

2024



Report on Aviation and Drones

User Needs and Requirements

#EUSpace 



Executive Summary

This report assesses the applications of Earth Observation (EO), Global Navigation Satellite System (GNSS), and Satellite Communications (SATCOM) in both manned aviation and drone operations, focusing on user needs, challenges, and emerging requirements. It outlines the primary user needs and expectations for these services and data, highlighting how they are utilised in various operational context. Additionally, the report identifies limitations and gaps encountered by end users, providing insight into areas where advancements are needed to better serve the sector's evolving requirements.

The aviation and drone domain benefits from the European Union Space Programme's User Consultation Platform (UCP), which brings together a diverse range of stakeholders to explore synergies among the program's components. Key users of space-based services in this sector include airports, airlines, drone operators, regulatory authorities, and international bodies, each with unique use cases and requirements. This collaborative approach enables stakeholders to harness the full potential of space-based technologies, addressing the specific needs of each user group and advancing the capabilities within aviation and drone operations.

Priority applications have been updated with insights gathered from stakeholder interviews, including input from service providers and end-users, as well as recent regulatory updates and industry developments. Non-priority applications, while less critical, have also been reviewed and updated since the last report to incorporate the latest advancements in technology, regulatory changes, and innovations.

Drones increasingly rely on EO, GNSS, and SATCOM to support diverse operational scenarios. For drones, Beyond Visual Line of Sight (BVLOS) operations, precise navigation, conspicuity in uncontrolled airspace, and resilience in urban environments drive user needs for GNSS and SATCOM integration. The EO provides datasets (GHS-POP or Urban Atlas) relevant for Specific Operations Risk Assessment (SORA) helping drone operators to assess the ground risk and to comply with the current regulations. The accurate and consistent data from Copernicus is a stepping stone towards the use of dynamic data taking into account variability in population density. The use of GNSS can complement the EO data further, resolving some of the limitations of EO images. To date, a real-time or near-real-time population data is still too expensive to be used by drone operators. Copernicus Digital Elevation Model (DEM) supports drone operations at very low level by providing information on terrain and obstacles.

In manned aviation the report investigates Performance-Based Navigation (PBN) applications, environmental monitoring, and asset management. The GNSS-based positioning and electronic conspicuity are critical in enabling airspace integration to operate safely in complex, congested airspaces. In response to European Green Deal objectives, manned aviation puts emphasis on environmental factors, including contrail formation monitoring, particulate matter monitoring and monitoring of air quality near airports. The EO data plays a pivotal role by increasing the efficiency of data collection, data analysis and proactive decision-making, supporting operational safety and compliance.

The current industry challenges are related to GNSS Radio Frequency Interference (RFI), lacking standards for GNSS supporting drone navigation and its performance in urban canyons. A gap in high-bandwidth, low-latency SATCOM systems essential for real-time data transfer and operational control across large distances was highlighted by the users. The use of multi-constellation, multi-frequency GNSS and Galileo differentiators (HAS and OSNMA) offer promising improvements in resilience and accuracy. Additionally, the secure SATCOM services are essential for long-range missions, ensuring that unmanned aircraft can maintain connectivity and operational security, crucial for high-stakes applications such as border surveillance or emergency response.

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1 INTRODUCTION AND SCOPE OF THE REPORT

1.1 Scope

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 the Aviation & Drone community, reporting the most up-to-date user needs and requirements in the Aviation & Drone market segment for Position, Navigation and Timing (PNT), Earth Observation (EO) and secure telecommunications (SATCOM) technologies. Its scope is to cover needs and requirements from the user's 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 is a regular event, where users from different market segments meet to discuss their needs and application-level requirements for GNSS PNT, EO and SATCOM with the conclusions 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.

The report is organised as follows:

- **Section 2.1** describes the role of the EU Space Programme in meeting the user needs towards the EO, GNSS and SATCOM services.
- **Section 2.2** presents market evolution and key trends in Aviation & Drones segment, together with definition 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** provides current segment applications and operational scenarios relevant for EO, GNSS and SATCOM, presenting main user needs and expectations towards services and data to serve operational scenarios, together with limitations and gaps identified by end users.
- Finally, **Section 2.5**, summarises the main User Requirements for Aviation & Drones in the applications domains analysed in this report.

The main changes compared to the previous issue (2023) reflect the emergence of new priority applications or change in the maturity of some applications. HAPS, as a new airspace user, is addressed for the first time from both GNSS and EO perspective. Emphasis is also placed on GNSS resilience and ways to mitigate RFI (Radio Frequency Interference) issues impacting both manned and unmanned operations. From drones' perspective, detailed requirements for Navigation (PNT) were collected through EUSPA's survey and the UCP process. The contribution of EO to SORA was already discussed in 2023, however with the new SORA 2.5 [RD51], population data becomes instrumental. In response to these updates, EUSPA invested resources to assess how Copernicus data could be used.

1.2 Methodology

The UCP process is composed by the systematic steps that are implemented in a continuous, iterative manner, with logical order. The repeated steps allow transparency and continuous updates of the results, considering the new market developments and evolving user needs and requirements. For each step, depending on the peculiarities of the market segments and technological components of the analysis, additional steps, involving specific expertise might be added.

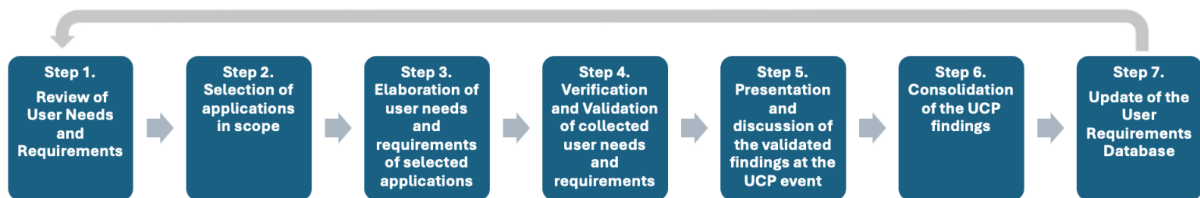


Figure 1: User Consultation Process high level methodology with continuous steps

In each market segment there is a constant evolution due to the changes in legislation, standards, technological trends and so forth, therefore the update of the Report on User Need and Requirements occurs 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 [RD46] 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), 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.

UCP event is organized by EUSPA on an annual basis and offers a forum to present and discuss the findings, being additional layer of updates, gaps filling and validation 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 in the EUSPA User Requirements Database (Step 7).

2 AVIATION AND DRONES

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

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. EUSPA's role contains:

1. User-Centric Approach

EUSPA adopts strategies that prioritise 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.

6. Key Activities and Initiatives

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.

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 satellite 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.
- 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 contributing 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:



Atmosphere

Atmosphere
Monitoring
Service (CAMS)



Climate

Climate
Change Service
(C3S)



Emergency

Emergency
Management
Service (CEMS)



Land

Land
Monitoring
Service
(CLMS)



Marine

Marine
Environment
Monitoring
Service (CMEMS)



Security

Security
Service
(CSS)¹

Through the User Consultation Platform (UCP) [RD54], EUSPA brings all stakeholders together, allowing them to leverage the synergies of the Space Programme's individual components to support various use cases. The key users of space-based services within aviation and drones segment include airports, airlines, drone operators, and other authorities and international bodies; all with varying use cases and needs. Further description of the EU Space programme can be found in EUSPA's Market Report [RD1].

In this year's UCP, number of Copernicus applications were addressed. More specifically, High Altitude Platform Systems (HAPS) utilising EO data for SORA operations planning and ground risk assessment and identification of potential emergency landing sites; environmental monitoring around airports; and Instrument Flight Procedures (IFP) design. These applications are described in more detail in section 2.4.

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 20 cm 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, and already operational in more than 400 airports and helipads.

The user requirements are constantly evolving in response to advancements in technology and the latest challenges, e.g. Radio Frequency Interference (jamming and spoofing). The emerging applications also pose new requirements on the system.

In unmanned aviation, the user needs are driven by the raising levels of drone operations requiring better coverage and higher positioning accuracy to operate in non-open sky environments (built-up areas). A lot of

¹ Copernicus Security Service is provided to registered public users only.

emphasis is put on electronic conspicuity solutions which are expected to enable safe integration of drones into uncontrolled airspace.

The unmanned industry is still lacking the necessary standardisation, including for the GNSS which is partially addressed within EUROCAE WG-105 SG6 (SORA).

The manned aviation, on the other hand, is powered by certified solutions supporting all-weather operations and improving operations' efficiency. This is where wider deployment of GNSS can support navigation infrastructure rationalisation and efficiency of operations.

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.

In the context of drone operations, secure SATCOM is essential for enabling BRLOS operations, providing reliable communication links that ensure continuous connectivity, facilitate real-time data sharing, and enhance situational awareness for operators navigating complex urban environments.

To achieve safe and efficient drone integration into airspace, it is essential to establish a stable, compliant, and effective satellite-based C2 link (command and control) that meets critical performance and regulatory requirements, including OSO 6, OSO 5, and OSO 24. Whilst SATCOM-based C2 links exist and are operational in specific applications, their broad deployment in civilian drone operations still needs evolving to meet regulatory and technical requirements.

The manned aviation, on the other hand, is powered by certified solutions supporting all-weather operations and improving operations' efficiency. This is where wider deployment of GNSS can support navigation infrastructure rationalisation and EO to monitor environmental performance.

2.2 Market Overview & Trends

2.2.1 Market Evolution and Key Trends

Introduction to the Aviation & Drones

The aviation and drone industries are experiencing major transformations due to technological advancements and a firm commitment to sustainability. A key focus is reducing aviation's carbon footprint through sustainable technologies such as electric and hybrid aircraft. Recent progress in battery technology has made electric and hybrid aircraft viable for shorter regional routes, with hybrid-electric propulsion and alternative fuels, including hydrogen and Sustainable Aviation Fuel (SAF), advancing this shift. SAF, derived from renewable sources like biofuels, can cut greenhouse gas emissions by up to 80% over its lifecycle. The EU mandate for SAF usage and the rising adoption of SAF blends by airlines are expected to drive demand significantly. To further reduce climate impact, new tools are being developed to detect and avoid Ice Super-Saturated Regions (ISSR), where contrails are likely to form, thereby helping to mitigate their warming effects on the atmosphere.

Innovative Air Mobility (IAM) is reshaping urban transport with electric Vertical Take Off and Landing (eVTOL) aircraft, supported by electric propulsion and autonomous technologies. Leading companies are actively trialling these vehicles, with infrastructure developments, including vertiports and charging stations, which are essential for large-scale operations. eVTOL operations are expected to improve efficiency and reliability, with numerous tests underway. As IAM evolves, regulatory bodies are setting guidelines for operations, including Beyond Visual Line of Sight (BVLOS), which allow drones to operate over extended ranges, making last-mile drone deliveries feasible for remote and difficult-to-reach areas. BVLOS regulations open new possibilities for time-sensitive logistics applications, such as medical deliveries.

The integration of conventional Air Traffic Management (ATM) with Unmanned Traffic Management (UTM) is essential for the safe, commercial operation of drones. Such integration will be possible thanks to incorporation of elements like enhanced situational awareness through electronic conspicuity and digitalisation of ATM via System Wide Information Management (SWIM), which supports data sharing between all types of airspace users. This will enable a coordinated approach to airspace management as drone operations increase.

Artificial Intelligence (AI) and big data are playing a transformative role in aviation, particularly in predictive maintenance, where sensors in aircraft engines and other components monitor system health and identify potential failures based on historical data. These technologies also provide valuable insights into passenger behaviours, weather patterns, and aircraft performance, supporting better decision-making in flight routing, fuel management, and scheduling. This leads to more efficient and cost-effective operations across the aviation sector.

High-Altitude Operations (HAO) performed by a variety of High-Altitude Platform Systems (HAPS), bring a range of potential services. These platforms offer extended communication and surveillance coverage, particularly in regions lacking ground-based Communication, Navigation, and Surveillance (CNS) infrastructure. HAPS provide critical connectivity and monitoring solutions over large areas, extending communication and surveillance capabilities and offering an added layer of resilience to satellite networks. With the rise of autonomous drone systems, ensuring CNS resilience has become increasingly important. As GNSS is vulnerable to spoofing and jamming, the equipage with multi-constellation and multi-frequency systems, enhances robustness in navigation services. Moreover, HAPS offer an ideal platform for EO able to keep position above an area of interest over prolonged periods, complementing satellite and ground-based infrastructure.

The GNSS and EO are integral to supporting safe and efficient operations of manned aviation, aligning it with sustainability objectives. GNSS underpins navigation, offering precision and enhanced safety. By utilising dual-frequency multi-constellation (DFMC), operators can also achieve an increased resilience to RFI compared to standard GNSS. A notable advancement is the certification of Galileo's Satellite-Based Augmentation System (SBAS) and the deployment of DFMC GNSS, which will significantly enhance

navigation reliability and precision once aviation users start equipping with the necessary avionics (to be available by the end of the decade). The Galileo Open Service Navigation Message Authentication (OSNMA) further mitigates some types of spoofing risks to Galileo, helping to ensure accurate positioning data, especially in interference-prone areas.

For drones, GNSS advancements are crucial for achieving precise and reliable navigation, particularly in complex urban environments. High Accuracy Services (HAS) and hybridisation with additional sensors enable accurate positioning during BVLOS operations, particularly important for landing phase in densely populated areas. In locations where signal might be obstructed (i.e. urban canyons) the accuracy starts degrading, despite utilising HAS. In such cases, hybridisation of sensors (e.g. use of cameras, lidars, etc.) enhances missions' continuity. GNSS-based navigation supports a range of drone applications, including infrastructure inspection, emergency response, agriculture and logistics, where precise positioning is critical. The scalability of drone services will be possible through successful safety cases providing evidence of industry maturity. The GNSS will play a key role in such safety cases and regulatory compliance. However, the enhanced performance provided by GNSS still need to be recognised by authorities as mean of compliance when establishing operation safety case.

EO technologies are also revolutionising aviation, especially in environmental monitoring. EO data from systems like Copernicus enables operators to track and avoid contrail formation and particulate matter emissions, reducing aviation's environmental impact. This data helps adjust flight paths to minimise emissions and fuel use, supporting sustainability goals. EO further assists with route planning and airport monitoring by providing insights into weather patterns and terrain, helping ensure operational efficiency. For instance, tracking volcanic ash clouds with EO data allows airlines to reroute flights when needed, optimising fuel use and enhancing passenger safety. The Copernicus Digital Elevation Model (DEM) can be used for some of the steps of the flight procedure design process, such as conceptual design or feasibility analyses. Compared to free Global DEMs, it provides better accuracy and offers homogeneous data regardless of national borders. Similarly, the population data from Copernicus i.e. Global Human Settlement Population (GHS-POP) can be used for airport environmental impact assessments such as air quality and noise studies.

In the drone sector, EO data supports regulatory compliance and mission planning, particularly through tools like the GHS-POP dataset from Copernicus, which allows operators to assess ground risk in populated areas as per SORA guidelines [RD51][RD8]. EO data enhances the effectiveness of drone missions across sectors like public safety, agriculture, and infrastructure monitoring. In high-altitude operations, EO data plays a crucial role in identifying suitable landing sites and monitoring weather, vital for sustained HAPS operations that support extended communications and surveillance networks.

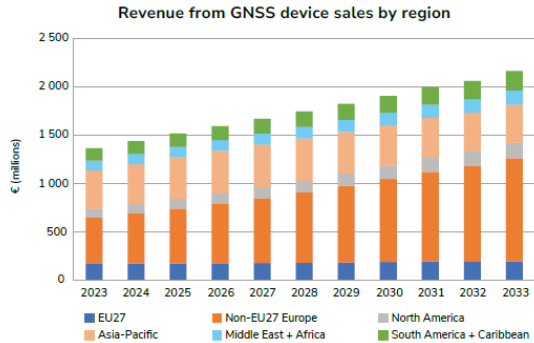
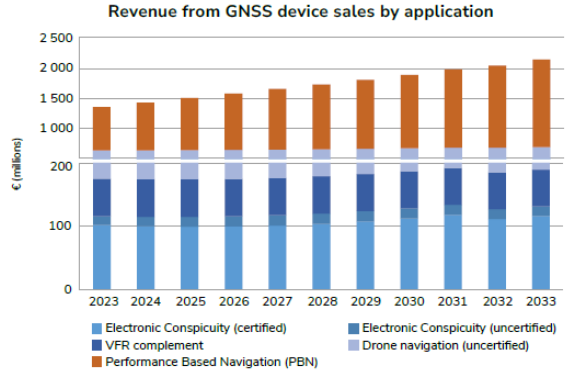
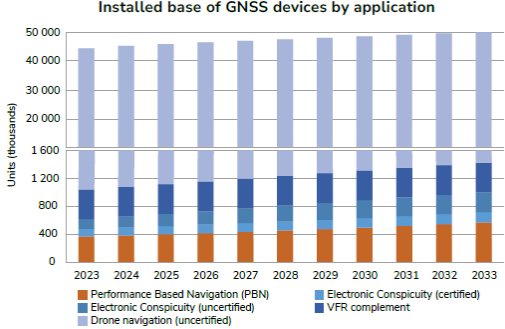
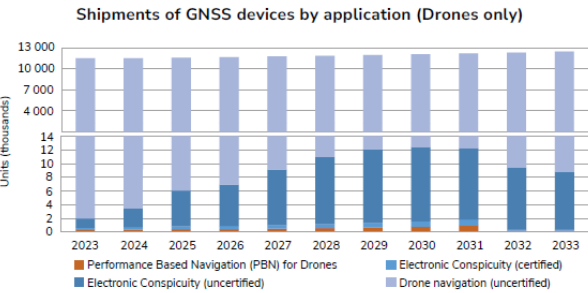
Key operational scenarios across aviation and drones demonstrate the critical roles of GNSS and EO. A precise and reliable satellite-based navigation is a prerequisite for concepts like Performance-Based Navigation (PBN) which enables manned traffic to navigate through complex airspaces and Instrument Flight Rules (IFR) environments. In an unmanned sector, concepts like Urban Air Mobility rely heavily on accurate navigation, as managing densely populated airspaces and integrating diverse aerial vehicles introduces various safety challenges. Urban Air Mobility (UAM) and BVLOS operations also rely on GNSS for accurate navigation, with EO data providing population and building density maps that help operators plan safer routes through urban areas. This GNSS and EO integration meets safety and regulatory requirements, reducing risks when flying over densely populated regions.

For aircraft maintenance and optimisation, EO and GNSS support effective scheduling and cost management. EO-based particulate monitoring tracks exposure to environmental factors affecting aircraft components, while GNSS tracking supplies precise operational data. Together, these tools enable proactive maintenance, reducing the frequency and cost of unplanned repairs.

High-Altitude Operations depend on SATCOM for real-time communication across large distances, while GNSS and EO extend coverage for high-altitude platforms. This combination allows HAO platforms to monitor vast areas and provide continuous data for applications like environmental monitoring and emergency response.

To conclude, the convergence of EO, GNSS, and SATCOM technologies is enabling more precise, resilient, and environmentally conscious aviation and drone services. EO services increasingly support aviation safety and environmental compliance, providing high-resolution data for airport infrastructure, obstacle monitoring, and emissions management. These data complement GNSS's precision, building a robust framework for safety and regulatory adherence. The expanding use of GNSS augmentation and DFMC systems further strengthens aviation's performance, addressing interference vulnerabilities and enhancing navigation integrity during critical phases of flight. Additionally, GNSS's role in U-space and Electronic Conspicuity systems underscores its foundational place in future airspace management, especially as drone use grows.

In summary, SATCOM advancements ensure reliable long-range communication for high-altitude and urban mobility applications, enabling real-time actionability of EO and GNSS data. This synergy between EO, GNSS, and SATCOM reflects a progressive shift in aviation towards interoperability, enhanced precision, and sustainable operational practices.



2.2.2 Main User Communities

In Aviation & Drones segment the users' communities are present along the value chain expressing various needs. The UCP analysis focuses on the needs and requirements of the end users and intermediate users (service providers). Considering the user domain, the following groups can benefit from GNSS and EO data:

- **Core users:** International institutions and bodies and national, regional or local authorities entrusted with the definition, implementation, enforcement and monitoring of a public service or policy.
 - GNSS data supports authorities and regulators in carrying out their duties, especially in validation exercises (e.g. calibration flights), compliance checks or SAR missions.
 - EO contributes to the decision making of national governments tasked with, for example, setting up plans for disaster response, improving resilience against high-risk hazards, or adapting policy to the effects of extreme weather and climate change. Additional contributors are organisations such as the Intergovernmental Group on Earth Observations

(GEO) which coordinates Earth Observation systems and facilitates data and information sharing at a global level.

- **Airspace users and infrastructure providers:**

- GNSS is an integral part of the navigation infrastructure and will be strongly relied on by airports, ANSPs and airspace users. GNSS does also support surveillance, when aircraft broadcast their position, as well as communications, when used for time synchronisation. The equipment's manufacturers (receivers or avionics' manufacturers) are another relevant stakeholder affected by the requirements, but the final responsibility for using the equipment and getting the approval for that remains on the airspace user side. ANSPs are responsible for signal in space performance in the airspace where the flight procedures are going to be flown, complying with ICAO Annex 10 [RD2] requirements and others supporting both certified and uncertified applications. In the field of drones, GNSS is the main positioning source. Therefore, it is relevant for drone operators, USSP/ANSP, drone manufacturers and integrators.
- EO data and analysis tools not only help businesses address sustainability and climate risks but also optimise their use of resources (e.g. farmers, shipping companies, airlines, drone operators, etc.). The use of EO by these communities is abundant – use cases and examples of applications can be found throughout this report, both in general and in each market segment.

- **Scientific bodies and researchers:**

- Scientists, universities and start-ups are also an important contributor to GNSS market through research activities and testing of GNSS capabilities for new use cases.
- The availability of EO data in combination with technological developments (e.g. artificial intelligence, cloud computing, and machine learning) enables research communities to generate a vast amount of insights – these include tracking and visualising forest and coral-reef loss or predicting disease outbreaks and glacier melts.

This entire value chain of the Aviation & Drones can be found in the Market Report [RD1].

2.3 Key market drivers – Polices, Regulations, Standards

The aviation & drones segment is a heavily regulated market. Local, European and international regulations and standards drive not only the need for the improved and new services but also many innovations on the market. The basic alignment of regulation within manned aviation is done by ICAO whereas EASA provides more stringent regulatory framework at the European level. In the drone industry, JARUS plays a role equivalent of ICAO while EASA is an important regulatory body for drones. The standardisation for both segments is done within RTCA, ITU and EUROCAE. There are a number of relevant organisations representing different groups of stakeholders, including IATA or CANSO.

The following chapter gathers a non-exhaustive list of relevant organisations, regulations, standards and other guidelines that influence implementation of satellite-based services and define their requirements.

2.3.1 Relevant organisations

International regulators

ICAO: International Civil Aviation Organisation is a specialized agency of the United Nations; ICAO's main task is to manage the administration and governance of the Convention on International Civil Aviation (Chicago Convention).

ITU: International Telecommunication Union is the UN specialised agency responsible for telecommunications, in particular for spectrum management and technical characteristics of systems.

IATA: The International Air Transport Association is the trade association for the world's airlines, representing some 340 airlines or over 80% of total world air traffic.

CANSO: the Civil Air Navigation Services Organisation groups a large number of air navigation service providers, civil aviation authorities and industrial actors.

JARUS: the Joint Authorities for Rulemaking on Unmanned Systems is a group of experts from the National Aviation Authorities (NAAs) and regional aviation safety organisations which recommends technical, safety, and operational requirements to safely integrate Unmanned Aircraft Systems (UAS) into aviation.

European organisations

European Commission: The EC plays a major role in the aviation domain in Europe. It defines the global strategy at economical level, issues regulations related to aviation, notably in the frame of Single European Sky and conducts research in that domain (SESAR).

EASA: The European Union Aviation Safety Agency created in 2002 that was initially competent for rule-making and aircraft type certification.

EUROCONTROL: The European Organisation for the Safety of Air Navigation created in 1963 with mission to harmonise Air Traffic Management in Europe for civil and military airspace users and to increase safety and efficiency while reducing environmental impact.

ECAC: The European Civil Aviation Conference is an institution created in 1955 for cooperation with the European Council of Europe. It groups 44 Member States.

National Aviation Authorities (NAAs): national NAAs have to implement ICAO recommendations (or to publish any deviation to these recommendations).

Airlines associations: In Europe the main regional airlines associations are the AEA (Association of European Airlines), the European Regions Airline Association (ERAA), and Airlines for Europe (A4E). All these associations lobby for better traffic conditions and lower air navigation/airport fees.

Airspace user associations: In Europe there are several associations that represent the diverse activities undertaken by communities ranging from commercial activities such as air taxi, business travel, flight training, through to recreational flight and air sports. Associations include Europe Air Sports (EAS), International Aircraft Owners and Pilots Association (IAOPA), European Helicopter Association (EHA) and the European Business Aviation Association (EBAA).

European standardisation organisations

EUROCAE: the European Organisation for Civil Aviation Equipment is a non-profit organisation dedicated to aviation standardisation since 1963. It produces different standards for aviation equipment or systems and often works jointly with RTCA.

Drone European associations

Drone Alliance Europe (DAE): A coalition of leading technology companies representing the commercial drone industry before European political leaders, regulators, and other industry stakeholders, as well as international regulatory and advisory bodies.

JEDA, Joint European Drone Associations: is a new (2021) policy-oriented partnership of European drone-related associations, created to promote the interests of the growing number of stakeholders engaged in the operation, production, research and development, service, and applications of all kinds of unmanned aircraft systems (UAS) in Europe.

Regional bodies

AFCAC: African Civil Aviation Commission, created in 1969, is a specialised aviation body of the African Union. It comprises 53 Member States.

ACAC: Arab Civil Aviation Commission, created in 1996, is a specialised aviation body of the Arab League. It comprises 18 Member States.

