, covering the broadcast of traffic and transport information to end users. Recently, TISA has developed the TPEG2 Emergency Alerts and Warnings (EAW) technology, supporting the distribution of official Emergency Alerts and Warnings as issued by public authorities and/or authorized agencies, without language barriers.

OADF: The Open Auto Drive Forum is an initiative to harmonize the activities from NDS, TISA, ADASIS and SENSORIS created in 015. The overarching objective is to generate an ecosystem of production-ready automotive standards including navigation and positioning.

Cloud LSVA (Large Scale Video Analysis) project – Open Group: This project focusses on navigation data and maps and supports the development of suitable standards for video data sets and video annotation. It aims to develop a standard on video content annotation to be published by an existing appropriate SDO.

SAE International: The Society of Automotive Engineers (SEA) International has a committee focussing on On-Road Automated Driving (ORAD). They produced four relevant documents: 1) J3016 Taxonomy and Definitions for Terms Related to On-Road Motor Vehicle Automated Driving Systems; 2) J3018 Guidelines for Safe On-Road Testing of SAE Level 3, 4, and 5 Prototype Automated Driving Systems; 3) J3092 Dynamic Test Procedures for Verification & Validation of Automated Driving Systems; 4) J3131 Automated Driving Reference Architecture. The last two documents are still to be completed.

2.3.5 Relevant Standards for SATCOM

3GPP

Release 17: introduced the first normative specifications for Non-Terrestrial Networks (NTN) in 5G NR, enabling direct satellite connectivity for narrowband IoT (NB-IoT/eMTC) and initial NR over satellite using transparent GEO/LEO/MEO payloads.

Release 18: builds on Rel-17 with store-and-forward NTN, RedCap (reduced capability) devices over satellite (~2Mbps), and initial broadband NTN support including transparent payload video/text streaming with TN/NTN handover procedures. Automotive implementations gain higher-throughput fleet diagnostics, OTA software updates, and passenger connectivity, with enhanced side link (NR-V2X) over NTN for safety-critical messaging continuity and improved power-saving features for always-on vehicle modems.

Release 19 (preparatory work ongoing): targets full broadband NTN (>10Mbps downlink) with regenerative satellite payloads, inter-satellite links, and C-V2X integration over LEO constellations for low-latency applications. It enables automotive remote driving, platooning, immersive HMLs, and V2X collective perception extension beyond terrestrial networks, including precise timing synchronization via GNSS-SATCOM fusion for L4+ highway autonomy.

ISO

ISO 21217:2023 (ITS station architecture): defines the reference architecture for ITS stations (vehicles, RSUs, central systems), specifying multi-radio communication interfaces including cellular (5G NR), short-range (C-V2X/ITS-G5), and emerging NTN/SATCOM gateways within a unified host/modem abstraction layer. For SATCOM implementation, it mandates modular integration of satellite modems via standardized APIs (e.g., PCIe, Automotive Ethernet), ensuring seamless handover, security bootstrapping, and QoS mapping between terrestrial and non-terrestrial bearers in CCAM zonal architectures.

ISO 19091:2023 (Detection and Communication for Cooperative and Automated Driving): specifies DSRC/ETSI hybrid profiles for vehicle-to-infrastructure (V2I) and collective perception messaging, extended to include GNSS+SATCOM positioning for tolling and ITS continuity in GNSS-denied environments like tunnels. It defines message sets (e.g., CAM/DENM over SATCOM fallback) and performance requirements for satellite augmentation of C-ITS, ensuring interoperable service continuity with minimal latency degradation during NTN handovers.

IATF 16949 :2016 (with 2024 SATCOM-specific guidance) establishes the global QMS standard for automotive suppliers, requiring ASPICE Level 3+ processes for SATCOM modem/software development including traceability, change management, and field anomaly handling. For NTN components, it mandates accelerated life testing (AEC-Q100), supply chain risk assessment for satellite service dependencies, and zero-defect delivery of phased-array antennas and 3GPP NTN stacks to OEM zonal controllers.

2.3.6 Relevant Standards for EO

There is a rich variety in EO sensor types, performances, configurations, observation scenarios and geometries. Data vendors vary how their clients may task and access the satellite data and describe the metadata. This creates a set of challenges for downstream analytical tasks in building workflows that maintain robustness when satellite inputs, geographies or time horizons change. Geospatial, Earth observation and application layer communities are working to establish shared understanding and raise the quality of products along the value chain.

There is a good foundation of standards that Earth observation community is relying on. The internationally adopted standards in data formats and metadata associated with geospatial data are provided by ISO, IEEE, OGC, GRSS, CEOS, WMO SEOAH and Group on Earth Observations (GEO).

There are no explicit EO standards for road and automotive - general geospatial data standards apply. Automotive industry standards for EO derivative products such as maps for manned or autonomous navigation, weather forecasts, hazard warnings and similar are not covered.

- **EO data standards:**
 - The International Organization for Standardization (ISO);
 - ISO/TR19121:2000 concerning Geographic information, imagery, and gridded data
 - ISO 19115:2014 Geographic Information - Metadata.
 - The Open Geospatial Consortium (OGC) provides Standards and Schemas (XSD, JSON Schema, etc) for the geospatial information interoperability and implementation used by international organizations.
 - EO product metadata: OGC's GML Application Schema for EO Products
 - Collection and service discovery: OGC's Cataloguing of ISO Metadata using the ebRIM profile of CS-W.
 - Catalogue Service: OGC's Catalogue Services Specification 2.0 Extension Package for ebRIM Application Profile: EO Products.
 - Order: OGC's Ordering Services for EO Products
 - Feasibility Analysis: OGC's Sensor Planning Service Application Profile for EO Sensors
 - Online Data Access: OGC's WMS EO Extension
 - Identity (User) Management: OGC's User Management Interfaces for EO Services.
 - Geoscience and Remote Sensing Society (GRSS) created the Standards in Earth Observations (GSEO) Technical Committee to support the development and promotion of technical standards related to the generation, distribution, and utilization of interoperable data products from remote sensing systems.
 - The Standards in Earth Observations Ad Hoc Committee (SEOAH) is the managing organizational unit within GRSS to handle standards development within the IEEE.
- **Standards for EO enabled activities**
 - **Geotechnical investigation of infrastructure:** The Geotechnical Monitoring by Field Instrumentation Panel (ISO TC 182/WG2) has ISO/DIS 18674-9 "Geotechnical investigation and testing — Geotechnical monitoring by field instrumentation Part 9: Measurement of displacements by geodetic means" at the stage of draft standard. An annex introduces novel technologies one of them being displacement monitoring with satellite MTInSAR. Shared understanding of features, applicability and limitations of novel technologies is likely to foster wider operational adoption.
 - **ISO 14090 and ISO 14091** are international standards that provide guidance for organizations planning and implementing **climate change adaptation**. ISO 14090 establishes the overall framework and principles for integrating climate adaptation into organizational governance, planning, and decision-making, including infrastructure planning and asset management. ISO 14091 complements it by providing detailed guidance on how to assess climate risks, including identifying hazards, analysing exposure and vulnerability, and evaluating impacts on systems such as transport infrastructure. Together, the standards support infrastructure managers and public authorities in systematically assessing climate risks and developing adaptation strategies to increase resilience to future climate conditions.
 - **EuroStruct** emerged from COST Action TU146 "Quality specifications for roadway bridges, standardization at a European level (BridgeSpec)", which aimed to achieve the European economic and societal needs by standardizing the condition assessment and maintenance level of roadway bridges. MTInSAR is among the prospective technologies where shared best practices are published.

2.4 User Needs and Requirements

This chapter provides an analysis of user needs and requirements pertaining to road and automotive applications, describing the different roles and needs covered by GNSS, EO and SATCOM, and, ultimately, identifying the corresponding requirements from a user perspective.

The table below depicts the main applications making use of GNSS, EO or SATCOM technologies in Road and Automotive. The list of applications is non-exhaustive and is expected to potentially grow and adapt according to the expected adoption of space technologies in the coming years and the innovations that should come with it.

The Reports on User Requirements are living documents, evolving periodically and so they will be updated and expanded by EUSPA in their next releases.

<i>Sub-segments</i>	<i>Applications</i>	<i>Use cases</i>
GNSS	Connected, Cooperative and Automated Mobility (CCAM)	Parking Confined areas Urban environments Rural environments
	eCall (Emergency assistance)	
	Smart tachographs	
	Navigation – In-Vehicle Systems (IVS)	
EO	Infrastructure Planning and Designing, Finance Planning	Determination of surface ground movements Weather Impact Assessments and Adaptation to Climate Change Determination of soil moisture Environmental impact assessment
	Infrastructure construction	Geotechnical and structural monitoring during the construction Worksite progress monitoring Resource availability planning Environmental impact monitoring Monitoring for forensic investigation
	Infrastructure operations and maintenance	Determination and prediction of surface ground movements Vegetation monitoring Environmental impact monitoring Winter service

Sub-segments	Applications	Use cases
		Pavement deterioration monitoring and prediction Bridge monitoring
	Resilience to natural hazards	Flood risk management Forest fire risk management
	Climate resilience	Climate risk assessments and adaptation plans Road design standards Nature based solutions
SATCOM	Narrowband	
	Wideband	
	Broadband	Connected fleet

Table 3: Applications covered

Requirements are defined in a technology-specific manner, reflecting the distinct performance characteristics and operational constraints of each satellite technology. The following tables present and describe the essential user requirements applicable to each technology,

GNSS user requirements for [Application]		
Accuracy	Horizontal	m/cm-level
	Vertical	m/cm-level
Availability	Urban canyon	Yes/no
	Natural canyon	Yes/no
	Canopy	Yes/no
	Indoor	Yes/no
	Better than 95%	High/medium/low
	Better than 99%	High/medium/low
Robustness		High/medium/low
Integrity and reliability		High/medium/low
Size, weight, autonomy (when smartphone or handheld based)	Relevance	Yes/no
	Time a device can run	>h
TTFaF	In hot start	Seconds/minutes
Service area	Geographical coverage	National/Regional

Table 4: GNSS requirements covered per application

EO user requirements for [Application]	
ID	xxx
Application	xxx
Users	xxx
Operational scenario	xxx
Size of area of interest	xxx
Frequency of information needed	xxx
Type of service (continuous, forecasting, one-off?)	xxx
Satellite EO Data Requirements	
Spatial resolution	xxx
Temporal resolution	xxx
Spectral resolution	xxx
Other requirements (if applicable)	xxx
Technology used	xxx
Data supplements	xxx

Table 5: EO requirements covered per application

SATCOM user requirements for [Application]	
Users	xxx
Operational scenario	xxx
End user application needs	xxx
Frequency band	xxx
Data traffic requirements	Kbps/Mbps
Latency needs	(High/Medium/Low)
Availability needs	(High/Medium/Low)
Technology	xxx
SATCOM access technology	xxx

Table 6: SATCOM requirements per application

2.4.1 Current GNSS use and requirements per application

Cooperative, Connected and Automated Mobility (CCAM)

Cooperative, Connected and Automated Mobility (CCAM) refers to the progressive integration of connectivity, cooperation and automation to enable vehicles to operate more safely and efficiently as part of an intelligent transport ecosystem. In practice, many vehicles have already become connected devices through links to external services for infotainment, security, comfort and maintenance, while radio-based interaction between vehicles, pedestrians and roadside infrastructure has been deployed in various forms, primarily through technologies like DSRC (Dedicated Short-Range Communications) and C-V2X, in pilot projects, field trials, and early commercial applications [IRIS² Regulation].⁶

What is changing with CCAM is the degree of cooperation and automation. Cooperative exchanges (vehicle-to-vehicle and vehicle-to-infrastructure) are increasingly expected to complement onboard automation so that automated vehicles can interact predictably with legacy vehicles and other road users (e.g., bicycles or trams) and so that traffic management can evolve from reactive control to coordinated, real-time optimisation. This convergence is widely seen as a necessary step to unlock the full benefits of connected and automated vehicles (CAVs), higher safety, smoother traffic flow and improved environmental performance, across use cases ranging from automated shuttles and buses to smart intersections and cooperative assistance services.

Within this CCAM landscape, precise positioning is a core enabling capability, and GNSS remains the primary source of **absolute** positioning at scale. While cameras and LiDAR can localise a vehicle relative to its surroundings and HD maps can encode road geometry with high precision, CCAM functions ultimately require a stable global reference to determine where the vehicle is on Earth and to align vehicle motion, maps and cooperative messages consistently over time. Field and stakeholder evidence points to the same conclusion: CCAM navigation performance is typically framed around availability, accuracy and integrity, and GNSS, because it is globally available and comparatively cost-effective, forms the backbone for absolute positioning even when other sensors and maps are present. At the same time, multiple studies and industry consultations underline that standalone GNSS performance is not sufficient in all environments and that the highest automation ambitions require more than “GNSS-only” positioning [RD6], [RD7].^{7, 8}

This is why sensor fusion has become the prevailing architectural approach for CCAM positioning. CCAM platforms combine GNSS (often multi-constellation) with inertial sensors (IMU), odometry/wheel speed and perception sensors such as cameras, radar and LiDAR, and in connected settings may also use V2X/roadside units to exchange information or process data at the edge. Work on sensor selection and placement highlights that this multi-sensor stack is essential because each sensing modality has distinct strengths and vulnerabilities. Radar performs well in adverse weather, cameras are information-rich and cost-effective, LiDAR supports detailed ranging and mapping, while IMU/odometry provide continuity during GNSS outages but drift over time. The fusion layer is therefore tasked with exploiting complementarity to produce a continuous best-estimate state (position, velocity, attitude) and to manage uncertainty when any single sensor degrades **Error! Reference source not found.**⁹ In practice, this fusion

⁶ Car-2-Car Communication Consortium. (2025). *Objectives and organisational structure – Status on C-ITS in Europe*. <https://wiki.unece.org/download/attachments/279019635/ITS-11-05e.pdf>

⁷ European Union Agency for the Space Programme (EUSPA). (2025). *Road and automotive user consultation platform (UCP)*. <https://www.euspa-ucp.eu/>

⁸ Schiess, S., Berget, G. E., Arnesen, P., Brunet, M. T., Seter, H., & Muggenrud, A. M. F. (2023). *GNSS technology for precise positioning in CCAM: A comparative evaluation of services*. IEEE Access, 11, 47816–47826. <https://doi.org/10.1109/ACCESS.2023.3276821>

⁹ Kiraz, M., Sivrikaya, F., & Albayrak, S. (2024). *A survey on sensor selection and placement for connected and automated mobility*. IEEE Open Journal of Intelligent Transportation Systems. <https://doi.org/10.1109/OJITS.2024.3481328>

is implemented through filtering or optimisation approaches that adapt weighting and fault handling to the operating context; however, an important practical constraint is that fusion strategies differ significantly by OEM and supplier, and the resulting algorithms are often treated as proprietary “black boxes,” complicating cross-comparisons and standardised performance claims [RD8].¹⁰

Against this backdrop, three GNSS-specific considerations are particularly important for CCAM: accuracy needs, time to convergence and integrity.

First, accuracy requirements tighten as automation and cooperation increase. Positioning for CCAM is frequently discussed in the decimetre-to-sub-metre range, reflecting the shift from road-level navigation to lane-level decision-making. Stakeholders consulted in the Road & Automotive UCP emphasised that reliable lane-level absolute positioning is essential for ADAS and CCAM and that continuous sub-metre accuracy is a growing need, including in challenging environments [RD6] **Error! Reference source not found.**¹¹

Second, time to convergence becomes a user-critical metric once high-accuracy techniques and corrections are used. CCAM systems must recover quickly after start-up or after signal obstruction (e.g., tunnels, urban canyons); long convergence times delay or degrade automated functions and reduce perceived usability. In the road & automotive consultation material, time to convergence is flagged as an adoption barrier for high-accuracy services in real-time applications, and improving convergence performance is repeatedly highlighted as a priority requirement for CCAM.

Third, integrity, the ability to bound positioning error and provide timely alerts when performance is unsafe, emerges as a decisive factor as positioning becomes safety- and liability-relevant. UCP discussions explicitly link CCAM to high integrity requirements and note that robustness against spoofing/jamming and system-level redundancy are essential; in practice, integrity is often achieved at the solution level through fusion, diagnostics and redundancy rather than relying on GNSS alone, but the need for stronger integrity mechanisms and trust frameworks is increasing as automation advances and as GNSS is used for safety- and compliance-relevant functions.

Galileo differentiators are positioned to address several of these CCAM needs, but their contribution depends on technical readiness and integration choices across the value chain. Stakeholder feedback from the UCP road session highlights that Galileo's High Accuracy Service (HAS) and OSNMA are seen as strategic enablers to improve accuracy and robustness for ADAS/CCAM, while high integrity remains a core requirement. HAS is valued because it supports higher-accuracy positioning that can help meet lane-level needs, and the fact that high accuracy can be accessed as a service is attractive in a cost-sensitive automotive context; however, consultation material also stresses that convergence time is a critical limitation for real-time road use cases and that improvements are necessary to better meet CCAM requirements. OSNMA addresses spoofing resilience by authenticating Galileo navigation messages, which can strengthen trust in the underlying signal-in-space and can be used either directly by the end receiver (when relying on the broadcast message) or indirectly by service providers that authenticate Galileo signals before producing augmentation/correction products.

