2023

Report on Aviation and Drones

User Needs and Requirements

#EUSpace

EUSPA European Union Agency for the Space Programme

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1 INTRODUCTION AND CONTEXT OF THE REPORT

Civil aviation is highly regulated in all domains (safety, technical, operational, environmental, economic and legal) through a complex regulatory framework at international, regional and national levels. At all levels, the regulation-making process gathers all aviation stakeholders, i.e. the safety and regulatory authorities, the Air Navigation Service Providers (ANSP) and regional agencies (e.g. EUROCONTROL, ASECNA etc.), airport operators, airspace users and related associations (IATA, regional airlines, business and general aviation etc.) as well as aviation industry (aircraft and equipment manufacturers, maintenance and training organisation etc. that are subject to specific EASA approval). Since aviation rules usually evolve based on a positive benefits/costs ratio, all categories of stakeholders see their specific requirements considered through public consultations.

The **User Consultation Platform (UCP)** is a periodic forum organised by the European Commission (EC) and the European Union Agency for the Space Programme (EUSPA), where users from different market segments meet to discuss their needs for applications relying on Position, Navigation and Time (PNT), Earth observation and secure governmental communications. The event is involving end users, user associations and representatives of the value chain, such as receiver and chipset manufacturers and application developers. It also gathers organisations and institutions dealing, directly and indirectly, with the European Global Navigation Satellite System (EGNSS), encompassing Galileo and EGNOS and newly since 2020, also with the EU Earth Observation system, Copernicus, and with GOVSATCOM, the upcoming system for secure governmental communications. The UCP event is a part of the process developed at 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 latest User Consultation Platform meeting took place in Prague on 03 October 2022 covered number of topics in both manned aviation and drone industry.

The overall aviation priorities in using GNSS have not changed significantly since the previous UCP. Despite the PBN mandate approaching (2030) stakeholders keep turning their attention to more pressing issues, some of them being linked to **pandemic recovery**. Therefore, the GNSS user requirements are foreseen to remain unchanged in the near future unless new use cases emerge. With regards to Earth observation (EO), participants highlighted, that EO can add value over and above the ICAO requirements and make the data more user-friendly or improve the way data is collected and displayed. Further to that, having good quality data can help prevent or mitigate the impact of aviation on climate change and vice versa, the impact of climate change on aviation.

In drone segment, a need for enhanced navigation accuracy and integrity remains valid. The novel requirements are linked to having redundant systems, authentication of GNSS services and monitoring system providing timely and accurate information about the Unmanned Aircraft System (UAS) status. In addition to this, operators expressed a need for a common reference system to define and measure the altitude. While Earth Observation (EO) is already used in drone segment, it has been identified that it could be exploited further. In particular, to support operators in SORA assessments identifying overflown population and a critical infrastructure. The Copernicus provides harmonised, validated and consistent data sets across the European Union and therefore could potentially be a trusted source of data for some requirements of SORA.

In this context, the objective of this document is to provide a reference for the EU Space Programme and for the aviation and drone community, reporting periodically the most up-to-date user needs and requirements in the aviation and drone market segment. This report a living and evolving document that will periodically be updated by EUSPA. It served as a key input to the UCP, where it was reviewed and subsequently updated and expanded in order to reflect the evolutions in the user needs, market and technology captured during the event.

The report aims to provide EUSPA with a clear and up-to-date view of the current and potential future user needs and requirements in order to serve as an input to the continuous improvement of the services provided by the EU Space Programme components. In line with the extended mandate of EUSPA, the **Report on User needs and Requirements** (RURs) previously focused on GNSS, have been revamped to also encompass the needs of commercial users with regards to Earth Observation (EO) and is now organised according to the market segmentation of the EUSPA EO and GNSS Market Report.