LACAC (1973): Latin American Civil Aviation Commission, created in 1973 by 12 Latin America States, this regional aviation body is mostly interested in civil aviation economics rather than technical matters.

RTCA: founded in 1935; the Radio Technical Commission for Aeronautics, this non-profit organisation produces standards for equipment and systems.

Other relevant organisations

HAPS Alliance: unites companies from telecommunications, technology, aviation and aerospace industries to eliminate the digital divide and bring connectivity to more people, places and things worldwide by accelerating the promotion of High Altitude Platform Systems (HAPS) in the stratosphere.

GUTMA: is a global UTM association connecting private and public organisations, including regulators, that are involved in UTM and drone activities.

2.3.2 Selection of applicable regulations²

E.g. UN regulation

ICAO Annex 10 (Aeronautical Telecommunications) [RD2]: This annex deals with GNSS systems and includes standards and recommended practices for their use in aviation, covering areas like performance, integrity, and availability.

² Not an exhaustive list of all applicable regulations

ICAO Annex 19 (Safety Management) [RD18]: This includes guidelines for the safety management of GNSS operations, emphasizing the importance of monitoring and mitigating GNSS-related risks.

Global Navigation Satellite System (GNSS) Manual (ICAO Doc 9849) [RD19] : Provides comprehensive guidance on the implementation and use of GNSS in aviation, focusing on safety, security, and operational considerations.

E.g. EU legislation

Regulation (EU) No. 965/2012 [RD20]: Includes provisions for the use of GNSS in the operational procedures of aircraft, ensuring that operators adhere to safety standards related to navigation.

Regulation: (EU) 2018/1048 [RD21]: Includes airspace usage requirements and operating procedures concerning performance-based navigation (PBN).

Regulation (EU) No. 2019/947 [RD22]: Establishes rules for the operation of unmanned aircraft systems (UAS) in the European Union, ensuring safety, security, and environmental protection while promoting innovation in drone operations.

Regulation (EU) No. 2019/945 [RD23]: Focuses on the market and safety requirements for unmanned aircraft, defining standards for the design and manufacture of drones to enhance safety and minimize risks during their operation.

Regulatory framework for U-space (EU) No. 2021/664 [RD24]: Amends previous drone regulations to clarify the technical and operational requirements for UAS, particularly regarding the use of remote identification and operational limitations, to improve safety and accountability in drone operations.

2.3.3 Other (standards, practices, guidelines, ...)

2.3.3.1 Relevant Standards for EO

EO techniques present a lack of consistency between sensors and their calibration, in data formats and structures, in accuracies and terminology, and structures. Uptake of some EO techniques has been slow and there have been challenges in ensuring interpretability. International standards would help address these issues, and these guidelines aim to go some way towards improving the accessibility of EO data products and technologies.

There are currently very few standards or regulatory documents in EO, either in data quality or in processing or products. The internationally adopted standards in data formats and metadata associated with digital spatial data were provided by ISO, IEEE, OGC, GRSS and SEOAH:

- The International Organization for Standardization (ISO);
 - ISO/TR19121:2000 [RD25] concerning Geographic information, imagery, and gridded data.
 - ISO 19115:2014 [RD26] 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 organisational unit within GRSS to handle standards development within the IEEE.

2.3.3.2 Relevant Standards for GNSS

EUROCAE

ED-88 [RD27]: MOPS for Multi-Mode Airborne Receiver (MMR) including ILS and MLS and GPS used for Supplemental Means of Navigation. This document specifies minimum performance standards for airborne equipment which may receive transmissions from three types of ground transmitters, ILS, MLS, and GPS.

ED-102 [RD28]: MOPS for 1090 MHz Extended Squitter ADS-B and TIS-B. This document contains Minimum Operational Performance Standards (MOPS) for airborne equipment for Automatic Dependent Surveillance – Broadcast (ADS-B) and Traffic Information Service – Broadcast (TIS-B) utilizing 1090 MHz Mode-S Extended Squitter (1090ES).

ED-114 [RD29]: MOPS For Global Navigation Satellite Ground Based Augmentation System Ground Equipment to support Precision Approach and Landing as part of a Global Navigation Satellite System (GNSS) to support all categories of precision approach and landing.

ED-126 [RD30]: Safety and Performance and Interoperability Requirements Document for ADS-B in Non-Radar Areas.

ED-129C [RD31]: Technical specification for a 1090 MHz Extended Squitter ADS-B Surveillance System in which the ADS-B System is sensor element of an overall infrastructure supporting ATS Surveillance Service(s), such as the Approach Control and Area Control Services within the European Air Navigation Region.

ED-160 [RD32]: Safety and Performance and Interoperability Requirements Document for Enhanced Visual Separation on Approach (ATSA-VSA) in which the GNSS display forms an integral part.

ED-161 [RD33]: Safety and Performance and Interoperability Requirements Document for ADS-B in radar-controlled airspace. It defines the minimum requirements for the end-to-end operational, safety, performance and interoperability aspects for all implementations at Aircraft and Ground Domain level.

ED-163 [RD34]: Safety and Performance and Interoperability Requirements Document for ADS-B Airport Surface Surveillance Application (ADS-B-APT). This document defines and allocates the set of minimum requirements for the end-to-end operational, safety, performance and interoperability aspects for implementations of the ADS-B-APT application.

ED-259A [RD35]: Minimum Operational Performance Standard for Dual-Frequency Multi-Constellation Satellite-Based Augmentation System (SBAS) avionics.

ED-301 [RD36]: Guidelines for the Use of Multi-GNSS Solutions for UAS Specific Category - Low Risk Operations SAIL I and II - that improves the capability to manage external services that affecting UAS operations.

RTCA

DO-229 [RD37]: MOPS for airborne navigation equipment relying on the Global Positioning System (GPS) and augmented by SBAS.

DO-228 [RD38]: MOPS for antenna performance used by GNSS receiver equipment specifically designed to use GPS or GLONASS and augmented as required to meet navigation performance requirements

DO-242 [RD39]: Minimum Aviation System Performance Standards (MASPS) for Automatic Dependent Surveillance Broadcast (ADS B) for aircraft and ground vehicles periodically broadcasting position vectors and other information.

DO-253 [RD40]: MOPS for airborne navigation equipment using GPS and augmented by the Local Area Augmentation System to support CAT I precision approach minima.

DO-301 [RD41]: MOPS for GNSS Airborne Active Antenna designed to used GPS or Galileo on the L1 Frequency Band and augmented as required to meet navigation performance requirements

2.3.3.3 Relevant Standards for SATCOM

SATCOM is governed by a combination of regulatory frameworks, technical standards, and operational guidelines set by various organizations. Some of the key standards and regulatory bodies include:

International Telecommunication Union (ITU) Standards³

ITU Radio Regulations (RR): These are global standards for the use of the radio frequency spectrum, including satellite services. They govern frequency allocations and ensure interference-free operations of satellite communications worldwide.

ITU-T Recommendations: Technical standards for satellite communication systems, including operational and performance criteria for satellite payloads, power management, and link budgets.

European Union Aviation Safety Agency (EASA) Guidelines

EASA's UAS Regulations: These include guidelines for SATCOM use in BVLOS (Beyond Visual Line of Sight) operations, particularly in relation to flight termination systems and communication requirements for unmanned aircraft.

OSO⁴ 5: Focuses on C2 (Command and Control) link performance, ensuring the robustness and reliability of the communication system during extended-range operations.

OSO 6 (C2 Link): EASA's operational safety objectives (OSOs) that ensure compliance for communication systems, including SATCOM, used for C2 (Command and Control) links in extended-range operations.

OSO 13: Addresses geographic limitations of SATCOM systems and ensures reliable and secure communications over large areas for aviation operations, including unmanned aircraft.

OSO 24: Relates to the availability and integrity of the communication link, ensuring that the SATCOM system remains operational during critical phases of flight, particularly in remote areas or for operations requiring high-reliability systems.

International Civil Aviation Organization (ICAO) Standards

ICAO Annex 10 [RD2]: Contains key standards for aeronautical telecommunications, including SATCOM for air traffic control, communication during oceanic and remote operations, and data link communications such as CPDLC (Controller-Pilot Data Link Communication).

³ ITU is also relevant for other domains, supporting navigation and surveillance.

⁴ OSO 5, OSO 6, OSO 13, and OSO 24 are operational safety objectives (OSOs) defined in the Joint Authorities for Rulemaking on Unmanned Systems (JARUS) Specific Operations Risk Assessment (SORA) framework, which guides safe, risk-based operation of Unmanned Aircraft Systems (UAS).

2.4 User Needs and Requirements

This chapter provides summary of user needs and requirements pertaining to Aviation & Drones applications introduced before, describing the different roles and needs covered by EO, GNSS and SATCOM and, ultimately, identifying the corresponding requirements from a user perspective.

The table below depicts the main applications making use of EO/GNSS/SATCOM technologies in Aviation & Drones, with indication whether this report covers it in the scope of the analysis or not. 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. While each one of the applications addressed in this document can benefit or potentially benefit from satellite technologies, the current issue of the RUR does not cover in detail the needs and requirements of all applications. Some applications are more mature than the others as it comes to uptake of EO/GNSS/SATCOM, therefore there is no equal level of details provided to all of them. The table below presents the scope of the analysis covered in the current version of user needs and requirements report.

Table 1: Applications analysed in the report

Sub-segments	Applications		Relevance
Communication	Time synchronisation		GNSS
	ATM system timing		GNSS
Environmental Monitoring	Particulate Matter Monitoring		EO
	Contrail formation and monitoring		Synergetic
Navigation	Resilience requirements for a total PBN environment		GNSS
	PBN Applications	RNAV / RNP for En-route and TMA	GNSS
		RNP APCH (LNAV)	GNSS
		RNP APCH (LNAV/VNAV)	GNSS
		RNP APCH (LPV)	GNSS
		RNP AR APCH	GNSS
		A-RNP	GNSS
		RNP 0.3	GNSS
	GBAS CAT I		GNSS
	GBAS CAT II/III		GNSS
	Precision approaches with autoland		GNSS
	Transition from P-RNAV/RNP/RNP AR to LPV		GNSS
	Transition from continuous descent approach (CDA) to LPV continuous descent approach		GNSS
	Steep approach (5°) based on GNSS (EGNOS)		GNSS
	PBN Approach procedures in simultaneous operations to instrument parallel runways (SOIR)		GNSS
VFR complement		GNSS	

Sub-segments	Applications	Relevance
	Jamming & Spoofing	GNSS
Operations Management	Aircraft Maintenance and Operation Optimisation	EO
	Airport Asset Monitoring	EO
	Monitoring Terrain Obstacles near an Airport	EO
Surveillance	Search and Rescue (GADSS)	GNSS
	Terrain awareness	EO
Weather Services	Hazardous Weather Identification	EO
Drones	SORA ground risk assessment	EO
	Positioning for non-navigation functions	GNSS
	Navigation (PNT) for drones	GNSS
	HAPS	Synergetic
	Geo-awareness System	GNSS
	Geo identification System	GNSS
	eConspicuity ⁵	GNSS
SATCOM	Maritime Surveillance applications	SATCOM
	Land Border Surveillance applications	SATCOM

⁵ The application investigates the user requirements from both manned aviation and drone users.

2.4.1 Aviation & Drones Applications and current EO/GNSS/SATCOM needs and requirements

2.4.1.1 Communication

2.4.1.1.1 Time synchronisation

GNSS provides precise time information that is used in many aviation systems to synchronise local clocks to Coordinated Universal Time (UTC); these synchronised clocks are used to assign globally valid and comparable time stamps to events.

In the aviation domain, surveillance sensor data exchange with ATM systems is the most common application using GNSS timing as this data is timestamped, to inform the system of the target position measurement event time. For this purpose, both surveillance systems and ATM systems at air traffic control (ATC) centres rely on GNSS for time referencing that is synchronised with a local time server for resilience purposes to provide time signals to the rest of the ATM or surveillance modules.

Recent developments in time synchronisation within the aviation sector and other critical infrastructure highlight the growing importance of enhancing resilience against GNSS vulnerabilities, such as jamming and spoofing. Modern synchronisation technologies are evolving to support more resilient and precise timing solutions. The synchronisation solutions, featuring STL (Satellite Time and Location) technology, are emerging. They are designed to be less vulnerable to interference and compatible with various network configurations, including those that traditionally rely on GNSS. This dual-source approach, combining GNSS and STL, aligns with the industry's shift towards a zero-trust architecture, ensuring continuous and precise synchronisation even when GNSS signals are compromised.

2.4.1.1.2 ATM system timing

The ground systems used by air traffic control are increasingly connected. The systems rely on precise and high integrity timing for synchronization of logs, communication and traffic handover at system level - all of which are dependent on GNSS derived timing. The accuracy requirement for this timing is linked to the above application.

2.4.1.2 Environmental monitoring

2.4.1.2.1 Particulate Matter Monitoring

Particulate Matter (PM), also called particle pollution, defines the concentration of solid particles and liquid droplets in the air. Examples include ash, dust, soot, smoke, sand or ice. Usually, PM_{2.5} and PM₁₀ is monitored. The number expresses the size (diameter) of the particle in microns. Provisions for notifying airspace users of meteorological events, such as ash clouds, are already prescribed within ICAO Annex 3 [RD17] which stipulates the ASHTAM message format. Other types of precipitation and weather are also defined within this document.

Earth Observation provides a means in parallel with dedicated weather observation satellites, to monitor for the presence of particulates (specifically volcanic ash) which can have a significant impact on aircraft engines. Limited but frequent exposure to PM increases the wear of engine parts and significantly shortens the maintenance cycles. Very high concentration of PM sucked into an engine may also cause a sudden shutdown of the engine. An engine loss infers significant safety risks and therefore route planners and pilots always avoid areas with higher PM concentration. Several examples of this have been reported over the years during volcanic eruption. The severity of these particulates means that nine Volcanic Ash Advisory Centres (VAAC) are established to provide global monitoring and reports which can be disseminated via aviation's usual channels to inform flight crew. These centres rely on a variety of sensors (space and ground) to detect eruptions and monitor cloud formation from volcanic ash. However, the way

in which the VAACs communicate details of volcanic ash, or indeed any other form of atmospheric particulate, must remain compliant with the requirements of ICAO Annex 3 [RD17]. The resulting output remains therefore textual, variable in accuracy and difficult to interpret relying on third party products to integrate and visualise. Warnings about other particulates (e.g. sand) are advised on a national basis through Terminal Area Forecasts (TAFs) and METARs.

The EO systems and services (e.g. Copernicus Atmosphere Monitoring Service, CAMS) are capable of monitoring PM concentration. The user requirements for this application can be described by:

- Vertical coverage – range of flight levels (altitudes) at which the data is collected,
- Vertical resolution – ability to resolve a parameter along different flight levels (altitudes),
- Horizontal coverage – the extent of observed region,
- Horizontal resolution – the size of an area represented by a single data point,
- Temporal resolution – observation revisit period or forecast interval period,
- Temporal coverage – length of historical records, length of forecast horizon,
- Latency – time from observation to delivery.

The aim of the application is to provide an indication of PM extent and therefore nautical miles (NM) are deemed to be sufficient for horizontal resolution. Current guidance in offsetting of routes within ICAO Airport Air Quality Manual (Doc 9889) [RD42] is for offsets of 10-15 NM **Error! Reference source not found.** Given the guidance to avoid by this margin, it would be expected that a resolution at this level is also needed to support modifications of trajectories by ATC and/or flight crew in uncontrolled airspace. However, this also depends on the use of the data. For meteorological purposes, ICAO Airport Air Quality Manual (Doc 9889) [RD42] specifies at the order of 1 degree (or approximately 60 NM). But to support route offsets based on MET would imply that there is added value from accuracy closer to the 10-15 NM.

Flight crews are responsible for checking the weather conditions prior to conducting any flight. This has to be performed with the latest data available and weather reports – including significant winds – which are generally reported with <12 hr validity. However, where the weather conditions are not expected to change significantly, the forecasts are sufficient out to 18 hours [RD17]. Therefore, the EO solution must be able to support a forecast valid for an 18-hr timeframe after which a new forecast valid for a 18-hr wind should be supported. An example, of a current graphical representation of a volcanic ash graphic (VAG) that the service could support is provided below. This can be considered a minimum since users also expressed a need for more frequent updates at the sub-hourly level (e.g. 15 minutes) to support model validations and observation of initial development of, for example, contrails. Thus, the update frequency can be considered to vary per application.

Volcanic Ash Graphic (VAG)

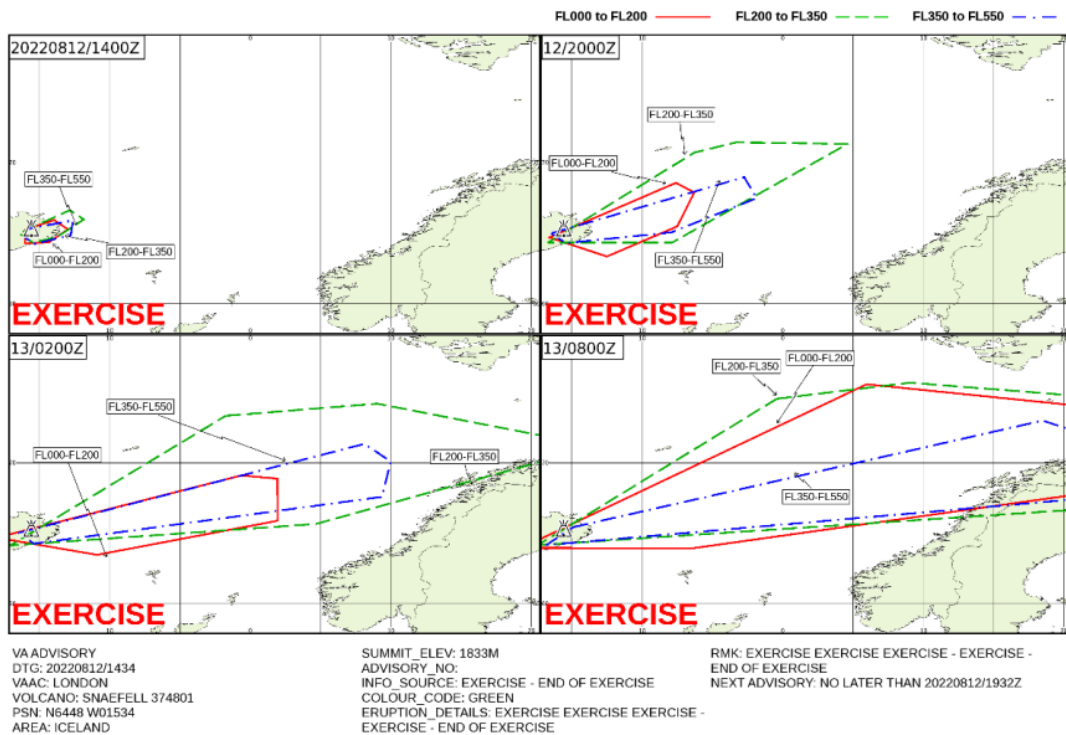


Figure 2: Example of volcanic ash graphic⁶

The requirements elicited by this application are summarised in the following table.

Table 2: Particulate Matter Monitoring EO needs & requirements

ID	EUSPA-EO-UR-AVI-0001
Users	Common users of the product/service
User Needs	
Operational scenario	<p>Numerous examples provided during consultation with users. Operational scenarios will vary depending on the data provided, but all contribute to the safety of the flight operations and help to determine the most flight efficient and environmentally sustainable operation. The information provided is pre-tactical/tactical depending on when the information is received but is provided ahead of the flight and influences decisions made by the pilot on which operations are to be conducted.</p> <p>Examples include:</p> <ul style="list-style-type: none"> Following the eruption of a volcano or a large sandstorm, the application will support the production of warnings provided to the aviation community of areas that should be avoided for flight due to the risk posed to aircraft. It will provide information of sufficient resolution that a decision will be possible to re-route the flight and understand the operational trade-offs for flights proceeding or being cancelled.

⁶ <https://www.metoffice.gov.uk/services/transport/aviation/regulated/vaac/advisories>

	Supporting evaluation of flight levels for flight planning considering contrail avoidance and balancing the competing contributions of winds, fuel burn and moisture levels supporting contrail development.
Size of area of interest	Global.
Frequency of information	Every three hours to support flight planning activities. Can be supported by modelling forecasts with validation based on actual historical measurements.
Other (if applicable)	For avoiding particulates, information should be provided in graphical and textual nature to allow production of alerts similar to that provided by ASHTAM, SNOWTAM within ICAO Annex 3 [RD17] to achieve the regulatory minimum. Advantage should be taken of any additional information that can be extracted and extend the information provided beyond that required as a regulatory minimum. All charting products should support more granular representation than is currently provided (c.f. the IWXXM ⁷).
Satellite EO Data Requirements	
What the service does	Provides an indication to airspace users of where there are significant amounts of particulate matter which should be avoided. With monitoring of the particulate matter, the service may enable forecasts to be provided at shorter intervals and with more precision than current solutions.
How does the service work	The service monitors for the presence of specific particulates through all flight levels (e.g. volcanic ash, sand dust) which are known to cause either engine or airframe corrosive damage in high concentrations. The service should monitor over the period of interest and support the production of more precise and dynamic graphical information whilst remaining compliant with the regulatory standards (e.g. ICAO Annex 3 [RD17]).
Satellite EO Data Requirements	
Spatial resolution	Depending on the application. 10 NM lateral grids for ash and sand and other non-water-based particulates. Vertically, 1,000 ft layers between FL180 and FL450.
Temporal resolution	Data should be no older than 18 hours. To support model validation, 15-minute increments would be required.
Data type / Spectral range	NIR, SWIR, TIR, UV.
Other (if applicable)	Other requirements as per ICAO Annex 3 [RD17] (e.g. time stamped in UTC).
Service Inputs	
Satellite data sources	Sentinel-3, Sentinel-5P and weather observation satellites.
Other data sources	Volcano data; satellite-based, ground-based and aircraft observations; weather forecast models and dispersion models.

The revision of the European Ambient Air Quality Directives⁸, finalised in 2024, has introduced stricter standards for PM_{2.5} and PM₁₀. This regulatory change has emphasised the importance of using advanced EO technologies, like those provided by Copernicus, to meet these new stringent monitoring requirements. The updated directives now explicitly mention the use of Copernicus Atmosphere Monitoring Service (CAMS) data to help Member States comply with air quality regulations.

With the growing emphasis on sustainability, the EO technologies have significantly advanced. For instance, the Copernicus Sentinel-5P satellite, equipped with the Tropospheric Monitoring Instrument (TROPOMI), is now central to global efforts in monitoring air pollution, including particulate matter.

⁷ <http://schemas.wmo.int/iwxxm/2023-1RC1/>

⁸ Revision of the Ambient Air Quality Directives - European Commission

Sentinel-5P provides daily high-resolution data on various pollutants, such as nitrogen dioxide, sulphur dioxide, and aerosols, which are crucial for understanding and mitigating air quality issues affecting aviation.

2.4.1.2.2 Contrail formation and monitoring

According to EUROCONTROL, two-thirds of aviation's climate change impact are caused by aircraft non-CO₂ emissions. Condensation trails (contrails) have a significant contribution to these effects. The contrails are formed when a water vapour from the aircraft engines is ejected into a cold air and subsequently condensates and freezes, creating a small ice crystal. Under specific conditions, these crystals create a layer of cirrus clouds causing a "blanket" effect which prevents the warm air from climbing and thus overheating the lower atmosphere.

Both EUROCONTROL and DLR are developing systems and procedures to mitigate these effects. Relatively, minor operational measures such as flight level adjustments can significantly decrease the environmental impact of contrails. To successfully support such operational measures, recent and accurate EO data is needed.

Research & Development

A number of research and innovation projects like BeCoM (DLR/THALES), CICONIA or CONCERTO (both SESAR projects) are driving future advancements in aircraft emission measurement and monitoring. These initiatives focus on developing technologies to monitor and reduce emissions. By leveraging advanced EO technology and AI, they aim to optimise flight paths, reduce emissions, and ensure regulatory compliance, contributing to a more sustainable aviation industry.

During the stakeholder engagement, EUROCONTROL noted that effective means of monitoring and forecasting contrails are still in R&D phase. Although the physical modelling approach (using cameras to collect data) is relatively developed, there are major limitations due to post-processing which does not allow for a timely identification and association of contrails to specific flights causing the effect. Furthermore, ground-based sensors monitoring the sky have limited coverage and thus the system requires a dense observation network in order to be operational.

DLR, the leader in contrail monitoring, use a Contrail Cirrus Prediction Tool (CoCiP) to model contrail formation. The tool integrates weather prediction data (numerical) to identify sensitive areas and to optimise flight paths to reduce atmospheric impact. Furthermore, DLR notes that validation challenges exist, especially in comparing model outputs with satellite data. Improvement is needed in predicting isostatic regions (with fluctuating land levels) and enhancing validation against physical observations to enhance the model's reliability.

EO data integration

Using satellite-based sensors (e.g. SAR), would greatly improve efficiency in both – operational costs and data turnaround to allow linking between flights and contrails. The linking has been a major challenge since after ~30 min it becomes impossible to identify the contrail origin. The EO/GNSS data can support various operational scenarios within contrail monitoring and forecasting:

- **Post-operational confirmation and re-routing** using EO data with update frequency and high spatial resolution to confirm contrail formation and support re-routing to minimise environmental impact. Such capability would benefit airlines and Air Navigation Service Providers if regulatory bodies (e.g. European Commission) decide to incentivise better environmental performance.
- **Enhancing predictive models for contrail formation** using EO data with high spatial resolution to challenge and improve physical models developed by scientists and research institutions.
- **Modelling contrail creation and environmental impact** using EO data with high update frequency and high spatial resolution to support airlines and regulatory bodies.
- **Joint data collection for contrail confirmation** to improve contrail detection algorithms.