At the same time, stakeholders note practical adoption constraints: automotive-grade receiver and antenna capabilities are not uniformly ready for all advanced signals and features, and further market penetration of these differentiators requires progress on hardware readiness and integration into vehicle electronic architectures. In other words, Galileo differentiators can materially improve CCAM positioning performance (accuracy, robustness and trust), but they must be deployed within an end-to-end architecture that also manages convergence, redundancy and integrity at the solution level [RD6].¹²

¹⁰ Yang, H., Hong, J., Wei, L., Gong, X., & Xu, X. (2022). *Collaborative accurate vehicle positioning based on global navigation satellite system and vehicle network communication*. Electronics, 11(19), 3247. <https://doi.org/10.3390/electronics11193247>

¹¹ European Union Agency for the Space Programme (EUSPA). (2025). *Road and automotive user consultation platform (UCP)*. <https://www.euspa-ucp.eu/>

¹² Ibid

In terms of applications, ETRAC's CCAM Roadmap **Error! Reference source not found.**¹³ provides a structured view of priority domains that drive positioning needs and shape requirements for GNSS and its integration into vehicle and infrastructure systems. These applications, with their requirements being covered below are;

- Parking (including automated parking in facilities), the roadmap-aligned application framing highlights the need for high-accuracy manoeuvring, integration with smart infrastructure and real-time coordination, while recognising that covered or underground conditions increase multipath and reduce satellite visibility, making fusion and augmentation essential.
- Confined areas (industrial sites, logistics hubs, ports and restricted zones) are particularly relevant for early automation because operational design domains can be controlled, yet they remain GNSS-challenged due to structures, interference and dense operations; here, the emphasis shifts to reliable navigation under limited sky view, safe coordination in mixed traffic and robust integration with local sensing and, where available, augmentation.
- Highways and corridors support higher-speed automated driving and cooperative assistance, requiring continuous lane-level positioning and integration with traffic management and cooperative services; these use cases make absolute positioning continuity and integrity especially important because errors propagate rapidly at speed and the tolerance for misleading information is low.
- Beyond these, the roadmap also extends into urban/peri-urban mixed traffic and rural/secondary road networks, where the balance between perception, connectivity and absolute positioning varies with infrastructure support and environmental complexity, reinforcing the need to express GNSS requirements as ranges tied to each operational domain and to the role GNSS plays in the overall positioning mix.

The GNSS user requirements for future PNT solutions supporting the development of CCAM are summarised in the table below.

¹³ European Road Transport Research Advisory Council (ETRAC). (2022). *Connected, cooperative and automated mobility roadmap*. <https://www.etrac.org/wp-content/uploads/2022/07/ETRAC-CCAM-Roadmap-V10.pdf>

GNSS user requirements for future PNT		
Accuracy	Horizontal	20 cm-level
	Vertical	2 m-level
Availability	Urban canyon	Yes
	Natural canyon	Yes
	Canopy	Yes
	Indoor	Yes, for specific applications such as indoor parking
	Better than 99%	High
Robustness		High
Integrity and reliability		R of 10-8 /h with TTA $\leq$ 5s and AL = 20cm [
TTFaF	In hot start	TTARF <10s assuming hot start conditions for the receiver & an error of the known position >0.5m
Service area	Geographical coverage	Regional

Table 7: GNSS user requirements for future PNT solutions supporting CCAM

The GNSS user requirements for CCAM prioritised applications are summarised in the tables below;

GNSS user requirements for CCAM - parking		
Accuracy	Horizontal	5 m-level
	Vertical	10 m-level
Availability	Urban canyon	Yes. 10 meters (95%)
	Natural canyon	Yes. 5 meters (95%)
	Canopy	Yes. 5 meters (95%)
	Indoor	Yes.
	Better than 95%	High
Robustness		L1/E5a signals cannot deteriorate greater than 1 dB-Hz.
Integrity and reliability		High
TTFaF	In hot start	<2 seconds (hot start) <10 seconds (warm start) <45 seconds (cold start)
Service area	Geographical coverage	Regional

Table 8: GNSS user requirements for Parking

GNSS user requirements for CCAM – Confined areas		
Accuracy	Horizontal	5 m-level
	Vertical	10 m-level
Availability	Urban canyon	Yes. 10 meters (95%)
	Natural canyon	No
	Canopy	No
	Indoor	No
	Better than 95%	High
Robustness		L1/E5a signals cannot deteriorate greater than 1 dB-Hz.
Integrity and reliability		High
TTFaF	In hot start	<2 seconds (hot start) <10 seconds (warm start) <45 seconds (cold start)
Service area	Geographical coverage	Regional

Table 9: GNSS user requirements for Confined areas

GNSS user requirements for CCAM – Highways		
Accuracy	Horizontal	2 m-level
	Vertical	4 m-level
Availability	Urban canyon	Yes. 2 meters (95%)
	Natural canyon	Yes
	Canopy	Yes
	Indoor	No
	Better than 95%	High
Robustness		L1/E5a signals cannot deteriorate greater than 1 dB-Hz.
Integrity and reliability		High
TTFaF	In hot start	<2 seconds (hot start) <10 seconds (warm start) <45 seconds (cold start)
Service area	Geographical coverage	Regional

Table 10: GNSS user requirements for Highways

GNSS user requirements for CCAM – Urban areas		
Accuracy	Horizontal	2 m-level
	Vertical	20 m-level
Availability	Urban canyon	Yes. 2 meters (95%)
	Natural canyon	Yes
	Canopy	Yes
	Indoor	No
	Better than 95%	High
Robustness		L1/E5a signals cannot deteriorate greater than 1 dB-Hz.
Integrity and reliability		High
TTFaF	In hot start	<2 seconds (hot start) <10 seconds (warm start) <45 seconds (cold start)
Service area	Geographical coverage	Regional

Table 11: GNSS user requirements for Urban areas

GNSS user requirements for CCAM – Rural areas		
Accuracy	Horizontal	2 m-level
	Vertical	4 m-level
Availability	Urban canyon	Yes. 2 meters (95%)
	Natural canyon	Yes
	Canopy	Yes
	Indoor	No
	Better than 95%	High
Robustness		L1/E5a signals cannot deteriorate greater than 1 dB-Hz.
Integrity and reliability		High
TTFaF	In hot start	<2 seconds (hot start) <10 seconds (warm start) <45 seconds (cold start)
Service area	Geographical coverage	Regional

Table 12: GNSS user requirements for Rural areas

Emergency assistance – eCall

The eCall application is an emergency assistance system designed to bring rapid assistance when severe road accidents occur by automatically or manually contacting emergency services. eCall is activated automatically when the vehicle's sensors detect a severe collision; it can also be activated manually if the driver is able to do so or if a vehicle witnesses an accident. The system initiates a call with the European emergency services (via 112) and transmits the accident details, which include a timestamp and the

precise location of the vehicle. Vehicles equipped with 112-based eCall in-vehicle systems are not traceable and are not subject to constant tracking; when an accident occurs, the information sent corresponds to the minimum set of data required for the appropriate handling of emergency calls. The use of positioning services (GNSS) provided by Galileo and EGNOS plays a crucial role in achieving highly accurate positioning of the distress signal.

The goal of eCall is to enhance road safety by ensuring rapid response in the event of a road accident. Thus, rapid activation and efficient transmission of relevant data, such as accurate location, vehicle direction, and other fundamental details, are essential. Users also expect high system reliability to minimize false alarms and ensure genuine calls are not missed, alongside robust network dependability. GNSS is a critical component, enabling precise location determination that is transmitted with accident details (e.g., time and travel direction) to a Public Safety Answering Point (PSAP).

The European eCall Implementation Platform is recommending practical steps to optimize eCall's performance and unlock its full potential for saving lives in crashes. Since eCall must function throughout a vehicle's entire lifespan, additional rules may soon cover regular safety checks and safe disposal at end-of-life.

EU rules already mandate eCall in new vehicles but rolling it out fleet-wide takes years, and still many cars on roads today lack it. OEMs were encouraged to retrofit existing models voluntarily; now, with mobile networks and emergency centres (PSAPs) fully ready for data-based eCalls (4G/5G), OEMs are required to develop or certify aftermarket kits to equip older vehicles, ensuring compliance during inspections to avoid fines or market exclusion [RD10].¹⁴

Drivers and fleet owners gain access to life-saving automatic crash alerts (with precise GNSS location) in vehicles not originally equipped, potentially cutting response times by up to 50% in rural areas. Aftermarket devices from European and global vendors (some direct 112-eCall, others via third-party services) will soon hit the market, making retrofits affordable and widespread. However, without strict standards, users risk unreliable devices sending false alarms, overwhelming PSAPs or failing in real emergencies.

The GNSS user requirements for eCall are summarised in the table below;

¹⁴ European Commission. (2025). eCall (RP2025). Interoperable Europe Portal. <https://interoperable-europe.ec.europa.eu/collection/rolling-plan-ict-standardisation/ecall-rp2025>

GNSS user requirements for eCall		
Accuracy	Horizontal	0.15 m - 0.75 m (3σ) or 0.15 m - 0.75 m (99.7% confidence) Position must be accurate enough to determine the correct vehicle in multi-vehicle accidents
	Vertical	10 meters
	Timing	Approximately 1 second
Availability	Urban canyon	Yes
	Natural canyon	Yes
	Canopy	Yes
	Indoor	No
	Better than 95%	Medium
Robustness	Position authenticity	Pfa<1% and PD>75%
	Robustness to interference	Medium
Integrity and reliability		Medium PL<25m at IR=10exp-4
Size, weight, autonomy (when smartphone or handheld based)	Time a device can run	>5h
	In hot start	Less than 30 seconds
TTFaF		<30s
Service area	Geographical coverage	National/Regional
Authentication		The positioning system should provide an authentication message
Interference detection		The positioning system shall be able to detect GNSS interferences and inform the driver

Table 13: GNSS user requirements for eCall

Smart tachograph

A tachograph is a regulated onboard device used in road transport to record driving times, rest periods, vehicle speed, and other activity data. Its primary objective is to prevent driver fatigue, ensure fair competition among transport operators, and improve road safety by enabling the enforcement of European Union social legislation on driving and rest times. Tachographs are mandatory in the EU for commercial vehicles with a maximum permissible mass above 3.5 tonnes used for goods transport, as well as for vehicles carrying more than nine passengers, including the driver.

Smart tachographs represent the latest evolution of this system and have been mandatory for newly registered vehicles since 2019. Compared with earlier analogue and digital tachographs, smart tachographs integrate additional technologies that increase automation, accuracy, and enforcement efficiency. In particular, they incorporate GNSS positioning and timing to automatically record journey start and end points and to log vehicle locations at predefined intervals. They also use short-range communication technologies to enable remote roadside checks by enforcement authorities without requiring vehicles to stop, while secure data storage and encryption mechanisms protect driver and vehicle data against tampering or unauthorised access.

As a regulated and safety-critical application, the smart tachograph is subject to strict legal and technical requirements. These include accurate and reliable GNSS-based positioning and timing, robust protection against manipulation such as spoofing or jamming, user-friendly interfaces for drivers and operators, and real-time or near-real-time access to data for enforcement authorities. In addition, smart tachographs support integration with intelligent transport systems (ITS), enabling interoperability with telematics services such as fleet management, smart parking, or pay-as-you-go applications, while remaining fully compliant with EU regulatory frameworks.

Recent regulatory updates have introduced the second-generation smart tachograph, often referred to as Smart Tachograph version 2, which has been deployed since 2023. This version extends the functional scope of the system in response to updated transport legislation. Key enhancements include automatic detection and recording of border crossings using GNSS location and time data, expanded data sets to support more effective enforcement, and technical provisions for enhanced positioning integrity. These changes reflect a growing regulatory emphasis on trustworthy, verifiable location data in commercial road transport.

A central element of this evolution is the introduction of Galileo Open Service Navigation Message Authentication (OSNMA). OSNMA is a security feature of the European Galileo GNSS that allows receivers to authenticate navigation messages and verify that they originate from genuine Galileo satellites. For smart tachographs, OSNMA addresses a critical user need: authenticated GNSS signals that enhance trust in recorded positioning and timing data. By cryptographically validating navigation messages, OSNMA strengthens resistance to GNSS spoofing and manipulation, thereby increasing the integrity and credibility of tachograph records used for compliance and enforcement. In this way, OSNMA contributes directly to the broader objectives of tachographs, namely improving road safety, strengthening enforcement, ensuring fair competition, and supporting driver wellbeing.

Despite its regulatory importance, the implementation of OSNMA in smart tachographs, faces several technological challenges that affect its prioritisation and integration. Challenges related to satellites and signal include the limited number of visible satellites currently transmitting OSNMA and the reliability of authenticated data streams. Infrastructure-related issues include service availability across the satellite constellation, connection bandwidth constraints, and the lack of over-the-air (OTA) software update mechanisms. Environmental factors such as external interference sources, weather conditions, and signal reflection or absorption further impact OSNMA performance. At the user and receiver level, antenna placement, dynamic driving conditions, and vehicle-borne interference sources also play a significant role [RD6].¹⁵

In addition, OSNMA introduces constraints related to authentication latency. OSNMA has disadvantages regarding the time to an authenticated fix, which is significantly longer than the standard time to first fix. If the time drift of the trusted real-time clock exceeds 163 seconds, OSNMA authentication can no longer be relied upon [RD6].¹⁶ This limitation is particularly relevant for systems that depend on continuous trusted positioning and timing.

Findings from implementation and testing activities have further highlighted environmental challenges, including physical obstacles, electromagnetic interference, and even unintentional jamming, all of which

¹⁵ European Union Agency for the Space Programme (EUSPA). (2025). *Road and automotive user consultation platform (UCP)*. <https://www.euspa-ucp.eu/>

¹⁶ *Ibid*

can adversely affect OSNMA performance. These results underline the complexity of deploying authenticated GNSS services in real-world automotive environments and illustrate why OSNMA integration, while strategically important, requires careful consideration of system architecture, operational constraints, and regulatory timelines.

The GNSS user requirements for smart tachographs are summarised in the table below;

GNSS user requirements for digital tachograph		
Accuracy	Horizontal	Around 10 meters
	Vertical	Around 10 meters
	Timing	1 second
Availability	Urban canyon	Yes
	Natural canyon	Yes
	Canopy	Yes
	Indoor	No
	Better than 99.9%	High
Robustness	Position authenticity	High: $P_{fa} < 0.2\%$ and $PD > 85\%$
	Robustness to interference	High
Integrity and reliability		Medium: $PL > 25m$ at $IR = 10 \times 10^{-4}$
Size, weight, autonomy (when smartphone or handheld based)	Time a device can run	>5h
TTFF		Between 10 and 15 seconds
Service area	Geographical coverage	National/Regional
Authentication		The positioning system should provide an authentication message
Interference detection		The positioning system shall be able to detect GNSS interferences and inform the driver

Table 14: GNSS user requirements for smart tachographs

Navigation – In-Vehicle Systems (IVS)

In-vehicle road navigation increasingly relies on integrated digital systems rather than standalone devices. Navigation is today primarily delivered through In-Vehicle Systems (IVS) embedded in vehicle dashboards and through smartphone-based applications mirrored onto the vehicle interface via Bluetooth, Android Auto, or Apple CarPlay.

Modern IVS provide advanced route guidance, traffic-aware rerouting, and multi-stop trip planning, increasingly enhanced by real-time hazard alerts. Drivers now expect interactive, data-driven navigation that accounts for live traffic conditions, roadworks, weather, and points of interest across multi-leg journeys. These systems are progressively integrated into wider urban mobility ecosystems, supporting optimised routing, electric-vehicle charging guidance, and safety-related notifications. Key design priorities include real-time updates, seamless cross-device synchronisation, and distraction-free human-machine interfaces.

Precise positioning for these applications is provided by GNSS. GNSS positioning, combined with map-matching algorithms, enables accurate vehicle localisation by correcting satellite-derived positions against digital road networks, even in challenging urban environments.

Beyond traditional navigation functions, new satellite-based services are emerging that extend the role of in-vehicle systems. One such development is the Galileo Emergency Warning Satellite Service (EWSS), which addresses the need for enhanced disaster preparedness. Unlike conventional alerting mechanisms that depend on terrestrial communication networks, EWSS offers an independent channel capable of delivering warnings even when mobile networks are unavailable due to congestion, damage, or poor coverage. This independence provides redundancy and resilience in crisis scenarios, making EWSS a complementary safety service rather than a navigation function.

The implementation of EWSS in automotive environments can follow two main approaches: deployment via Personal Navigation Devices or direct integration into the vehicle architecture. PNDs are standalone, portable electronic devices that provide turn-by-turn navigation and real-time location guidance using GNSS and digital maps. Although their popularity has declined with the rise of smartphone-based navigation, EWSS integration could renew interest in PNDs as dedicated safety devices. A key advantage of this approach is that PNDs are powered directly by vehicles, avoiding battery-drain issues. They also already incorporate the essential hardware for EWSS delivery, including GNSS chipsets, displays, and audio outputs for alerting.

Direct integration of EWSS into vehicle architecture is more complex. While most modern vehicles are equipped with at least one GNSS receiver and sufficient power supply, not all vehicles have suitable display or alerting systems to support consistent EWSS deployment across the fleet. For vehicles lacking such capabilities, PNDs may therefore remain a viable alternative. In addition, integrating EWSS into vehicle systems may strain existing processing resources, as many in-vehicle platforms are designed with limited spare computational capacity. Nonetheless, OEMs, system integrators, and aftermarket devices vendors have expressed interest in EWSS integration, particularly in the context of the industry's broader transition toward software-defined vehicles. In this context, EWSS can be viewed as an additional service layer, complementing existing safety-related functions such as automatic crash notification systems and leveraging existing vehicle antennas without requiring new hardware.

Despite this interest, several implementation challenges remain unresolved.

Alert presentation must be carefully adapted to the in-vehicle environment, as distress sounds may not be appropriate for road safety. Users may also receive the same alert simultaneously via their vehicle system and their smartphone, potentially causing confusion. While highway driving conditions generally offer good reception for Galileo-based alerts, synchronising information across vehicles, road infrastructure, and personal devices remains technically challenging. Finally, users cannot be expected to remain inside their vehicles to receive alerts, requiring EWSS delivery to be seamless across multiple channels while remaining non-intrusive.