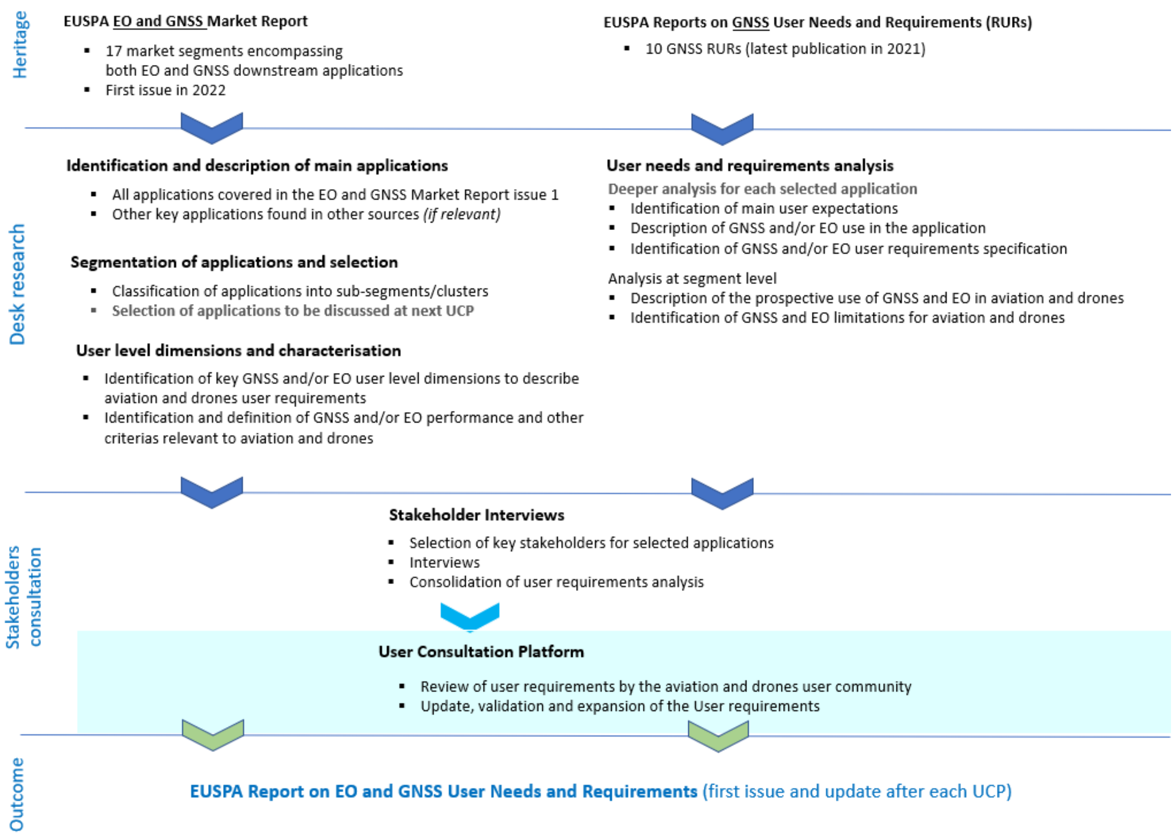
Finally, as the report is publicly available, it also serves as a reference for users and industry, supporting planning and decision-making activities for those concerned with the use of PNT and of Earth observation data and services.

It must be noted that the listed user needs and requirements cannot usually be addressed by a single technological solution but rather by a combination of several signals and sensors. Therefore, the report does not represent any commitment of the EU Space Programme to address or satisfy the listed user needs and requirements in the current or future versions of the services and/or data delivered by its different components.

1.1 Methodology

The following figure details the methodology adopted for the analysis of the aviation and drones user requirements at application level.

Figure 1: Aviation and drones user requirements analysis methodology



As presented in the figure 1, the work leverages on the latest EUSPA EO and GNSS Market Report, adopting as starting point the market segmentation for EO and GNSS downstream applications and takes on board the baseline of GNSS user needs and requirements compiled in the previous RURs published by the agency.

The analysis is split into two main steps, including a "desk research", aiming at refining and extending the heritage inputs and at gathering main insights, and a "stakeholders' consultation" to validate main outcomes.

More in details, the "desk research" was carried out to consolidate when required the list of applications and their classification, to identify the key parameters driving their performances or other relevant requirements together with the main requirements specification, etc. A deeper analysis was conducted for a set of applications prioritised for discussion at the last UCP event. The outcomes of this preliminary user requirements analysis were shared and consolidated prior to the UCP with a small group of key stakeholders, operating in the field of the selected applications.

These user requirements analysis results were then presented and debated at the UCP with the aviation and drones user community. The outcomes of the aviation and drones forum discussions were finally examined in order to validate and fine-tune the study results.

The steps described above have resulted in the outcomes that are presented in detail hereafter.

1.2 Scope

This document is part of the User Requirements documents issued by the European Union Agency for the Space Programme for the Market Segments where Position, Navigation and Time (PNT) and Earth Observation (EO) data play a key role. Its scope is to cover user requirements on PNT and Earth Observation-based solutions from the strict user perspective and considering the market conditions, regulations, and standards that drive them.

The document starts with a market overview for aviation and drones (section 3), focusing on the market evolution and key trends applicable to the whole segment or more specific ones relevant to a group of applications or to the use of GNSS or EO. This section also presents the main market players and user communities. The report then provides a panorama of the applicable policies, regulations and standards (section 4). It then moves to the detailed analysis of user requirements (section 5). This section first presents an overview of the market segment downstream applications, and indicates for each application, the depth of information available in the current version of the report: ie broad specification of the GNSS and/or EO user needs and requirements relevant to GNSS and EO, partial specification limited at this stage to GNSS user needs and requirements, or limited to an introduction to the application and its main use cases at operational level. The content of this section will be expanded and completed in the next releases of the RUR.