- **Training of models to automate contrail identification** through gathering good quality data for machine-learning models and EO data experts from EUROCONTROL and other research institutions.

Challenges of using EO

The use of machine learning models over “legacy” image detection strategies significantly reduces the need for extensive manual labelling of datasets. Despite the potential of machine learning, the lack of large, agreed-upon datasets holds back its application. From this perspective, “legacy” methods require smaller amounts of data (although manually processed) and thus are currently more feasible. This issue is tackled by Airbus, Thales, and EUROCONTROL as part of the Contrail Net project.

Even the “legacy” methods are not perfect since the manual labelling of contrails is subjective, necessitating guidelines and multiple labellers to ensure consistency. While there are some agreed protocols, detailed consensus is lacking. A comprehensive set of rules for labelling should also be one of the outcomes of the Contrail Net initiative. DLR notes that this is crucial for future monitoring, reporting, and verification systems, particularly if there are financial implications for airlines based on contrail formation.

User needs

According to EUROCONTROL’s feedback, all the operational scenarios mentioned above require EO data with EU-wide coverage and real-time, near real-time or periodic updates (in hours). This is currently not achievable by the current Copernicus Sentinels. The closest useful update rate can be provided by the Sentinel-5P capable of providing daily update rate.

The current achieved horizontal resolution of relevant EO data is 2-5 km². Such resolution is also insufficient for detailed contrail monitoring. In the vertical plane, DLR notes that high-resolution 3D contrail models require resolution of 300 m in order to capture contrail formation regions, which cannot be achieved with the current systems either.

Unless such performance is available, using EO data for contrail monitoring will remain a challenge and so scientists and researchers will tackle other (EO unrelated) challenges. One of these challenges is to develop a comprehensive dataset that links observed contrails to their originating flights, which is crucial for model validation. The datasets developed by EUROCONTROL as part of Contrail Net, will be used for labelling contrail observations. However, the datasets may need to be enhanced to include data fusion approaches to accurately attribute contrails to specific flights. This would enable more effective model validation and operational strategies. Contrail detection and attribution to specific flights could also be done through using high-resolution polar orbiting satellites with thermal infrared channels, such as those proposed by Google for wildfire detection.

Additionally, there is a need for extensive network of ground-based observation sensors as some of the contrails are only observed 20-30 minutes after their formation which makes linking them to flights challenging.

2.4.1.3 Navigation / Positioning

2.4.1.3.1 Resilience requirements for a total PBN environment

The Performance Based Navigation (PBN) is a concept of navigation based on using Area Navigation (RNAV). The performance requirements (e.g. accuracy, integrity or continuity) are expressed as navigation specifications. The introduction of PBN aims to move from sensor-based navigation methods to performance-based which allows to reduce the network of ground-based stations. Other PBN benefits are linked to more efficient airspace usage with direct effects on fuel efficiency, route optimisation and noise and emission reduction.

The PBN Implementing Rule (EC) No 2018/1048 mandates the implementation of EGNOS approaches (LPV and CAT I) to all instrument runways (by 2024) and exclusive use of PBN after June 2030 where SBAS will be the main means of navigation for CAT I approaches .

The role of GNSS in PBN environment is to compute PVT (position, velocity and time). In order to guarantee signal in space for safe and reliable operations, performance requirements are defined by ICAO (Annex 10, Volume I Radio Navigation Aids, Table 3.7.2.4-1) [RD2]. It encompasses:

- horizontal/vertical accuracy,
- integrity (integrity risk, time to alert and alert limits),
- continuity, and
- availability.

For different phases of flight and various types of approaches. Some of these parameters determine the target level of safety. In some cases, the required level of performance may also be a consequence of business continuity requirements.

Table 3.7.2.4-1 Signal-in-space performance requirements

Typical operation	Accuracy horizontal 95% (Notes 1 and 3)	Accuracy vertical 95% (Notes 1 and 3)	Integrity (Note 2)	Time-to-alert (Note 3)	Continuity (Note 4)	Availability (Note 5)
En-route	3.7 km (2.0 NM)	N/A	$1 - 1 \times 10^{-7}/h$	5 min	$1 - 1 \times 10^{-4}/h$ to $1 - 1 \times 10^{-8}/h$	0.99 to 0.99999
En-route, Terminal	0.74 km (0.4 NM)	N/A	$1 - 1 \times 10^{-7}/h$	15 s	$1 - 1 \times 10^{-4}/h$ to $1 - 1 \times 10^{-8}/h$	0.99 to 0.99999
Initial approach, Intermediate approach, Non-precision approach (NPA), Departure	220 m (720 ft)	N/A	$1 - 1 \times 10^{-7}/h$	10 s	$1 - 1 \times 10^{-4}/h$ to $1 - 1 \times 10^{-8}/h$	0.99 to 0.99999
Approach operations with vertical guidance (APV-I)	16.0 m (52 ft)	20 m (66 ft)	$1 - 2 \times 10^{-7}$ in any approach	10 s	$1 - 8 \times 10^{-6}$ per 15 s	0.99 to 0.99999
Approach operations with vertical guidance (APV-II)	16.0 m (52 ft)	8.0 m (26 ft)	$1 - 2 \times 10^{-7}$ in any approach	6 s	$1 - 8 \times 10^{-6}$ per 15 s	0.99 to 0.99999
Category I precision approach (Note 7)	16.0 m (52 ft)	6.0 m to 4.0 m (20 ft to 13 ft) (Note 6)	$1 - 2 \times 10^{-7}$ in any approach	6 s	$1 - 8 \times 10^{-6}$ per 15 s	0.99 to 0.99999

Typical operation	Horizontal alert limit	Vertical alert limit
En-route (oceanic/continental low density)	7.4 km (4 NM)	N/A
En-route (continental)	3.7 km (2 NM)	N/A
En-route, Terminal	1.85 km (1 NM)	N/A
NPA	556 m (0.3 NM)	N/A
APV-I	40 m (130 ft)	50 m (164 ft)
APV- II	40 m (130 ft)	20.0 m (66 ft)
Category I precision approach	40 m (130 ft)	35.0 m to 10.0 m (115 ft to 33 ft)

Figure 3: GNSS signal in space performance requirements – ICAO Annex 10 Vol I [RD2]

According to the European Navaid Infrastructure Planning Handbook [RD12], the expected availability and continuity of the navigation service determines the redundancy of the DME/DME coverage and finally the density of ground stations. In order to determine the Minimum Operating Network - MON (the smallest network of non-GNSS navigation equipment that is capable to support operations in case of GNSS outage) of ground stations, consideration must be given to the possible loss or degradation of GNSS signals and how to maintain ATM operations using only ground-based Nav aids. Further requirements need to be defined for resilience of the system (e.g. probability of signal interference, event duration, geographical scope of the event or probability of frequency saturation) to reduce the chance of GNSS interference since GNSS signals are weak and there are limited ways of protecting the signal. There is a need to improve the resilience of the Communication, Navigation and Surveillance infrastructure within the total PBN environment given the reliance on GNSS.

Signal-in-Space (SiS) monitoring is important and the flight crew will be the first to detect anomalies, which they shall report to ATC. Further to that, Air Navigation Service Providers or aircraft operators can also report the anomalies through the EUROCONTROL's common platform for voluntary ATM incident reporting - EVAIR. It is noted that GNSS Requirements for PBN are already defined, and industry do not expect new requirements for manned aviation to emerge, unless there are new use cases for manned aviation. Having increased availability, continuity and integrity can be beneficial and has implications on safety. If achieved, this could also enable approaches below ILS CAT I minima which would be of interest. However, currently EGNOS and Galileo both meet the required performance except for continuity of EGNOS according to EGNOS SoL SDD, Issue 3.6, section 3.4.2..⁹

DFMC (Dual Frequency Multi Constellation) provides extra robustness, but nevertheless the MON should be kept supporting the PBN contingencies. Having MON in place also relieves some of the PBN requirements but progress on addressing DFMC within ICAO is slow. It is important to note that although MON reduction leads to cost-efficiencies, the current level of safety should not be impacted.

In addition to the requirements that are placed on the core GNSS signal in space, other advances such as that from the development of Advanced RAIM (A-RAIM) also contribute to the overall robustness of the aircraft's PBN solution. This concept was developed in the frame of the EU-US Cooperation on Satellite navigation – WG C - ARAIM Technical Subgroup. The A-RAIM concept aims at overcoming the limitations of the conventional RAIM algorithms mainly applicable to a single constellation and not able to address the vertical plane. To this end, A-RAIM will allow:

- to consider all navigation core constellations with different failure probabilities, implementing an Integrity Support Message (ISM) reflecting these parameters,
- to significantly improve the current RAIM availability on the globe, thus removing “RAIM holes” when using 2 or more constellations,
- to significantly improve the receiver integrity performance, allowing worldwide LPV 200 and possibly more stringent operations.

The A-RAIM concept distinguishes two application steps:

- horizontal ARAIM (H-ARAIM) that could be implemented in the first generation of DFMC GNSS receivers.
- vertical A-RAIM that needs maturation, mainly for the implementation options of the ground infrastructure that would be needed for distribution of ISM message with other augmentation data. This concept is only foreseen for long term (not before 2030).

Several R&D projects on A-RAIM have been funded in Europe. The SAFE project, funded by EUROCONTROL, demonstrated the feasibility and benefits of introducing H-ARAIM in the first generation of DFMC receivers.

In June 2022, the EU/US Working Group C provided a ARAIM CONOPS to support the validation of H-ARAIM Standards and Recommended Practices (SARPs). In January 2023, the ICAO Navigation System Panel (NSP) validated the ARAIM SARPs, which were endorsed by the ICAO Air Navigation Commission in October 2023 when it endorsed and formally proposed the standards for inclusion in the next amendment of ICAO Annex 10: Aeronautical Telecommunications, Volume I Radio Navigation Aids [RD2] (publication expected in 2025). The ICAO NSP has also developed the ARAIM CONOPS based on past work performed by the EU/US Working Group C.

⁹ “EGNOS also meets the ICAO Annex 10¹³, Standards and Recommended Practices (SARPs) for Global Navigation Satellite System (GNSS) Satellite Based Augmentation System (SBAS), [RD-1], except for the continuity requirements where some waivers exist as detailed in section 6.3.1.4 for NPA service level, in section 6.3.2.5 for APV-I service level and in section 6.3.3.5 for LPV-200 service level.”

2.4.1.3.2 PBN Applications

There are several implementations of PBN applications that each have a different level of performance and are detailed in the following sections.

The PBN Manual [RD3] (ICAO Doc 9613) has been updated in 2023. The 5th Edition has been updated to reflect new requirements, such as the use of the Radius to Fix (RF) legs and the introduction of RNP AR departures. It also provides additional or revised guidance on a range of subjects in the Performance-Based Navigation (PBN) Manual. This includes (but is not limited to):

- changes to the Advanced RNP navigation (A-RNP) specification,
- additional guidance on the implementation of A-RNP,
- additional positioning sources such as ground-based augmentation systems (GBAS) and dual frequency multiple constellation technologies are accounted for in RNP navigation specifications which require use of a core GNSS constellation, supplemented by an augmentation system, as appropriate,
- explicit definition of the RNP 0.3 navigation specification as helicopter only,
- replacement of guidance and functional specifications for barometric VNAV across multiple flight phases,
- provision of guidance and information for vertical navigation on the final approach segment,
- guidance on air traffic control (ATC) status monitoring for GNSS.

GNSS independent back-up should be kept, but its form is still not decided. The DME/DME is not precise enough for approach, not widely deployed and siting is challenging due to mobile data for most space. Airports have not reported any plans to rationalise ILS regardless of category, although they are aware of the 2030 deadline.

The PBN mandate, as per Regulation (EU) 2018/1048, requires the gradual implementation of PBN routes and approach procedures across European airspace. The PBN IR implementation deadlines are as follows:

Implementation from the 3rd of December 2020:

- RNP APCH or RNP AR to all IREs (instrument runway end) without PA (precision approach), except at some airports',
- RNAV 5 for all ATS routes at or above FL150.

Implementation from the 25th of January 2024:

- RNP APCH or RNP AR to all IREs, and, where required, RF legs,
- for all IREs, RNAV 1 or RNP 1(+) for at least one established SID/STAR,
- for all IREs, RNP 0.3 or RNP 1 or RNAV 1 for at least one established SID/STAR for rotorcraft operations,
- RNAV 5 for ATS routes established below FL150,
- RNP 0.3 or RNP 1 or RNAV 1 for ATS routes established below FL150 for rotorcraft operations.

Implementation by the 6th of June 2030:

- RNAV 1 or RNP 1(+) applicable to all SIDs/STARs when established,
- RNP 0.3 or RNP 1 or RNAV 1 applicable to all SIDs/STARs for rotorcraft operations when established.

EASA has been actively updating regulations to include more advanced specifications like RNP 4 and RNAV 10 for oceanic and remote continental operations, which are being considered for inclusion in the PBN framework.

Due to the increase in GNSS RFI and outages, EASA has engaged discussions at European level to tackle this issue and find mitigations to counter aviation safety threat from GNSS spoofing and jamming. Potential regulatory amendment could be envisaged (with regards to the decommissioning of legacy navigation means). After the completion of the impact assessment planned 2025, a new rule making task to propose regulatory amendment should be launched in 2025 (including NPA and Opinion).

The new global standards for Dual Frequency Multi-Constellation (DFMC) capabilities have been adopted by ICAO. These standards allow the use of dual-frequency signals from multiple GNSS constellations (including GPS, Galileo, GLONASS, and BeiDou). This development is aimed at enhancing the robustness and accuracy of GNSS in aviation, supporting better airspace management and more efficient routing. The implementation of DFMC GNSS is expected to gradually begin between 2025 and 2028, as more aircraft are equipped with the necessary avionics.

DFMC SBAS and Galileo SARPS have been published in July 2023, and are applicable starting November 2024, 2nd as part of Annex 10 [RD2] Amendment 93. In October 2023, the GPS/Galileo SBAS DFMC MOPS (ED-259A/DO-401) [RD47] was published. The EUROCAE WG-62 intends to focus next on the updated ED-259B/DO-401A for Q1 2025. Although the final scope is still to be agreed, this update is expected to be the first DFMC GNSS receiver standard defining the requirements and test procedures for aviation equipment certified against a TSO and/or an ETSO. The ICAO NSP is simultaneously working on a new DFMC GBAS concept and corresponding standards with the intent to complete Baseline Development Standards by Q4 2024: a high-level concept agreed in ICAO and RTCA/ EUROCAE, a detailed concept paper, a draft of airborne and ground RTCA/EUROCAE MOPS and a baseline development SARPs.

2.4.1.3.2.1 RNP / RNAV for En-Route and Terminal operations

- GNSS will be used in Air Navigation under the so called PBN concept, enabling all current PBN navigation specifications. The PBN evolution makes GNSS the main means of navigation while other sources, such as conventional nav aids, are kept on some level and where feasible, as back-up systems for safety reasons. Within PBN, RNAV and RNP applications are commonly characterised by a designator X referring to the lateral navigation accuracy in nautical miles. In case the required lateral accuracy varies along the path a suffix is used (e.g. RNP APCH for approach). The lateral accuracy performance is expected to be achieved at least 95 per cent of the flight time by the population of aircraft operating within the airspace, route or procedure. The fundamental difference between RNAV and RNP applications is the need for a positioning monitoring and alerting function for RNP applications which mandates the use of GNSS. Oceanic and remote continental airspace concepts: they are supported by three navigation applications (RNAV 10, RNP 4 and RNP 2) relying primarily on GNSS for navigation.
- Continental en-route airspace concepts: they are currently supported by RNAV and RNP applications (RNAV 2, RNAV 5, RNP 5).
- Terminal airspace concepts (for arrival and departure): they are supported by RNAV applications and RNP used in the European (EUR) Region, the United States and, increasingly, elsewhere. The European terminal airspace RNAV application was known as P-RNAV (Precision RNAV), that has been recently replaced by RNAV-1, as it is required in the PBN mandate.

RNAV 5 is currently mandated in the European airspace for all ATS routes, mostly above FL 95 (according to IR PBN Regulation (EU) 2018/1048). It is also applicable in numerous non-European airspaces. In parallel, more and more airports define local mandate to implement the PBN procedure. E.g. RNP-1 mandate at CDG airport.

2.4.1.3.2.2 RNP APCH (LNAV)

LNAV GNSS approaches provide no vertical guidance and are only provided lateral guidance based on GNSS. The flight crew are required to monitor the vertical descent based on QNH pressure settings.

Modern avionics equipped with EGNOS can provide a guidance in the vertical sense to the flight crew (LNAV+V) but there are additional requirements that determine based on how the procedure is coded and what avionics is on board whether this will be possible.

2.4.1.3.2.3 RNP APCH (LNAV/VNAV)

LNAV/VNAV GNSS approaches are sensitive to QNH setting errors since the final approach segment is defined based on barometric data. Now it is possible to perform them leveraging EGNOS vertical guidance with is geometric.

The percentage of aircraft equipped to perform RNP APCH (LNAV/VNAV) is progressing from 60,4% to 64,7 % between September 2022 and September 2024 (EUROCONTROL CNS dashboard).

2.4.1.3.2.4 RNP APCH LPV

EGNOS enables steep approaches. LPV with different GS (Glide Slope) angles, angles up to 4,5° for normal approaches and above in the case of steep approaches can be implemented. Most turboprops and many Business Jets are able to operate with GS angles up to 7°. For the obstacle clearance purposes and improved accessibility to aerodromes, such LPVs in combination with curved approaches (RF leg) could be developed whilst also reducing fuel consumption.

Within the RNP APCH navigation specification, EGNOS enables LPV (Localizer Performance with Vertical guidance). LPV approaches are the most essential function provided by SBAS technology. LPV are 3D look alike ILS approaches, and are considered as precision approaches if designed with VAL = 35 m. Two types of LPV benefits are realised:

- For non-precision approach (NPA) runways (mostly small & local airports) the main benefit is to allow approaches with minima down to 250 ft and even down to 200 ft for aircraft equipped with SVS (Synthetic Vision System). Herein the objective is to allow approaches in low ceiling conditions.
- For precision approach runways (regional & larger airports), the main benefit is to allow CAT I instrument approach with no need for an ILS to that runway-end, that might be decommissioned once most of the fleet operating at the airport is duly equipped with SBAS avionics. On such runway LPV200 will be implemented, meaning DH as low as 200 ft above the runway threshold, obstacles permitting, and RVR of 1,800 ft. Complemented with EVS (Enhanced Vision System) it will be possible to operate with RVR of 1,000 ft and even lower in the future.

Furthermore, at non-instrument runways and VFR airports, EGNOS improves flight safety and enables the provision of LPV to all runway ends without any additional ground-based radio-navigation infrastructure requirements.

It also enhances safety of general aviation users already equipped with IFR and SBAS avionics. PBN Implementing Rule, Regulation (EC) No 2018/1048, addresses the safety, interoperability, proportionality and coordination issues related to the implementation of Performance-Based Navigation (PBN) within European airspace.

The regulation included the following provisions – which are still yet to be met:

- by 2020: EGNOS approaches (LPV) are to be available to all instrument runways not currently served by ILS,
- by 2024: EGNOS approaches (LPV and CAT I) are to be available to all instrument runways,
- by 2030: Preference is given to PBN approaches (LNAV/VNAV and LPV) and ILS will be rationalised to a minimum network level.

In practice this implies that PBN (LPV200) would replace ILS CAT I, with ILS being reserved for CAT II/III.

This is being addressed within the development of EGNOS V3, which planned entry in operations dates are 2028 for V3.1 (Legacy L1) and 2029 for V3.2 (DFMC L5 services L1-L5 dual frequency, GPS Galileo).

2.4.1.3.2.5 RNP AR

RNP AR “Authorization required” operations are mostly developed when due to obstacles, straight forward approaches (LPV) cannot be developed or outside SBAS service areas or in obstacle-rich scenarios. EGNOS provides benefits on such approaches such as: providing better navigation accuracy, better availability and continuity and the increased capacity of the aerodromes with the parallel runways, based on EUR Doc 025 EUR RNP APCH Guidance Material.

In the latest version of the Manual PBN, the RNP AR APCH specification is complemented by the RNP AR DP (departure procedures) with consequential changes relating to criteria for the development of AR DP procedures, charting requirements for RNP AR departures, process for authorization of new AR DP specifications and Route spacing standards for AR Departures [RD3].

2.4.1.3.2.6 A-RNP

The A-RNP specification, described in the ICAO PBN Manual [RD3], is intended to cover all phases of flight, in such a way that an operator can fly ATS Routes, SID, STAR and approaches with one single approval.

The A-RNP aircraft qualification can be more broadly applicable to multiple navigation specifications without the need for re-examination of aircraft eligibility. This enables an operator’s approved procedures, training, etc., to be common to multiple navigation applications. The A-RNP aircraft qualification will also facilitate multiple operational specification approvals. The navigation specifications included under A-RNP is scalable from RNP 2 to RNP 0.3. A-RNP meets RNAV 5, RNAV 1, RNAV 2, RNP 2, RNP 1 and RNP APCH and Radius to Fix Requirements.

The PBN Manual 5th Edition [RD3] includes changes to the Advanced RNP navigation (A-RNP) specification, including:

- final approach segment no longer considered a part of A-RNP; and
- scalability requirements replaced by use of RNP value of 0.3 NM outside of the final approach segment.

During the Notice of Proposed Amendment phase, when seeking to apply A-RNP with specific aircraft guidance modes, the objective was to allow ANSP to deploy improved en-route structure with more parallel airways requiring less lateral separation thus improving the airspace throughput.

The A-RNP requirements are also specified in EASA CS-ACNS Issue 4 which requires the aircraft to have the ability to execute radius to Fix (RF) legs, to implement parallel offset routes and to operate scalable RNP values (from 0.3 to 1.0 NM in steps of 0.1 NM).

2.4.1.3.2.7 RNP 0.3

RNP 0.3 represents the same Advanced RNP philosophy but now solely for helicopter operations (as clarified in the PBN Manual 5th edition). It is intended for all phases of flight: ATS Routes, SID, STAR and transitions to RNP APCH final approach or Point in Space (e.g. hospital helipads in urban environments).

According to the EASA NPA 2022-06 [RD13], RNP 0.3 navigation specification would be applicable for operations with VTOL-capable aircraft (SPA.PBN.100 PBN operations). Additional information on PBN is addressed in UAM.OP.MVCA.126 Performance-based navigation on (PBN) within the proposed new AIR OPS Annex IX – Part IAM for VTOL-capable aircraft in manned configuration (MVCA). New PBN navigation specifications beyond RNP 0.3 tailored to VTOL-capable aircraft may be developed in conformance to Part IAM.

To be noted that EGNOS is already required for RNP 0.3 operations flown by helicopters according to EASA CS-ACNS AMC2 ACNS.C.PBN.205 RNP system approval, and this requirement could be extended to manned VTOL capable aircraft (pilot onboard). However, the Opinion No. 03/2023 nor the NPA 2024-01 on innovative air mobility with manned VTOL-capable aircraft do not include any reference to PBN.

2.4.1.3.3 GBAS CAT I

GBAS CAT I based on GPS is available at some airports in several states and, based on GPS and GLONASS, in the Russian Federation. GBAS can support approaches to several runways and airports, requiring installation and maintenance of ground stations.

In Europe, four GBAS CAT I stations are operational in Zurich, Frankfurt, Bremen and Málaga. The use of SBAS to enhance GBAS performance is now proposed in order to augment the operational capability of existing GBAS avionics. Doing this provides significant operational improvement for GBAS equipped users, where leveraging observations of ionospheric perturbations corrected through SBAS is seen as an intermediate step to achieving CAT II/III. The GBAS Cat I operations are supported by ICAO GAST (GBAS Approach Service Type) standards.

2.4.1.3.4 GBAS CAT II/III

The GAST D (GBAS Approach Service Type D) enabling GBAS CAT II/III operations is currently standardised with an ongoing certification and could become operational in the following years.

The GAST F supporting CAT III (DFMC GBAS) is at the prototype stage. The ICAO NSP is working on a new DFMC GBAS concept and corresponding standards. A high-level concept agreed in ICAO and RTCA/EUROCAE, a detailed concept paper, a draft of airborne and ground RTCA/EUROCAE MOPS and a baseline development SARPs. Planned next steps include:

- Update to GNSS Manual to allow GBAS support via multiple constellations and frequencies, targeted Q4 2030 for Mar 2033 applicability.
- Update to Annex 10, Volume I [RD2] to add standards to support GBAS via multiple constellations and frequencies, targeted Q4 2030 for Nov 2033 applicability.

It is expected that the GBAS CATII/III L1 system will enable automatic approach and landing down to Cat IIIB minima for mainline aircraft, automatic approach and landing down to CAT II or CAT IIIa minima for business and regional aircraft, CAT IIIB considerations for business aircraft for possible future use.

According to the 2025 edition of the European ATM Master Plan [RD50], GBAS CAT II/III leveraging Galileo is envisaged by 2045 (A.2 CNS roadmap).

2.4.1.3.5 Precision approaches CAT I with autoland

This application is still under development and extends the capability of an LPV approach by adding Autoland capabilities. Autoland Category I has been already certified on Airbus aircraft using GBAS and some studies are assessing how EGNOS can be used for this application.

2.4.1.3.6 Transition from RNP/RNP AR to LPV

A PBN approach can be defined as an RNP APCH (LPV, LNAV/VNAV, LNAV) or an RNP AR. RNP APCH has a performance requirement of 1 NM (in the initial, intermediate, and missed approach segments) and RNP AR down to 0.1 NM.

An LPV final approach, using SBAS 3D guidance, provides a better level of safety than the other RNP final approaches which are based on barometric vertical guidance. However, RNP APCH navigation specification has a navigation performance requirement of 1 NM for the initial, intermediate, and missed approach segments which can limit the benefits of LPV approaches in constraining environment.