From a logistical perspective, implementation depends on access to relevant data streams and the availability of Galileo chipsets capable of receiving EWSS messages. While technical integration is relatively straightforward, it is contingent on chipset support from manufacturers. Alternative data sources, including open-source datasets, may also be considered, though their use would require coordination and agreement with EUSPA. Technical requirements include extremely precise location referencing, with location accuracy on the order of 100 metres, low-latency updates typically within 2–5 minutes from event occurrence to vehicle notification, and support for live updates. Some location-referencing methods, such as OpenLR, are currently not supported, which presents additional challenges. Functional requirements may also include the introduction of new alert codes, for example to instruct vehicles not to proceed under certain hazardous conditions. Legal considerations include compliance with data-protection regulations, clarity on licensing terms, and transparent indication of data sources for commercial use.

Despite strong industry interest, there is currently no clear indication that large-scale EWSS deployment in automotive navigation systems is underway. This is likely linked to the relative immaturity of the service

and the complexity of integration at the service and system levels. Several unresolved challenges remain, including the need to adapt alert presentation to the in-vehicle environment, where distress sounds may not be appropriate for road safety. Users may also receive the same alert simultaneously via their vehicle system and their smartphone, potentially causing confusion. While highway driving conditions generally offer good reception for Galileo-based alerts, synchronising information across vehicles, road infrastructure, and personal devices remains technically challenging. Finally, users cannot be expected to remain confined to their vehicles to receive alerts, making seamless, multi-channel, and non-intrusive delivery essential.

The GNSS user requirements for smart tachographs are summarised in the table below;

<i>GNSS user requirements for road navigation</i>		
Accuracy	Horizontal	Around 10 meters
	Vertical	Around 10 meters
	Timing	Between 1 microsecond and 1 second
Availability	Urban canyon	Yes
	Natural canyon	Yes
	Canopy	Yes
	Indoor	No
	Between 95% and 99.9%	High
Robustness	Position authenticity	Medium: $P_{fa} < 1\%$ and $PD > 75\%$,
	Robustness to interference	High
Integrity and reliability		Medium: $PL > 25m$ at $IR = 10 \times 10^{-4}$
Size, weight, autonomy (when smartphone or handheld based)	Time a device can run	>5h
TTF		Between 10 and 15 seconds
Service area	Geographical coverage	National/Regional
Authentication		The positioning system should provide an authentication message
Interference detection		The positioning system shall be able to detect GNSS interferences and inform the driver

Table 15: GNSS user requirements for In-vehicle navigation systems (IVS)

2.4.2 Current EO use and requirements per application

For a long time, the road infrastructure sector has been employing remote sensing techniques to carry out tasks such as surveying, mapping, monitoring, and disaster response. In addition to this, many recent developments in satellite technologies, data analytics and machine learning have been expanding EO's role.

Nowadays, EO is integrated with the classical geotechnical technologies that consist of sensors and in-situ surveys and inspections providing fundamental information for planning, design, construction, monitoring of the state and the structural health of existing road infrastructures and for the prediction of maintenance and the reduction of geohazard risks.

EO has already become a key technology applied for the continuous monitoring and alerting systems of large infrastructure and limited areas.

EO is also playing an important role in managing and mitigating environmental risks affecting the road infrastructure, and pre-empting their evolution based on climate change, by providing the following information:

- **Identifying Environmental Risks:** EO involves assessing the potential environmental impacts of proposed infrastructure projects before they are implemented. This includes evaluating the potential effects on ecosystems, biodiversity, air and water quality, and communities. By identifying these risks early on, developers can take steps to mitigate or avoid them altogether. Monitoring of impact on environment is needed throughout the lifecycle of infrastructure.
- **Optimizing Design and Location:** Through EO, developers can explore alternative designs and locations that minimize environmental impact. For example, they may choose to build infrastructure in less ecologically sensitive areas or use sustainable materials and construction techniques that reduce resource consumption and pollution. Reliable information on exposure to natural hazards in design stage can save cost and time.
- **Mitigating Environmental Damage:** EO strategies often include measures to mitigate any unavoidable environmental damage. This might involve creating green infrastructure to replace lost habitat, implementing pollution control measures, or restoring ecosystems affected by construction activities. Regulatory or voluntary commitments such as no net biodiversity loss require monitoring.
- **Incorporating Sustainability:** EO encourages the incorporation of sustainability principles into infrastructure development. This could include designing buildings with energy-efficient features, integrating renewable energy sources into transportation projects, or implementing green infrastructure solutions like rain gardens and permeable pavements to manage stormwater runoff.
- **Engaging Stakeholders:** EO typically involves engaging stakeholders, including local communities, environmental groups, and government agencies, in the decision-making process. By considering their input and concerns, developers can better understand the potential environmental impacts of their projects and identify ways to address them.

An additional use of EO is enhancing the climate resilience of infrastructures. Using EO data, a deeper understanding of evolving climate conditions can be obtained and thus, the safeguarding of infrastructures can be improved.

EO-based applications have therefore been clustered in five main groups that follow the stages of infrastructure life cycle:

- **Infrastructure planning and design, finance planning** - applications related to the selection of sites for the construction of new infrastructures and the assessment of the impact that said infrastructure may have on the surrounding environment and the economic trade-off. Those applications support decision making to establish the road standards and traffic services levels and to identify construction techniques and the determination of costs.

- **Infrastructure construction** – applications for the monitoring of ground and structure movements (including those linked to the construction phase), construction progress, and applications for machine guidance and control.
- **Infrastructure operations and maintenance** - applications related to the post-construction phase for the maintenance and mitigation of geological process that can affect the infrastructure and for the strengthening of road resilience and safety. This entails continuous monitoring for the identification of new geological processes and for controlling their evolution. In addition, this group also covers the monitoring of the growth of vegetation surrounding the roads and the identification for the presence of diseased trees, valuable for the maintenance of the infrastructures and avoid incidents.
- **Management of natural hazards** – includes two applications. Management of flood and forest fire risk. Scope includes preparedness, response and recovery activities.
- **Risk and vulnerability assessments** – applications related to assessment of the risks and vulnerability that may compromise their functionality, safety, or integrity related to the climate change and extreme weather events such as flooding, severe storms, landslides, rock fall, avalanches can have a devastating impact on the safety and the expected lifetime of infrastructures which are becoming unreliable, unpredictable, inadequate, and unsafe.

Note: Several terms used in this document refer to technologies, domain or activities which are relevant to several applications related to the monitoring/management of infrastructures. The corresponding definitions are provided in Annex A.1.

User needs	EO Applications covered in the report
Infrastructure Planning and Designing, Finance Planning	• Determination of surface ground movements • Weather Impact Assessments and Adaptation to Climate Change • Determination of soil moisture • Environmental impact assessment
Infrastructure construction	• Geotechnical and structural monitoring during the construction • Worksite progress monitoring • Resource availability planning • Environmental impact monitoring • Monitoring for forensic investigation
Infrastructure operations and maintenance	• Determination and prediction of surface ground movements • Vegetation monitoring • Environmental impact monitoring • Winter service • Pavement deterioration monitoring and prediction • Bridge monitoring
Resilience to natural hazards	• Flood risk management • Forest fire risk management

User needs	EO Applications covered in the report
Climate resilience	• Climate risk assessments and adaptation plans • Road design standards • Nature based solutions

Table 16: User needs and EO Applications

Infrastructure planning and design, finance planning

Description

The planning phase is focused on the surveying of the areas to understand the site characteristics, which include site topography, geology, land cover/land use on the site and its vicinity, terrain stability, exposure to risks and exposure to climate change impacts.

The phase includes the evaluation of environmental and economic trade-off and provides all the information for the identification of the route and infrastructures elements to be build.

After the planning phase of an infrastructure, the design phase is performed with the scope to establish the road standards and traffic services levels and to identify construction techniques and provide the determination of the costs useful for the financial planning.

Overview of user needs

During this phase, the main needs from the user perspective with regard to the above-mentioned site characteristics are the following ones:

- **Topography:** determine the elevation and slope of the site to assess if it is well-adapted to the type of infrastructure to be built.
- **Geology:** analyse soil characteristics (e.g., density, depth of bedrock) to identify possible complications and design plans to remediate these complications.
- **Land cover/land use** be informed about the natural and manmade characteristics of the site land cover and land use characteristics of the potential site and of its surroundings (e.g., presence of built areas, agricultural lands, natural areas, rivers, roads, railways, etc.).
- **Terrain stability:** be informed about the extent to which the potential site is subject to ground deformation and if so, be informed about the associated subsidence risk.
- **Exposure to risks** be informed about the natural risks the potential site is exposed to, such as floods, landslides, subsidence, wildfires, avalanches, earthquakes, tsunamis, soil salinization.
- **Exposure to climate change impacts** be informed about the long-term impacts of climate change the potential site will be exposed to (e.g., higher risk of exposure to droughts).
- **Environmental impact assessment:** be informed about the potential environmental effects of a proposed project, development, or policy before it is implemented.

The planning phase mainly consists of surveying activities and involve the staking out of reference points and markers that will guide the execution of the construction project. These activities include establishing basic lines, grade control and principal points, positioning for corners, delineating the working areas, determining ground profiles and the placement of utilities, and preparing large-scale topographic maps for drainage and site design. The establishment of the coordinate framework for a construction site involves both high-order control surveys and low-order control surveys.

During this phase, users need to perform the construction surveying activities with a sufficient level of accuracy to guarantee that construction operations benefit from a high-quality reference framework.

The infrastructure designing phase is a critical stage in the development of any infrastructure project and it is essential for ensuring financial viability and securing funding for the project. Typically the design phase involves several key steps and considerations:

- **Project Definition:** Clearly defining the objectives, scope, and requirements of the infrastructure project. This includes identifying the purpose of the infrastructure, target users, expected capacity, and performance criteria.
- **Site Selection and Analysis:** Assessing potential sites for the infrastructure project, considering factors such as geographical features, land use, environmental sensitivity, accessibility, and existing infrastructure networks.
- **Feasibility Studies:** Conducting feasibility studies to evaluate the technical, economic, environmental, and social viability of the proposed infrastructure project. This involves analyzing costs, benefits, risks, and potential impacts to determine whether the project is feasible and worth pursuing.
- **Design Concept Development:** Developing conceptual designs and layouts for the infrastructure project, considering factors such as functionality, safety, efficiency, aesthetics, and sustainability. This may involve brainstorming sessions, workshops, and consultations with stakeholders to explore different design options.
- **Engineering Design:** Detailed engineering design of the infrastructure project, including structural design, civil engineering, electrical systems, mechanical systems, and other technical aspects. This phase involves creating detailed drawings, specifications, and plans that will guide the construction and implementation of the project.
- **Environmental Assessment:** Conducting environmental assessments to identify and mitigate potential environmental impacts of the infrastructure project. This may involve Environmental Impact Assessments (EIAs), as discussed earlier, as well as other studies and analyses to ensure compliance with environmental regulations and standards.
- **Stakeholder Engagement:** Engaging with stakeholders, including government agencies, local communities, businesses, and other relevant parties, to gather input, address concerns, and build support for the infrastructure project. Effective stakeholder engagement is essential for ensuring the project's success and minimizing conflicts.
- **Regulatory Approvals:** Obtaining necessary permits, licenses, and approvals from regulatory authorities for the infrastructure project. This may include obtaining planning permissions, environmental permits, zoning approvals, and other regulatory clearances required for construction and operation.
- **Risk Management:** Identifying and managing risks associated with the infrastructure project, including technical, financial, environmental, and social risks. This involves developing risk management plans and strategies to mitigate or address potential threats to project success.
- **Cost Estimation and Budgeting:** Estimating the total cost of the infrastructure project, including design, construction, land acquisition, permits, contingencies, and other expenses. Establishing a realistic budget is essential for ensuring financial viability and securing funding for the project.
- **Value Engineering:** Evaluating design options and construction methods to optimize project performance, quality, and cost-effectiveness. Value engineering involves finding ways to maximize value and minimize waste while meeting project objectives.

Applications	Description
Determination of surface ground movements	Determination of surface ground movements caused by geological processes such as landslides, subsidence, ground failures, sinkholes, uplifts, faults, and seismic displacements poses significant challenges for the planning and projecting of new infrastructures.

Applications	Description
Determination of soil moisture	Determination of soil moisture, the total amount of water, including the water vapor in a land surface provides a basic information for the geotechnical engineering (e.g. to assess column performance).
Weather Impact Assessments and Adaptation to Climate Change	Climate change and extreme weather events such as flooding, severe storms, landslides, rock fall, avalanches can have a devastating impact on the safety and the expected lifetime of infrastructures which are becoming unreliable, unpredictable, inadequate, and unsafe. Activity is relevant in design phase but is described in more detail in the dedicated application in subsequent section.
Environmental impact assessment	An Environmental Impact Assessment (EIA) in European road infrastructure projects is a legally required process that evaluates how a proposed road or highway may affect the environment before it is approved or built. Under the Directive 2011/92/EU on Environmental Impact Assessment project developers must assess impacts such as noise, air quality, biodiversity, water, landscape, and climate effects, and propose mitigation measures. The process includes preparation of an environmental report, consultation with authorities and the public, and consideration of the findings by the competent authority before granting development consent.

Table 17: Applications for Road Infrastructures Planning and Designing, Finance planning

ID	EUSPA-EO-UR-ROA-0010
Application	Determination of surface ground movements
Users	Infrastructure owners and/or operators.
Application	
Operational scenario	Millimetric determination of surface ground movements derived by geological processes such as landslides, subsidence, ground failures, sinkholes, uplifts, faults, and seismic displacements poses significant challenges for the planning and projecting of new infrastructures.
Size of area of interest	In general, a buffer of 500 m around the road infrastructure is sufficient but it can be incremented depending on the geomorphology of the area to monitor and by the origin of ground movements.
Frequency of information	Once – during site assessment. Cadence of supporting observations shall be commensurate to behaviour of deformation phenomena.
Type of service (continuous, forecasting, one-off?)	One off analysis of historical data.
Satellite EO Requirements	
Spatial resolution	From 1 m up to 100 m
Temporal resolution	From daily to monthly

Spectral resolution	N/A
Other requirements (if applicable)	Spectral range: SAR X,C and L bands Acquisition orbit geometry – polar and inclined for N-S lateral displacement.
Technology used	MTInSAR with PSI, SBAS or other techniques
Data supplements	GNSS and precise levelling measurements for the determination of the movements of ground reference points. Extensometers and determination of displacements between ground points and inclinometers to measure the tilt or slope of the ground. Piezometers for the determination of the level of ground water and pluviometers.

Table 18: EO requirements for “Determination of surface ground movements”

ID	EUSPA-EO-UR-ROA-0020
Application	Determination of soil moisture
Users	Infrastructure owners and/or operators.
Application	
Operational scenario	Determination of soil moisture, the total amount of water, including the water vapor in a land surface provides a basic information for the geotechnical engineering.
Size of area of interest	A buffer up to 2000m around the road infrastructure
Frequency of information	Ad-hoc
Type of service (continuous, forecasting, one-off?)	Ad-hoc
Satellite EO Data Requirements	
Spatial resolution	From 10 m up to 100 m
Temporal resolution	From daily to weekly
Spectral resolution	N/A
Other requirements (if applicable)	Spectral range: SAR (C, X, L bands) Multi and hyper spectral
Technology used	SAR, PolSAR
Other data sources	In-situ inspection and sensors such as piezometers.

Table 19: EO requirements for “Determination of soil moisture”

ID	EUSPA-EO-UR-ROA-0030
Application	Weather Impact Assessments and Adaptation to Climate Change
Users	Infrastructure owners and/or operators, environmental and governmental agencies, authorities, financial institutions and insurances.
Application	
Operational scenario	Determination of the risk and of the vulnerability for the planning of safety, durable and resilient infrastructures. Climate change and extreme weather events such as flooding, severe storms, landslides, rock fall, avalanches can have a devastating impact on the safety and the expected lifetime of infrastructures which might become unreliable, unpredictable, inadequate, and unsafe. ISO 14090 and 14091 provides guidance on climate risk assessments.
Size of area of interest	Road network

Frequency of information	Ad-hoc
Type of service (continuous, forecasting, one-off?)	Ad-hoc
Service Provider Satellite EO Requirements	
Spatial resolution	From 10 m up to 100 m
Temporal resolution	Depending on data input from hourly to monthly
Spectral resolution	SAR (C, X, L) Multi and hyper spectral, Meteosat
Other requirements (if applicable)	Not applicable
Technology used	Earth observation, Earth systems modelling (Digital Twins) spanning climate, extreme weather, soil, water and vegetation systems and their interactions. Climate risk assessment methodology.
Data supplements	Atmospheric, geomorphological, and geographical data, historical archives.

Infrastructure construction

Description

Table 20: EO requirements for “Weather Impact Assessments and Adaptation to Climate Change”

Construction operations cover the activities carried out between the end of the “site selection and planning” phase and the time at which the infrastructure enters its operational phase. They include activities such as earth-moving, excavation, concrete work, installation work, etc. Depending on the type of infrastructure, they may also include activities such as tunnelling and boring.

Overview of user needs

The monitoring of construction progress aims at verifying that construction operations are progressing in line with the foreseen schedule and with design plans. Users need to identify delays and deviations as soon as possible in the process while minimising inspection costs. Users need to assess location and volumes of bulk material on work sites, track presence and activity of machinery. Users need to assess availability of key natural resources such as water especially during in locations and times of water scarcity.