Following its introduction, section 5 is organised as follows:

- Section 5.1 aims to present current GNSS and/or EO use and requirement per application, starting with a description of the application, presenting main user expectations and describing the current use of GNSS and/or EO space services and data for the application and providing a detailed overview of the related user requirements. The section addresses and categorises applications according to their levels of maturity.
- Section 5.2 describes the main limitations of GNSS and EO to fulfil user needs in the market segment.
- Prospective use of GNSS and EO in aviation and drones is addressed in section 5.3.
- Section 5.4 concludes the section with a synthesis of the main drivers for the user requirements in aviation and drones.

Finally, section 6 summarises the main User Requirements for aviation and drones in the applications domains analysed in this report.

The current version of the report will be expanded and completed through its future releases.

The RUR is 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.

2 EXECUTIVE SUMMARY

Key trends and market evolution

The impact of GNSS and EO on the world around us is on the rise driven by improved technical equipment and accuracy, but also the number of new segments that can use new technologies.

GNSS systems (GPS, several SBAS systems and GBAS) will be soon complemented by other GNSS systems with new functions like dual frequency, SAR transponders, etc. Even more market segments can be reached this way and various global challenges mitigated. This trend is visible from the increasing numbers of annual shipments of GNSS receiver and, based on estimations, more than 10 billion GNSS devices will be operational by 2031. This growth in devices also brings rising market revenues, estimated to reach €492 billion by 2031.

The EO market is growing even faster. Satellite EO-based data and value-added services are increasing in volume and coverage of segments, benefiting from satellite remote sensing. The most visible ones are Climate Services, Urban Development and Cultural Heritage, Agriculture, Energy and Raw Materials and the Insurance and Finance segment, with potential also in Consumer Solutions, Tourism and Health. Based on EUSPA EO and GNSS Market Report 2022, It is expected that revenues will reach over €5.5 billion over next decade.

Current and prospective use of GNSS and EO in aviation and drones

Some GNSS functions have been in use for years, while others constitute currently-emerging markets. Their performance has been measured through several key parameters.

Aviation and drones are dependent on GNSS for their operations. Both can be considered mature users of GNSS technology. However, whilst manned aviation has matured to the point that it has well established performance requirements, these requirements are developing for drones. The expansion of available GNSS systems will be a benefit for aviation and drones and is expected to improve the performance of the GNSS signal in space. All the latest valid GNSS requirements are listed in this Report on Aviation user needs and requirements.

The use of EO data provides several advantages and has been used for several years by aviation. This report also looks at the user requirements from an EO perspective irrespective of the constellation that is able to address these requirements. It is expected that to meet these requirements there will be a mix of Copernicus services and other terrestrial and space based services that will be used to provide a composite view to address the user needs. The report focuses on creating a list of the main key EO parameters (at minimal level), required to build the services to be offered by the service providers to the end users. User needs have been collected through different channels and discussed and validated with industry experts at the UCP 2022 to reflect EO user requirements around the key EO parameters in a technology agnostic manner.

Drivers for users' requirements

Users participating in UCP have identified the following priorities and actions:

- For EGNSS, the focus of the actions should be on:
  - Increased continuity and resilience to support the total PBN environment of 2030;
  - Development of drone receivers and autopilot implementing tailored algorithms to support SAIL IV;
  - Development of a tool/service to warn drone users about EGNSS forecast (information and alerts related to EGNSS under performance and outages);
  - Assessment and solutions for HAS within aeronautical band;
  - Assessment and solutions for authentication for drones;

  - Evaluation of the possibility for a common geometric altitude basis for drones and lower airspace operations;
- For EO, the focus of the actions should be on:
  - Developing a single-data repository of data (maps and methods) supporting drone ground risk assessment;
  - High-accuracy Digital Surface Models for both aviation and drones;
  - More frequent updates of data (differences / new features) for both aviation and drones;
  - Population datasets to support diurnal and seasonal reporting for drone operations;
- Further R&D is needed to support specifically:
  - Simple funding mechanisms for small airlines and drone operators;
  - The definition and optimization of datasets (including obstacles) that support the drone risk assessment;
  - Develop drone navigation performance specifications for drones based on EGNSS increasing confidence and repeatability of containment with initiation of standardisation activities;
  - Galileo receivers for aviation.

3 MARKET OVERVIEW & TRENDS

3.1 Market Evolution and Key Trends

Aviation uses GNSS extensively, with Satellite-Based Augmentation Systems (SBAS) providing better access to small and medium airports through Performance Based Navigation procedures, increasing safety and enabling business growth across Europe. GNSS is the primary positioning source for aviation and drones, and meets the present day performance requirements for all airspaces, from low-level to sub-space. GNSS supports advances in urban air mobility with evaluation of flight risk (e.g. geofencing, populated area avoidance, landing site optimisation), automation and tracking through position self-reporting (known as Electronic Conspicuity).