The current regulation allows now to improve the design of such LPV approaches by:

- **The use of RF leg:** RF legs may be used in the initial and intermediate approach segments and the final phase of the missed approach segment. The criteria for designing procedures with RF legs are detailed in the Procedures for Air Navigation Services — Aircraft Operations (Doc 8168) Volume 2, and specific criteria are defined to ensure transition with angular deviation associated to LPV approaches.
- **The use of A-RNP navigation specification upstream and downstream an LPV final approach segment:** This combination allows to consider a navigation performance requirement of 0.3 NM for the initial and intermediate approach segments. For A-RNP missed approach RNP value is normally 1 NM, but states may authorise 0.3 NM on an exceptional basis, subject to a safety assessment.

Another combination studied in the frame of SESAR project 5.6.3 was the transition between RNP AR segments to LPV final segment as initial and intermediate segments for RNP AR APCH can have a performance requirement down to 0.1 NM.

For the time being, EASA CS-ACNS [RD11] and AC 20-138D [RD48] & AC 90-101A AR [RD49] and PBN Manual [RD3] do not allow a transition from RNP AR to LPV procedures based on SBAS.

However, EASA CS-ACNS AMC2 ACNS.C.PBN.670 Vertical accuracy notes “Where SBAS/GNSS geometric altitude is used, the installation of equipment that supports a 50-m vertical alert limit (VAL) satisfies the requirement for operations down to RNP 0.3 and the installation of equipment that supports a 35-m vertical alert limit (VAL) satisfies the requirement for operations down to RNP 0.1”.

2.4.1.3.7 Transition from continuous descent approach (CDA) to LPV continuous descent approach

Transition from continuous descent approach (CDA) to LPV continuous descent approach allows an aircraft to descend from an optimal point with minimum thrust. This technique has relevant environmental benefits (noise and emission) and fuel savings.

PBN airspace design is an enabler that optimises vertical profiles and the development of PBN to RNP or ILS approaches is growing in Europe.

The European CCO/CDO Action Plan describes how potential constraints influence the ability to fly CCO/CDO together with key information on the mitigation proposals addressing these constraints in order to optimise the vertical flight efficiency of the climb and descent phases of flight.

In addition, the European CCO/CDO Performance Dashboard has been developed to measure CCO/CDO performance for all airports in Europe and all airlines in Europe based on the indicator recommended by the European CCO/CDO Task Force: average time in level flight.

2.4.1.3.8 Steep approach (> 4.5°) based on GNSS (EGNOS)

Steep approaches with a greater angle (>4.5°) can give operational benefits and enhance the access to airports sited in mountainous or urban areas. SBAS approaches (LPV) are very suitable to environments with difficult relief, so steep approaches can be an additional benefit to improve accessibility to these aerodromes. This can also be considered with the application of increased glide slopes which may not require the application of a steep approach for obstacle limitation purposes but provided benefits of reduced noise to residents living in close proximity to the final approach path.

Currently, the Procedures for Air Navigation Services — Aircraft Operations (Doc 8168) Volume 2, provides criteria for LPV approaches up to 6.3° (11%).

2.4.1.3.9 PBN Approach procedures in simultaneous operations to instrument parallel runways (SOIR)

Since 2020, PBN operations can be used to develop simultaneous approach operations to parallel runways:

- RNP APCH down to SBAS CAT I minima and RNP AR APCH conforming to specific criteria defined in the SOIR Manual [RD43] can be used without any additional demonstrations (as ILS, GLS and MLS approaches).
- RNP AR APCH non-conforming to the specific criteria defined in the SOIR Manual and RNP APCH down to APV SBAS minima and LNAV/VNAV can be used if an approach and mitigation-specific, documented safety assessment has shown that an acceptable level of safety can be met, and operations are approved by the appropriate ATS authority.
- PBN transition can also be used in parallel approach operations in the intermediate segment of ILS/GLS/MLS approaches.

However, RNP APCH down to LNAV minima cannot be used for simultaneous approach operations.

Concerning RNP AR APCH, a new concept named “Established on RNP AR APCH” has been developed. The major benefit of this concept is that, once the aircraft is established on the RNP AR APCH procedure, the application of vertical separation with the aircraft on parallel approach may be discontinued (currently it is necessary to keep at least a vertical separation of 1,000 ft between aircraft before the final approach segment). This will have a positive effect on the capacity of the airports with parallel runways and moves the focus beyond only complex obstacle scenarios. This will require GNSS performance to meet at a minimum the requirements expressed previously for the total PBN robustness and resilience and supported by other aircraft systems.

Finally, it should be noted that procedure design criteria regarding simultaneous approaches operations provided by the Procedures for Air Navigation Services — Aircraft Operations (Doc 8168) volume 2, have been amended to introduce specially PBN transition and the “established on RNP AR” concept. These new criteria are applicable since November 2021.

2.4.1.3.10 VFR complement

This application specifically focuses on the uncertified applications used by VFR pilots. The certified PBN applications described previously are also utilised by General Aviation, but being certified are subject to additional regulatory and standardisation requirements. Use of GNSS as a VFR complement implies not only the use of GNSS to supplement map reading and other visual navigation techniques but also improved situational awareness, electronic conspicuity, flight tracking amongst others.

Continuing improvements to the accuracy, affordability and usability of GNSS and its flying-related applications has led to an increasing number of VFR pilots using it as a navigation aid. GNSS should only be used as a supplementary tool for VFR flights and shall not replace visual navigation techniques. However, the use of VFR ‘Moving Map’ devices is now commonplace in General Aviation. Supported by GNSS these devices have considerably enhanced the process of flight planning and execution for GA pilots. Moving Maps encompass a range of electronic navigation solutions, including portable VFR GNSS devices and applications running on smart phones or tablets. Viewing the aircraft’s position in real time mitigates a variety of risks compared to the sole use of traditional VFR navigation techniques.

2.4.1.3.11 Jamming & Spoofing

Jamming and spoofing are significant threats, especially for aviation industry which relies on GNSS as a key asset for navigation and positioning. Jamming involves deliberate interference with GNSS signals, making them unusable by overwhelming the receiver with noise or garbling signals. This interference occurs as a result of a jamming device emitting signals on the same frequency (L1), thereby blocking or

disrupting signal reception. In aviation, this can lead to missed approaches, delays, and diversions due to the inability to use GNSS for navigation and landing.

Spoofing, on the other hand, is more complex and often used in “high-stake” scenarios such as military operations, protection of critical infrastructure, or management of public events. Spoofing misleads navigation systems by transmitting false GNSS signals, causing receivers to calculate incorrect position, navigation or timing information. The rising sophistication and availability of spoofing technology significantly increases the threat to aviation safety if misused. Both jamming and spoofing can disrupt essential GNSS signals, leading to increased pilot and air traffic controller workload, potential flight deviations, and safety incidents.

The spoofing may also impact Ground Proximity Warning Systems (GPWS) as alerts issued for terrain avoidance may either be suppressed or triggered by positioning the aircraft as either clear of terrain or too close to terrain – directly the opposite of what may be the actual situation. As a result, pilots may receive false alerts leading to lower trust in the system or not be alerted at all. In the recent years, jamming and spoofing occurrences have become so common that a number of airlines have developed specific procedures to mitigate such risk.

Means of mitigation

Maintaining a large ground-based network of nav aids to seamlessly support navigation in case of jamming or spoofing events is costly and thwarts the benefits of GNSS. To date, there is no technical solution deployable to civil aviation at scale and short term to repel jamming and spoofing attacks. However, detection and understanding of the system behaviour during such attacks is crucial to mitigate the safety risks. The strategies to address spoofing may include monitoring of unexpected signal shifts and subsequently using alternative navigation methods like inertial systems or terrestrial navigation aids. EUSPA contributes to efforts aiming to enhance GNSS robustness through developing technologies such as the Galileo Open Service Navigation Message Authentication (OSNMA), which verifies the authenticity of the GNSS signal. An early warning will trigger the pilots to take measures and minimise the risks caused by spoofing.

Airspace users relying on GNSS are calling for technical and financial support to accelerate the implementation of advanced navigation avionics (e.g. more resistant receivers). Since there are no certified GNSS receivers using Galileo yet, GPS-only avionics is available to fly IFR based on GNSS. From an airline perspective, avionics modernisation is a significant cost when renewing the aircraft fleet and thus all stakeholders should be involved in actions to upgrade the system.

As a leading aircraft manufacturer, Airbus is developing solutions to mitigate jamming impacts. One such solution includes the integration of multi-frequency multi-constellation receivers which enhance resilience against jamming and spoofing threats primarily by providing an alternative frequency. This would mean that for a signal to be jammed, more than one frequency would have to be affected. In the case of dual-frequency multi-constellation receivers, currently being developed for aviation, this would still mean a total loss of service if two separate frequencies were jammed but would still be harder for someone to spoof as all constellations on the frequencies would have to be affected.

Another initiative is to switch the timing source from GNSS to a certified High Accuracy clock on board to solve GNSS time reference loss by jamming and spoofing. This initiative aims to provide more reliable and robust navigation for users.

In summary, mitigation of RFI stands on two pillars – GNSS receiver robustness through using DFMC; and the RFI monitoring service provided at EU-level allowing members states to collaborate in collecting data, monitor RFI occurrences and mitigate impacts.

User perspective

Widerøe, an airline operating in a number of GNSS interference hotspots (e.g. Northern Norway, Baltics, near the Russian border, southern Europe, and Turkey) is experiencing significant jamming incidents, especially since the annexation of the Crimea and the ongoing war in Ukraine. The jamming incidents have become a daily routine, mostly happening during en-route and the descent phase of flight. Widerøe

pilots note that this is because the jamming sources were so far stationed on the ground and thus the aircraft at low altitudes are shielded by the terrain. Once the jamming sources become airborne, it will impact all phases of flight, including the final approach and landing, thus becoming safety critical.

Widerøe have been using GBAS for 20 years and have adapted to increased jamming occurrences by relying on backup solutions like DME, DME/VOR, or dead reckoning. In case of a jamming event, their navigation performance reduces from 0.3 to 10-15 NM.

Despite daily jamming events, Widerøe's pilots had not reported any spoofing incidents. Nonetheless, the airline takes the threat seriously and thus have implemented measures such as quick reference cards for pilots to identify GNSS interference and to understand the behaviour of their FMS system during interference events.

Widerøe has raised concerns about the proposed PBN plan and its implications to safety and regulatory requirements. From their perspective, having more reliable IRS (Inertial Reference System) units and better SSR (Secondary Surveillance Radar) coverage in jamming-exposed areas could be a way to address increasing jamming and spoofing events.

Spirent, an expert on jamming and spoofing detection, described an incident of an aircraft's receiver showing zero integrity, leading to a "GNSS signal lost" alert in the cockpit. Despite the severity of the issue, having an alert is an essential factor in dealing with interference.

If a spoofing event is not detected, pilots might unknowingly continue flying without GNSS, potentially losing critical systems like ground proximity sensors and RNP accuracy during arrival procedures. Spirent suggests that to mitigate the impacts, pilots should receive alerts prompting them to turn off their GNSS systems when spoofing occurs and initiate the recovery procedures as recommended by the aircraft manufacturer. This would prevent corrupted data from entering inertial systems.

The spoofing events are becoming more frequent near the Russian and Belarusian borders while detecting spoofing remains a challenge, as the methods of spoofing are constantly evolving. More sophisticated spoofing techniques, such as meaconing, code-aligned attacks, and navigation data attacks were reported in Poland. Droneradar shared various examples both jamming and spoofing events occurring near Polish-Belarusian border causing GA aircraft equipped with a Garmin GPS-only system continuously losing GNSS signal at 1,500 ft.

User needs

The results of the UCP survey [RD54] revealed that RFI interference is indeed a problem requiring attention, as 86% of respondents have experienced jamming or spoofing when flying. As a result, all of them have implemented a contingency or mitigation plan. The potential solutions for RFI mitigation, as considered by users, could include DFMC receivers (71%), OSNMA (57%), SBAS authentication or CRPA (Control Reception Pattern Antennas) both at 43%. All of which require additional work on certification for manned aviation and the development of receivers capable of supporting such mitigation measures.

Users highlighted the need for testing and development of robust receivers and antennas, followed by appropriate and up-to-date PNT standards.

An overarching user requirement is to experience no jamming and spoofing events. Unfortunately, current technology only allows limited protection from such attacks and thus the following solutions were proposed by the stakeholders as potential mitigations:

- **Reliable IRS:** Having more reliable IRS (Inertial Reference System) unit on board in case of GNSS outage.
- **Reliance on GNSS:** Cut off GPWS (Ground Proximity Warning System) system's reliance on GNSS. In an event of jamming/spoofing, a lost GNSS implies the outage of GPWS as well.
- **Antennae's resilience:** Majority of jamming/spoofing originates from the ground. Shielding the antennae to prevent ground-based jamming may decrease the probability.
- **Long-term solution** for operations' continuity while subject to jamming/spoofing should be developed.

The jamming and spoofing user needs confirmed by participants are centred around:

- **Testing and development:** testing antennas and receivers to develop solutions,
- **Awareness maps:** displaying affected areas, number of aircraft affected and related statistics,
- **On board detection and alerting:** spoofing alerts for the crews,
- **Antennae's resilience:** Majority of jamming/spoofing originates from the ground; Shielding the antennae to prevent ground-based jamming may decrease the probability (CRPA antennas),
- **Encryption and Authentication:** OSNMA is one of the solutions offered by Galileo,
- **Alternate/complementary PNT system** in case of GNSS outages,
- **Multi-Constellation Multi Frequency** future development adding specific spoofing algorithms.

2.4.1.4 Operations Management

2.4.1.4.1 Aircraft Maintenance and Operation Optimisation

Identifies areas where aircraft have flown through large areas of particulate matter, and in turn require early or more maintenance actions helping airlines and manufacturers save costs. When combined with innovative digital and satellite-based solutions, it also supports new tools and traffic optimization mechanisms for multimodal access, passenger and freight flows into and out of the airport, as well as between airports, facilitating improved airport access and reducing traffic from / to the city or other key transport nodes.

2.4.1.4.2 Airport Asset Monitoring

EO is a valuable asset to support Advanced-Surface Movement Guidance and Control System (A-SMGCS) surveillance and safety support services as well as helping airport managers to maintain high quality and complete knowledge of their airport assets.

EO can provide airports with an accurate, high-resolution, and up-to-date map to improve ground situation awareness. This way, operational efficiency can be improved.

2.4.1.4.3 Monitoring Terrain Obstacles near an Airport

EO assists airport operators to monitor and manage potential threats to aviation safety from changes to airport surroundings and helping to secure safe flight for departure and approach operations.

2.4.1.5 Surveillance

2.4.1.5.1 Search and Rescue (GADSS)

After the aircraft losses in the ocean (flights AF447 and MH370), ICAO recognised in the second High Level Safety Conference (HLSC 2015) the need to increase significantly the effectiveness of the current alerting and Search and Rescue services. At European level, such recommendation was included in EASA AIR OPS with requirements for flight tracking. These regulations aimed at enhancing the following functions:

- Location of an aircraft in distress,
- Position tracking systems.

Acceptable Means of Compliance and Guidance material of EASA parts ORO, CAT, NCC and SPO related to flight recorders, underwater locating devices and aircraft tracking systems were amended to reflect new developments. The issues of aircraft tracking, location of an aircraft in distress, CVR recording protection, data link recording applicability, and performance specifications for the FDR and the FDR

parameters trying to prevent the problems found in the location of some major aircraft distresses were addressed.

Already used by numerous air operators for operation and maintenance purposes, there are different flight tracking systems able to either periodically or, in case of aircraft failure, report the aircraft position by different telecommunication means (e.g. ACARS, FANS 1/A) with the support of a communication service provider. The current estimation is that 80% of the wide-body aircraft are equipped with such systems. However, the reporting rate cannot always satisfy requirements for Search and Rescue.

For aircraft in distress, ICAO defines an Emergency Locator Transmitter (ELT) as equipment which broadcasts distinctive signals on designated frequencies and depending on the application, may be automatically activated by impact or be manually activated. An ELT may take any of the following forms:

- Automatic fixed ELT (ELT(AF)). An automatically activated ELT which is permanently attached to an aircraft.
- Automatic portable ELT (ELT(AP)). An automatically activated ELT which is rigidly attached to an aircraft but readily removable from the aircraft.
- Automatic deployable ELT (ELT(AD)). An ELT which is rigidly attached to an aircraft, and which is automatically deployed and activated by impact, and, in some cases, also by hydrostatic sensors. Manual deployment capability is also provided.
- Survival ELT (ELT(S)). An ELT which is removable from an aircraft, stowed so as to facilitate its ready use in an emergency, and manually activated by survivors.
- Distress Tracking ELT (ELT(DT)). An ELT designed to be activated prior to a crash and to function in compliance with the ICAO GADSS requirements for the location of an aeroplane in distress. ELT (DT) may be activated automatically upon detection of a distress condition while in flight or it may also be activated manually.

The Global Aeronautical Distress and Safety System (GADSS) is a concept developed by ICAO which enhances the effectiveness and alerting of search and rescue services in the event of an aviation tragedy. It ensures that the aircraft is tracked and that the latest known GNSS derived position is always recorded, maintaining an up-to-date record of aircraft progress.

GADSS has three components: Aircraft Tracking; Autonomous Distress Tracking (ADT, same as Location of Aircraft in Distress); and Post Flight Localisation and Recovery. Aircraft Tracking is enabled through the on-board GNSS equipment (either the PBN or electronic conspicuity device) plus a means of communication, whilst the other components can be provided by Emergency Locator Transmitters, among other solutions.

After the Amendment 39 to ICAO Annex 6 **Error! Reference source not found.**, flight tracking systems have been generalised from November 2018, allowing a position report at least every 15 minutes even in airspaces where an ATS Unit only obtains aeroplane position information at greater than 15-minute intervals.

The ADT capability is mandatory for new aircraft above 27 tons by January 2025 (Ref. EASA AIR OPS, CAT.GEN.MPA.210 Location of an aircraft in distress — Aeroplanes). Although there are various technical solutions for ADT, ELT(DT) has been selected by major airframers.

The Remote Beacon Activation (RBA) based on Galileo SAR service is an optional feature that can be implemented in ELT(DT) beacons, within the ADT concept, and it is complementary to automatic triggers (according to EUROCAE ED-237, [RD45]) and manual (by the crew) triggers.

2.4.1.5.2 Terrain awareness

Terrain Avoidance and Warning System (TAWS) can be generically divided into:

- Ground Proximity Warning System (GPWS): this system appeared in the 70's and is a safety net based on the radio altimeter providing alarms to the crew. This kind of system does not use GNSS.
- Terrain Avoidance and Warning System (TAWS) or Enhanced Ground Proximity Warning System (EGPWS): this kind of system has been introduced by Honeywell in the late 90's and is based on the aircraft position (mostly GNSS) correlated with an almost worldwide terrain/obstacles/airport database regularly updated by the system manufacturer. It provides sophisticated alerts to the crew depending on functions installed in the equipment. Such systems (two classes, A and B, are defined) are mandatory for aircraft of more than 5,700 kg and with more than 9 seats as well as for helicopters of more than 3,175 kg and 9 seats for IFR operations.

2.4.1.6 Weather services

At the UCP 2022 [RD55] it was highlighted that work on models to monitor and evaluate global emissions, aircraft noise, airport local air quality or third party and subsequently put in place mitigation measures if needed has been ongoing in Europe since 1997. It highlighted the importance of data of good quality, suggesting that satellite observation/data are used for the following purposes:

- Atmospheric observation of pollutants such as CO₂, NO_x/CH₄/Ozone, Particulate Matter (nvPM, vPM, UFP) or Sox.
- Contrails monitoring to anticipate areas where contrails form and evolve into persistent contrails/cirrus-contrails and implement avoidance measures.
- Land-use planning to monitor the population living around airports, exposure to noise levels, third-party risk exposure and impact on biodiversity.

Although it is clear that aviation has an impact on climate change, it is important to realise that climate change as well poses significant and increasing risks to aviation in the years ahead. A recently published study from EUROCONTROL concerning the climate change risks for European aviation assesses how existing weather trends have impacted aviation in the recent years, factoring in climate change impacts that have been emerging faster than expected. The study investigated the impact of long-term extreme weather events such as changes in wind patterns/intensity or sea level rise and the impact of short-term extreme weather events such as storms, lightning, heat waves or heavy precipitation. The study shows that airports and their surrounding transport infrastructure face a rising risk of flash flooding and rising sea levels, while flight operations are set to be increasingly delayed by violent storms, that will increase delays, raise fuel burn, and lead to higher emissions.

2.4.1.6.1 Hazardous Weather Identification

EO is used to identify and monitor hazardous weather conditions such as storms, enabling aircraft and air traffic management to detect and avoid these weather phenomena earlier. In the case of Innovative Air Mobility (IAM), it focuses on the identification of wind and micro turbulence in low level altitude in highly built-up areas. This leads a reduction in the number of safety incidents and increased flight efficiency.

The short-term weather forecasts are outside the scope of Copernicus and therefore not covered by this application.

2.4.1.7 Drones

2.4.1.7.1 SORA ground risk assessment

Regulatory context

Drone operators under the requirements of (EU) 2019/947 [RD22], utilising EASA specific category drones are required to identify the risks of the operational environment, geographical area and, in

particular, to the overflowed population. The way in which this is required to be executed is through a Specific Operations Risk Assessment (SORA) as part of the flight planning process with the objective of minimising the risks in the air and on the ground. Specifically of interest to this application are the risks associated with fatal injuries to uninvolved people on the ground and damage to critical infrastructure. Given the elements that need to be measured as part of this risk assessment, there is an opportunity for the Earth Observation data to add real value to provide a quantitative measure of the risk applied in a uniform method.

The EASA open category operations follow a prescriptive approach, specific category operations perform SORA assessments [RD51] and rules for certified category operations were adopted as Opinion No 03/2023 [RD53] in September 2023. Under a typical flight planning scenario, the drone operator will know its departure and destination points and will consider as part of the process the performance of the drone under the environmental conditions in place at the time. These will be influenced by factors such as: wind, temperature, altitude, , duration of flight required (taking wind and leg length into account), where diversions may be possible, any obstacles or significant features (e.g. schools, railways, roads, towers, masts etc.) which need to be avoided. All these factors will need to be considered by the operator and are captured through the SORA process.

The SORA methodology [RD51] was defined by JARUS as a multistage process harmonised across Europe which includes risk analysis and appropriate mitigations. There are two classes of risk – ground risk class (GRC) and air risk class (ARC). Both risk classes are linked to Specific Assurance and Integrity Levels (SAIL) which express the level of confidence that a drone operation will stay under control and within the boundaries of the intended operational volume. As a part of ground risk assessment, an Intrinsic Ground Risk Class (iGRC) score should be calculated which represents the combination of population density within the ground risk buffer area requiring the operator to identify uninvolved population and critical infrastructure.

The EUROCAE document ED-301 [RD36] introduces the concept of data assurance in which the drone operator needs to consider the quality of data being used to support operations provided via a third-party service. To remain consistent with the ED, guidance is specifically given with respect to the use of GNSS for UAS navigation (OSO#13) and the operator is encouraged to assess the risks to the operation from a dependency on GNSS as an external service. This relationship between the navigation performance and the EO data supporting the application of the SORA process needs to be considered.

Existing solutions to calculate iGRC using population data

The SORA requires distinguishing between sparsely and non-sparsely populated areas. While the SORA 2.0 version [RD52] did not explicitly specify or guided the operator on the appropriate population density thresholds, spatial resolutions or other criteria for data and methods, the version SORA 2.5 version [RD51] (applicable from beginning of 2025) contains specific values. Having the thresholds defined, will allow operators to use various data sources to calculate the iGRC value more consistently. During the UCP 2024, EASA noted that work is ongoing on future revisions, mainly focusing on air risk. EASA and EUSPA are assessing the feasibility of using Copernicus GHSL (Global Human Settlement Layer) data. Although, authorities are calling for real-time data, the use of consistent and available population data from Copernicus (although static) is a reasonable starting point.

Intrinsic UAS Ground Risk Class						
Maximum UA characteristic dimension		1m	3m	8m	20m	40m
Maximum speed		25 m/s	35 m/s	75 m/s	120 m/s	200 m/s
Maximum iGRC population density (people/km ²)	Controlled ground area	1	1	2	3	3
	< 5	2	3	4	5	6
	< 50	3	4	5	6	7
	< 500	4	5	6	7	8
	< 5,000	5	6	7	8	9
	< 50,000	6	7	8	9	10
	> 50,000	7	8	Not part of SORA		

Figure 4: SORA 2.5 [RD51]

There have been several R&D initiatives to predict human mobility and population density at higher temporal and spatial fidelity e.g. EO-STAT focused on geo-marketing or project HOPE aimed to support SORA. Project HOPE developed a world-wide system using artificial intelligence (AI) and a number of sources (e.g. CCTV cameras, open data, census data, Copernicus, etc.) to predict hourly movements of people.

During the UCP, EASA noted that once the population data with higher temporal resolution is available, operators will be able to consider seasonality and predict the population density more accurately. The current work is focused on the first layer, i.e. to identify critical areas using GHSL data and look into creating different layers for various parts of the season or even times of the day.

The Copernicus Land Monitoring Service (CLMS) which contains land use/land cover maps can be proxies for ground risk levels, but to complete the SORA in the future it will also be necessary to distinguish sheltered from non-sheltered (i.e. outdoors) population at the time of day of the mission. This is because the “shelter” factor affects the number of people injured in case of a drone crash. Persons protected by the roof will not be injured and this it is a relevant information when conducting risk assessment.

Existing solutions do not provide sufficient resolution of population data which is particularly important in complex urban environments where a high resolution is essential. Current datasets (e.g. Copernicus Global Human Settlement Layer) offer resolution of 100x100 m which is useful for SORA to help identify inhabited areas and those with a lower population density. Nevertheless, there will still be a requirement from the authorities for a manual sense check which remains important until confidence in the data can be improved.