Applications	Description
Geotechnical and structural monitoring during the construction	Continuous geotechnical and structural monitoring to control slopes and works to be built during the construction of a road infrastructure such as the excavation of tunnels, the construction of viaducts, bridges, and road sections.
Worksite progress monitoring	Road infrastructure construction progress monitoring refers to the continuous tracking and verification of how construction activities advance relative to the approved design, schedule, and budget. Infrastructure managers and contractors need to monitor the completion status of works (e.g., earthworks, structures, pavement layers), quantities executed, and spatial extent of construction, ensuring that work follows the design specifications and planned timeline. This monitoring supports project management, quality control, contractor payments, risk management, and early detection of delays or deviations so corrective actions can be taken during the construction phase.
Resource availability planning	Road construction works require large amounts of natural resources. Water is scarce and rationed in drought prone areas and seasons. Construction work planners need near term (weeks) and seasonal (months) forecasts of water availability to plan their construction work. Effective monitoring and prediction help project managers anticipate shortages, optimize logistics and procurement, schedule works efficiently, and avoid delays or cost overruns during road construction projects.
Environmental impact monitoring	During the construction phase of road infrastructure, environmental impact monitoring ensures that actual impacts remain within the limits defined during the Environmental Impact Assessment and environmental permits. Authorities, contractors, and road infrastructure managers need to monitor air quality (dust and emissions), noise and vibration, water quality and runoff, soil disturbance and erosion, waste generation, and impacts on nearby ecosystems or protected habitats. Monitoring is used to verify compliance with environmental regulations, detect unexpected impacts early, and trigger mitigation measures such as dust suppression, sediment control, noise barriers, or adjustments to construction practices. Continuous monitoring also provides documented evidence for regulators and stakeholders that environmental protection commitments are being respected during the works.
Monitoring for forensic investigation	For road infrastructure construction (including tunnels), forensic investigation needs arise when accidents, structural failures, excessive deformation, or safety incidents occur during or after construction. Investigators require accurate records of construction activities, geotechnical conditions, design specifications, material properties, and monitoring data (e.g., deformation, settlement, groundwater levels, vibration) to reconstruct what happened and determine the root causes. These needs support liability assessment, compliance verification, and lessons learned for future projects, particularly in complex works such as tunnels where geological uncertainty, excavation methods, and support systems can significantly influence safety and structural performance.

Table 21: Applications for Road Infrastructures Construction

ID	EUSPA-EO-UR-ROA-0040
Application	Geotechnical and structural monitoring during the construction
Users	Infrastructure owners and/or operators, construction and public works companies, financial institutions financing the construction that can include international organisations.
Application	
Operational scenario	Continuous geotechnical and structural monitoring to control slopes and works to be built during the construction of a road infrastructure such as the excavation of tunnels, the construction of viaducts, bridges, and road sections.
Size of area of interest	The entire area susceptible to ground shifts caused by the construction or excavation of an infrastructure project.
Frequency of information	Weekly
Type of service (continuous, forecasting, one-off?)	Continuous monitoring and near-term forecasting and alerting.
Service EO Data Requirements	
Temporal resolution	Daily to weekly
Spectral resolution	N/A
Other requirements (if applicable)	Observation of horizontal surface motion in all directions; observation of surface motion under low and high vegetation.
Technology used	MTinSAR with PSI and SBAS techniques
Other data sources	GNSS and precise levelling measurements for the determination of the movements of ground reference points. Piezometers for the determination of the level of ground water and pluviometers, historical archive

Table 22: EO requirements for “Geotechnical and structural monitoring during the construction”

Infrastructure operations and maintenance

Description

Built infrastructures can suffer from natural phenomena (e.g. ground deformation, vegetation encroachment, extreme weather events, natural hazards) or anthropogenic activities (e.g. construction works in the vicinity of existing infrastructures). In this document, post-construction operations refer to the monitoring of the state (mainly the structural health) of existing infrastructures once their construction is completed.

Overview of user needs

Users need to ensure the protection of their infrastructures, to optimise maintenance operations and possibly to extend the infrastructure lifecycle within safety margin. To achieve this, they need to monitor aging damages, to improve maintenance effectiveness in terms of planning and cost reduction, reduce risks notably from more frequent extreme weather events and predict possible failures.

GNSS contribution

Concerning GNSS, the stability of built infrastructure can be monitored via high-precision GNSS methods, e.g. by post-processing of static relative GNSS observations at field control points (established directly into or in the vicinity of the object) with station data from local or global CORS networks. In addition, GNSS data may be utilised to feed various smart sensors, mounted into the infrastructure body for real-time stability monitoring.

EO contribution

As far as EO is concerned, it is considered very cost-effective for monitoring infrastructure on a large scale and with high frequency.

For the infrastructure monitoring, several user needs have been considered and are described in the table below.

Applications	Description
Determination of surface ground movements (See Table 17)	Determination of surface ground movements derived by geological processes such as landslides, subsidence, ground failures, sinkholes, uplifts, faults, and seismic displacements poses significant challenges for the for the maintenance and mitigation of existing ones. A continuous monitoring is almost requests for the identification of new geological processes and for controlling their evolution.
Vegetation monitoring	The monitoring of vegetation, growth, and the identification of diseased trees surrounding the roads can be useful to the maintenance of road infrastructures and avoid incidents.
Environmental impact monitoring	During the operations and maintenance phase of road infrastructure, environmental impact monitoring focuses on tracking the long-term effects of road traffic and maintenance activities on the surrounding environment. Road operators need to monitor air pollution from traffic, noise levels, stormwater runoff and water quality, soil contamination, and impacts on nearby ecosystems and wildlife corridors. The purpose is to ensure compliance with environmental regulations, evaluate the effectiveness of mitigation measures (e.g., noise barriers, drainage systems),

Applications	Description
	and detect emerging environmental risks so that maintenance actions or operational changes can be implemented to reduce environmental impacts over the road's lifecycle.
Winter service	Road winter service operations require timely and accurate data to support decisions on snow clearance, de-icing, and traffic safety management. Road operators need high-resolution weather forecasts, road surface temperature predictions, precipitation type and intensity (snow, freezing rain), wind conditions, and humidity, as well as observations from road weather stations and pavement sensors that measure surface temperature, moisture, and ice formation. Information on road geometry, elevation, shading, traffic levels, and historical treatment records helps refine predictive models of when and where icy conditions will occur. These data allow winter service managers to optimize the timing and location of salting, ploughing, and other treatments, improving safety while minimizing costs and environmental impacts from excessive salt use.
Pavement deterioration monitoring and prediction	Road infrastructure managers need to monitor and predict pavement deterioration to maintain safety, ride quality, and cost-effective asset management across the road network. This requires systematic data on pavement condition indicators such as cracking, rutting, surface roughness, skid resistance, and structural deformation, along with information on traffic loads, axle weights, climate conditions, and maintenance history. By combining periodic inspections, sensor measurements, and predictive deterioration models, operators can forecast how pavement condition will evolve over time and identify sections likely to fail prematurely. These insights support preventive maintenance planning, prioritization of rehabilitation works, and optimization of lifecycle costs while minimizing disruptions to road users.
Bridge monitoring	Bridge safety monitoring requires continuous or periodic data that describe the structural condition, loads, and environmental influences affecting the bridge. Infrastructure managers need measurements of structural deformation, strain, vibration, displacement, and tilt, as well as information on traffic loads, temperature variations, wind, and water levels or scour around foundations. Regular inspection data on cracks, corrosion, joint condition, and deck deterioration are also essential to detect early signs of structural problems. By integrating these datasets into structural health monitoring and predictive models, operators can identify emerging risks, assess structural integrity, and plan timely maintenance or restrictions to ensure bridge safety and reliability. A recent study by CEDR project INFRACOMS outlines detailed monitoring needs, specific observables and available technologies with MTInSAR being among the those with the higher maturity.

Table 23: Applications for Road infrastructures monitoring operations and maintenance

ID	EUSPA-EO-UR-ROA-0050
Application	Vegetation monitoring
Users	Infrastructure owners and/or operators.
Application	
Operational scenario	The presence of vegetation along and close to the roads can create obstacles and impact the transport. The monitoring of the status and growth of vegetation along

	the road corridors can prevent hazards such as fallen trees or overgrown branches that can interrupt the transport. The goal is the determination of the distance between vegetations and roads. Identification of the types of vegetation, and determination of height, species and volume of trees. Depending on local context and maintenance strategies road stakeholders may need vegetation data for: • Drainage infrastructure is prone to overgrowth and loss of function resulting in chronic (gradual loss of earthworks or structural integrity) or acute damage (washout, slope failure etc). • dry vegetation mapping for fire hazard management. • Roadside areas are vulnerable to invasive species. Road managers need to monitor their presence to inform invasive species management decisions.
Size of area of interest	A buffer until 100m around the road infrastructure
Frequency of information	Depending on parameter, local context and asset maintenance strategy – from weekly to annual.
Type of service (continuous, forecasting, one-off?)	Continuous
Satellite EO Data Requirements	
Spatial resolution	Depending on the parameter
Temporal resolution	Depending on parameter, from weekly to annual
Spectral resolution	Multi and hyper spectral
Other requirements (if applicable)	Not applicable
Technology used	VHR multispectral, Multi and hyperspectral and Lidar for mapping tasks, Satellite, airplane, drone, vehicle and hand EO instruments. Machine learning.
Data supplements	VHR DTM, soil map, hydrography, cadastre, on-ground tree inspection data

Table 24: EO requirements for “Vegetation monitoring”

Resilience to natural hazards

Flood monitoring

Description

Flood monitoring is typically performed using a combination of technologies, data sources, and processes to detect, track, and respond to potential or ongoing flooding events.

Overview of user needs

Flood risk modelling, early warning, and event monitoring are essential for managing the vulnerability of road infrastructure to extreme precipitation and river overflow. Infrastructure managers need models that integrate topography, drainage networks, soil conditions, and hydrological data to simulate how rainfall translates into surface runoff, river discharge, and potential inundation of roads, bridges, and tunnels. Early warning systems combine weather forecasts, river gauge data, and real-time monitoring to alert operators before critical thresholds are reached, allowing traffic management measures, asset protection, and emergency response to be activated. During flood events, monitoring of water levels, flow velocity, and the spatial extent of inundation helps operators assess impacts on the network and supports rapid recovery and post-event analysis.

The key components of flood monitoring are:

- **Remote Sensing and Satellite Imagery:** Remote sensing technologies, including satellites, are used to monitor weather patterns, precipitation levels, and changes in water bodies such as rivers and lakes. This data can help predict and monitor potential flood events.
- **Radar Systems:** Weather radars are used to detect heavy rainfall and storm systems. Doppler radar, for instance, can measure the speed and direction of precipitation, helping forecasters determine if a weather event may lead to flooding.
- **Aerial and Drone Surveillance:** Drones and aerial surveys can be used to assess the extent of flooding and damage in real-time. They are particularly valuable for accessing areas that are difficult to reach.
- **Weather Forecasting:** Meteorological data and computer models are used to predict weather conditions and potential rainfall amounts. These forecasts can help authorities anticipate flood events and take preventative measures.
- **Flood Modelling:** Computer models are used to simulate potential flooding scenarios based on various factors, such as rainfall, snowmelt, topography, and land use. These models can help predict the extent and impact of floods.
- **GIS (Geographic Information Systems):** GIS technology is used to create floodplain maps, which show areas prone to flooding. These maps help in planning and response efforts.
- **River Gauges:** River gauges are instruments placed in rivers and streams to monitor water levels. They provide real-time data on water height and can trigger flood warnings if levels rise significantly.
- **Ground Sensors:** Ground-based sensors can monitor various environmental parameters, such as soil moisture and water quality, which can provide early warning signs of potential flooding.

For the Flood monitoring, several user needs have been considered and are described in the table below.

Applications	Description
Flood risk management	Road infrastructure managers need data support ability to prepare, respond and recover from floods. Preparedness involves flood risk assessment, adaptation planning and implementation. During floods it is necessary to identify the area and the road infrastructures that are involved in the flood, helping

Applications	Description
	the authorities to monitor the evolution of the situation, and in the management of the closing or reopening of the roads. Post event infrastructure has to be inspected for damage. EO data supports all of the above.

Table 25: Applications for Disaster Response to Floods

ID	EUSPA-EO-UR-ROA-0060
Application	Flood monitoring
Users	Infrastructure owners and/or operators. Local, regional, and national authorities and institutions.
Application	
Operational scenario	During floods, users need to identify road infrastructures that are involved in flood, helping the authorities to monitor the evolution of the situation, and in the management of the closing or reopening of the roads.
Size of area of interest	Road infrastructure network
Frequency of information	Ad-hoc, continuous monitoring
Type of service (continuous, forecasting, one-off?)	Risk assessment – ad hoc. Early warning – continuous Event monitoring – ad hoc
Satellite EO Requirements	
Spatial resolution	From 10 until 100 m
Temporal resolution	From daily to weekly
Spectral resolution	Not applicable
Other requirements (if applicable)	Not applicable
Technology used	Climate, seasonal, near term and now-casting weather data. Flood modelling.
Data supplements	Inputs to flood modelling – hydro-enforced DTMs, hydrography, soil sealing, soil type, soil moisture, land cover,

Table 26: EO requirements for “Flood risk management”

Forest fire risk management

Road infrastructure managers require data to assess and monitor fire hazards along road corridors and surrounding landscapes, particularly in regions exposed to drought, heatwaves, and flammable vegetation. Key data needs include vegetation type and density, fuel moisture conditions, land cover, proximity of forests or grasslands to road corridors, and historical fire occurrence. Meteorological data such as temperature, wind speed, humidity, and drought indices are also important to estimate ignition probability and potential fire spread near transport infrastructure. These datasets support fire risk mapping and planning of preventive measures, such as vegetation clearing, creation of firebreaks, and prioritization of high-risk road segments.

During high-risk periods and active fire events, infrastructure managers need near-real-time monitoring and predictive information to support operational decisions. This includes fire detection data, smoke and thermal observations, fire spread forecasts, and information on visibility conditions affecting traffic safety. Data on traffic flows, road network topology, and nearby settlements are also required to manage road closures, evacuation routes, and emergency access for firefighting services. Integrating these data streams enables road authorities to reduce fire impacts on infrastructure, maintain network resilience, and protect road users and surrounding communities.

Climate resilience

Section contains to applications Climate risk assessment and associated adaptation planning. Despite road design standards falling within system level adaptation measures, we describe it in a dedicated section.

Climate risk assessments and adaptation plans

Description

Risk and vulnerability assessments related to climate change are essential tools for understanding the potential impacts of climate change on infrastructures and help to develop strategies for adaptation and mitigation and reduce the economic impact. Continuous monitoring and review of climate risks and vulnerabilities are critical to assess the effectiveness of adaptation and mitigation strategies and adjust as needed.

The main types of risks to be considered include:

Hydrological hazards (water-related)

- River flooding and flash floods
- Coastal flooding and storm surges
- Intense precipitation leading to surface water flooding
- Drainage overload and culvert failure

Geotechnical hazards influenced by climate

- Landslides and slope instability
- Rockfalls and debris flows
- Soil erosion and embankment failure
- Subsidence related to groundwater changes

Temperature-related hazards

- Extreme heat and heatwaves (pavement rutting, rail/bridge expansion)
- Freeze–thaw cycles
- Permafrost thaw (in cold regions)

Cryospheric and winter hazards

- Snowstorms and snow accumulation
- Ice formation and freezing rain
- Avalanches affecting mountain roads

Wind and storm hazards

- Strong winds affecting vehicles and structures
- Storm damage to road assets
- Falling trees and debris on roads

Drought and wildfire hazards

- Drought affecting soil stability and vegetation
- Wildfires impacting road corridors, visibility, and infrastructure

Overview of user needs

Process of climate risk assessment is guided by ISO 14090 - Adaptation to climate change - Principles, requirements and guidelines, and ISO 14091 Adaptation to climate change — Guidelines on vulnerability, impacts and risk assessment. These are supplemented by frameworks and guidance Risk Management for Roads in a Changing Climate (RIMAROCC) (CEDR, 2010) and International Climate Change Adaptation Framework for Road Infrastructure project (PIARC, 2015). We invite readers to consult PIARC and CEDR frameworks for in-depth analysis on impact chains, vulnerability and hazard classification.

The key components of risk and vulnerability assessments is **Climate data collection and analysis**. Assessors gather historical climate data and future climate projections to understand temperature changes, precipitation patterns, sea-level rise, and extreme weather events in the region.

Infrastructure managers use a variety of input datasets summarized in the figure below (CEDR ICARUS Baseline report on determining impacts and risk due to climate change). These are provided by national met offices, Copernicus Climate change service, specialized private service providers. Key attributes are spatial resolution and level of processing (from raw climate data and simulations to risk assessments).

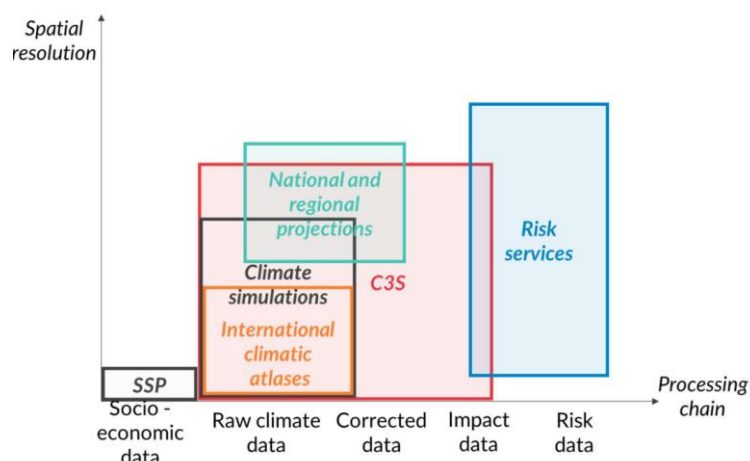


Figure 8: Climate data sources by resolution and processing level

Application	Description
Weather Impact Assessments and Adaptation to Climate Change	Climate change and extreme weather events such as flooding, severe storms, landslides, rock fall, avalanches can have a devastating impact on the safety and the expected lifetime of infrastructures which are becoming unreliable, unpredictable, inadequate, and unsafe.