Considering the nature of operations and to enable future applications, a solution providing density maps with resolution of 10x10 to 30x30 m was deemed sufficient during the UCP 2022 and such requirement still remains relevant. Further to that, better coverage and update rates of the Urban Atlas dataset (currently, only cities of >50K inhabitants are covered) would be considered useful to operators.

2.4.1.7.2 Navigation (PNT) for drones

Positioning, Navigation, and Timing (PNT) technologies are critical for the functionality and safety of modern drones, providing the precision and reliability essential for various applications. Drones leverage GNSS to navigate and perform tasks with high accuracy. This integration allows drones to operate in complex environments, execute precise landings, and follow predefined routes with minimal deviation. EUSPA has highlighted the importance of PNT technology in enhancing drone operations, specifically through the integration of Galileo's differentiators such as the High Accuracy Service (HAS) and the Open

Service Navigation Message Authentication (OSNMA), which significantly boost the positioning accuracy and signal resilience to spoofing, respectively.

The primary functions derived from PNT services include positioning, navigation, timing, electronic conspicuity, obstacle avoidance, and landing guidance. These functions are supported by the key components of GNSS such as satellite constellations and GNSS (user) receiver an antenna as well as inertial measurement units (IMUs), communication links, and data processing algorithms. Multiple GNSS constellations provide the foundational signals for positioning, while GNSS receivers onboard the drones process these signals. IMUs measure the drones' accelerations and turns, communication links transmit positioning data, and data processing algorithms integrate and process data from multiple sources to provide accurate positioning and navigation information.

The role of HAS and OSNMA

Such stringent PNT requirements can be supported by Galileo's differentiators like HAS and OSNMA. Galileo HAS can provide sub-meter accuracy through real-time corrections for satellite orbit and clock errors eventually improving the positioning accuracy, in particular, in open-sky scenarios¹⁰. However, Galileo HAS operates using the same constellation of satellites as Galileo OS and therefore physical limitations like severe signal obstruction or extreme multipath reflections remain a challenge which might not be completely mitigated by using Galileo HAS. This service can be used as Galileo-only as well as for both Galileo and GPS, resulting in even better accuracy (< 15 cm horizontal and < 20 cm vertical).

Galileo OSNMA can provide additional trust in GNSS (Galileo) signal in all phases of flight. In areas with increased likelihood of spoofing events, like nearby conflict zones, OSNMA can be an integral part of the system performance monitoring.

Hybridisation of sensors

Currently, technologies used for serving PNT applications include multi-constellation GNSS receivers, inertial navigation systems (INS), Real-Time Kinematic (RTK) positioning, supplementary sensors (e.g. barometric altimeter, air speed indicator, magnetic compass, camera, lidar) and advanced signal processing algorithms. Despite these technological advancements, there are limitations and challenges linked to specific environments and use cases e.g. signal availability in urban canyons or susceptibility to interference which might not be fully addressed by Galileo differentiators either.

In April 2024, EUSPA produced a GNSS questionnaire for drone operators and manufacturers to capture their PNT needs, in particular, those related to GNSS receivers installed onboard drones. The results show that the positioning needs vary per operational scenario or phase of flight (see the chart below). The required horizontal positioning accuracy (HNSE 95%) spans between 2 and 5 meters for cruise (open sky). For landing the requirements become more stringent (<1 meter).

¹⁰ Galileo HAS SDD, Issue 1.0, Jan 2023, page 40.

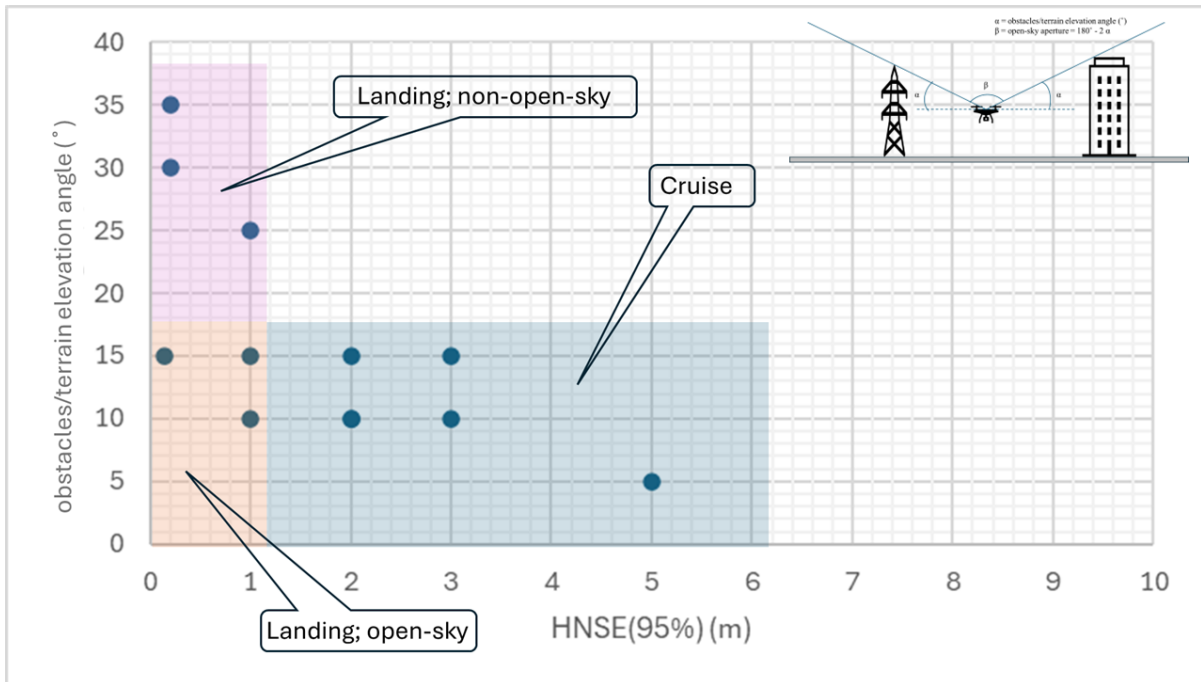


Figure 5: PNT user needs – horizontal positioning accuracy (EUSPA GNSS questionnaire)

Furthermore, users demand high positioning accuracy in non-open-sky conditions such as urban environments and built-up areas which is challenging for GNSS, so other sensors (e.g. 5G positioning, accelerometers, gyroscopes, compasses, lidar or cameras) can be used to complement GNSS. Evidence gathered during user interviews shows that most operators already use such sensors, not just as a back-up or safety net, but as a primary means to support certain phases of flights (e.g. landing). From the standardisation perspective, the drone operators would benefit from other sensors formally recognised as an acceptable means of (PNT) compliance.

User needs

The development of PNT services for drones is driven by several non-performance related factors, including regulatory requirements that mandate precise navigation and safety standards for drone operations, especially in urban areas and complex airspace. Additionally, optimising maintenance costs by reducing operational errors and accidents is a significant driver for users. Users require PNT services that provide high accuracy, reliability, efficiency, quick time to response, continuous updates of positioning data, availability of historic data for post-flight analysis, and coverage in vast areas. The following key points were raised during the user consultation:

- **Positioning accuracy** flying in scenarios where nearby terrain/obstacles block signals from GNSS satellites at low elevation, i.e. only receiving signals from high elevation angles above local horizon. Despite large number of drone operators conduct their flights in urban areas, achieving the same performance (sub-meter accuracy) based on GNSS at $>35^\circ$ elevation angle is challenging. GNSS generally satisfies user needs in open sky conditions and Galileo HAS may replace RTK for some applications. Testing and simulation are required to determine real performance, and guidance should be provided to operators for site assessment in such conditions. On the other hand, the reference for vertical positioning needs to be agreed. Drone operators may consider adjusting the GNSS receiver masking angle (according to guidance in the operations manual) to mitigate the impact of multipath and NLOS in obstacle-rich scenarios.
- **Multi-Constellation Testing:** Similarly, the performance of multi-constellation is not formally specified for non-open sky scenarios. Single constellation testing allows calculation of worst-

case scenarios, but multi-constellation testing may take up to two years to generate all possible geometries and results.

- **Lack of defined standards for drones:** There are no formal specifications of positioning needs for drone missions for all phases of flight. The industry needs to establish clear regulatory criteria for higher-risk operations in specific or certified category, similar to PBN navigation specifications for manned aviation (e.g. RNP APCH).
- **Need for clear guidance and requirements:** There is a need to balance out navigation requirements in the domain of the Total System Error (TSE) with practical landing space (greater separation from obstacles in case of GNSS degradation) as well as the apportionment of navigation user needs from TSE into its components: NSE, FTE and PDE. On the NSE, it is necessary to specify what systems or processes should be used in specific conditions, especially when GNSS signals are obstructed or reflected (NLOS and multipath).
- **Suitable means for PVT monitoring and alerting:** that is currently based on simple quality indicators provided by the GNSS receiver (e.g. number of satellites in view, DOP, signal to noise ratio). However, an integrity mechanism based on integrity risk, protection levels, alert limits and time to alert (TTA), tailored to UAS is not available yet. Drone operators informed at the UCP that their desired TTA would be very short, in the order of a couple of seconds or less, which is challenging with current augmentation systems. It would require multi-sensor, e.g. GNSS/INS or local augmentation.
- **Operational flexibility:** Operators should assess the satellite visibility at sites, possibly using 3D maps or other low-cost assessments. Various compliance options should be available, with complexity matching the operation type.
- **PVT resilience:** against unintentional RF interference as well as jamming and spoofing, based on MFMC GNSS and authentication, e.g. OSNMA to detect some types of spoofing events.

In the context of drone PNT services, less critical factors might include the aesthetic design of hardware components or excessive redundancy in non-critical systems, provided essential backup systems are in place. As PNT technology continues to evolve, it will enable more sophisticated and autonomous drone applications, driving innovation and efficiency in various sectors, including logistics, surveillance, and emergency response.

The UCP survey [RD54] revealed that most of the users (67%) operate in open sky (obstacles/terrain elevation angle $<10^\circ$) locations for landings while only 17% of users typically land in non-open sky conditions (up to $20-30^\circ$) and 17% in obstacle-rich conditions (with signal blockage even above 40°).

The required horizontal positioning error HNSE(95%) is between 2 and 5 meters for en-route flight and <1 meter for landing. The required vertical positioning error VNSE(95%) is between 2 and 5 meters for en-route flight and <1 meter for landing. The majority of users (38%) require <20 cm vertical accuracy for landing. The current capabilities of GNSS in combination with stringent user requirements for landing phase are underlined by the fact that only 26% of respondents rely purely on GNSS or augmented GNSS. The rest uses GNSS in combination with other sensors or completely different means for position determination. According to the survey, none of the operators currently use Galileo HAS, but most of them (75%) are interested in sub-meter accuracy without using RTK. The GNSS receivers may be a barrier to greater HAS uptake as 25% of respondents note that their receivers are not HAS-capable. Majority of respondents use tools to monitor performance of positioning sensors. The 86% of respondents can tolerate a horizontal positioning error of 3 to 10 meters without issuing an alert. Less tolerance is highlighted for vertical dimensions as 57% of respondents accept <5 meter error without receiving an alert. The majority of respondents (63%) have experienced RF interference and have implemented or are planning to implement measures to mitigate the effects, OSNMA being a potential solution for spoofing.

In general, users can accept a failure rate without an alert of 1 per 1,000 (10^{-3}) or 10,000 (10^{-4}) flight-hours while 26% of respondents can accept lower reliability (<100 hours, so $>10^{-2}$ per flight-hour). The majority of respondents (87%) confirm that they have implemented procedures to confirm GNSS operational availability before take-off.

2.4.1.7.3 HAPS

HAPS (High Altitude Platform Systems) are sophisticated drones that operate in the stratosphere, typically at altitudes between 18 and 22 kilometers. HAPS can consist of one or more unmanned vehicles with some degree of autonomy in performing tasks. HAPS can use various designs e.g. lighter-than-air (LTA) types like balloons and airships relying on buoyancy or heavier-than-air (HTA) types like fixed-wing aircraft. HAPS, especially LTA, offer nearly unlimited endurance.

Compared to satellites, HAPS operate closer to earth than satellites but higher than conventional aircraft, filling a gap in aerial services. Unlike satellites, HAPS maintain their relative position and thus can provide continuous services to desired areas. This is especially useful during emergencies e.g. to support natural disaster recovery teams.

HAPS are designed to carry various payloads depending on the mission needs. Some of the use cases may include enhancement of terrestrial and satellite communications, providing a range of services such as broadband connectivity, earth observation data (e.g. Synthetic Aperture Radar), and navigation support. HAPS have gained significant attention due to their potential to provide services in remote or underserved regions.

From the GNSS/EO perspective, HAPS are not just a user of GNSS/EO data, but also a provider. The performance requirements for such data provided by HAPS shall be defined by their users and thus this report will investigate HAPS as an end-user of GNSS/EO data, not as a complementary provider.

GNSS user perspective

GNSS plays a crucial role in HAPS operations, particularly in acquiring and maintaining accurate positioning and timing information. Depending on the payload, HAPS can transmit GNSS differential correction signals to other users, significantly improving the accuracy performance. Further to that, as being closer to the ground, HAPS can also serve as a platform to identify areas subject to GNSS spoofing and jamming events as well as to detect and locate interfering sources on the ground.

HAPS platforms, such as Thales Alenia Space's Stratobus and those developed by SCEYE, rely on GNSS for navigation and operational control. HAPS operators typically use basic GNSS modes with no emphasis on high accuracy.

The GNSS jamming and spoofing are significant threats to HAPS operations and necessitate robust detection and mitigation strategies. The process to achieve HAPS certification (e.g. some form of airworthiness and operational approval) is progressing slowly as it is complex and varies by region. In Europe institutions like EASA and JARUS are playing pivotal roles in establishing standards in this complex and process.

The operational GNSS performance requirements are less stringent compared to small drones or manned aviation. In terms of accuracy, horizontal NSE (Navigation System Error) of a few meters is sufficient since the aircraft dimensions are generally large (tens of meters, often surpassing 100 m), and the platform has low manoeuvrability thus requiring large separation from other airspace users and terrain. Users confirmed that vertical NSE is even less critical than HNSE due to stratospheric winds causing altitude fluctuations of even 100 m in some cases. Improving the currently achieved VNSE performance would not provide any tangible benefits to efficiency or safety of operations. During the UCP [RD54], operators noted that operating above 30-40 deg latitude (North or South) is not challenging for HAPS, but the amount of harnessed energy needs to be considered due to lower amount of sunlight at high latitudes in certain seasons.

Despite a remote-control design, number of redundancy systems are employed by the operators. This also includes back-up GNSS receivers and other sensors (e.g. barometers in lower altitudes or accelerometers) capable of providing positioning information in case of GNSS outage.

EO user perspective

Earth Observation (EO) data plays a role in HAPS missions. Operators like Stratobus and SCEYE utilise EO data to gain accurate atmospheric and stratospheric weather predictions, which are essential for mission planning.

The EO data can be used to calibrate, validate, or complement the data captured by HAPS. Such integration process can be done by cross reference data collected by HAPS and LEO satellites, where the LEO satellites provide information on environmental conditions and weather patterns. The main use is to help plan HAPS missions and assess risks and make real-time operation decisions. More specifically, to understand wind conditions, solar timeframes, and other environmental factors that could affect the flight. The EO data can also support operational decisions e.g. to identify suitable landing spots for HAPS.

Operators use various tools for trajectory analysis and scenario planning, incorporating both real-time data and historical data. For example, SCEYE uses tools with different update rates depending on the stage of the planning process. Early stages of planning use lower update rates, while higher update rates are employed moments before launch to analyse different scenarios. External tools and simulators are also used to enhance the accuracy of these predictions.

The EO user requirements are phrased around weather monitoring and population density. The weather monitoring informs mission planning by anticipating extreme weather events throughout the monitoring of various parameters in the stratosphere. The population data from Copernicus can be used to support safety assessments, particularly for identifying emergency landing areas.

While EO data is invaluable, there are limitations. Specifically, Copernicus providing historic data with no option of forecast, poses limitation on supporting real-time or tactical mission planning. Additionally, based on the users' feedback, the resolution of some EO datasets may not be sufficient to meet their operational needs.

On the regulatory framework, users highlighted number of shortcomings, especially the lengthy flight approval process. Users think that having more active engagement from the agencies and authorities would help with addressing this issue.

During the UCP [RD54], users noted that they might be interested in HAPS providing data on atmospheric conditions, weather, contrails monitoring and real-time monitoring. The operators currently see a number of barriers to use EO data in support of HAPS missions. Namely update rates and overall data quality. Update rates were also raised as a significant shortcoming. The majority of the respondents indicated that they would require at least weekly update rates, and the remaining respondents require daily updates to carry out a safety risk assessment to support HAPS operations.

The majority of users noted that horizontal accuracy of the EO data for weather monitoring should be of "few meters". The 20% of users need <1 km resolution while another 20% require less than "few meters" accuracy. None of the stakeholders finds spatial resolution of >1 km useful. The required temporal resolution of the EO data supporting anticipation of extreme weather events is daily or better. Lower temporal resolution was not identified as useful.

2.4.1.7.4 eConspicuity

Electronic Conspicuity¹¹ or eConspicuity is an umbrella term for technologies that provide self-reporting of position from an aircraft to other aviation actors. The eConspicuity can be considered in two groups: Certified (used in controlled airspace by users such as commercial aviation and certified category drones) and Uncertified (used outside controlled airspace typically by General Aviation or drones operating in EASA open category). It is also an essential enabler for U-space as the means to provide the ability to 'detect' other aircraft. No solution has yet been agreed to enable interoperability between manned and

¹¹ The electronic conspicuity refers to transmission of position and iConspicuity is the interoperability/reception concept developed by EASA (<https://www.easa.europa.eu/en/research-projects/i-conspicuity-interoperability-electronic-conspicuity-systems-general-aviation>).

unmanned aviation within U-space. Currently, the GNSS positioning and reporting is enabled through the established ADS-B and a mix of proprietary solutions gaining traction with some users. There are several solutions including Automatic Dependent Surveillance Broadcast (ADS-B) (1090 MHz and UAT), Flight Alarm (FLARM), LTE/5G, 802.11 and the new ADS-L (light) operating on the SRD860 frequency band.

The introduction of ADS-L by EASA [RD56] in 2022 aims to monitor manned aircraft in U-space. Currently, the ADS-L 4 SRD-860 Technical specification is established, with ADS-L 4 Mobile's specification still under development, which will allow live tracking through the GSM (mobile) network, thereby increasing coverage.

eConspicuity solutions

ADS-B

The Automatic Dependent Surveillance – Broadcast (ADS-B) is a certified form of eConspicuity defined by ICAO for aircraft, aerodrome vehicles, and other objects to automatically transmit and/or receive data like identification and position. ADS-B is crucial for surveillance, especially in areas without radar coverage, by using ground stations or satellite telecom for remote areas. The ITU WRC 2015 allocated a frequency band for AMSS (Aeronautical Mobile Satellite Service) to enable worldwide flight tracking via ADS-B. New ADS-B applications are being developed, with some already in use, such as the In Trail Procedure (ITP) over the North Atlantic. The ADS-B is becoming integral to ATM, though COVID-19 delayed compliance deadlines for business aviation operators in Europe.

ADS-B UAT

ADS-B UAT (Universal Access Transceiver) operates on the 978 MHz frequency band, distinct from the 1090 MHz frequency used by traditional ADS-B. It is primarily used in the United States for General Aviation aircraft flying below 18,000 ft. It provides position, velocity, and other essential flight data, and supports weather and traffic information services (TIS-B and FIS-B). Broadcasted GNSS-derived positional data can be received by other aircraft and ground stations.

ADS-B UAT devices can receive data from various sources, including ADS-B, MLAT, Remote ID, and other tracking protocols on 868 MHz. Additionally, they provide services such as weather information and Traffic Information Service-Broadcast (TIS-B), enhancing the situational awareness and safety of General Aviation (GA) pilots.

The deployment of the ADS-B UAT ground stations is notably cost-effective. To fully cover area of the size of Finland, an estimated 30 ground stations are required, making this a realistic goal for improving aviation safety and operational efficiency, especially in mixed-use airspace environments.

ADS-L

Automatic Dependent Surveillance – Light (ADS-L) is another form of surveillance similar to ADS-B but utilises a different frequency band (SRD-860). It is designed to offer robust and reliable surveillance capabilities, particularly in areas where standard ADS-B frequencies might be congested or less effective. ADS-L operates within the L-band frequency range, which is less crowded compared to the 1090 MHz frequency used by ADS-B, thus reducing potential interference and congestion issues.

The technical specifications for ADS-L using the SRD860 frequency band were published in early 2023. However, it is primarily an air-to-ground system and not optimised for air-to-air interactions, which means it may not replace systems like FLARM for collision avoidance. Instead, ADS-L complements existing systems by reducing congestion on standard ADS-B frequencies and offering a cost-effective surveillance option, especially in the European context where the 978 MHz UAT frequency is not widely available for aviation use.

FLARM

FLARM continues to be a critical tool for collision avoidance, particularly in the general aviation and glider communities. While ADS-L provides broader surveillance capabilities, FLARM remains the go-to system for air-to-air interaction, especially in environments with a high concentration of non-commercial aviation activities. FLARM is working towards compatibility with the new ADS-L standards, ensuring that future

devices might be able to transmit ADS-L signals, thereby expanding their utility within the U-space airspace.

Remote ID

Drones use Remote Identification (Remote ID) technology, to broadcast position data (identification, position, altitude, and velocity), making the drone conspicuous to other traffic. This technology has a number of limitations, mainly the one-way communication channel and short-range nature of the broadcasts, which are delivered either via Wi-Fi or Bluetooth.

As of January 1, 2024, all drones operating in the EASA-specific category and those with EASA class marks in the open category are required to have an active and up-to-date Remote ID System. This system enables safe integration of drones into controlled airspace and allows authorities to track and identify drones in real-time, ensuring compliance with safety and security regulations across Europe. This requirement is part of the European Union's broader efforts to integrate drones safely into its airspace, enhancing accountability and oversight of drone operations.

The technologies supporting Remote-ID (e.g. Bluetooth or mobile phone networks) were not designed for high security and high-capacity transmissions. However, it is likely that the network of ground sensors in an area with dense drone operation could collect a significant amount of data, and that appropriate measures (bandwidth and security) will be required to transmit such data towards a central server in charge of processing it

Altitude reference

Drones equipped with ADS-B Out and Remote ID solutions, transmit the geometric altitude as height above WGS-84 ellipsoid¹². The barometric pressure altitude (based on International Standard Atmosphere - ISA) is optional, resulting in greater dependence on GNSS. For operations in U-space airspace, the USSPs convert heights above the WGS-84 ellipsoid to height above mean sea level (AMSL) before providing it to drone operators.

The role of HAS and OSNMA

The OSNMA and HAS services can contribute to the development and enhancement of eConspicuity technologies. OSNMA provides a mechanism for authenticating the navigation signals transmitted by Galileo satellites, ensuring the integrity and authenticity of the position information received by users. It enhances the reliability of position data reported by aircraft, reducing the risk of spoofing or other malicious activities that could disrupt the safety and security of airspace operations. During the UCP [RD54], users highlighted the importance of OSNMA and highlighted better positioning enabled by HAS as one of the key user needs. The limited number of affordable OSNMA and multi-constellation capable receivers was also raised by the users. Currently, very few lower-end solutions are available on the market.

HAS can provide centimetre-level accuracy, which is vital for operations in dense or complex airspace environments, where precise location data is necessary to prevent collisions and ensure smooth traffic flow.

User needs

The user needs for eConspicuity, as conveyed by the users, focus on safety and reliability. The efficiency of airspace operations is not considered relevant due to low levels of unmanned traffic. However, users acknowledge that it will have to be addressed in future. The following feedback was collected from the community:

- **Latency:** In order to ensure real-time situational awareness, having low latency is instrumental. It is particularly critical events of traffic proximity. The feedback provided by the GA community calls for a latency of <1 s within the coverage of ADS-B UAT ground stations. The 15 s is

¹² EASA CS-ACNS Issue 4, CS ACNS.D.ADSB.085 Geometric Altitude and ASTM F3411/EN 4709-002

generally acceptable for cross-country flights (outside of ADS-B UAT coverage). The feedback is consistent with manufacturers objectives, aiming to provide latency of 1 s, ideally 1/4 s. In special cases, the system can be configured to provide 1/10 s but there are limited use cases for such performance.

- **Accuracy:** A trade-off between the size of the chipset and its performance drives the decision-making. System manufacturers noted that the current achieved performance (horizontal and vertical accuracy of a few meters) is sufficient. Users noted that there is no need for sub-meter accuracy as the system aims to provide surveillance picture to airspace users (mainly GA pilots and drone operators) who may want to ensure separation in hundreds of meters anyway.
- **Consistency in behaviour and performance:** For GA, continuity of data is crucial. The accuracy of the systems (FLARM, ADS-B, etc.) is well-tested and generally reliable, but there is a need for consistent performance across different technologies, especially once drones are integrated into the airspace.
- **Authentication and Integrity:** There is a need for authentication at every level to prevent spoofing and interference. Although the market is not fully ready for widespread implementation, it is recognised as a future requirement for critical operations. Users are interested in the integrity of the data, ensuring that the information received is reliable and accurate.
- **Cost:** The cost of implementing eConspicuity solutions should be reasonable. For instance, ADS-B UAT ground stations are relatively inexpensive, and low-cost receivers are available for GA aircraft. The solutions should also be practical and easy to integrate into existing systems without requiring significant modifications or additional equipment. For Safety-of-Life (SoL) applications, limited OSNMA-capable and multi-constellation receivers are currently available.