Table 27: Applications for Assessing the weather impact and the climate risk

ID	EUSPA-EO-UR-ROA-0070
Application	Weather Impact Assessments and Adaptation to Climate Change
Users	Infrastructure owners and/or operators, environmental and governmental agencies, and authorities, financial institutions, insurance companies.
Application	
Operational scenario	Climate change and extreme weather events such as flooding, severe storms, landslides, rock fall, avalanches can have a devastating impact on the safety and the expected lifetime of infrastructures which are becoming unreliable, unpredictable, inadequate, and unsafe.
Size of area of interest	Road network
Frequency of information	Ad-hoc
Type of service (continuous, forecasting, one-off?)	One-off forecasting
Satellite EO Requirements	
Spatial resolution	From 10 m up to 10km depending on the input.
Temporal resolution	From weekly to monthly
Spectral resolution	SAR (C, X, L) Multi and hyper spectral, Meteosat
Other requirements (if applicable)	Uncertainty assessment of climate forecasts
Technology used	Climate modelling, extreme weather modelling.

Other data sources	Atmospheric, geomorphological, and geographical data and models, historical archives
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Table 28: EO requirements for “Assessing the weather impact and the climate risk”

<u>Case study: ADAPTARE</u> ADAPTARE is a unique risk assessment tool developed by Ferrovial in collaboration with the University of Cantabria. The tool aims to identify potential climate risks to Ferrovial’s infrastructure projects, which typically span over long periods of time (i.e., 90 years) making them highly susceptible to climate impacts. By leveraging space data and climate models, ADAPTARE can forecast potential risk scenarios by analysing the hazards, vulnerability exposure, and sensitivity of the infrastructures to climatic risks. The tool plays a crucial role in the stages of infrastructure planning and construction. It helps evaluate the mid-to-long-term possible impact of climate change, which then guides decision-making throughout the construction process. This extends from site selection to the choice of materials and structural design, considering possible climate-related risks (e.g., a toll road is planned to be built in a specific area, the platform assesses that this area is prone to flooding and then determines the mid- and long-term economic benefit of investing in introducing materials better suited to flooding when building the infrastructure). Through EO, ADAPTARE addresses specific climate risks such as flooding, extreme weather temperatures, and severe weather conditions such as forest fires and sea level rise. Factors that present challenges for Ferrovial’s portfolio of investments, particularly for toll road and airport infrastructures, energy grids, and desalinisation plants. Regarding the implementation of EO into the platform, there are two design conditions which are fundamental, granularity of the models and scale and frequency of observation. The need for diverse scales and granularities is determined by the type of infrastructure, ranging from small spaces to large linear infrastructures. For instance, when dealing with projects like desalinisation or wastewater management, ADAPTARE works at a scale and granularity of hundreds of meters. Frequency of observation also varies depending on the activity being monitored. For mid-to-long-term impacts less frequency is needed, whereas for extreme weather events such as fires, higher frequencies are needed to capture real-time effects. This contributes towards both tactical and strategic decision-making processes.
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Road design standards

Updating road design standards requires comprehensive data on how existing road infrastructure performs under real operating conditions and evolving environmental stresses. Road authorities need long-term datasets on traffic volumes, axle loads, vehicle types, pavement performance, structural durability of bridges and tunnels, and failure or maintenance records to understand how current designs behave over time. In addition, information on geotechnical conditions, drainage performance, and material behaviour helps engineers evaluate whether existing design assumptions remain valid or require revision.

With climate change and evolving mobility patterns, design standards also need data on extreme weather conditions, temperature trends, precipitation intensity, flooding frequency, and other environmental loads that affect infrastructure resilience. Combining historical observations with climate projections, hydrological modelling, and hazard maps allows engineers to reassess parameters such as drainage capacity, pavement temperature resistance, slope stability requirements, and bridge hydraulic clearance.

These data support evidence-based updates of design guidelines so that future road infrastructure can remain safe, durable, and resilient under changing climatic and operational conditions.

Nature based solutions

Implementing nature-based solutions (NbS) around road infrastructure—such as vegetated swales, retention basins, green embankments, restored wetlands, or wildlife corridors—requires diverse data to support planning and design. Road authorities need information on topography, soil properties, hydrology, groundwater levels, land cover, and local ecosystems to identify suitable locations and determine the expected performance of these interventions. Climate and meteorological data, including precipitation intensity, runoff patterns, and temperature conditions, are also important to ensure that NbS can effectively manage stormwater, reduce erosion, mitigate heat, or enhance biodiversity along road corridors.

During impact assessment and long-term maintenance, additional data are required to evaluate how these solutions perform over time and whether they deliver the intended environmental and operational benefits. This includes monitoring vegetation health and growth, soil moisture, water retention capacity, sediment accumulation, biodiversity indicators, and potential impacts on nearby habitats or water bodies. Infrastructure managers also need data on drainage performance, slope stability, and maintenance activities to ensure that NbS continue to function effectively without compromising road safety or structural integrity. Continuous monitoring and evaluation help optimize maintenance strategies and demonstrate the effectiveness of nature-based approaches in improving the resilience and environmental performance of road infrastructure.

Case study: National Highways natural habitat baseline.

A useful case study comes from a project where **Ramboll** worked with National Highways (NH) UK to develop an inventory of natural habitats along England's Strategic Road Network. The project established a baseline map of habitats and land cover along 7000 kilometres of motorway over 30 000ha of verges and lands adjacent to the carriageways. The goal was for the NH to understand how its infrastructure interacts with surrounding ecosystems and meet **its voluntary** biodiversity policy targets, including a 10% biodiversity net gain by 2025 requirement. Using Earth-observation data and machine-learning tools, Ramboll created digital maps showing the distribution of habitats across the road estate.

The system produced a network-wide inventory of land cover and habitat types, identifying the most common ecosystem categories across the road corridor and adjacent land. In the prototype, 14 major land-cover classes were mapped, allowing the road authority to identify biodiversity hotspots and locations where habitats could be enhanced or reconnected. The resulting geospatial dataset enabled National Highways to track biodiversity performance across the network and assess how infrastructure projects affect surrounding ecosystems, something that would be extremely difficult and expensive to achieve through traditional field surveys alone.

Copernicus Sentinel-2 data played a key role in this work. The satellite's multispectral imagery and frequent revisit time allowed Ramboll to classify vegetation and land cover across the entire road network and detect changes over time. Because Sentinel-2 provides consistent, repeatable observations, the system can be updated regularly to monitor habitat change, identify areas of biodiversity improvement or decline, and support annual reporting on environmental performance for the road authority.

Transversal challenges in using EO for road infrastructure monitoring

The EO-based monitoring of road infrastructures requires a multidisciplinary approach, involving remote sensing experts, data scientists, engineers, and policymakers. These players can encounter a series of challenges in using EO, including:

- **Data Processing and Analysis:** Copious amounts of data are generated by EO systems. Processing and analysing these data to detect changes or damage to infrastructure can be time-consuming and resource intensive .
Data processing and analysis are a huge challenge especially for SAR data. The setting of parameters applied to the SAR processing of images, and the time-series analysis of displacements, can influence and provide different results. For this reason, the analysis of results requires multidisciplinary approach to be conducted with the supervision of experts and considering the geotechnical and geomorphological features of the monitored area.
- **Weather Conditions:** Weather conditions can impact the quality of EO data. Cloud cover, for instance, can obscure the view of the Earth's surface. Overcoming this challenge may require the use of radar or other sensors that can penetrate clouds.
- **Data Integration:** road infrastructure monitoring often requires the integration of data from multiple sources, including aerial photography, and ground-based sensors. Ensuring compatibility and accuracy in such integrated systems is a challenge.
- **Data Accessibility:** While there is a wealth of EO data available, accessing and using this data can be challenging. It may require special software and expertise, which is not always readily available to those who need it.
- **Data Privacy and Security:** Road networks data can be sensitive, and there are privacy and security concerns related to collecting and using EO data, especially in urban areas.
- **Legal and Regulatory Issues:** There can be legal and regulatory challenges related to using EO data, especially when it comes to issues like privacy, data ownership, and international cooperation.
- **Human Error:** Interpreting EO data and identifying changes or issues in infrastructure can be subject to human error, which underscores the need for automation and machine learning techniques to assist in analysis.

2.4.3 Current SATCOM use and requirements per application

In their roadmap for the integration of SATCOM in automotive, 5GAA identifies data rate requirements as a key factor in the classification of SATCOM applications. Based on this, automotive SATCOM applications are grouped into three broad categories [RD12]:¹⁷

- Narrowband (up to 400 kbps);
- wideband (up to 10 Mbps);
- and broadband (> 10 Mbps).

The deployment of SATCOM technologies for automotive applications is expected to follow a phased approach. In the near term, geostationary (GEO) satellites, are expected to become commercially available first. These systems will support ultra-narrowband connectivity, with data rates of up to around 10 kbps, using the NB-IoT technology defined by 3GPP.

At a later stage, low-Earth orbit (LEO) satellite constellations, also based on 3GPP Release 17 Non-Terrestrial Networks (NTN), are expected to provide narrowband services with data rates of up to 400 kbps.

In subsequent phases, further satellite developments are anticipated to support wideband and broadband services, exceeding 10 Mbps, building on NR NTN specifications in Releases 17 and 18.

At present, no entirely new automotive use cases have been identified that rely exclusively on NTN. Instead, the main value of NTN lies in its ability to support existing automotive connectivity use cases under conditions where terrestrial mobile networks are insufficient or unavailable. In particular, NTN can provide connectivity in areas with permanent gaps in terrestrial coverage, such as remote or sparsely populated regions, thereby improving service ubiquity. NTN can also enhance network resilience by maintaining connectivity during temporary outages caused by disasters, infrastructure failures, or extreme congestion affecting terrestrial networks.

From a system perspective, NTN are therefore viewed as a complement to terrestrial networks rather than a replacement. NTN can either provide connectivity where no terrestrial network is available or improve service quality, for example by increasing data rates where terrestrial coverage is limited. However, NTN connectivity requires a clear line of sight between the vehicle terminal and the satellite, meaning that it cannot provide service in tunnels, underground parking facilities, or most indoor environments.

In general, existing user needs and requirements for connected vehicle applications can be reused when considering the introduction of SATCOM. However, not all implementation options for a given application may be compatible with NTN connectivity, and several key connectivity-related service-level requirements must be considered:

- Data rates: refer to the amount of information exchanged, including the volume of data and the required data rate. This determines the type of satellite link (narrowband, wideband or broadband) and may limit the feasibility of certain services.
- Latency needs (low/medium/high): satellite systems inherently introduce additional delays including the long distances signals must travel. Depending on the satellite orbit, typical one-way end-to-end latency is estimated at approximately 35 milliseconds for LEO satellites, 95 milliseconds for medium-Earth orbit (MEO) satellites, and 285 milliseconds for GEO satellites. These delays must be taken into account when designing time-sensitive automotive services.
- Availability needs (low/medium/high); the need for an application to continue operating when the signal is temporarily unavailable. Temporary loss of availability may result from limited-service reliability, satellite connectivity being affected by environmental conditions,

¹⁷ 5G Automotive Association. (2024). *Maximising the benefit of future satellite communications for automotive. Technical report*. <https://5gaa.org/content/uploads/2024/09/5gaa-ntn-ras-technical-report.pdf>

signal obstruction, or constrained satellite resources. In addition, high user density can impact availability, as a large number of vehicles within the coverage area of a single satellite may compete for limited connectivity capacity.

Narrowband applications

Narrowband satellite communication typically supports low data rates, often in the range of a few kilobits per second. This is sufficient for applications that require small, infrequent data exchanges, such as vehicle tracking, remote diagnostics, or emergency alerts. These services are often referred to as “mission-critical” or “safety” applications, where reliability and coverage are more important than speed. Narrowband services are commonly delivered over lower frequency bands, such as the L-band, which offer good signal penetration and are less affected by weather or obstacles.

A significant number of automotive applications require only the transmission of only small amounts of data. These applications are usually classified as safety applications. These are all accessible by narrowband connectivity with data rates up to 400 kbps in uplink, downlink, or both.

Out of these applications, in this report the following applications will be covered:

- Emergency call: Provides immediate voice or data connectivity to emergency services when terrestrial networks are unavailable, ensuring safety in critical situations.
- Traffic management in disaster situations: Enables communication for rerouting and coordination during natural disasters or major incidents where terrestrial infrastructure is compromised.

The SATCOM user requirements for narrowband applications are summarised in the tables below;

<i>SATCOM user requirements for emergency call</i>	
Users	Drivers, Emergency Services
Operational scenario	Vehicle accident or breakdown in remote area
End user application needs	Reliable voice/data
Frequency band	L-band
Data traffic requirements	~512 Kbps
Latency	Low latency
Availability need	High
Technology	MSS
SATCOM access technology	Mobile terminal, integrated in vehicle

Table 29: SATCOM user requirements for emergency call

<i>SATCOM user requirements for traffic management in disaster situation</i>	
Users	Government agencies, OEMs
Operational scenario	Disaster recovery zone with terrestrial outage

SATCOM user requirements for traffic management in disaster situation	
End user application needs	Reliable voice/data
Frequency band	L-band
Data traffic requirements	~512 Kbps
Latency	Low latency
Availability	High
Technology	MSS
SATCOM access technology	Mobile terminal, integrated in vehicle

Table 30: SATCOM user requirements for traffic management in disaster situation

Wideband applications

In satellite communications for vehicles, the term “wideband” typically refers to the ability to support higher data rates and more advanced communication protocols. It is important to note that wideband does not necessarily mean using high-frequency satellite bands like Ku or Ka. In fact, wideband automotive satellite links can also be implemented in lower frequency bands, such as the L-band or S-band.

Applications that require wideband data connectivity need data rates from 0.4 to 10 Mbps. The following applications belong in this category:

- Road and safety information in remote areas: Delivers essential safety alerts and road condition updates in regions with limited or no terrestrial coverage.
- Local hazard and traffic information: Supports real-time exchange of localized hazard warnings and traffic updates to improve driver awareness and safety.
- Remote access: Allows secure remote diagnostics and control of vehicle systems for maintenance or troubleshooting purposes.
- Vehicle health monitoring: Transmits periodic telemetry and diagnostic data to backend systems for predictive maintenance and fleet management.
- Teleoperated Driving Support (objects): Provides low-latency connectivity for remote driving assistance, including object detection and control commands.
- Data collection and sharing for HD maps: Uploads high-definition map data from vehicles to cloud platforms for accurate navigation and automated driving.
- Hazard Information Collection and Sharing: Aggregates and shares hazard-related data (e.g., accidents, obstacles) to improve situational awareness for connected vehicles.
- OTA including Delta Update and Update Message: Delivers software patches and updates over-the-air, ensuring vehicles remain secure and up to date without physical intervention.
- Audio Streaming and Data File Access: Supports infotainment services such as music streaming and file downloads for passenger convenience.
- Help Assist: Provides remote assistance features, including breakdown support or concierge services, via satellite connectivity.
- Audio Streaming and Data File Access: Supports infotainment services such as music streaming and file downloads for passenger convenience.
- Help Assist: Provides remote assistance features, including breakdown support or concierge services, via satellite connectivity.

The SATCOM user requirements for wideband applications are summarised in the tables below;

<i>SATCOM user requirements for road and safety information in remote areas</i>	
Users	Drivers, Fleet Operators
Operational scenario	Driving in rural or mountainous regions
End user application needs	Broadcast alerts
Frequency band	L-band
Data traffic requirements	~512 Kbps
Latency (Low/Medium/High)	low latency
Availability need	High
Technology	MSS
SATCOM access technology	Mobile terminal

Table 31: SATCOM user requirements for road and safety information in remote areas

<i>SATCOM user requirements for local hazard and traffic information</i>	
Users	Drivers, OEMs
Operational scenario	Urban or highway hazard detection
End user application needs	Timely alerts, reliable connectivity
Frequency band	L-band
Data traffic requirements	~512 Kbps
Latency	low latency
Availability	High
Technology	MSS
SATCOM access technology	Mobile terminal

Table 32: SATCOM user requirements for local hazard and traffic information

<i>SATCOM user requirements for remote access</i>	
Users	OEMs, Service Providers
Operational scenario	Remote diagnostics and control
End user application needs	Secure access, authentication
Frequency band	L/S-band

Data traffic requirements	0.4–2 Mbps
Latency	Low latency
Availability	Medium
Technology	MSS
SATCOM access technology	Mobile terminal

Table 33: SATCOM user requirements for remote access

<i>SATCOM user requirements for vehicle health monitoring</i>	
Users	OEMs, Fleet Operators
Operational scenario	Continuous telemetry upload
End user application needs	Reliable narrowband link
Frequency band	L/S-band
Data traffic requirements	0.4–1 Mbps
Latency	Low latency
Availability	Low
Technology	MSS
SATCOM access technology	Mobile terminal

Table 34: SATCOM user requirements for vehicle health information

<i>SATCOM user requirements for Teleoperated Driving Support (objects)</i>	
Users	OEMs, Mobility Operators
Operational scenario	Remote driving assistance
End user application needs	Ultra-low latency, reliable control
Frequency band	L/S-band, Ku-band
Data traffic requirements	0.4–4 Mbps
Latency	Low latency
Availability	High
Technology	MSS

SATCOM access technology	Mobile terminal
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Table 35: SATCOM user requirements for Teleoperated driving (objects)

<i>SATCOM user requirements for Data Collection and Sharing for HD Maps</i>	
Users	OEMs, Mobility Operators
Operational scenario	Periodic HD map updates
End user application needs	Moderate throughput, reliability
Frequency band	L-band, Ku-band
Data traffic requirements	0.4–10 Mbps
Latency	Medium
Availability	Medium
Technology	MSS
SATCOM access technology	Mobile terminal

Table 36: SATCOM user requirements for data collection and sharing for HD Maps

<i>SATCOM user requirements for Hazard Information Collection and Sharing</i>	
Users	OEMs, Fleet Operators
Operational scenario	Real-time hazard data exchange
End user application needs	Low latency, secure
Frequency band	L-band
Data traffic requirements	0.4–10 Mbps
Latency	Low latency
Availability	High
Technology	MSS
SATCOM access technology	Mobile terminal

Table 37: SATCOM user requirements for hazard information and collection and sharing

<i>SATCOM user requirements for OTA Updates (Delta and Message)</i>	
Users	OEMs
Operational scenario	Software updates over-the-air
End user application needs	Secure, authenticated updates
Frequency band	L-band
Data traffic requirements	0.4–10 Mbps
Latency	Low latency
Availability	Low
Technology	MSS
SATCOM access technology	Mobile terminal

Table 38: SATCOM user requirements for OTA updates (delta and message)

<i>SATCOM user requirements for Audio Streaming and Data File Access</i>	
Users	Drivers, Passengers
Operational scenario	Infotainment services
End user application needs	Consistent throughput
Frequency band	L-band, Ku-band
Data traffic requirements	0.4–10 Mbps
Latency (Low/Medium/High)	low latency
Availability	Medium
Technology	MSS
SATCOM access technology	Mobile terminal

Table 39: SATCOM user requirements for audio streaming and data file access

<i>SATCOM user requirements for Help Assist</i>	
Users	OEMs, Service Providers
Operational scenario	Remote assistance

End user application needs	Reliable voice/data
Frequency band	L-band
Data traffic requirements	0.4–10 Mbps
Latency (Low/Medium/High)	low latency
Availability	High
Technology	MSS
SATCOM access technology	Mobile terminal

Table 40: SATCOM user requirements for help assist

Narrowband and wideband antennas for automotive SATCOM

As satellite communication technologies evolve, both narrowband and wideband services are becoming increasingly viable for automotive applications. A key development is the ability to support these services in lower frequency bands, such as the L-band and S-band, without relying on higher-frequency Ku- or Ka-band systems [RD6].¹⁸ This shift opens the door to more accessible and cost-effective satellite connectivity for vehicles, particularly in mass-market scenarios.