The UCP survey [RD54] on eConspicuity showed that users consider availability (50%) and integrity (43%) as key parameters. Accuracy, continuity and latency were considered less important. The 84% of users think they would benefit from using OSNMA to support the integrity of GNSS. There is a diversity when it comes to preferred eConspicuity solutions, with 54% of users opting for RemotID/NetworkID¹³ and the rest split between ADS-L, ADS-B, FLARM, ADS-B UAT or other solutions. The poll has revealed that altitude reference might be point to address when it comes to integrating manned aviation and drones within the same airspace. The 50% of users use reference to main sea level (AMSL), the 21% to the ground (AGL) and the 29% of users use other altitude reference.

A need for tracking, from a legal perspective, and a need for exchanging data with legal value was raised by one of the users. Further to that, the importance of choosing the right antenna for drones (Helix antennas vs patch) and trade-offs with mitigating multipath in urban environments were highlighted. Users think that wider use of LTE (5G) could support operations expansion.

2.4.1.8 Secure SATCOM

General

Secure SATCOM is technology that provides one or two-way reliable, accessible, and guaranteed satellite capacity/service for communications. Secure SATCOM can be provided with any type of frequency band by COMSATCOM, GOVSATCOM, and MILSATCOM.

- **COMSATCOM:** Available on the global market with 'on-demand' access, supporting sectors like telecommunications, broadcasting, and aviation, and enabling global connectivity.
- **GOVSATCOM:** Tailored for government needs, providing secure, resilient communication for defence, public safety, and diplomacy. Offers moderate protection, higher than COMSATCOM but lower than MILSATCOM.

¹³ RemotID and NetworkID are solution used exclusively by drones

- **MILSATCOM:** Designed for military use, offering maximum protection with nuclear hardening, anti-jamming capabilities, and secure telemetry. Highly specialised and under national control.

This report focuses on secure SATCOM services provided by GOVSATCOM today (and IRIS2 in the future) to users such as governmental entities from the European Union Member States, European Union agencies, and organisations located in the European Union or deployed worldwide.

GOVSATCOM aims to support manned aviation and BVLOS drone flights by providing a unified, resilient, and cost-efficient communication environment for governmental operations. The GOVSATCOM HUB ecosystem will centralise resources and ensure additional capacity for unexpected events. Its infrastructure includes automation, user anonymisation, a diverse service portfolio, and security monitoring.

Certain levels of SATCOM services will be accessible through tokens provided by the European Commission; additional services will require a top-up. Full operational capability is anticipated by 2027, with IRIS² (LEO/MEO) services also integrated into GOVSATCOM.

The secure SATCOM market is divided into 13 use cases across four categories:

- **Surveillance** (Land, Border, and Maritime),
- **Crisis Management** (Maritime Emergency, Humanitarian Aid, Civil Protection, Law Enforcement Interventions, EU (European Union) External Actions, and Forces Deployment),
- **Key Infrastructure** (Transport Infrastructures, Space Infrastructures, Institutional Communications, and Other Critical infrastructures), and
- **Secure communications** in Polar regions.

This section addresses secure SATCOM applications for the Surveillance market segment.

2.4.1.8.1 Maritime Surveillance applications

Secure SATCOM will play a crucial role in supporting maritime surveillance.

Unlike traditional systems such as AIS (Automatic Identification System), secure SATCOM offers encrypted communications, ensuring that sensitive information about vessel locations and activities remains confidential and protected from unauthorised access. Secure SATCOM operates via satellite, offering global coverage in areas beyond terrestrial networks, such as open seas and remote coastal regions. With significantly higher bandwidth than older technologies like AIS, it enables robust data transmission even in high-traffic areas. Additionally, secure SATCOM can integrate with other maritime surveillance tools, including GPS, radar, and satellite imagery, to deliver comprehensive situational awareness.

Secure SATCOM can support continuous, encrypted tracking of vessels, providing authorities with accurate location data even when ships attempt to conceal their positions. By maintaining constant communication between ships and shore, secure SATCOM improves maritime safety, and enables rapid response to emergencies or security threats. The high-bandwidth capabilities allow for the exchange of large volumes of data, including imagery, weather information, and intelligence reports, crucial for maritime domain awareness. Secure SATCOM facilitates coordination between naval forces and aerial operations, optimising the deployment of patrol vessels and aircraft for interception or monitoring activities. The technology also supports environmental monitoring by enabling the transmission of sensor data and satellite imagery to track maritime pollution and protected areas. Additionally, secure SATCOM aids in identifying patterns of illegal behaviour at sea, such as illegal fishing, smuggling, and piracy, by providing a secure channel for sharing intelligence and coordinating responses. By utilising secure SATCOM, maritime authorities can significantly improve their surveillance capabilities, ensuring safer and more secure oceans while safeguarding sensitive information from potential threats.

More specifically related to Aviation & Drones, **integrating SATCOM with RPAS** (Remotely Piloted Aircraft Systems) has become essential in maritime surveillance, enabling RPAS to operate over vast,

remote ocean areas beyond the limits of radio line-of-sight. Secure SATCOM will not only extend RPAS operational reach but also allow real-time data sharing and control, providing maritime authorities with timely insights even in communication-limited zones.

EMSA RPAS Service is a good example of application in several keyways like EMSA reported in its study ¹⁴.

Indeed, EMSA's extensive RPAS portfolio enables simultaneous operations across multiple locations, as demonstrated by 9 active operations in 2024. Key use cases include long-range flights beyond traditional communication limits, using separate data links for command/control and payload, as well as satellite internet for ship-based and land operations in areas without standard internet access. This capability allows RPAS to operate beyond radio line-of-sight, covering larger areas and remote regions where terrestrial communication is unavailable.

High-bandwidth SATCOM facilitates real-time transmission of sensor data, video feeds, and control signals, ensuring timely and accurate information for maritime authorities. It enhances operational flexibility, allowing RPAS deployment from various platforms without the need for extensive ground-based infrastructure. Secure SATCOM also supports the integration of RPAS data with other surveillance systems, contributing to a comprehensive maritime situational awareness picture.

Key SATCOM requirements include global coverage, high accuracy, flexible operational frameworks, and cost-efficiency. However, EMSA's operational experiences highlight areas for improvement, such as GNSS interference and SATCOM concerns. The potential of High-Altitude Platform Stations (HAPS) to bridge the gap between satellite Earth Observation and lower-altitude RPAS missions is also being explored. Additionally, EMSA acknowledges the need for enhanced detect and avoid capabilities and a 'lighter' version of U-space for maritime environments.

EASA emphasizes the importance of SATCOM and flight termination systems for Beyond Radio Line of Sight (BRLOS) operations.

The BRLOS (Beyond Theoretical Radio Line of Sight) framework applies to specific medium-range operations where radio link degradation occurs at distances of 20-50 km, prompting a switch to satellite-based C2 links. For operations between 50-500 km—such as linear inspections, environmental surveys, or security surveillance—three links are necessary to ensure network reliability. EASA currently issues authorizations for SAIL II operations, which involve lower C2 link requirements, whereas SAIL III operations demand medium robustness for the C2 link. SATCOM-based C2 links for these operations must meet OSO 6 communication standards, with functional performance requirements tied to OSO 5 and OSO 24.

2.4.1.8.2 Land Border Surveillance applications

Land and border surveillance in Europe is a critical aspect of maintaining the security and stability of the region. With vast external borders across both land and sea, European countries work collectively to monitor and control the movement of people and goods, focusing on preventing unauthorised entry, managing migration, and addressing cross-border crime.

Organisations like Frontex, the European Border and Coast Guard Agency, collaborate with EU Member States to enhance border security efforts through advanced technology and operational support. Using surveillance tools such as RPAS, manned aircraft, helicopters, radar, and ground sensors, they achieve greater situational awareness. This is essential for addressing challenges like human trafficking, smuggling, and other security threats.

A variety of assets benefit from secure SATCOM in EU border surveillance, coordinated by Frontex alongside Member States. By detecting and identifying irregular migration or other border-related

¹⁴ Remotely Piloted Aircraft Systems Services (RPAS) - EMSA RPAS Services for Maritime Surveillance 2017-2023 - EMSA - European Maritime Safety Agency (europa.eu)

criminal activities, Frontex aims to create situational awareness that enables effective border control measures to be implemented. This surveillance is conducted through the use of advanced technologies, such as RPAS, as well as through extensive cooperation with national authorities and other international partners. From an innovation perspective, Frontex activities are driven by operational needs, guiding research and development efforts to meet the EBCG community emerging needs.

The most recent initiatives related to drones are:

- Tactical land border and coastal surveillance with RPAS, long endurance and reduced logistic footprint,
- VTOL RPAS for multi-purpose surveillance, and
- Counter-UAS.

This section focuses on tactical land border and coastal surveillance with RPAS where Secure SATCOM is anticipated to provide substantial enhancements, improving mission effectiveness and security in border surveillance operations.

Indeed, RPAS missions face several critical challenges that must be addressed to ensure their success:

- **Potential security threats:** RPAS are vulnerable to data interception, unauthorised access, and deliberate disruptions such as jamming and spoofing attacks. These security risks can compromise the integrity of mission-critical communications, potentially leading to the loss of sensitive data or disruption of operations. Ensuring secure communications through encryption and robust cybersecurity measures is vital to protecting these systems from malicious interference.
- **Long-range mission capability:** RPAS are often required to operate BVLOS and up to BRLOS (Beyond Radio Line-of-sight), where pilots cannot maintain direct radio contact with the drones. This capability is essential for covering large surveillance areas, but it introduces operational challenges such as ensuring reliable communication links and precise control over extended distances. The second case (BRLOS) will accelerate in the future with more advanced operations and demanding missions therefore, technologies like satellite communication and automated flight systems are key to enabling these long-range missions.
- **Real-time data collection:** The ability to gather and transmit real-time data, including video feeds, telemetry data, and sensor information, is fundamental for mission effectiveness. This data must be reliably transmitted back to control centres for immediate analysis and decision-making, but it also requires substantial bandwidth and low-latency communication systems to ensure accurate and timely delivery of information.

Secure SATCOM will enable seamless, low-latency connectivity for RPAS BVLOS/BRLOS operations, offering a real-time data transmission link in a fully secured end-to-end environment.

In addition, RPAS equipped with independent SATCOM systems will offer **enhanced operational flexibility** by eliminating the need for extensive ground-based communication infrastructure. This technical capability allows RPAS to operate autonomously, deploying from remote or hard-to-reach locations without relying on local networks.

User needs

The user needs for secure SATCOM, as expressed by the users, focus on security and efficiency. Indeed, the major challenges, especially when considering RPAS operations, are ensuring reliable connectivity over vast and often remote areas, supporting real-time data transmission, and enabling secure communication links that can withstand cyber threats.

BRLOS (Beyond Radio Line-of-sight) missions represent a significant efficiency improvement for RPAS operations. By utilising secure SATCOM, RPAS can maintain connectivity and control even when they are outside the range of traditional radio communications. This capability allows operators to conduct extended surveillance missions over large areas without the limitations imposed by radio line-of-sight

restrictions. Operating BRLOS enhances the operational range and flexibility of RPAS, enabling them to gather critical intelligence, perform border surveillance, and support search and rescue operations more effectively.

Users require SATCOM systems that facilitate high-speed data exchange for BRLOS missions, robust security protocols to protect sensitive information, and seamless integration with existing communication networks. High-bandwidth satellite connections of up to 5 Mbps or 10 Mbps allow RPAS to stream high-resolution imagery, video, and sensor data in real time back to control centres, enabling immediate analysis and response to maritime situations.

In addition, RPAS equipped with independent SATCOM systems offer enhanced operational flexibility by eliminating the need for extensive ground-based communication infrastructure. This technical capability allows RPAS to operate autonomously, deploying from remote or hard-to-reach locations without relying on local networks.

Furthermore, encrypted satellite links ensure that sensitive surveillance data and RPAS control signals remain protected from interception or interference. With secure SATCOM, RPAS can e.g. conduct extensive patrols over large maritime zones, complementing satellite and ship-based surveillance. Long-endurance RPAS can maintain extended on-station times, providing continuous monitoring of specific areas of interest and significantly enhancing overall operational effectiveness.

Challenges and needs for Secure SATCOM requirements include bandwidth, latency, availability, link type, and coverage. Key requirements also encompass link symmetry, distribution, setup speed, and security measures.

The UCP survey [RD54] on Secure SATCOM complemented by additional interviews led by EUSPA allowed to capture these requirements. The identified priority needs in the survey and the interviews include the following aspects:

- Bi-directional data flows (for 71% of the users),
- High availability (for 57% of the users),
- Medium latency of <500 m/s (for 71% of the users),
- High bandwidth - greater than 10mb (for 57% of the users),
- Regional coverage (Europe) (for 43% of the users) to worldwide,
- 50/50 for bi-directional use or 80/20 for internet use (both for 50% of the users),
- To serve user-to-user communication (for 57% of the users),
- Immediate responsiveness within minutes (for 57% of the users),
- To support normal movements speed of >40km/h (for 57% of the users),
- Data integrity (for 100% of the users), availability (for 71% of the users) and confidentiality (for 57% of the users) seen as key parameters.

2.5 User Requirements Specification

This chapter provides a synthesis of the requirements described in section 2.4.1. The content of this section will be updated, completed, and expanded by EUSPA in the next releases of the RUR based on the results of further investigations discussed and validated in the frame of the UCP.

2.5.1 Synthesis of Requirements Relevant to GNSS

2.5.1.1 Navigation

2.5.1.1.1 Resilience requirements for a total PBN environment

Table 3: GNSS resilience requirements for a total PBN environment

Id	Description	Type	Source
EUSPA-GN-UR-AVI-0110	The PBN solution shall enable a minimum horizontal accuracy (95%), HNSE(95%), of 0.4 NM in En route and arrival route (STAR) and 220 m in departure (SID).	Performance (Horizontal Accuracy)	ICAO Annex 10 Vol I [RD2] (Table 3.7.2.4-1)
EUSPA-GN-UR-AVI-2120	The PBN solution shall enable a minimum vertical accuracy (95%), VNSE(95%), of 6 to 4 m for CAT I precision approach.	Performance (Vertical Accuracy)	ICAO PBN Manual [RD3]
EUSPA-GN-UR-AVI-0120	The PBN solution shall provide an alert within 10 s if the Horizontal Protection Level computed by the system exceeds the Horizontal Alert Limit of 1 NM in en-route and STAR, and of 0.3 NM in SID.	Performance (integrity, Horizontal Alert Limit and Time to Alert)	RTCA and EUROCAE GNSS receiver MOPS [RD4]
EUSPA-GN-UR-AVI-2140	The PBN solution shall provide an alert within 10 s if the Vertical Protection Level computed by the system exceeds the Vertical Alert Limit of 50 m for APV-I and 35 m for LPV 200.	Performance (integrity, Vertical Alert Limit and Time to Alert)	(EU) 2018/1048 Airspace usage requirements and PBN operating procedures [RD5]
EUSPA-GN-UR-AVI-0130	The GNSS signal in space ¹⁵ shall ensure an integrity performance of $1-1 \times 10^{-7}$ per hour, or better. ¹⁶	Performance (Integrity)	(EU) 2021/116 Establishment of Common Project One [RD6]
EUSPA-GN-UR-AVI-0140	The GNSS signal in space shall provide an availability of 0.99 (99%) to 0.99999 (99.999%) of the time.	Performance (Availability)	
EUSPA-GN-UR-AVI-0150	The GNSS signal in space shall provide a continuity performance of $1-1 \times 10^{-4}$ to $1-1 \times 10^{-8}$ /h or better for en-route, terminal and non-precision approach. For approach with vertical guidance (APV-I and LPV 200) the continuity requirement is $1 - 8 \times 10^{-6}$ per 15 s..	Performance (Continuity)	
EUSPA-GN-UR-AVI-2180	Probability of GNSS signal interference should not be higher than ... TBD Probability of losing L1 ... TBD Probability of losing L5 ... TBD Event duration ... TBD Geographical scope of the event ... TBD Probability of frequency saturation ... TBD	Resilience of the signal	European Navaid Infrastructure Planning Handbook [RD12]

¹⁵A fault-free user receiver is assumed to have no failures that affect the integrity, availability and continuity performance.

¹⁶RNP requirement only

2.5.1.1.2 PBN applications

Table 4: RNP / RNAV for En-Route and Terminal operations, requirements for RNAV 10 and RNP 4 operations – GNSS

Id	Description	Type	Source
EUSPA-GN-UR-AVI-0010	The PBN solution shall enable a minimum horizontal accuracy (95%), HNSE(95%), of 2 NM. (NSE 2σ).	Performance (Horizontal Accuracy)	ICAO Annex 10 [RD2]
EUSPA-GN-UR-AVI-0020	The PBN solution shall provide an alert within 5min if the Horizontal Protection Level computed by the system exceeds the Horizontal Alert Limit of 4 NM in Oceanic Airspace and of 2 NM in Continental Airspace.	Performance (integrity, Horizontal Alert Limit and Time to Alert)	ICAO PBN Manual [RD3]
EUSPA-GN-UR-AVI-0030	The GNSS signal in space shall ensure an Integrity performance of $1-1 \times 10^{-7}$ per hour or better. ¹⁷	Performance (Integrity)	RTCA and EUROCAE GNSS receiver MOPS [RD4]
EUSPA-GN-UR-AVI-0040	The GNSS signal in space shall provide an availability of 0.99 (99%) to 0.99999 (99.999%) of the time.	Performance (Availability)	
EUSPA-GN-UR-AVI-0050	The GNSS signal in space shall provide a continuity performance of $1-1 \times 10^{-4}$ to $1-1 \times 10^{-8}$ per hour, or better.	Performance (Continuity)	

Table 5: RNP / RNAV for En-Route and Terminal operations, requirements for RNAV 5 operations – GNSS

Id	Description	Type	Source
EUSPA-GN-UR-AVI-0060	The PBN solution shall enable a minimum horizontal accuracy (95%), HNSE(95%), of 0.4 NM.	Performance (Horizontal Accuracy)	ICAO Annex 10 [RD2]
EUSPA-GN-UR-AVI-0070	The PBN solution shall provide an alert within 15 s if the Horizontal Protection Level computed by the system exceeds the Horizontal Alert Limit of 1 NM.	Performance (integrity, Horizontal Alert Limit and Time to Alert)	ICAO PBN Manual [RD3]
EUSPA-GN-UR-AVI-0090	The GNSS signal in space shall provide an availability of 0.99 to 0.99999 of the time.	Performance (Availability)	RTCA and EUROCAE GNSS receiver MOPS [RD4]
EUSPA-GN-UR-AVI-0100	The GNSS signal in space shall provide a continuity performance of $1-1 \times 10^{-4}$ to $1-1 \times 10^{-8}$ per hour, or better.	Performance (Continuity)	

Table 6: RNP / RNAV for En-Route and Terminal operations, requirements for RNP 1 and 2, RNAV 1 and 2 operations – GNSS

Id	Description	Type	Source
EUSPA-GN-UR-AVI-0110	The PBN solution shall enable a minimum horizontal accuracy (95%) of 0.4 NM in enroute and arrival route (STAR) and 220 m in departure (SID).	Performance (Horizontal Accuracy)	ICAO Annex 10 [RD2]
EUSPA-GN-UR-AVI-0120	The PBN solution shall provide an alert within 10 s if the Horizontal Protection Level computed by the system exceeds the Horizontal Alert Limit of 1 NM in en-route and STAR, and of 0.3 NM in SID.	Performance (integrity, Horizontal Alert Limit and Time to Alert)	ICAO PBN Manual [RD3]
EUSPA-GN-UR-AVI-0130	The GNSS signal in space shall ensure an integrity performance of $1-1 \times 10^{-7}$ per hour, or better. ¹⁸	Performance (Integrity)	RTCA and EUROCAE GNSS receiver MOPS [RD4]
EUSPA-GN-UR-AVI-0140	The GNSS signal in space shall provide an availability of 0.99 to 0.99999 of the time.	Performance (Availability)	

¹⁷ RNP requirement only

¹⁸ RNP only requirement

Id	Description	Type	Source
EUSPA-GN-UR-AVI-0150	The GNSS signal in space shall provide a continuity performance of $1-1 \times 10^{-4}$ to $1-1 \times 10^{-8}$ per hour, or better.	Performance (Continuity)	

Table 7: RNP APCH (LNAV), requirements for operations – GNSS

Id	Description	Type	Source
EUSPA-GN-UR-AVI-0160	The PBN solution shall enable a minimum horizontal accuracy (95%) of 220 m.	Performance (Horizontal Accuracy)	ICAO Annex 10 [RD2]
EUSPA-GN-UR-AVI-0170	The PBN solution shall provide an alert within 10 s if the Horizontal Protection Level computed by the system exceeds the Horizontal Alert Limit of 0.3 NM	Performance (integrity, Horizontal Alert Limit and Time to Alert)	ICAO PBN Manual [RD3]
EUSPA-GN-UR-AVI-0180	The GNSS signal in space shall ensure an Integrity performance of $1-1 \times 10^{-7}$ per hour, or better.	Performance (Integrity)	RTCA and EUROCAE GNSS receiver MOPS [RD4]
EUSPA-GN-UR-AVI-0190	The GNSS signal in space shall provide an availability of 0.99 to 0.99999 of the time.	Performance (Availability)	
EUSPA-GN-UR-AVI-0200	The GNSS signal in space shall provide a continuity performance of $1-1 \times 10^{-4}$ to $1-1 \times 10^{-8}$ per hour, or better.	Performance (Continuity)	

Table 8: RNP APCH (LNAV/VNAV), requirements for operations - GNSS

Id	Description	Type	Source
EUSPA-GN-UR-AVI-0210	The PBN solution shall enable a minimum horizontal accuracy (95%) of 220 m.	Performance (Horizontal Accuracy)	ICAO Annex 10 [RD2]
EUSPA-GN-UR-AVI-0230	The PBN solution shall provide an alert within 10 s if the Horizontal Protection Level (HPL) computed by the system exceeds the Horizontal Alert Limit (HAL) of 40 m.	Performance (integrity, Horizontal Alert Limit and Time to Alert)	ICAO PBN Manual [RD3]
EUSPA-GN-UR-AVI-0250	The GNSS signal in space shall ensure an Integrity performance of $1-1 \times 10^{-7}$ per hour, or better.	Performance (Integrity Risk)	RTCA and EUROCAE GNSS receiver MOPS [RD4]
EUSPA-GN-UR-AVI-0260	The GNSS signal in space shall provide an availability of 0.99 (99%) to 0.99999 (99.999%) of the time.	Performance (Availability)	
EUSPA-GN-UR-AVI-0270	The GNSS signal in space shall provide a continuity performance of $1-1 \times 10^{-4}/h$ to $1-1 \times 10^{-8}$ per hour, or better (considering the new PBN regulation that leads to the whole fleet being equipped, an appropriate performance figure should be met to ensure safe operations).	Performance (Continuity)	

Table 9: RNP APCH LPV, requirements for operations - GNSS

Id	Description	Type	Source
EUSPA-GN-UR-AVI-0420	The PBN solution shall enable a minimum horizontal accuracy HNSE(95%) of 16 m.	Performance (Horizontal Accuracy)	ICAO Annex 10 [RD2]
EUSPA-GN-UR-AVI-0420	The PBN solution shall enable a minimum vertical accuracy VNSE(95%) of 20 m.	Performance (Vertical Accuracy)	ICAO PBN Manual [RD3]
EUSPA-GN-UR-AVI-0440	The PBN solution shall provide an alert within 10 s if the Horizontal Protection Level computed by the system exceeds the Horizontal Alert Limit of 40 m.	Performance (integrity, Horizontal Alert Limit and Time to Alert)	RTCA and EUROCAE GNSS receiver MOPS [RD4]
EUSPA-GN-UR-AVI-0441	The PBN solution shall provide an alert within 10 s if the Vertical Protection Level computed by the system exceeds the Vertical Alert Limit of 50 m.	Performance (integrity, Vertical Alert Limit and Time to Alert)	
EUSPA-GN-UR-AVI-0320	The GNSS signal in space shall ensure an Integrity performance of $1-2 \times 10^{-7}$ in any approach (150 s) or better.	Performance (Integrity Risk)	

Id	Description	Type	Source
EUSPA-GN-UR-AVI-0470	The GNSS signal in space shall provide an availability of 0.99 to 0.99999 of the time.	Performance (Availability)	
EUSPA-GN-UR-AVI-0340	The GNSS signal in space shall provide a continuity performance of $1-8 \times 10^{-6}$ per 15 s, or better.	Performance (Continuity)	

Table 10: RNP APCH LPV200, requirements for operations - GNSS

Id	Description	Type	Source
EUSPA-GN-UR-AVI-0280	The PBN solution shall enable a minimum horizontal accuracy (HNSE, 95%) of 16 m.	Performance (Horizontal Accuracy)	ICAO Annex 10 [RD2]
EUSPA-GN-UR-AVI-0290	The PBN solution shall enable a minimum vertical accuracy (VNSE, 95%) of 4 m.	Performance (Vertical Accuracy)	ICAO Annex 10, [RD2] Table 3.7.2.4-1
EUSPA-GN-UR-AVI-0300	The PBN solution shall provide an alert within 6 s if the HPL computed by the system exceeds the HAL of 40 m.	Performance (integrity, Horizontal Alarm Limit and Time to Alert)	ICAO PBN Manual [RD3]
EUSPA-GN-UR-AVI-0310	The PBN solution shall provide an alert within 6 s if the VPL computed by the system exceeds the VAL of 35 m.	Performance (integrity, Vertical Alarm Limit and Time to Alert)	RTCA and EUROCAE GNSS receiver MOPS [RD4]
EUSPA-GN-UR-AVI-0320	The GNSS signal in space shall ensure an Integrity performance of $1 - 2 \times 10^{-7}$ in any approach (150 s) or better.	Performance (Integrity)	
EUSPA-GN-UR-AVI-0330	The GNSS signal in space shall provide an availability of 0.99 to 0.99999 of the time.	Performance (Availability)	
EUSPA-GN-UR-AVI-0340	The GNSS signal in space shall provide a continuity performance of $1 - 8 \times 10^{-6}$ per 15 s or better.	Performance (Continuity)	

Table 11: RNP AR APCH operations, requirements for operations - GNSS

Id	Description	Type	Source
EUSPA-GN-UR-AVI-0420	The PBN solution shall enable a minimum horizontal accuracy (HNSE, 95%) of 16 m. <i>Note: RNP AR APCH is flown with GPS/ABAS & barometric altimetry down to LNAV/VNAV minima but may also be flown with GNSS/SBAS for both horizontal and vertical guidance according to EASA CS-ACNS issue 4.</i>	Performance (Horizontal Accuracy)	ICAO Annex 10 [RD2]
EUSPA-GN-UR-AVI-0440	The PBN solution shall provide an alert within 10 s if the HPL computed by the system exceeds the HAL of 0.3 NM.	Performance (Horizontal Alarm Limit and Time to Alert)	ICAO Annex 10, [RD2] Table 3.7.2.4-1
EUSPA-GN-UR-AVI-0460	The GNSS signal in space shall ensure an Integrity performance of $1 - 2 \times 10^{-7}$ in any approach (150 s), or better.	Performance (Integrity)	ICAO PBN Manual [RD3]
EUSPA-GN-UR-AVI-0470	The GNSS signal in space shall provide an availability of 0.99 (99%) to 0.99999 (99.999%) of the time.	Performance (Availability)	RTCA and EUROCAE GNSS receiver MOPS [RD4]
EUSPA-GN-UR-AVI-0480	The GNSS signal in space shall provide a continuity performance of $1-1 \times 10^{-4}$ to $1 - 1 \times 10^{-8}$ per hour, or better.	Performance (Continuity)	

2.5.1.1.3 GBAS CAT I

Table 12: Requirements for PA to CAT I minima - GNSS

Id	Description	Type	Source
EUSPA-GN-UR-AVI-0490	The nav. solution shall enable a minimum horizontal accuracy (HNSE, 95%) of 16 m.	Performance (Horizontal Accuracy)	ICAO Annex 10 [RD2]
EUSPA-GN-UR-AVI-0500	The nav. solution shall enable a minimum vertical accuracy (VNSE, 95%) of 4 m.	Performance (Vertical Accuracy)	ICAO Annex 10, [RD2] Table 3.7.2.4-1 I
EUSPA-GN-UR-AVI-0510	The nav. solution shall provide an alert within 6 s if the HPL computed by the system exceeds the HAL of 40 m.	Performance (Horizontal Alert Limit and Time to Alert)	ICAO PBN Manual [RD3]
EUSPA-GN-UR-AVI-0520	The nav. solution shall provide an alert within 6 s if the VPL computed by the system exceeds the VAL of 10 m. (CAT I Autoland enabled)	Performance (Vertical Alert Limit and Time to Alert)	RTCA and EUROCAE GNSS receiver MOPS [RD4]
EUSPA-GN-UR-AVI-0530	The nav. solution shall ensure an Integrity performance of $1 - 2 \times 10^{-7}$ in any approach (150 s), or better.	Performance (Integrity Risk)	
EUSPA-GN-UR-AVI-0540	The nav. solution shall provide an availability of 0.99 to 0.99999 of the time.	Performance (Availability)	
EUSPA-GN-UR-AVI-0550	The nav. solution shall provide a continuity performance of $1 - 8 \times 10^{-6}$ per 15 s, or better.	Performance (Continuity)	

2.5.1.1.4 VFR complement

Table 13: Requirements on VFR complement - GNSS

Id	Description	Type	Source
EUSPA-GN-UR-AVI-2210	The system shall provide a minimum horizontal accuracy of 2 NM.	Performance (Horizontal Accuracy)	ICAO Annex 11 [RD7], Chapter 3, 3.7.2.4 UCP 2022 [RD55]
EUSPA-GN-UR-AVI-2220	The system shall provide an integrity of $1 - 1 \times 10^{-7}$ per hour, or higher.	Performance (Integrity)	
EUSPA-GN-UR-AVI-2230	The system shall provide time-to-alert of 5 min, or lower	Performance (Time to Alert)	
EUSPA-GN-UR-AVI-2240	The system shall provide a continuity of $1 - 1 \times 10^{-4}$ per hour, or better.	Performance (Continuity)	
EUSPA-GN-UR-AVI-2250	The system shall provide availability of 0.99, or better.	Performance (Availability)	

2.5.1.2 Surveillance

2.5.1.2.1 eConspicuity (E.g. ADS-B)

Table 14: ADS-B Airport (APT)

Id	Description	Type	Source
EUSPA-GN-UR-AVI-0870	The system shall provide a minimum horizontal accuracy of 10 m.	Performance (Horizontal Accuracy)	EUROCAE ED 163 [RD9]
EUSPA-GN-UR-AVI-0880	The system shall implement a Horizontal Alarm Limit of 10 m.	Performance (Integrity)	
EUSPA-GN-UR-AVI-0890	The system shall provide an integrity risk (SDA) of 1×10^{-4} per hour, or lower.	Performance (Integrity)	

Id	Description	Type	Source
EUSPA-GN-UR-AVI-0900	The system shall provide a velocity accuracy of 1 to 3 m/s.	Performance (Velocity Accuracy)	
EUSPA-GN-UR-AVI-0910	The system shall provide a continuity of 1 - 3x10 ⁻⁴ per hour, or better.	Performance (Continuity)	

Table 15: ADS-B ATSA - Airborne Situational Awareness (AIRB)

Id	Description	Type	Source
EUSPA-GN-UR-AVI-1000	The system shall provide a minimum horizontal accuracy of 0.5 NM.	Performance (Horizontal Accuracy)	EUROCAE ED 164
EUSPA-GN-UR-AVI-1010	The system shall provide a velocity accuracy of 10 m/s.	Performance (Velocity Accuracy)	

Table 16: ADS-B ATSA – Visual Separation in Approach

Id	Description	Type	Source
EUSPA-GN-UR-AVI-0920	The system shall provide a minimum horizontal accuracy of 0.3 NM.	Performance (Horizontal Accuracy)	EUROCAE ED 160 RTCA DO 314 [RD10]
EUSPA-GN-UR-AVI-0930	The system shall implement a Horizontal Alarm Limit of 0.75 NM.	Performance (Integrity)	
EUSPA-GN-UR-AVI-0940	The system shall provide an integrity risk (SDA) of 1x10 ⁻³ per hour, or lower.	Performance (Integrity)	
EUSPA-GN-UR-AVI-0950	The system shall provide a velocity accuracy of 10 m/s.	Performance (Velocity)	

Table 17: ADS-B ATSA SURF – Surface Traffic Awareness

Id	Description	Type	Source
EUSPA-GN-UR-AVI-1020	The system shall provide a minimum horizontal accuracy of 30 m.	Performance (Horizontal Accuracy)	EUROCAE ED 165
EUSPA-GN-UR-AVI-1030	The system shall provide a velocity accuracy of 10 m/s.	Performance (Velocity Accuracy)	
EUSPA-GN-UR-AVI-1040	The system shall provide a Source Integrity Level (SIL) of 1x10 ⁻⁵ per hour, or lower.	Performance (Integrity)	

Table 18: ADS-B ITP (In Trail Procedure)

Id	Description	Type	Source
EUSPA-GN-UR-AVI-0960	The system shall provide a minimum horizontal accuracy of 0.5 NM.	Performance (Horizontal Accuracy)	EUROCAE ED 159 RTCA DO 312
EUSPA-GN-UR-AVI-0970	The system shall implement a Horizontal Alarm Limit of 1 NM.	Performance (Integrity)	
EUSPA-GN-UR-AVI-0980	The system shall provide an integrity risk (SDA) of 1×10^{-5} per hour, or lower.	Performance (Integrity)	
EUSPA-GN-UR-AVI-0990	The system shall provide a velocity accuracy of 10 m/s.	Performance (Velocity)	

Table 19: ADS-B Non Radar Airspace (NRA 3 NM separation)

Id	Description	Type	Source
EUSPA-GN-UR-AVI-0660	The system shall provide a minimum horizontal accuracy of 0.3 NM.	Performance (Horizontal Accuracy)	FAA AC 20-165A [RD14] EUROCAE ED 126, RTCA DO 303 [RD15] and ED 102A, DO 260B [RD16]
EUSPA-GN-UR-AVI-0670	The system shall provide an alert within 10 sec when the computed HPL exceeds the Horizontal Alarm Limit of 1 NM.	Performance (Integrity)	
EUSPA-GN-UR-AVI-0680	The system shall provide an integrity risk (SDA) of 1×10^{-5} per hour, or lower.	Performance (Integrity)	
EUSPA-GN-UR-AVI-0690	The system shall provide a continuity of $1 - 2 \times 10^{-4}$ per hour, or better.	Performance (Continuity)	

Table 20: ADS-B Non Radar Airspace (NRA 5 NM separation)

Id	Description	Type	Source
EUSPA-GN-UR-AVI-0620	The system shall provide a minimum horizontal accuracy of 0.5 NM.	Performance (Horizontal Accuracy)	EASA AMC 20-24 Error! Reference source not found. EASA CS-ACNS FAA AC 20-165A [RD14] EUROCAE ED 126, RTCA DO 303 [RD15]
EUSPA-GN-UR-AVI-0630	The system shall provide an alert within 10 sec when the computed HPL exceeds the Horizontal Alarm Limit of 2 NM.	Performance (Integrity)	
EUSPA-GN-UR-AVI-0640	The system shall provide an integrity risk (SDA) of 1×10^{-5} per hour, or lower.	Performance (Integrity)	
EUSPA-GN-UR-AVI-0650	The system shall provide a continuity of $1 - 2 \times 10^{-4}$ per hour, or better.	Performance (Continuity)	

Table 21: ADS-B Radar Airspace (Independent and parallel Approach)

Id	Description	Type	Source
EUSPA-GN-UR-AVI-0840	The system shall provide a minimum horizontal accuracy of 121 m.	Performance (Horizontal Accuracy)	EUROCAE ED 161 RTCA DO 318 [RD33]
EUSPA-GN-UR-AVI-0850	The system shall implement a Horizontal Alarm Limit of 0.2 NM.	Performance (Integrity)	

Id	Description	Type	Source
EUSPA-GN-UR-AVI-0860	The system shall provide an integrity risk (SDA) of 1×10^{-5} per hour, or lower.	Performance (Integrity)	

Table 22: ADS-B Radar Airspace (RAD < 2.5 NM separation)

Id	Description	Type	Source
EUSPA-GN-UR-AVI-0800	The system shall provide a minimum horizontal accuracy of 171 m.	Performance (Horizontal Accuracy)	EUROCAE ED 161 RTCA DO 318 [RD33]
EUSPA-GN-UR-AVI-0810	The system shall implement a Horizontal Alarm Limit of 0.2 NM.	Performance (Integrity)	
EUSPA-GN-UR-AVI-0820	The system shall provide an integrity risk (SDA) of 1×10^{-5} per hour, or lower.	Performance (Integrity)	
EUSPA-GN-UR-AVI-0830	The system shall provide a Source Integrity Level (SIL) of 1×10^{-7} per hour, or lower.	Performance (Integrity)	

Table 23: ADS-B Radar Airspace (RAD 3 NM separation)

Id	Description	Type	Source
EUSPA-GN-UR-AVI-0750	The system shall provide a minimum horizontal accuracy of 0.1 NM (EU) – 0.05 NM (US).	Performance (Horizontal Accuracy)	EASA CS ACNS [RD11] FAA AC 20-165A [RD14] EUROCAE ED 126, RTCA DO 303 [RD15] and ED 102A, DO 260B [RD16]
EUSPA-GN-UR-AVI-0760	The system shall implement a Horizontal Alarm Limit of 0.6 NM (EU) – 0.1 NM (US).	Performance (Integrity)	
EUSPA-GN-UR-AVI-0770	The system shall provide an integrity risk (SDA) of 1×10^{-5} per hour, or lower.	Performance (Integrity)	
EUSPA-GN-UR-AVI-0780	The system shall provide a Source Integrity Level (SIL) of 1×10^{-7} per hour, or lower.	Performance (Integrity)	
EUSPA-GN-UR-AVI-0790	The system shall provide a velocity accuracy of 10 m/s.	Performance (Velocity Accuracy)	

Table 24: ADS-B Radar Airspace (RAD 5 NM separation)

Id	Description	Type	Source
EUSPA-GN-UR-AVI-0700	The system shall provide a minimum horizontal accuracy of 0.1 NM (EU) – 0.05 NM (US).	Performance (Horizontal Accuracy)	EASA CS ACNS [RD11] FAA AC 20-165A [RD14] EUROCAE ED 126, RTCA DO 303 [RD15] and ED 102A, DO 260B [RD16] [RD15]
EUSPA-GN-UR-AVI-0710	The system shall implement a Horizontal Alarm Limit of 1 NM (EU) – 0.2 NM (US).	Performance (Integrity)	
EUSPA-GN-UR-AVI-0720	The system shall provide an integrity risk (SDA) of 1×10^{-5} per hour, or lower.	Performance (Integrity)	
EUSPA-GN-UR-AVI-0730	The system shall provide a Source Integrity Level (SIL) of 1×10^{-7} per hour, or lower.	Performance (Integrity)	
EUSPA-GN-UR-AVI-0740	The system shall provide a velocity accuracy of 10 m/s.	Performance (Velocity Accuracy)	

2.5.1.2.2 Search and Rescue (GADSS)

Table 25: Requirements for Aircraft Tracking and Autonomous Distress Tracking

Id	Description	Type	Source
EUSPA-GN-UR-AVI-1100	C/S First Generation 406Mhz distress beacons ELT (DT) 2D static: accuracy <= 500 m. Altitude, static: accuracy <=700 m.	Performance (Accuracy)	C/S T.001, Issue 4 – Revision 10, Nov 2022, section 4.5.5.3 [RD58]
EUSPA-GN-UR-AVI-1110, 1115	C/S Second Generation 406 MHz distress beacons ELT (DT): <ul style="list-style-type: none"> • 2D: accuracy <= 30 m, (95%) • Altitude, accuracy <= 50 m (95%) 	Performance (Accuracy)	C/S T.018, Issue 1– Revision 10, Nov 2022 [RD59]
EUSPA-GN-UR-AVI-1120	Galileo RLS enabling ELT(DT) remote activation from the Airline Operation Centre (AOC) offering the possibility to localize in-flight a non-cooperative aircraft. Remote Beacon Activation (RBA) is an optional feature that can be implemented in ELT(DT) beacons, within the ADT concept, and it is complementary to automatic (ED-237) and manual (by the crew) triggers.	Functionality	EUROCAE MASPS for Aircraft ELT Remote Command via Return Link Service, 02/2021[RD60]
EUSPA-GN-UR-AVI-1121	For ELT(DT)s the value of the repetition period shall be: <ul style="list-style-type: none"> • 5 s + 0.0 / - 0.2 s during the first 120 s after beacon activation; • 10 s + 0.0 / - 0.2 s between 120 s and 300 s after beacon activation; and • after the first 300 s after beacon activation until the beacon is deactivated, the period shall be randomised around a mean value of 28.5 s, so that time intervals between transmissions are randomly distributed on the interval 27.0 to 30.0 s. 	Performance	C/S T.001, Issue 4 – Revision 10, Nov 2022 [RD58]

2.5.1.3 Navigation (PNT) for drones

The figures in the table below represent tentative PNT user needs gathered from interview with drone operators. They must be validated through flight trials, considering the typology of drones, the assumptions taken and their operational context.

Table 26 PNT needs for UAS operations

Id	Description	Type	Source
EUSPA-GN-UR-AVI-1318	Environment (obstacles/terrain up to elevation angle) <ul style="list-style-type: none"> ○ UAS en-route 15° - open sky ○ UAS landing 15° - open sky 35° - non-open sky 	Elevation angle during operations (indicator that characterises the environment in terms of satellite visibility) 	User interviews [RD54]
EUSPA-GN-UR-AVI-1319	<ul style="list-style-type: none"> ○ UAS en-route HNSE (95%) in the range of 2 - 3 m VNSE (95%) of 2 - 6 m ○ UAS landing HNSE (95%) of 0.2 - 1 m VNSE (95%) of 0.2 - <1 m <p>The requirements are dependent on drone typology (multi-copter, fixed wing, etc.). Drones can use combination of sensors (e.g. cameras, radioaltimeter, LIDARs) to compensate for the GNSS performance (e.g. VNSE) in certain cases, e.g. non-open sky environments.</p>	Horizontal & Vertical Accuracy (positioning accuracy) Those values are derived from the TSE(95%), which depends on the nature of the mission, considering the other error sources (FTE and PDE).	User interviews

Id	Description	Type	Source
EUSPA-GN-UR-AVI-1320	<ul style="list-style-type: none"> ○ UAS en-route and UAS landing (open sky) From $1 - 10^{-4} / h$ to $1 - 10^{-5} / h$ <p><i>Cont. risk(pos.) < 10⁻⁵ per flight h and TTA=2 s → 333 flights per navigation outage, considering an average drone flight duration = 10 min Linked to safety risk or business risk.</i></p>	<p>Continuity (capability of the system to perform its function without unscheduled interruptions during the intended operation).</p>	User interviews
EUSPA-GN-UR-AVI-1321	<ul style="list-style-type: none"> ○ UAS en-route and UAS landing (open sky) 0.999 to 0.9999 <p>Unavailability < 10⁻³ per year = 8.76 h per year or 3.6 s per hour</p>	<p>Availability (portion of time the system is to be used for navigation during which reliable navigation information is presented to the autopilot [remote pilot, or other system managing the flight of the drone]). It is the probability of the required PNT at the start of a mission.</p>	User interviews
EUSPA-GN-UR-AVI-1322	The PNT solution shall provide the velocity accuracy of <0.5 m/s . The value equals to a threshold set by the flight control system (e.g. PX4).	Velocity accuracy	User interviews
EUSPA-GN-UR-AVI-1323	The PNT solution shall provide TTFF/TTFaF of 30-60 s . <i>Note: During this time, drone operators usually run number of checklists and actions associated with flight preparation taking significantly longer than standard TTFF/TTFaF.</i>	Signal acquisition (TTFF/TTFaF)	User interviews
EUSPA-GN-UR-AVI-1324	<p>SAIL III. Onboard checks based on metrics such as number of Sat in view ≥ Nmin; DOP ≤ DOPmax; Signal strength; PVT outage duration, H/V Accuracy (e.g. NACp), ...</p> <p>SAIL IV: comparison of protection levels with alert limits</p> <ul style="list-style-type: none"> ○ If xPL > xAL → alert ○ IR = 10⁻⁵ / h ○ TTA ≤ 2 – 3 s ○ H/V Alert Limits: xAL = 2 * (semi-width of the 95% corridor) – FTE (95%) $Integrity Risk = \frac{1}{10} P_{loc} < \frac{10^{-(SAIL+1)}}{FH}$ <p>TTA: max. amount of time allowed from the onset of a failure condition to the annunciation to the onboard autopilot (or to the remote human pilot). HALVAL: maximum position error allowed for an operation.</p> <p>Number of drone operators use default autopilot (e.g. PX4) thresholds which shall be more stringent than SAIL integrity requirements.</p>	<p>Integrity (on-board performance monitoring and alerting)</p>	User interviews
EUSPA-GN-UR-AVI-1325	The K-index (characterising the magnitude of geomagnetic storms that may cause signal interference). The monitoring of the K-index shall be part of the flight planning.	Interference	User interviews
EUSPA-GN-UR-AVI-1326	Measures against RFI, including jamming and spoofing: Multi-frequency, signal analysis, Crypto, (e.g. OSNMA), multi sensor.	Resilience to RFI	User interviews

Id	Description	Type	Source
EUSPA-GN-UR-AVI-1326b	The system shall provide a minimum position update rate of 5 Hz	Position update rate (output of the positioning sensor)	User interviews

2.5.1.4 eConspicuity

Table 27: eConspicuity

Id	Description	Type	Source
EUSPA-GN-UR-AVI-1327	The eConspicuity should provide latency of: 1s within the coverage of ADS-B UAT stations and near aerodromes where traffic density is higher, 15s outside the coverage of ADS-B UAT and further from aerodromes where traffic density is lower	Latency	User interviews
EUSPA-GN-UR-AVI-1328	There is a trade-off in size and performance of eConspicuity devices. The preferred option delivering horizontal (HSNE (95%)) and vertical accuracy (VSNE (95%)) of a few meters is considered sufficient as the airspace is currently not busy. With the uptake of unmanned traffic, this requirement will have to be revised. In case of Remote ID, the system uses data (including GNSS data) from the flight controller and is able to provide same performance. Standalone solutions should provide similar performance.	Horizontal & Vertical Accuracy	User interviews
EUSPA-GN-UR-AVI-1329	The system currently provides a Time to First Fix (TTFF) of 30-60 s on average (longer in more challenging environments). The users noted that the current performance is sufficient for both manned and unmanned operations as time taken for the pre-flight checklists is considerably longer.	Signal Acquisition (TTFF/TTFaF)	User interviews
EUSPA-GN-UR-AVI-1330	Currently, the velocity accuracy is not important for users because the airspace not busy. As the U-space develops, the velocity accuracy will become a factor as well.	Velocity Accuracy	User interviews

2.5.1.5 HAPS

Table 28: HAPS

Id	Description	Type	Source
EUSPA-GN-UR-AVI-0060	The PBN solution shall enable a minimum horizontal accuracy (95%), HNSE(95%), of 0.4 NM.	Performance (Horizontal Accuracy)	ICAO Annex 10 [RD2] ICAO PBN Manual [RD3]
EUSPA-GN-UR-AVI-0070	The PBN solution shall provide an alert within 15 s if the Horizontal Protection Level computed by the system exceeds the Horizontal Alert Limit of 1 NM.	Performance (integrity, Horizontal Alert Limit and Time to Alert)	
EUSPA-GN-UR-AVI-0090	The GNSS signal in space shall provide an availability of 0.99 to 0.99999 of the time.	Performance (Availability)	RTCA and EUROCAE GNSS receiver MOPS [RD4]
EUSPA-GN-UR-AVI-0100	The GNSS signal in space shall provide a continuity performance of 1-1x10 ⁻⁴ to 1-1x10 ⁻⁸ per hour, or better.	Performance (Continuity)	

2.5.2 Synthesis of Requirements Relevant to EO

Table 29: Aircraft Emission Measurement and Monitoring

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-AVI-0001	Contrail Formation Monitoring	Post-operational confirmation and re-routing	Large	Real-time or near real-time	<200m ²	Real-time or near real-time	Uses infra-red sensors to monitor contrails, including at night
EUSPA-EO-UR-AVI-0002	Physical Modelling	Enhancing predictive models for contrail formation	Large	Periodic updates	<200m ²	Periodic updates	Integrates remote sensing data to enhance the predictive ability of contrail models
EUSPA-EO-UR-AVI-0003	Environmental Impact Assessment	Modelling contrail creation and environmental impact	Large	Periodic updates	<200m ²	Periodic updates	Combines EO data with physical models to assess the environmental impact of contrails
EUSPA-EO-UR-AVI-0004	Data Collection and Verification	Joint data collection for contrail confirmation	Large	Continuous	<200m ²	Continuous	Uses a network of sensors and satellites to collect and verify contrail data
EUSPA-EO-UR-AVI-0005	Machine Learning Model Training	Training models to automate contrail identification	Large	Continuous	<200m ²	Continuous	Uses camera data and manual work by experts to train machine-learning models

Table 30: EO for PM monitoring for flight planning

ID	Application	Abstract of the Need & Requirement	Size of Area of Interest	Frequency of Information	Spatial Resolution	Temporal Resolution	Type of EO Data
EUSPA-EO-UR-AVI-0010	Particulate Matter Monitoring for flight planning	<p>The service provides an indication to airspace users of where there are significant amounts of particulate matter which should be avoided. With monitoring of the particulate matter, the service may enable forecasts to be provided at shorter intervals and with more precision than current solutions.</p> <p>The service monitors for the presence of specific particulates through all flight levels (e.g. volcanic ash, sand dust) which are known to cause either engine or airframe corrosive damage in high concentrations. The service should also monitor for moisture and ice at flight levels from FL250 and above where the formation of cirrus clouds is most likely resulting from aircraft activity. The service should monitor over the period of interest and support the production of more precise and dynamic graphical information whilst remaining compliant with the regulatory standards (e.g. ICAO Annex 3 [RD17]).</p>	Global	Every three hours to support flight planning activities. Can be supported by modelling forecasts with validation based on actual historical measurements.	Depending on the application. 10NM lateral grids for ash and sand and other non-water based particulates. Vertically, 1,000 ft layers between FL180 and FL450.	Data should be no older than 18 hrs. To support model validation, 15 minute increments would be required.	NIR, SWIR, TIR, UV

Table 31: HAPS

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-AVI-0006	Weather Monitoring	Provides weather data to support mission planning.	HAPS operations vary by application but generally cover a footprint radius of around 30 km, operating at altitudes between 18-22 km.	Hourly to daily	from sub-kilometre scales for high-resolution models and some satellite products, to tens or hundreds of kilometres for global models and longer-range forecasts.	Hourly to daily	Precipitation data, temperature data, multispectral imagery, atmospheric chemistry data, microwave radiometry, Synthetic Aperture Radar (SAR), wind data.
EUSPA-EO-UR-AVI-0007	Safety Risk Assessment (Population Data)	Assesses landing areas in emergencies with respect to population density.	They provide persistent surveillance over large areas, can scale from wide-area coverage to focused monitoring, and are effective for maritime and border surveillance. HAPS complement satellite systems, offering significant coverage capabilities. Exact dimensions depend on mission requirements and platform capabilities.	Daily	<100 m	Daily	Density of population; Land cover
EUSPA-EO-UR-AVI-0008	Trajectory Analysis	Analyse different flight scenarios.		Ad-hoc (Weekly in many cases)	Ad-hoc (<1 km is acceptable)	Ad-hoc (Weekly in many cases)	Wind data: Information on wind speed and direction at stratospheric altitudes (18-22 km)
EUSPA-EO-UR-AVI-0009	Anticipation of Extreme Weather Events	Monitors atmospheric parameters to detect extreme weather events that could jeopardise operations.		Ad-hoc (Daily in many cases)	Ad-hoc (<1 km is acceptable)	Ad-hoc (Daily in many cases)	Precipitation data, temperature data, multispectral imagery, atmospheric chemistry data, microwave radiometry, Synthetic Aperture Radar (SAR), wind data.