Lower frequency bands offer strong signal penetration and resilience to environmental factors such as rain, foliage, and partial obstructions. Importantly, the same lower bands can also support wideband services, which require higher data rates for functions like over-the-air software updates, map refreshes, and real-time traffic information. This means that a wide range of connected vehicle services can be delivered using existing spectrum allocations and antenna designs.

The transition to wideband services in lower frequency bands is being facilitated by advancements in satellite standards, particularly 3GPP Releases 17 and 18. As a result, mass-market automotive services can be enabled with relatively minor modifications to existing systems.

One of the most promising developments in this space is the emergence of Direct-to-Device (D2D) satellite communication. D2D refers to the ability of satellites to communicate directly with end-user devices, such as smartphones or vehicles, without the need for specialized satellite dishes or terminals. In the automotive context, this means that vehicles equipped with omnidirectional antennas can receive satellite signals for both narrowband and wideband services. However, because these systems operate in lower frequency bands and use compact antennas, the available capacity is limited. Satellite operators, particularly those deploying low-Earth orbit (LEO) constellations, must carefully manage their resources by allocating satellite beams strategically to serve areas with high demand [RD6].¹⁹

The feasibility of D2D services is further supported by the growing availability of mass-market chipsets that are compatible with 3GPP Releases 17 and 18. Leading chipset manufacturers such as MediaTek and Qualcomm have announced support for these standards, leveraging their strong presence in the global smartphone market. This development is significant for the automotive industry, as it allows original equipment manufacturers (OEMs) to reuse existing antennas that already operate in the L- and S-bands. This minimizes the need for changes on the vehicle assembly line and simplifies the integration of satellite connectivity into new vehicle models.

¹⁸ European Union Agency for the Space Programme (EUSPA). (2025). *Road and automotive user consultation platform (UCP)*. <https://www.euspa-ucp.eu/>

¹⁹ *Ibid*

Broadband applications

Broadband SATCOM services are capable of delivering high data rates suitable for applications like in-car video streaming, multi-user Wi-Fi, or real-time cloud-based services. They require the use of higher frequency bands. In the context of automotive connectivity, this typically means operating in the Ku-band or Ka-band. These bands offer the large bandwidths necessary to support broadband services, but they also introduce a range of technical and commercial challenges that must be addressed before widespread adoption in vehicles becomes feasible.

Currently, only the Ka-band is formally standardized within the 3GPP as part of its Release 17 specifications for NTN in the FR2 (Frequency Range 2) category. Discussions are ongoing within 3GPP to potentially include the Ku-band in future releases, which would expand the options available for broadband satellite services. However, the lack of standardization for Ku-band today limits its immediate use in mass-market automotive applications.

One of the primary challenges facing broadband satellite services in vehicles is the absence of dedicated chipsets. Existing FR2 chipsets are designed for terrestrial networks and typically operate using Time Division Duplex (TDD) protocols. Satellite communications, by contrast, often rely on different transmission schemes, making current chipsets incompatible without significant redesign. This technical mismatch adds complexity and cost to any potential solution.

Moreover, there is currently no strong commercial case for millimetre-wave (mmWave) use in terrestrial consumer devices, particularly in Europe. For example, iPhones sold in European markets are shipped with mmWave functionality disabled, reflecting limited demand and infrastructure support. This lack of market traction further discourages chipset manufacturers from investing in the development of satellite-compatible broadband chipsets, especially when the automotive sector alone may not provide sufficient volume to justify the cost [RD6].²⁰

Hardware integration also presents significant barriers. Antennas capable of supporting broadband satellite services in Ku- or Ka-band are relatively large, typically around 20 by 20 centimetres, and require precise alignment or beam steering to maintain a stable connection. This makes them difficult to integrate into modern vehicle designs, particularly those with panoramic glass roofs or limited roof space. With broadband, there is a combination of cost, design constraints, and production complexity.

Applications that require broadband data connectivity need data rates >10 Mbps. The following applications belong in this category:

- Entertainment (HD Video Streaming, Video Calls, Gaming): Enables high-bandwidth applications for passenger entertainment, requiring robust throughput and low latency.
- Teleoperated Driving Support (video streaming): Streams real-time video from the vehicle to remote operators for teleoperation, demanding ultra-low latency and high reliability.
- Data Collection and Sharing for Maps (full HD): Streams real-time video from the vehicle to remote operators for teleoperation, demanding ultra-low latency and high reliability.
- Remote Collection and Processing; Uploads sensor and operational data for cloud-based analysis, supporting AI-driven features and predictive insights.

The SATCOM user requirements for broadband applications are summarised in the tables below;

²⁰ European Union Agency for the Space Programme (EUSPA). (2025). *Road and automotive user consultation platform (UCP)*. <https://www.euspa-ucp.eu/>

<i>SATCOM user requirements for entertainment (HD video streaming, video calls, gaming)</i>	
Users	Passengers
Operational scenario	In-vehicle entertainment
End user application needs	High throughput
Frequency band	Ku-band, Ka-band
Data traffic requirements	>10 Mbps
Latency (Low/Medium/High)	Medium latency
Availability	Medium
Technology	MSS
SATCOM access technology	Mobile terminal

Table 41: SATCOM user requirements for entertainment (HD video streaming, video calls, gaming)

<i>SATCOM user requirements for teleoperated driving support (video streaming)</i>	
Users	OEMs, Mobility/fleet Operators
Operational scenario	Remote driving with video feed
End user application needs	Ultra-low latency, high throughput
Frequency band	Ku-band, Ka-band
Data traffic requirements	>10 Mbps
Latency (Low/Medium/High)	Low latency
Availability	High
Technology	MSS
SATCOM access technology	Mobile terminal

Table 42: SATCOM user requirements for teleoperated driving support (video streaming)

<i>SATCOM user requirements for data collection and sharing for maps (full HD)</i>	
Users	OEMs, Mobility/fleet operators, Map Providers

Operational scenario	Uploading/downloading large map datasets
End user application needs	High throughput
Frequency band	Ku-band, Ka-band
Data traffic requirements	>10 Mbps
Latency (Low/Medium/High)	Medium latency
Availability	Low
Technology	MSS
SATCOM access technology	Mobile terminal

Table 43: SATCOM user requirements for data collection and sharing for maps (full HD)

<i>SATCOM user requirements for remote collection and processing</i>	
Users	OEMs, Mobility/fleet operators
Operational scenario	Uploading sensor data for cloud processing
End user application needs	High throughput
Frequency band	Ku-band, Ka-band
Data traffic requirements	>10 Mbps
Latency (Low/Medium/High)	High latency
Availability	Low
Technology	MSS
SATCOM access technology	Mobile terminal

Table 44: SATCOM user requirements for remote collection and processing

Connected fleet

While broadband SATCOM faces integration challenges in passenger vehicles, such as antenna size, cost sensitivity, and limited roof space, certain segments of the automotive industry are better positioned to adopt these technologies. Commercial vehicle manufacturers, including truck, bus, and coach OEMs, as well as logistics and fleet operators, represent a promising early market for broadband SATCOM applications.

Heavy-duty vehicles offer more generous surface area and structural flexibility, making it easier to accommodate larger antennas required for Ku- or Ka-band broadband services. Roof-mounted terminals measuring 20x20 cm or more, which are difficult to integrate into sleek consumer vehicle designs, can be more readily installed on the flat, expansive rooftops of trucks, trailers, or buses. This physical advantage

reduces the design and engineering burden associated with antenna integration and allows for more robust and higher-gain terminals to be deployed.

Beyond physical feasibility, the value proposition of broadband SATCOM is, at the moment, stronger for commercial and logistics applications. SATCOM can be a way to close critical coverage gaps, enhance real-time fleet operations, and enable advanced services like remote vehicle monitoring and autonomous operations.

However, widespread adoption will depend on clear operational benefits, suitable technology (e.g. compact antennas and chipsets), and a strong return on investment to justify additional costs. Industry insights from logistics operators and vehicle manufacturers confirm that while continuous satellite connectivity is attractive for closing coverage gaps and enabling advanced fleet management features, current limitations, hardware availability, latency, and cost, mean these solutions are approached cautiously and seen as a mid-to-long term prospect rather than an immediate addition to fleets.

For commercial fleet stakeholders, the primary appeal of satellite broadband lies in resilient, ubiquitous connectivity for vehicles and cargo. Connectivity gaps in certain regions cause real operational pain points. For instance, dead zones in rural or mountainous areas can result in lost truck positions and communication blackouts, which jeopardize driver safety, complicate scheduling, and even interfere with accurate driver time logging and billing. For logistics providers, it is important to maintain a “digital twin” of shipments. For this, continuous, end-to-end visibility of the cargo’s location, condition, and estimated arrival time is needed, aspects which satellite links could help achieve by bridging stretches of a journey (such as overseas or remote segments) where terrestrial networks are unavailable.

Beyond coverage, broadband SATCOM can unlock advanced, data-intensive applications that add strategic value for commercial fleets:

- Real-time fleet management and telematics: High-throughput satellite links allow constant monitoring of vehicle parameters, driver behaviour, and cargo conditions on long-haul routes. This can improve route optimization, fuel management, and responsiveness to events.
- OTA updates and remote diagnostics: With satellite broadband, trucks could receive software updates and security patches or send detailed diagnostic information back to base regardless of location. This reduces dependency on depot visits or local networks and helps maximize vehicle uptime. Although some logistics companies currently downplay truck-specific maintenance needs (especially if they outsource transportation), fleet operators who own vehicles see value in remotely updating onboard systems to improve performance and comply with regulations without waiting for a return to headquarters.
- Remote and autonomous operations: Looking to the future, remote driving and autonomous vehicle operation are areas where satellite connectivity could play a role. Highly automated trucks and shuttles will require near-uninterrupted links for supervision and occasional remote control. Regulators currently require a remote operator to oversee or even intervene in vehicle operation, meaning a lost connection can force these vehicles to stop in their tracks. In controlled trials, these companies rely on robust 4G/5G networks (often private) to meet strict latency and reliability needs. While today’s satellite latency is too high for direct teleoperation, the concept of augmenting connectivity in coverage “black spots” with satellites is attractive to ensure vehicles remain connected at all times. This could allow one remote supervisor to safely monitor multiple autonomous vehicles without interruption, potentially accelerating the removal of onboard safety drivers and improving the economics of autonomous transport.

Overall, the strategic value of broadband SATCOM for commercial fleets boils down to improving operational continuity and enabling new services. Continuous connectivity is not just a convenience but a cornerstone for efficient logistics and emerging autonomous operations. These stakeholders see satellite

broadband as a key enabler for truly “no dead-zone” coverage and high-throughput data access on the move, whether for sending rich data from trucks or for receiving critical information aboard the vehicle. This stands in contrast to many passenger car applications of connectivity (like streaming entertainment or in-car Wi-Fi), which are less critical to the vehicle’s core function. For commercial players, connectivity is directly tied to business performance and safety outcomes.

Technical feasibility and integration considerations

While commercial and heavy-duty vehicles have inherent advantages for integrating satellite hardware, there are still technical aspects that need to be taken into consideration;

- Even though commercial and heavy-duty vehicles offer more installation space, power, and tolerance for equipment than consumer vehicles, terminals still need to remain low-profile, so the vehicle still clears bridges and overpasses.
- Weight is another consideration; any equipment added to a commercial truck counts against its payload capacity and could even push it over legal weight limits if not kept very light. For this reason, fleet operators expect satellite terminals to be compact and lightweight.
- Power consumption is also scrutinized, especially for electric vehicles, anything above roughly 30 W power draw for a satellite terminal might noticeably reduce an electric vehicle’s range and therefore would be problematic.

From a technology standpoint, commercial fleets are also closely watching developments in standards like 3GPP’s NTN specifications. Fleet connectivity solutions today already use multi-channel redundancy (for example, dual cellular modems from different providers) to minimize coverage blackouts. Ideally, a truck would switch intelligently between cellular networks and satellite as needed, without driver intervention. Achieving this kind of integration will require progress in hybrid network solutions and possibly new communication protocols or satellite constellations optimized for mobility.

Commercial vehicles offer a promising platform for SATCOM integration, but only if hardware meets stringent automotive requirements: low-profile design, minimal weight, reasonable power consumption, and plug-and-play compatibility with existing vehicle systems. These factors are less of a concern for passenger cars, where the bigger issue is preserving style and minimizing cost for consumers. For fleets, the hurdles are more about engineering and maintenance – and they look to their OEMs and technology partners to overcome these hurdles in the coming years.

The level of interest in SATCOM adoption for connected fleet cases, varies significantly depending on the stakeholder’s business model, operational environment, and technology strategy.

Commercial vehicle OEMs and logistics operators with traditional, cost-sensitive operations (e.g. long-haul freight, third-party logistics) tend to approach SATCOM cautiously. Their primary interest lies in narrowband applications that support low-cost, low-data services such as tracking, telemetry, and safety alerts. These stakeholders prioritize affordability, simplicity, and battery efficiency, and they are unlikely to adopt broadband SATCOM unless it delivers a clear return on investment. For them, SATCOM is seen as a potential complement to terrestrial networks, but only if it can be integrated seamlessly and cost-effectively into existing fleet systems.

In contrast, technology-driven OEMs and autonomous vehicle developers view SATCOM, particularly broadband, as a strategic enabler. These stakeholders operate in environments where continuous, high-throughput connectivity is essential for remote supervision, teleoperation, and scaling autonomous operations. They are more tolerant of current hardware limitations and are already testing or deploying SATCOM solutions. For them, SATCOM is not just a fallback but a core component of their connectivity architecture.

SATCOM adoption is most likely to begin with innovation-led fleets and OEMs that require high-reliability, high-bandwidth connectivity for advanced use cases. Broader adoption among traditional

logistics operators will depend on the maturity of the technology, reductions in cost, and the development of compact, low-power terminals that meet strict operational constraints. The path to adoption is therefore segmented: early uptake by autonomy-focused fleets, followed by gradual expansion into mainstream logistics as technology becomes more accessible and aligned with commercial fleet economics.