Table 32: EO for SORA ground risk assessment

ID	Application	Abstract of the need & requirement	Size of Area of Interest	Frequency of Information	Spatial Resolution	Temporal Resolution	Data Type / Spectral Range
EUSPA-EO-UR-AVI-0011	SORA ground risk assessment	The service will take the EO data and implement a more frequently updated dataset categorising changes in buildings, land use to provide a risk classification linked to the drone operation. The service will integrate various data sources associated with population information and other data as needed to provide a centralised "score" which can be provided to the drone operator in advance of any flight.	Europe	Yearly	100x100m (population density for ground risk assessment)	All datasets within the service should be updated annually (population density for ground risk assessment)	SAR, VS stereo photogrammetry

2.5.3 Synthesis of Requirements Relevant to SATCOM

Table 33: SATCOM user requirements

ID	Market segments	Application	Operational Scenario	Link type	Availability	Coverage	Setup	Security protection	Speed	Challenges and gaps	Source	Source type	Technical / performance	Latency	Bandwidth (bit rate)	Symmetry up/down	Distribution	Other	Source Technical	Source Technical Type
EU SP A-SAT-UR-AVI-001	Secure SATCOM	Land border surveillance	RPAS missions for land border surveillance	Bi-directional voice and data	High	Regional to Worldwide	Normal	Confidentiality, Integrity and Availability	Normal >40 km/h (average speed is 90 knots)	<p>Potential security threats: Data interception and unauthorized access, jamming and spoofing attacks;</p> <p>Limited operational range due to the radio communications coverage preventing the possibility to perform long range missions (BVLOS) where pilots operate drones without maintaining direct visual contact</p> <p>Real-time data collection: Video feeds, telemetry data and sensor information.</p>	Interview FRONT EX	Primary	Yes	Low: immediate, <300 ms)	Medium (order of MB)	<ul style="list-style-type: none"> o 50/50 for bi-directional voice (Frontex has lot of manned operations that require Voice Communications) o 80/20 for internet use 	Ground Stations sends commands and data to the RPAS through a satellite Uplink. RPAS transmit telemetry data, sensor information, and live video feeds back to the ground control stations through a satellite Downlink.	N/A	Interview FRONT EX	Primary

ID	Market segments	Application	Operational Scenario	Link type	Availability	Coverage	Setup	Security protection	Speed	Challenges and gaps	Source	Source type	Technical / performance	Latency	Bandwidth (bit rate)	Symmetry up/down	Distribution	Other	Source Technical	Source Technical Type	
EU SP A-SA T-UR-AVI - 002	Secure SATCOM	Maritime surveillance	Maritime vessel monitoring and general surveillance	Bi-directional voice and data	High	Regional to Worldwide	Normal	Confidentiality, Integrity and Availability	Normal >40 km/h (average speed is 90 knots)	<p>Continuous Tracking: Vessels attempting to hide their positions pose a challenge to maritime surveillance.</p> <p>Reliable Communication: In maritime security, rapid response is often hindered by limited communication capabilities.</p> <p>Data Volume for Comprehensive Domain Awareness: Maritime surveillance requires high-bandwidth data exchange for timely analysis of imagery, weather data, and intelligence reports.</p> <p>Enhanced Interagency Coordination: The need for</p>	EMSA Report 2023	Primary	No								

ID	Market segments	Application	Operational Scenario	Link type	Availability	Coverage	Setup	Security protection	Speed	Challenges and gaps	Source	Source type	Technical / performance	Latency	Bandwidth (bit rate)	Symmetry up/down	Distribution	Other	Source Technical	Source Technical Type
										coordinated responses among naval and aerial forces in maritime zones is essential. Operational Flexibility in Remote Areas: Remote maritime regions often lack terrestrial communication infrastructure										

- Data from end users and service providers
- Data from service providers

2.5.4 Sources for the requirements

As this document is mostly based on interviews, the requirements come from the feedback from experts and various UCP [RD54] participants. The sources vary with the specific application.

3 ANNEXES

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 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 [RD1] 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: 0-10 cm; decimetre level: 10-100 cm; 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.

Alert Limit is an integrity parameter describing the maximum allowable horizontal (respectively vertical) position error beyond which the system should be declared unavailable for the intended application.

Time to alert (TTA) is an integrity parameter describing the maximum allowable time elapsed from the onset of the navigation system being out of tolerance until the equipment enunciates the alert.

A.4 Definition of key SATCOM performance parameters

Availability refers to the proportion of time a satellite communication link is usable and able to meet required performance standards, such as signal strength, data rate, and minimal interruption. High availability of secure SATCOM is crucial for applications requiring reliable, continuous communication, such as RPAS operations, remote monitoring, and emergency response.

Typically expressed as a percentage, availability is critical in SATCOM to meet operational needs, especially in mission-critical applications where uninterrupted communication is necessary.

Bandwidth is the amount of data that can be transmitted over a satellite link within a given time, typically measured in bits per second (bps) Mbps (megabits per second) or Gbps (gigabits per second). Bandwidth is a critical factor determining the capacity of a SATCOM system to support various applications, from basic messaging to high-definition video streaming.

In SATCOM, sufficient bandwidth is essential for supporting demanding applications like HD video feeds from RPAS, real-time data exchange for surveillance, and secure communication links. The right bandwidth allocation ensures smooth, efficient, and reliable SATCOM performance across various mission-critical application

Coverage refers to the geographical area or region where a satellite signal can be received effectively on the ground. Coverage is critical in SATCOM as it determines where users, like RPAS, can reliably access satellite services for applications like real-time video transmission, data transfer, and secure communication links.

Latency refers to the time delay between sending a signal from a ground station to a satellite and then back to the ground receiver, often called the round-trip time. This delay is measured in milliseconds (ms) and is a key performance parameter, especially for real-time applications like video streaming, remote control, or voice communication.

Low latency is essential for applications that require real-time responsiveness, such as remote piloting of RPAS, voice or video communication, and interactive data applications. Managing latency effectively in SATCOM networks is crucial to ensuring smooth and efficient operation across various use cases.

Security Protection refers to the measures and protocols implemented to safeguard satellite communication links, data, and user terminals from unauthorized access, interception, interference, and cyber threats. Security is paramount in SATCOM, especially for applications in defence, border surveillance, and other sensitive operations. Implementing comprehensive security protection in SATCOM systems is essential for protecting both the integrity and confidentiality of data, especially for critical communications.

Symmetry up/down refers to the balance of data transmission capacity (bandwidth) between the uplink (data sent from ground to satellite) and the downlink (data sent from satellite to ground).

1. A symmetrical SATCOM link provides equal bandwidth for both uplink and downlink. Symmetrical connections are often necessary for applications that require consistent data flow in both directions, such as real-time video conferencing, remote control of RPAS, or two-way voice communication.
2. In an asymmetrical link, the uplink and downlink bandwidth differ, usually with a higher downlink than uplink capacity. This configuration is useful for applications that require more data in one direction than the other, such as streaming data or video from the satellite to the ground, where most data flows in the downlink direction.

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.

SATCOM

Distribution refers to the way data is transmitted and shared among users. SATCOM systems can support various distribution methods to meet different communication needs, including:

- **User-to-User:** A two-way communication link established between two users, which can be either human operators or automated systems. This type of distribution allows direct, secure communication between two endpoints, enabling real-time, private exchanges. User-to-user SATCOM is commonly used for targeted applications like direct voice calls, video streaming between a command centre and a single remote RPAS, or secure messaging.
- **Multi-User:** A two-way communication setup that connects multiple users in a group, allowing data to flow between all participants. In this mode, each user (human or system) can send and receive data, fostering collaborative exchanges and shared situational awareness. Multi-user distribution is suitable for coordinating between teams or systems, such as in joint military operations, border surveillance, or search-and-rescue missions, where multiple users need to stay informed and responsive to each other's inputs.
- **Broadcasting:** A one-way distribution method in which a single source transmits data to multiple recipients. This is useful for delivering information where recipients only need to receive data without interacting back, such as satellite weather data broadcasts, alerts, or large-scale public information distribution. Broadcasting enables efficient communication to a broad audience while conserving resources, as the source does not handle return communications from each recipient.

Link type refers to the specific method of communication established for transmitting either voice or data. Different link types are optimized for varying requirements, such as bandwidth, latency, and security. Here are the primary link types in SATCOM:

- **Voice Link:** This type of communication is primarily used for transmitting voice data.
- **Data Link:** This link type is designed for transmitting data packets between users or systems.
- **Combined Voice and Data Link:** Some SATCOM systems provide the capability to support both voice and data traffic over the same link.

Set-up refers to a qualitative indication of the time to establish a voice or data communication session with the application that would be acceptable to a user and is sufficient to perform the operation.

Speed refers to the velocity at which a user or user terminal (such as a vehicle, aircraft, or vessel) is traveling while maintaining a stable satellite connection. This is crucial for mobile SATCOM applications, as higher speeds can affect signal stability and connectivity. The maximum value for speed is typically set by the capabilities of the satellite system and the type of terminal in use.

A.6 List of Acronyms

Acronym	Definition
A4E	Airlines for Europe
ACAC	Arab Civil Aviation Commission
ACARS	Aircraft Communication, Addressing and Reporting System
ADS-B	Automatic Dependent Surveillance – Broadcast
ADS-L	Automatic Dependent Surveillance – Light
AEA	Association of European Airlines
AFCAC	African Civil Aviation Commission
AGL	Above Ground Level
AI	Artificial Intelligence
AIR OPS	A short cut designation of (EU) No 965/2012
AMC	Acceptable Means of Compliance
AMSL	Above Mean Sea Level
AMSS	Aeronautical Mobile Satellite Service
ANSP	Air Navigation Service Provider
APCH	Approach (Abbreviation as part of designation of which type of approach)
APV	Approach Procedure with Vertical guidance
A-RAIM	Advanced - Receiver Autonomous Integrity Monitoring
ARC	Air Risk Class
A-RNP	Advanced-RNP
ASHTAM	NOTAM for volcanic activity
A-SMGCS	Advanced-Surface Movement Guidance and Control System
ATC	Air Traffic Control
ATM	Air Traffic Management
ATS	Air Traffic System
BRLOS	Beyond Radio Line of Sight
BVLOS	Beyond Visual Line of Sight
CAGR	Compound Annual Growth Rate
CAMS	Copernicus Atmosphere Monitoring Service
CANSO	Civil Air Navigation Services Organisation
CAT (I/II/III)	Category of precision approach operation
CCO/CDO	Continuous Climb Operation/Continuous Descent Operation

Acronym	Definition
CDPLC	Controller-Pilot Data Link Communication
CEN	European Committee for Standardisation
CENELEC	European Committee for Electrotechnical Standardisation
CLMS	Copernicus Land Monitoring Service
CNS	Communication, Navigation and Surveillance
CoCiP	Contrail Cirrus Prediction Tool
CRPA	Control Reception Pattern Antennas
CTR	Control Zone
CVR	Cockpit Voice Recorder
DME	Distance Measuring Equipment
DP	Departure Procedures
EARSC	European Association of Remote Sensing Companies
EASA	European Union Aviation Safety Agency
EBAA	European Business Aviation Association
EC	European Commission
ECAC	European Civil Aviation Conference
ED	EUROCAE Document
EGNOS	European Geostationary Navigation Overlay Service
EGNSS	European Global Navigation Satellite System
EGPWS	Enhanced Ground Proximity Warning System
ELT	Emergency Locator Transmitter
EMSA	European Maritime Safety Agency
EO	Earth Observation
ERAA	European Regions Airline Association
ETSO	European Technical Standard Orders
ETSI	European Telecommunications Standards Institute
EUROCAE	European Organisation for Civil Aviation Equipment
EUSPA	European Union Agency for the Space Programme
EVAIR	Eurocontrol voluntary ATM incident reporting
EVS	Enhanced Vision System
eVTOL	Electric Vertical Take off and Landing
EUROCONTROL	The European Organisation for Air Navigation Safety
FANS	Future Air Navigation System

Acronym	Definition
FDR	Flight Data Recorder
FIS-B	Flight Information Service-Broadcast
FL	Flight Level
FTE	Flight Technical Error
GA	General Aviation
GADSS	Global Aeronautical Distress and Safety System
GBAS	Ground Based Augmentation System
GEO	Group on Earth Observations; Geostationary Earth Orbit (satellite)
GHSL	Global Human Settlement Layer
GHS-POP	Global Human Settlement Population
GLONASS	Global Orbiting Navigational Satellite System
GM	Guidance Material
GNSS	Global Navigation Satellite System
GOVSATCOM	European Union Governmental Satellite Communications
GPS	Global Positioning System
GPWS	Ground Proximity Warning System
GRC	ground risk class
GS	Glide Slope
GSM	Global System for Mobile Communications
H-ARAIM	Horizontal ARAIM
HAL	Horizontal Alert Limit
HAO	High-Altitude Operations
HAS	High Accuracy Service
HAPS	High-Altitude Platform Systems
HLSC	High-Level Safety Conference
HNSE	Horizontal Navigation System Error
HPL	Horizontal Protection Level
HTA	Heavier-than-air
IADC	Inter-Agency Space Debris Coordination Committee
IAM	Innovative Air Mobility
IAOPA	International Aircraft Owners and Pilots Association

Acronym	Definition
IATA	International Air Transport Association
ICAO	International Civil Aviation Organisation
IFR	Instrument Flight Rules
ILS	Instrument Landing System
InSAR	Interferometric Synthetic Aperture Radar
IRIS	Infrastructure for Resilience, Interconnectivity, and Security by Satellite
IRS	Inertial Reference System
ISA	International Standard Atmosphere
ISO	International Organization for Standardisation
ISSR	Ice Super-Saturated Region
ITU	International Telecommunication Union
ITP	In- Trail Procedure (ADS-B application)
JARUS	Joint Authorities for Rulemaking on Unmanned Systems
LACAC	Latin American Civil Aviation Commission
LEO/MEO	Low Earth Orbit/Medium Earth Orbit
LNAV/VNAV	Lateral/Vertical Navigation
LPV	Localiser Performance with Vertical Guidance
LTA	Lighter-than-air
LTE	Long-Term Evolution (mobile communication standard)
LVC	Low Visibility Conditions
METAR	Meteorological Aerodrome Report
MILSATCOM	Military Satellite Communications
MLS	Microwave Landing System
MON	Minimum Operating Network
MOPS	Minimum Operational Performance Specifications
MTOM	Maximum Take-off Mass
NASA	National Aeronautics and Space Administration
NACp	Navigation Accuracy Category for Position
NCC	Non-commercial operations with complex motor-powered aircraft
NM	Nautical Mile
NPA	Non-Precision Approach

Acronym	Definition
NRT	Near-Real-Time
NSE	Navigation System Error
NSP	Navigation System Panel
ORO	Organisational Requirements for Air Operations
OS NMA	Open Service Navigation Message Authentication
OSO	Operational Safety Objective
PBN	Performance Based Navigation
PDE	Path Definition Error
PM	Particulate Matter
PNT	Position, Navigation and Time
PVT	Position, Velocity and Time
QNH	altimeter setting indicating vertical distance above mean sea level
R&D	Research and Development
RADAR	Radio Detection and Ranging
RD	Reference Document
RF	Radius to Fix
RFI	Radio Frequency Interference
RNAV	Area Navigation
RNP	Required Navigation Performance
RNP AR	Required Navigation Performance Authorisation Required
RPAS	Remotely Piloted Aircraft Systems
RR	Radio Regulations
RTCA	Radio Technical Commission for Aeronautics
RUR	Report on User needs and Requirements
SAF	Sustainable Aviation Fuel
SAIL	Specific Assurance and Integrity Level
SAR	Search And Rescue
SARPs	Standards and Recommended Practices
SATCOM	Satellite Communications
SBAS	Satellite-Based Augmentation System
SCN	Satellite Communication Network

Acronym	Definition
SES	Satellite Earth Stations and Systems
SESAR	Single European Sky ATM Research
SNOWTAM	NOTAM regarding runway conditions affected by snow, ice, or slush
SORA	Specific Operations Risk Assessment
SPO	Specialised Operations
SRD	Short Range Device
SSR	Secondary Surveillance Radar
STL	Satellite Time and Location
SVS	Synthetic Vision Systems
TAF	Terminal Area Forecasts
TAWS	Terrain Awareness Warning Systems
TC	Technical Committee
TIS-B	Traffic Information Service-Broadcast
TMA	Terminal Manoeuvring Area
TSE	Total System Error
TTA	Time to Alert
TTFaF	Time to First accurate Fix
TFFF	Time to First Fix
UAM	Urban Air Mobility
UAS	Unmanned Aerial System
UAT	Universal Access Transceiver
UCP	User Consultation Platform
USSP	U-space service provider
UTC	Coordinated Universal Time
UTM	Unmanned Traffic Management
VAAC	Volcanic Ash Advisory Centres
VAL	Vertical Alert Limit
VAG	Volcanic Ash Graphic
VFR	Visual Flight Rules
VNSE	Vertical Navigation System Error
VOR	Very High-Frequency Omnidirectional Range

Acronym	Definition
VPL	Vertical Protection Level
VTOL	Vertical Take-off and Landing
WG	Working Group
WRC	World Radiocommunication Conference

A.7 Reference Documents

Id.	Reference	Title	Date
[RD1]	EUSPA Market Report	EUSPA EO and GNSS Market Report (Issue 1)	Jan. 2022
[RD2]	ICAO Annex 10 Vol I	Annex 10 - Aeronautical Telecommunications - Volume I - Radio Navigational Aids	July 2006
[RD3]	ICAO PBN Manual, (ICAO Doc 9613)	ICAO Performance-based Navigation (PBN) Manual (Fifth Edition)	2023
[RD4]	RTCA and EUROCAE GNSS receiver MOPS		June 2020
[RD5]	(EU) 2019/1048 Airspace usage requirements and PBN operating procedures	Commission Implementing Regulation (EU) 2019/1048	2019
[RD6]	(EU) 2021/116 Establishment of Common Project One	COMMISSION IMPLEMENTING REGULATION (EU) 2021/116	Feb 2021
[RD7]	ICAO Annex 11	Air Traffic Services (2018)	2020
[RD8]	JARUS External Consultation WG-SRM "SORA Annex A"		
[RD9]	EUROCAE ED 163	Safety and Performance and Interoperability Requirements Document for ADS-B Airport Surface Surveillance Application (ADS-B-APT)	2010
[RD10]	EUROCAE ED 160 RTCA DO 314	Safety and Performance and Interoperability Requirements Document for Enhanced Visual Separation on Approach (ATSA-VSA)	2008
[RD11]	EASA CS ACNS, Issue 4	Certification Specification Airborne Communications, Navigation and Surveillance	April 2022
[RD12]	European Navaid Infrastructure Planning Handbook	European Navaid Infrastructure Planning Handbook including Minimum Operational Network (MON) PBN HANDBOOK No. 4	May 2021
[RD13]	NPA 2022-06	NPA 2022-06 Introduction of a regulatory framework for the operation of drones — Enabling innovative air mobility with manned VTOL-capable aircraft, the IAW of UAS subject to certification, and the CAW of those UAS operated in the 'specific' category	June 2022
[RD14]	FAA AC 20-165A	Airworthiness approval of Automatic Dependent Surveillance – Broadcast (ADS-B) Out systems in aircraft.	July 2012
[RD15]	EUROCAE ED 126 / RTCA DO 303	Safety and Performance and Interoperability Requirements Document for ADS-B-NRA Application	2006

Id.	Reference	Title	Date
[RD16]	EUROCAE ED 102A / RTCA DO 260B	MOPS for 1090 MHz Extended Squitter Automatic Dependant Surveillance – Broadcast (ADS-B) and Traffic Information Services – Broadcast (TIS-B) with Corrigendum 1	2009
[RD17]	ICAO Annex 3	Meteorological Service for International Air Navigation	2018
[RD18]	ICAO Annex 19	Safety Management	2016
[RD19]	ICAO Doc 9849	Global Navigation Satellite System (GNSS) Manual	2012
[RD20]	Regulation (EU) No. 965/2012	Air Operations	2012
[RD21]	Regulation (EU) 2018/1048	Airspace usage requirements & operating procedures concerning performance-based navigation (PBN)	2018
[RD22]	Regulation (EU) No. 2019/947	Rules and procedures for the operation of unmanned aircraft	2022
[RD23]	Regulation (EU) No. 2019/945	Unmanned aircraft systems and third-country operators of unmanned aircraft systems	2020
[RD24]	Regulation (EU) No. 2021/664	Regulatory framework for the U-space	2021
[RD25]	ISO/TR 19121:2000	Geographic information — Imagery and gridded data	2000
[RD26]	ISO 19115:2014	Geographic information — Metadata	2020
[RD27]	ED-88	MOPS for Multi-Mode Airborne Receiver (MMR) including ILS and MLS and GPS used for Supplemental Means of Navigation	1997
[RD28]	ED-102	MOPS for 1090 MHz Extended Squitter ADS-B and TIS-B	2021
[RD29]	ED-114	MOPS for Global Navigation Satellite Ground Based Augmentation System Ground Equipment to support Precision Approach and Landing	2022
[RD30]	ED-126	Safety and Performance and Interoperability Requirements Document for ADS-B in Non-Radar Areas	2006
[RD31]	ED-129C	Technical Specification for a 1090 MHz Extended Squitter ADS-B Surveillance System	2023
[RD32]	ED-160	Safety and Performance and Interoperability Requirements Document for Enhanced Visual Separation on Approach (ATSA-VSA)	2008
[RD33]	ED-161/ DO-318	Safety and Performance and Interoperability Requirements Document for ADS-B in radar-controlled airspace	2009

Id.	Reference	Title	Date
[RD34]	ED-163	Safety and Performance and Interoperability Requirements Document for ADS-B Airport Surface Surveillance Application (ADS-B-APT)	2010
[RD35]	ED-259A	Minimum Operational Performance Standard for Dual-Frequency Multi-Constellation Satellite-Based Augmentation System (SBAS) avionics	2022
[RD36]	ED-301	Guidelines for the Use of Multi-GNSS Solutions for UAS Specific Category	2023
[RD37]	DO-229	MOPS for airborne navigation equipment relying on the Global Positioning System (GPS) and augmented by SBAS	2016
[RD38]	DO-228	MOPS for antenna performance	2003
[RD39]	DO-242	Minimum Aviation System Performance Standards (MASPS) for Automatic Dependent Surveillance Broadcast (ADS-B)	2002
[RD40]	DO-253	MOPS for airborne navigation equipment using GPS and augmented by the Local Area Augmentation System to support CAT I precision approach	2017
[RD41]	DO-301	MOPS for GNSS Airborne Active Antenna designed to use GPS or Galileo on the L1 Frequency Band and augmented as required	2016
[RD42]	ICAO Doc 9889	ICAO Airport Air Quality Manual, second edition	2020
[RD43]	ICAO Doc 9643	Manual on Simultaneous Operations on Parallel or Near-Parallel Instrument Runways (SOIR), Second edition	2019
[RD44]	ICAO Annex 6	Operation of Aircraft, 12 th edition	2022
[RD45]	ED-237	Minimum Aviation System Performance Specification (MASPS) for Criteria to Detect In-Flight Aircraft Distress Events to Trigger Transmission of Flight Information	2016
[RD46]	GNSS Technology Report	GNSS and Secure SATCOM User Technology Report	2025
[RD47]	ED-259A / DO-401	Minimum Operational Performance Standard (MOPS) for Dual-Frequency Multi-Constellation Satellite-Based Augmentation System (SBAS) Airborne Equipment.	2023
[RD48]	FAA Advisory Circular (AC) 20-138D	Airworthiness Approval of Positioning and Navigation Systems	2016

Id.	Reference	Title	Date
[RD49]	FAA Advisory Circular (AC) 90-101A	Approval Guidance for Required Navigation Performance (RNP) Procedures with Authorization Required (AR) Including Change 1	2011
[RD50]	European ATM Master Plan	European ATM Master Plan 2025 Edition	Dec 2024
[RD51]	JARUS SORA 2.5	JARUS guidelines on Specific Operations Risk Assessment (SORA) v2.5 package	2024
[RD52]	JARUS SORA 2.0	SORA (Package) and Standard Scenarios	2019
[RD53]	EASA Opinion No 03/2023	Introduction of a regulatory framework for the operation of drones	2023
[RD54]	UCP 2024	User Consultation Platform conference	2024
[RD55]	UCP 2022	User Consultation Platform conference	2022
[RD56]	iConspicuity & ADS-L presentation	EASA – CASIA meeting	May 2023
[RD57]	EASA AMC 20-24	Certification Considerations for the Enhanced ATS in Non-Radar Areas using ADS-B Surveillance (ADS-B-NRA) Application via 1090 MHz Extended Squitter	2008
[RD58]	C/S T.001, Issue 4 – Revision 10	Specification for COSPAS-SARSAT 406 MHz distress beacons	2022
[RD59]	C/S T.018, Issue 1– Revision 10	Specification for second-generation COSPAS-SARSAT 406-MHz distress beacons	2022
[RD60]	ED-277	MASPS for Aircraft Emergency Locator Transmitter Remote Command via Return Link Service	2021

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