2.5 User Requirements Specifications

ID	Description	Type	Source
EUSPA-GN-UR-ROA-900101	The PNT solution shall provide the vehicle's position with a horizontal accuracy of approximately 20 cm. The PNT solution shall provide the vehicle's position with a vertical accuracy of approximately 2 meters.	Performance	[RD10] [RD13]
EUSPA-GN-UR-ROA-900102	The PNT solution shall be available in urban canyon with a high probability	Performance	[RD10] [RD13]
EUSPA-GN-UR-ROA-900103	The PNT solution shall be available in natural canyon with a high probability	Performance	[RD10] [RD13]
EUSPA-GN-UR-ROA-900104	The PNT solution shall be available under canopy with a high probability	Performance	[RD10] [RD13]
EUSPA-GN-UR-ROA-900105	The PNT solution shall be available in indoor circumstances for specific situations	Performance	[RD10] [RD13]
EUSPA-GN-UR-ROA-900106	The availability of the location information provided by the PNT solution fulfilling its performance requirements shall be High	Performance	[RD10] [RD13]
EUSPA-GN-UR-ROA-900107	The probability that the system provides misleading information without warning must be no more than 1 in 100 million per hour.	Functional	[RD10] [RD13]

ID	Description	Type	Source
EUSPA-GN-UR-ROA-900108	The PNT solution shall provide robustness against GNSS jamming threat	Functional	[RD10] [RD13]
EUSPA-GN-UR-ROA-900109	Under hot-start conditions and with a last-known position error exceeding 0.5 m, the receiver shall provide a valid position fix (or reacquire a reliable fix) within 10 seconds.	Performance	[RD10] [RD13]
EUSPA-GN-UR-ROA-900201	The PNT solution shall provide the vehicle's position with a horizontal accuracy of approximately 5 meters The PNT solution shall provide the vehicle's position with a vertical accuracy of approximately 2 meters	Performance	[RD10] [RD13]
EUSPA-GN-UR-ROA-900202	The PNT solution shall be available in urban canyon with a high probability	Performance	[RD10] [RD13]
EUSPA-GN-UR-ROA-900203	The PNT solution shall be available in natural canyon with a high probability	Performance	[RD10] [RD13]
EUSPA-GN-UR-ROA-900204	The PNT solution shall be available under canopy with a high probability	Performance	[RD10] [RD13]
EUSPA-GN-UR-ROA-900205	The PNT solution shall be available indoor	Performance	[RD10] [RD13]
EUSPA-GN-UR-ROA-900206	The availability of the location information provided by the PNT solution fulfilling its performance requirements shall be High	Performance	[RD10] [RD13]

ID	Description	Type	Source
EUSPA-GN-UR-ROA-900207	The system must be robust enough that the quality of the L1 and E5a GNSS signals it receives does not worsen by more than a very small amount (1 dB-Hz), even under expected operating disturbances.	Functional	[RD10] [RD13]
EUSPA-GN-UR-ROA-900208	The positioning system shall provide an integrity message	Functional	[RD10] [RD13]
EUSPA-GN-UR-ROA-900209	The system must deliver a reliable position almost immediately if it was recently active, within seconds if partially initialised, and within one minute even when starting from scratch.	Performance	[RD10] [RD13]
EUSPA-GN-UR-ROA-900301	The PNT solution shall provide the vehicle's position with a horizontal accuracy of approximately 5 meters The PNT solution shall provide the vehicle's position with a vertical accuracy of approximately 10 meters	Performance	[RD10] [RD13]
EUSPA-GN-UR-ROA-900302	The PNT solution shall be available under canopy with an accuracy better than or equal to 10 meters for at least 95% of the operating time.	Performance	[RD10] [RD13]
EUSPA-GN-UR-ROA-900303	The availability of the location information provided by the PNT solution fulfilling its performance requirements shall be High	Performance	[RD10] [RD13]
EUSPA-GN-UR-ROA-900304	The system must be robust enough that the quality of the L1 and E5a GNSS signals it receives does not worsen by more than a very small amount (1 dB-Hz), even under expected operating disturbances.	Functional	[RD10] [RD13]

ID	Description	Type	Source
EUSPA-GN-UR-ROA-900305	The system must deliver a reliable position almost immediately if it was recently active, within seconds if partially initialised, and within one minute even when starting from scratch.	Performance	[RD10] [RD13]
EUSPA-GN-UR-ROA-900401	The PNT solution shall provide the vehicle's position with a horizontal accuracy of approximately 2 meters The PNT solution shall provide the vehicle's position with a vertical accuracy of approximately 4 meters	Performance	[RD10] [RD13]
EUSPA-GN-UR-ROA-900402	The PNT solution shall be available in urban canyon with an accuracy better than or equal to 2 meters for at least 95% of the operating time.	Performance	[RD10] [RD13]
EUSPA-GN-UR-ROA-900403	The PNT solution shall be available in natural canyon with a high probability	Performance	[RD10] [RD13]
EUSPA-GN-UR-ROA-900404	The PNT solution shall be available under canopy with a high probability	Performance	[RD10] [RD13]
EUSPA-GN-UR-ROA-900405	The system must be robust enough that the quality of the L1 and E5a GNSS signals it receives does not worsen by more than a very small amount (1 dB-Hz), even under expected operating disturbances.	Functional	[RD10] [RD13]
EUSPA-GN-UR-ROA-900406	The system must deliver a reliable position almost immediately if it was recently active, within seconds if partially initialised, and within one minute even when starting from scratch.	Performance	[RD10] [RD13]

ID	Description	Type	Source
EUSPA-GN-UR-ROA-0410	The PNT solution shall provide the vehicle's position with a horizontal accuracy of 0.15 m - 0.75 m (3 σ) or 0.15 m - 0.75 m (99.7% confidence) The PNT solution shall provide the vehicle's position with a vertical accuracy of approximately 10 meters	Performance	[RD11] [RD14]
EUSPA-GN-UR-ROA-0420	The availability of the location information provided by the PNT solution fulfilling its performance requirements shall be High	Performance	[RD11] [RD14]
EUSPA-GN-UR-ROA-0430	The timing system shall provide an accuracy of 1 second	Performance	[RD11] [RD14]
EUSPA-GN-UR-ROA-0440	The PNT solution shall be available in urban canyon with a high probability	Performance	[RD11] [RD14]
EUSPA-GN-UR-ROA-0450	The PNT solution shall be available under canopy with a high probability	Performance	[RD11] [RD14]
EUSPA-GN-UR-ROA-0460	The level of position authenticity that the PNT system shall provide is High	Performance	[RD11] [RD14]
EUSPA-GN-UR-ROA-0470	The positioning system shall provide an integrity message	Functional	[RD11] [RD14]
EUSPA-GN-UR-ROA-0480	The PNT solution shall have a TTFF less than 30 seconds	Performance	[RD11] [RD14]
EUSPA-GN-UR-ROA-0490	The positioning system shall provide an authentication message	Functional	[RD11] [RD14]
EUSPA-GN-UR-ROA-0500	The positioning system shall be able to detect GNSS interferences and inform the driver	Functional	[RD13] [RD14]
EUSPA-GN-UR-ROA-4510	The PNT solution shall provide the vehicle's position with a horizontal accuracy of 10 meters The PNT solution shall provide the vehicle's position with a vertical accuracy of 10 meters	Performance	[RD13] [RD14]

ID	Description	Type	Source
EUSPA-GN-UR-ROA-4520	The availability of the location information provided by the PNT solution fulfilling its performance requirements shall be High	Performance	[RD13] [RD14]
EUSPA-GN-UR-ROA-4530	The timing system shall provide an accuracy of 1 second	Performance	[RD13] [RD14]
EUSPA-GN-UR-ROA-4540	The PNT solution shall be available in urban canyon with a high probability	Performance	[RD13] [RD14]
EUSPA-GN-UR-ROA-4550	The level of position authenticity that the PNT system shall provide is High	Performance	[RD13] [RD14]
EUSPA-GN-UR-ROA-4560	The positioning system shall provide an integrity message	Functional	[RD13] [RD14]
EUSPA-GN-UR-ROA-4570	The PNT solution shall have a TTFF of between 10 and 15 seconds	Performance	[RD13] [RD14]
EUSPA-GN-UR-ROA-4580	The positioning system shall provide an authentication message	Functional	[RD13] [RD14]
EUSPA-GN-UR-ROA-4590	The positioning system shall be able to detect GNSS interferences and inform the driver	Functional	[RD13] [RD14]

ID	Description	Type	Source
EUSPA-GN-UR-ROA-4610	The PNT solution shall provide the vehicle's position with a horizontal accuracy of 10 meters The PNT solution shall provide the vehicle's position with a vertical accuracy of 10 meters	Performance	[RD13] [RD14]
EUSPA-GN-UR-ROA-4620	The availability of the location information provided by the PNT solution fulfilling its performance requirements shall be High	Performance	[RD13] [RD14]
EUSPA-GN-UR-ROA-4630	The timing system shall provide an accuracy of between 1 microsecond and 1 second	Performance	[RD13] [RD14]
EUSPA-GN-UR-ROA-4640	The PNT solution shall be available in urban canyon with a high probability	Performance	[RD13] [RD14]
EUSPA-GN-UR-ROA-4650	The level of position authenticity that the PNT system shall provide is Medium	Performance	[RD13] [RD14]
EUSPA-GN-UR-ROA-4660	The positioning system shall provide an integrity message	Functional	[RD13] [RD14]
EUSPA-GN-UR-ROA-4670	The PNT solution shall have a TTFF of between 10 and 15 seconds	Performance	[RD13] [RD14]
EUSPA-GN-UR-ROA-4680	The positioning system shall provide an authentication message	Functional	[RD13] [RD14]
EUSPA-GN-UR-ROA-4690	The positioning system shall be able to detect GNSS interferences and inform the driver	Functional	[RD13] [RD14]

Table 45: Synthesis of Requirements Relevant to GNSS

ID	Application	Abstract of the Need & Requirement	Size of the area of interest	Frequency of information needed	Spatial resolution	Temporal resolution	Type of EO data
EUSPA-EO-UR-ROA-0010	Infrastructures planning and design, finance planning	Millimetric determination of surface ground movements derived by geological processes such as landslides, subsidence, ground failures, sinkholes, uplifts, faults, and seismic displacements poses significant challenges for the planning and projecting of new infrastructures.	In general, a buffer of 500 m around the road infrastructure is sufficient but it can be incremented depending on the geomorphology of the area to monitor and by the origin of ground movements.	Once – during site assessment. Cadence of supporting observations shall be commensurate to behaviour of deformation phenomena.	From 1 m up to 100 m	From daily to monthly	MTInSAR with PSI, SBAS or other techniques
EUSPA-EO-UR-ROA-0020	Infrastructures planning and design, finance planning	Determination of soil moisture, the total amount of water, including the water vapor in a land surface provides basic information for geotechnical engineering.	A buffer up to 2000m around the road infrastructure	Ad-hoc	From 10 m up to 100 m	From daily to weekly	Multi and hyper spectral SAR, PolSAR
EUSPA-EO-UR-ROA-0030	Infrastructures planning and design, finance planning	Determination of the risk and of the vulnerability for the planning of safety, durable and resilient infrastructures. Climate change and extreme weather events such as flooding, severe storms, landslides, rock fall, avalanches can have a devastating impact on safety and the expected lifetime of infrastructures which might become unreliable, unpredictable, inadequate, and unsafe. ISO 14090 and 14091 provides guidance on climate risk assessments.	Road network	Ad-hoc	From 10 m up to 100 m	Depending on data input from weekly hourly to monthly	Multi and hyper spectral, Meteosat Earth observation, Earth systems modelling (Digital Twins) spanning climate, extreme weather, soil, water and vegetation systems and their interactions. Climate risk assessment methodology.

ID	Application	Abstract of the Need & Requirement	Size of the area of interest	Frequency of information needed	Spatial resolution	Temporal resolution	Type of EO data
EUSPA-EO-UR-ROA-0040	Infrastructure construction	Continuous geotechnical and structural monitoring to control slopes and works to be built during the construction of a road infrastructure such as the excavation of tunnels, the construction of viaducts, bridges, and road sections.	The entire area is susceptible to ground shifts caused by the construction or excavation of an infrastructure project.	Weekly	From 1m for structural elements to 100m for wide area subsidence or settlement	Daily to weekly	MTInSAR with PSI and SBAS techniques

ID	Application	Abstract of the Need & Requirement	Size of the area of interest	Frequency of information needed	Spatial resolution	Temporal resolution	Type of EO data
EUSPA-EO-UR-ROA-0050	Infrastructure operations and maintenance	The presence of vegetation along and close to the roads can create obstacles and impact on the transport. The monitoring of the status and growth of vegetation along the road corridors can prevent hazards such as fallen trees or overgrown branches that can interrupt the transport. The goal is determination of the distance between vegetations and roads. Identification of the types of vegetation, and determination of height, species and volume of trees. Depending on local context and maintenance strategies road stakeholders may need vegetation data for: • Drainage infrastructure is prone to overgrowth and loss of function resulting in chronic (gradual loss of earthworks or structural integrity) or acute damage (washout, slope failure etc). • dry vegetation mapping for fire hazard management. • Roadside areas are vulnerable to invasive species. Road managers need to monitor their presence to inform invasive species management decisions.	A buffer until 100m around the road infrastructure	Depending on parameter, local context and asset maintenance strategy – from weekly to annual.	Depending on parameter	Depending on parameter, from weekly to annual	Multi and hyper spectral VHR multispectral, Multi and hyper spectral and Lidar for mapping tasks, Satellite, airplane, drone, vehicle and hand EO instruments.

ID	Application	Abstract of the Need & Requirement	Size of the area of interest	Frequency of information needed	Spatial resolution	Temporal resolution	Type of EO data
EUSPA-EO-UR-ROA-0060	Resilience to natural hazards	During floods, users need to identify road infrastructures that are involved in flood, helping the authorities to monitor the evolution of the situation, and in the management of the closing or reopening of the roads.	Road infrastructure network	Ad-hoc, continuous monitoring	From 10 until 100 m	From daily to weekly	Sentinel-1 and 2, ALOS, TerraSAR X, Cosmo SkyMed Climate, seasonal, near term and now-casting weather data. Flood modelling.
EUSPA-EO-UR-ROA-0070	Climate resilience	Climate change and extreme weather events such as flooding, severe storms, landslides, rock fall, avalanches can have a devastating impact on safety and the expected lifetime of infrastructures which are becoming unreliable, unpredictable, inadequate, and unsafe.	Road network	Ad-hoc	From 10 m up to 100 10km depending on the input.	From weekly to monthly	Multi and hyper spectral, Meteosat

Table 46: Synthesis of Requirements Relevant to EO

ID	Application	Operational Scenario	Link type	Availability	Coverage	Setup	Security protection	Speed	Latency	Bandwidth (bit rate)	Symmetry up/down	Distribution
EUSPA-SATCOM-UR-ROA-0101	Emergency call	Vehicle accident or breakdown in remote area	Bi-directional	High	Regional Worldwide	Immediate	Availability	High > 90 km/h	Low	~512 kbps	50/50	Multi-User: between a group of users, where a user can be a human or a system

ID	Application	Operational Scenario	Link type	Availability	Coverage	Setup	Security protection	Speed	Latency	Bandwidth (bit rate)	Symmetry up/down	Distribution
EUSPA-SATCOM-UR-ROA-0102	Traffic management in disaster situation	Disaster recovery zone with terrestrial outage	Bi-directional	High	Regional Worldwide	Immediate	Availability	High > 90 km/h	Low	~512 kbps	50/50	Multi-User: between a group of users, where a user can be a human or a system
EUSPA-SATCOM-UR-ROA-0201	Road and safety information in remote areas	Driving in rural or mountainous regions	Bi-directional	High	Regional Worldwide	Immediate	Availability	High > 90 km/h	Low	~512 kbps	50/50	Multi-User: between a group of users, where a user can be a human or a system
EUSPA-SATCOM-UR-ROA-0202	Local hazard and traffic information	Urban or highway hazard detection	Bi-directional	High	Regional Worldwide	Immediate	Availability	High > 90 km/h	Low	~512 kbps	50/50	Multi-User: between a group of users, where a user can be a human or a system
EUSPA-SATCOM-UR-ROA-0203	Remote access	Remote diagnostics and control	Bi-directional	High	Regional Worldwide	Immediate	Availability	Low < 30 km/h	Low	0.4–2 Mbps	50/50	Multi-User: between a group of users, where a user can be a human or a system
EUSPA-SATCOM-UR-ROA-0204	Vehicle health monitoring	Continuous telemetry upload	Bi-directional	High	Regional Worldwide	Immediate	Availability	High > 90 km/h	Low	0.4–1 Mbps	50/50	Multi-User: between a group of users, where a user can be a human or a system
EUSPA-SATCOM-UR-ROA-0205	Teleoperated Driving Support (objects)	Remote driving assistance	Bi-directional	High	Regional Worldwide	Immediate	Availability	High > 90 km/h	Low	0.4–4 Mbps	50/50	Multi-User: between a group of users, where a user can be a human or a system

ID	Application	Operational Scenario	Link type	Availability	Coverage	Setup	Security protection	Speed	Latency	Bandwidth (bit rate)	Symmetry up/down	Distribution
EUSPA-SATCOM-UR-ROA-0206	Data Collection and Sharing for HD Maps	Periodic HD map updates	Bi-directional	High	Regional Worldwide	Immediate	Availability	High > 90 km/h	Medium	0.4–10 Mbps	50/50	Multi-User: between a group of users, where a user can be a human or a system
EUSPA-SATCOM-UR-ROA-0207	Hazard Information Collection and Sharing	Real-time hazard data exchange	Bi-directional	High	Regional Worldwide	Immediate	Availability	High > 90 km/h	Low	0.4–10 Mbps	50/50	Multi-User: between a group of users, where a user can be a human or a system
EUSPA-SATCOM-UR-ROA-0208	OTA Updates (Delta and Message)	Software updates over-the-air	Bi-directional	High	Regional Worldwide	Immediate	Availability	High > 90 km/h	Low	0.4–10 Mbps	50/50	Multi-User: between a group of users, where a user can be a human or a system
EUSPA-SATCOM-UR-ROA-0209	Audio Streaming and Data File Access	Infotainment services	Bi-directional	High	Regional Worldwide	Immediate	Availability	High > 90 km/h	Low	0.4–10 Mbps	50/50	Multi-User: between a group of users, where a user can be a human or a system
EUSPA-SATCOM-UR-ROA-0210	Help Assist	Remote assistance	Bi-directional	High	Regional Worldwide	Immediate	Availability	High > 90 km/h	Low	0.4–10 Mbps	50/50	Multi-User: between a group of users, where a user can be a human or a system
EUSPA-SATCOM-UR-ROA-0301	Entertainment (HD video streaming, video calls, gaming)	In-vehicle entertainment	Bi-directional	High	Regional Worldwide	Immediate	Availability	High > 90 km/h	Medium	>10 Mbps	50/50	Multi-User: between a group of users, where a user can be a human or a system

ID	Application	Operational Scenario	Link type	Availability	Coverage	Setup	Security protection	Speed	Latency	Bandwidth (bit rate)	Symmetry up/down	Distribution
EUSPA-SATCOM-UR-ROA-0302	Teleoperated driving support (video streaming)	Remote driving with video feed	Bi-directional	High	Regional Worldwide	Immediate	Availability	High > 90 km/h	Medium	>10 Mbps	50/51	Multi-User: between a group of users, where a user can be a human or a system
EUSPA-SATCOM-UR-ROA-0303	Data collection and sharing for maps (full HD)	Uploading/downloading large map datasets	Bi-directional	High	Regional Worldwide	Immediate	Availability	High > 90 km/h	Medium	>10 Mbps	50/52	Multi-User: between a group of users, where a user can be a human or a system
EUSPA-SATCOM-UR-ROA-0304	Remote collection and processing	Uploading sensor data for cloud processing	Bi-directional	High	Regional Worldwide	Immediate	Availability	High > 90 km/h	Medium	>10 Mbps	50/53	Multi-User: between a group of users, where a user can be a human or a system

Table 47: Synthesis of Requirements Relevant to SATCOM

3 ANNEX

A.1 Definition of key EO performance parameters

This annex provides a definition of the most used EO performance parameters and includes additional details which are relevant for Road and Automotive community.

Spatial resolution refers to the level of detail and clarity in the images, specifically the size of the smallest discernible ground features. It is determined by the pixel size, which is the smallest unit in the image that represents a spatial area on the Earth's surface. Spatial resolution is usually measured in terms of meters per pixel. Thus, a spatial resolution of 1 meter means that each pixel represents a 1 by 1 meter area on the ground.

Spectral resolution refers to the ability of a sensor to differentiate electromagnetic radiation of different wavelengths. In other words, it refers to the number and “size” of wavelength intervals that the sensor is able to measure. The finer the spectral resolution, the narrower the wavelength range for a particular channel or band. In remote sensing, features (e.g. water, vegetation) can be characterised by comparing their “response” in different spectral bands.

Radiometric resolution expresses the sensitivity of the sensor, that is to say its ability to differentiate between different magnitudes of the electromagnetic energy. The finer the radiometric resolution, the more sensitive it is to small differences in the energy emitted or reflected by an object. The radiometric resolution is generally expressed in bit, e.g. an 8-bit image has a scale of $2^8=256$ nuances.

Temporal resolution relates to the time elapsed between two consecutive observations of the same area on the ground. The higher the temporal resolution, the shorter the time between the acquisitions of two consecutive observations of the same area. In absolute terms, the temporal resolution of a remote sensing system corresponds to the time elapsed between two consecutive passes of the satellite over the exact same point on the ground (generally referred to as “revisit time” or “orbit cycle”). However, several parameters like the overlap between the swaths of adjacent passes, the agility of the satellites and in case of a constellation, the number of satellites mean that some areas of the Earth can be reimaged more frequently. For a given system, the temporal resolution can therefore be better than the revisit time of the satellite(s).

Geolocation accuracy refers to the ability of an EO remote sensing platform to assign an accurate geographic position on the ground to the features captured in a scene. An accurate geolocation makes easier the combination of several images (e.g. combination of a Synthetic Aperture Radar image with a cadastral map and a vegetation map).

Spectral range refers to the wavelength range of a particular channel or band over in which remote sensing data must be collected.

Latency is the difference between the reference time of the satellite measurement and the time the final product is made available to the user (here the service provider).

A.2 Additional EO definitions

Ground deformation monitoring is the process which consists in tracking the vertical and horizontal movements of the land surface and their dynamics, whatever these movements are caused by natural phenomena (e.g. volcanic activity) or by human activities (e.g. aquifer exploitation).

Change detection is the process which aims at identifying difference in the state of “objects” (e.g. bridges, constructions, urban areas) or of a phenomenon (e.g. deforestation, soil sealing) by comparing snapshots of the situation at different times. In Earth Observation, change detection is extensively based on satellite imagery obtained through a wide variety of sensors (e.g. optical, radar, infrared, microwave, etc).

Geodesy (see [RD3]) is the earth science of accurately measuring and understanding three of Earth's fundamental properties: its geometric shape, orientation in space, and gravitational field. The field also studies of how these properties change over time. Today, geodesy goes beyond that, being the geoscience that deals among other with the monitoring the solid Earth (which includes the monitoring of displacement, subsidence or deformation of the ground and structures due to tectonic, volcanic, and other natural phenomena as well as human activity).

Interferometric Synthetic Aperture Radar (InSAR) is a technique enabling to generate surface deformation maps based on the processing of SAR images captured at different moments in time. The processing uses the fact that if the ground has moved between the times of two SAR images of the same area, a slightly different portion of the wavelength is reflected to the satellite resulting in a measurable phase shift that is proportional to displacement. The processing therefore consists in obtaining information about the vertical movements of the ground surface by calculating the phase difference between the emitted radar signal and the signal backscattered by the surface for successive images. InSAR can potentially measure deformations of millimetre-scale during periods ranging from days to years.

Near-Real-Time (NRT) refers, when used in the context of EO applications, to applications/services/products for which the time delay between the occurrence of a given event and the availability of the outcomes of the processing of the Earth observation data corresponding to that event is considered as being not significant from a user perspective. The notion of "near real-time" is therefore depending on user requirements. For Earth observation, the corresponding time delays may range from a few hours to a few days depending on the application/service/product.

A.3 Definition of key GNSS performance parameters

This annex provides a definition of the most commonly used GNSS performance parameters, taken from EUSPA EO and GNSS Market Report, and includes additional details which are relevant for Road and Automotive community.

Availability: the percentage of time the position, navigation or timing solution can be computed by the user. Values vary greatly according to the specific application and services used but typically range from 95-99.9%. There are two classes of availability:

- **System availability:** the percentage of time the system allows the user to compute a position - this is what GNSS Interface Control Documents (ICDs) refer to.
- **Overall availability:** considers the receiver performance and the user's environment. Values vary greatly according to the specific use cases and services used.

Accuracy is the difference between true and computed solution (position or time). This is expressed as the value within which a specified proportion – usually 95% – of samples would fall if measured. This report refers to positioning accuracy using the following convention: centimetre-level: 0-10cm; decimetre level: 10-100cm; metre-level: 1-10 metres.

Continuity is the ability of a system to perform its function (deliver PNT services with the required performance levels) without interruption once the operation has started. It is usually expressed as the risk of discontinuity and depends entirely on the timeframe of the application. A typical value is around 1×10^{-4} over the course of the procedure where the system is in use.

Indoor penetration is the ability of a signal to penetrate inside buildings (e.g. through windows). Indoor penetration does not have an agreed or typical means for expression. In GNSS this parameter is dictated by the sensitivity of the receiver, whereas for other positioning technologies there are vastly different factors that determine performance (for example, availability of Wi-Fi base stations for Wi-Fi-based positioning).

Integrity is a term used to express the ability of the system to provide warnings to users when it should not be used. It is the probability of a user being exposed to an error larger than the alert limits without timely warning. The way integrity is ensured and assessed, and the means of delivering integrity-related information to users are highly application dependent. Throughout this report, the “integrity concept” is to be understood at large, i.e. not restricted to safety-critical or civil aviation definitions but also encompassing concepts of quality assurance/quality control as used in other applications and sectors.

Latency is the difference between the reference time of the solution and the time this solution is made available to the end user or application (i.e. including all delays). Latency is typically accounted for in a receiver but presents a potential problem for integration (fusion) of multiple positioning solutions, or for high dynamics mobile devices.

Robustness relates to spoofing and jamming and how the system can cope with these issues. It is a more qualitative than quantitative parameter and depends on the type of attack or interference the receiver is capable of mitigating. Robustness can be improved by authentication information and services.

Authentication gives a level of assurance that the data provided by a positioning system has been derived from real signals. Radio frequency spoofing may affect the positioning system, resulting in false data as output of the system itself.

Power consumption is the amount of power a device uses to provide a position. It will vary depending on the available signals and data. For example, GNSS chips will use more power when scanning to identify signals (cold start) than when computing a position. Typical values are in the order of tens of milliwatts (for smartphone chipsets).

Probability of false alarm refers to the likelihood of the receiver to indicate the presence of a signal when no signal is present.

Probability of detection refers to the likelihood of a receiver to detect the presence of a GNSS signal when a signal is indeed present.

Time To First Fix (TTFF) is a measure of time between activation of a receiver and the availability of a solution, including any power on self-test, acquisition of satellite signals and navigation data and computation of the solution. It mainly depends on data that the receiver has access to before activation: cold start (the receiver has no knowledge of the current situation and must thus systematically search for and identify signals before processing them – a process that can take up to several minutes.); warm start (the receiver has estimates of the current situation – typically taking tens of seconds) or hot start (the receiver understands the current situation – typically taking a few seconds).

Time To First accurate Fix (TTFaF) is a measure of a receiver's/solution's performance covering the time between activation and output of a position within the required accuracy bounds.

A.4 Definition of key SATCOM performance parameters

Link type refers to the type of communication link used for transmitting voice or data.

Availability is qualitative indication of the reliability and uptime of the communications system. It refers to the percentage of time the communication system is operational and meets the required quality of service when the application is in use.

Latency refers to the delay between the transmission of a signal and the reception of the response. This is the time it takes for a signal to travel from the sender to the receiver and back.

Bandwidth (bit rate) is a qualitative indication of the anticipated rate of data transfer when using the application. It is the amount of data that can be transmitted over the communication link in a given amount of time, usually measured in bits per second (bps).

Coverage is an indication of the geographical area that can be reached by the service. It defines the regions where the satellite signal is available and can provide communication services.

Symmetry Up/Down is the ratio between the uplink traffic (data sent from the ground to the satellite) and the downlink traffic (data sent from the satellite to the ground). This ratio indicates whether the communication link is symmetric (equal uplink and downlink capacity) or asymmetric (different uplink and downlink capacities).

Distribution refers to the method and extent to which the communication service is distributed across different regions or users. It can include the distribution of signal strength, service availability, and user access.

Setup refers to a qualitative indication of the time required to establish a voice or data communication session with the application. It refers to the acceptable duration for setting up a communication link that is sufficient to perform the intended operation, such as railway operations.

Speed: the speed at which a user is traveling, with a maximum value specified. In satellite communication, this can affect the ability to maintain a stable communication link, especially for mobile users.

Security protection refers to the measures and protocols implemented to ensure the security of the communication link. This includes protecting the data from unauthorized access, interception, and ensuring the integrity and confidentiality of the transmitted information

A.5 Other performance parameters

EO

Agility corresponds to the ability of a satellite to modify its attitude and to point rapidly in any direction to observe areas of interest outside its ground trace. High agility can improve the temporal resolution compared with the revisit time of the satellite.

Swath corresponds to width of the portion of the ground that the satellite “sees” at each pass. The larger the swath, the bigger the observed area at each pass.

Off-nadir angle corresponds to the angle at which images are acquired compared with the “nadir”, i.e. looking straight down at the target. In practice, objects located directly below the sensor only have their tops visible, thus making it impossible to represent the three-dimensional surface of the Earth. High resolution images are therefore generally not collected at nadir but at an angle. A large off-nadir angle enables a wider ground coverage at each pass and the identification of features not visible at nadir, but it reduces the spatial resolution. For optical imagery, typical off-nadir angles are in the range of 25-30 degrees.

Sun-elevation angle corresponds to the angle of the sun above the horizon at the time an image is collected. High elevation angles can lead to bright spots on the imagery while low elevation angles lead to darker images and longer shadows. The most appropriate angle depends on the type of application: a high sun elevation is appropriate for spectral analysis since the objects to be observed are well illuminated while a lower elevation angle is better suited to interpretation of surface morphology (e.g. the projected shadows can enable a better image interpretation).

GNSS

Size, weight, autonomy, and power consumption. Power consumption and size are not strictly GNSS performance parameters, however they are also considered in this analysis, especially for GIS and Mapping-related applications.

- **Autonomy.** Power consumption is the amount of power a device uses to provide a position. The power consumption of the positioning technology will vary depending on the available signals and data. For example, GNSS chips will use more power when scanning to identify signals (cold start) than when computing a position. Typical values are in the order of tens of mW (for smartphone chipsets). GNSS is considered one of the heaviest drains on smartphones batteries
- **Size, weight.** Most GIS devices used by NGOs are handheld or rugged tablets/phones, which implies that they must remain small and lightweight.

Resiliency is the ability to prepare for and adapt to changing conditions and withstand and recover rapidly from disruptions; including the ability to recover from deliberate attacks, accidents, or naturally occurring threats or incidents. A resilient system will change its way of operations while continuing to function under stress, while a robust (but non-resilient) system will reach a failure state at the end, without being able to recover.

Connectivity refers to the need for a communication and/or connectivity link of an application to be able to receive and communicate data to third parties. Connectivity relies on the integration with both satellite and terrestrial networks, such as 5G, LEO satellites, or LPWANs.

Interoperability refers to the characteristic of a product or system, whose interfaces are completely understood, to work with other products or systems, in either implementation or access, without any restrictions (e.g. ability of GNSS devices to be combined with other technologies and the possibility to merge the GNSS output with the output coming from different sources).

Traceability is the ability to relate a measurement to national or international standards using an unbroken chain of measurements, each of which has a stated uncertainty. For Finance applications,

knowledge of the traceability of the time signal to UTC is essential to ensure regulatory compliance of the timestamp.

A.6 List of Acronyms

Acronym	Definition
3GPP	3rd Generation Partnership Project
5GAA	5g Automotive Association
ADAS	Advanced Driver Assistance Systems
ASIL	Automotive Safety Integrity Levels
BEVs	Battery-Electric Vehicles
C2C-CC	Car2car Communication Consortium
CAVs	Connected And Automated Vehicles
CCAM	Cooperative, Connected and Automated Mobility
CCM	Copernicus Contribution Missions
D2D	Direct-To-Device
DSRC	Dedicated Short-Range Communications
EARSC	European Association of Remote Sensing
EAW	Emergency Alerts and Warnings
EETS	European Electronic Toll Service
EGNOS	European Geostationary Navigation Overlay Service
EGNSS	European Global Navigation Satellite System
EMDS	<i>European Mobility Data Space</i>
EO	Earth Observation
ESAs	Electronically Steered Arrays
EUSPA	European Union Agency for the Space Programme
EWSS	Emergency Warning Satellite Service
FR	Frequency Range
GEO	Geostationary Orbit
GNSS	Global Navigation Satellite Service
GSMC	Galileo Security Monitoring Centre
HAS	High Accuracy Service
IEC	International Electrotechnical Commission
IMU	Internal Measurement Unit
IoT	Internet-Of-Things
ISO	International Organisation for Standardisation
ITS	Intelligent Transport Systems
IVS	In-Vehicle System
LEO	Low Earth Orbit
MAIT	Manufacturing, Assembling, Testing
MEO	Medium-Earth Orbit
MNOs	Mobile Network Operators
MSS	Mobile Satellite Services
MVNOs	Mobile Virtual Network Operators
NB-IoT	Narrowband IoT
NTN	Non-Terrestrial Networks

Acronym	Definition
OBUs	On-Board Units
OEMs	Original Equipment Manufacturers
OSNMA	Open Service Navigation Message Authentication
OTA	Over-The-Air
PNT	Of Position, Navigation and Timing
PRS	Public Regulated Service
PSAPs	Public Safety Answering Points
RUR	Report On User Needs and Requirements
SAE	Society Of Automotive Engineers
SARs	Synthetic Aperture Radars
SATCOM	Satellite Communications
SBAS	Satellite-Based Augmentation System
TDD	Time Division Duplex
TISA	Traveller Information Services Association
TN	Terrestrial Networks
TTFF	Time-To-First-Fix
UCP	User Consultation Platform
V2I	Vehicle-To-Infrastructure
V2N	Vehicle-To-Network
V2V	Vehicle-To-Vehicle
V2X	Vehicle-To-Everything
VHR	Very-High Resolution
VLEO	Very Low Earth Orbit
VNIR	Visible Near Infrared T

Table 48: List of acronyms

A.7 Reference Documents

Id.	Reference	Title	Date
RD3	EUSPA Market Report	EUSPA EO and GNSS Market Report (Issue 2)	2024
RD4	C2C Status of C-ITS development in Europe	Car-2-Car Communication Consortium. Objectives and organisational structure – Status on C-ITS in Europe	2025
RD5	IRIS² Regulation	REGULATION (EU) 2023/588 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 15 March 2023 establishing the Union Secure Connectivity Programme for the period 2023-2027	2023
RD6	SpaceRISE	SpaceRISE consortium website	N/A
RD7	UCP2025 MoMs SATCOM	UCP 2025 Minutes of Meeting SATCOM Road and Automotive session	2025
RD8	Road and Automotive UCP	Road and automotive user consultation platform (UCP)	2024
RD9	GNSS technology for precise positioning in CCAM	GNSS technology for precise positioning in CCAM: A comparative evaluation of services	2023
RD10	Sensor selection and placement for connected and automated mobility	A survey on sensor selection and placement for connected and automated mobility	2024
RD11	Collaborative accurate vehicle positioning based on GNSS	Collaborative accurate vehicle positioning based on global navigation satellite system and vehicle network communication	2022
RD12	ERTRAC Roadmap	Connected, cooperative and automated mobility roadmap	2022
RD13	eCall (RP2025)	Interoperable Europe Portal eCall 2025	2025
RD14	5GAA roadmap	Maximising the benefit of future satellite communications for automotive. Technical report	2025
RD13	UCP2025 Interviews		2025
RD14	Road RUR 2023	2023 Road and Automotive Report on User Needs and Requirements	2023

Table 49: Reference documents

EUSPA Mission Statement

The mission of the Agency is defined by the EU Space Programme Regulation.

EUSPA's mission is to be the user-oriented operational Agency of the EU Space Programme, contributing to sustainable growth, security and safety of the EU. In the execution of its mission, EUSPA counts on strong partnerships with the European Commission, European Parliament, Member States, European Space Agency, and private actors across the EU.

EUSPA:

- Provides state-of-the-art, safe and secure positioning, navigation and timing services based on Galileo and EGNOS, cost-effective satellite communications services for EU GOVSATCOM and soon IRIS² and Front Desk services of the EU Space Surveillance Tracking whilst ensuring the systems' service continuity and robustness.
- Promotes and maximises the use of data and services offered by Galileo, EGNOS, Copernicus, EU GOVSATCOM and soon IRIS² 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.

EUSPA: linking space to user needs

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