Combining GNSS and EO data advances emissions monitoring systems. EO itself enables the monitoring of volcanic ash clouds, emissions, terrain (supporting optimised routing), flight procedure development and flight planning. This benefits airlines, leisure pilots, drone operators, airports, air traffic control and public agencies serving global aviation communities.

Aircraft sales have historically been the main market driver for aviation and probably will be again once global traffic levels recover after COVID-19 pandemic. This should be applicable also for drones. Both commercial and consumer drones are already using GNSS for positioning and GNSS is a powerful enabler for both current and future functions that will be required in the coming years (e.g. sense and avoid, remain well clear) even if certain performance requirements could be more stringent than for manned aircraft.

Today, GNSS systems operationally used in aviation are GPS and GLONASS (to a much lesser extent) and operational SBAS systems (WAAS, EGNOS, MSAS, GAGAN). In the foreseeable future, additional core constellations will be operationally available (Galileo, BeiDou) as well as improvements natively brought by these navigation constellations (e.g. multi-frequency, SAR transponders) while GPS is predicted to deliver an aviation multi-frequency service around 2024 and EGNOS V3 (DFMC SBAS) will augment Galileo.

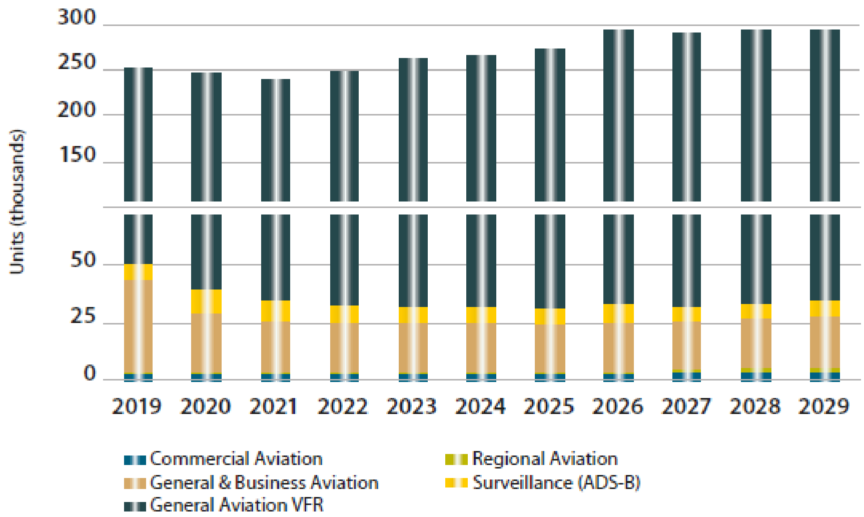
These evolutions will give birth to a new generation of aviation-grade GNSS receiver implementing multi-constellation and multi-frequency capabilities, most of them also implementing the DFMC SBAS capability which is deemed to be the universal configuration for GNSS receiver.

High grade equipment for commercial and business aircraft will also include new GBAS capabilities (CAT II/III and dual frequency/multi constellation capability). For other aircraft categories this trend might be more spread over time, since aircraft equipage is more linked to local evolution of airport approach navigation aids equipment renewal.

The 2022 EUSPA EO and GNSS Market Report identifies roles and key trends of GNSS and EO within aviation and drone segment. It points out airlines' consolidation of fleet and evolution of standards in navigation and surveillance. It stresses the role of EO in the monitoring of volcanic ash clouds and hazardous weather and helping aviation identify preventative maintenance as a response to particulate matter.

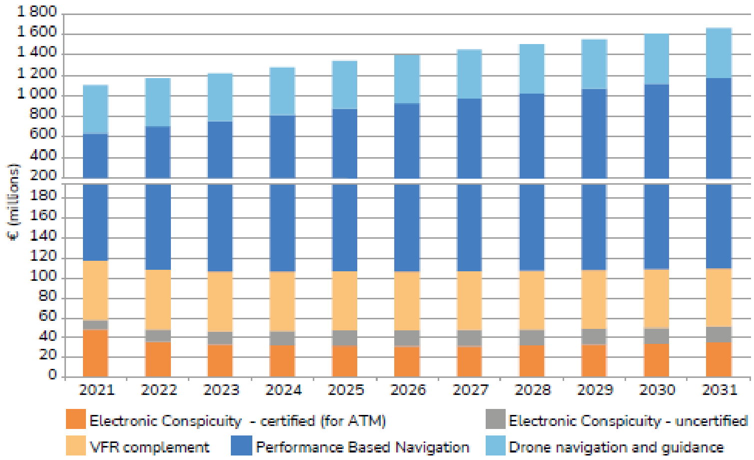
Following diagrams show expected shipments and revenues of GNSS devices as forecasted for upcoming years.

Shipments of GNSS devices by application

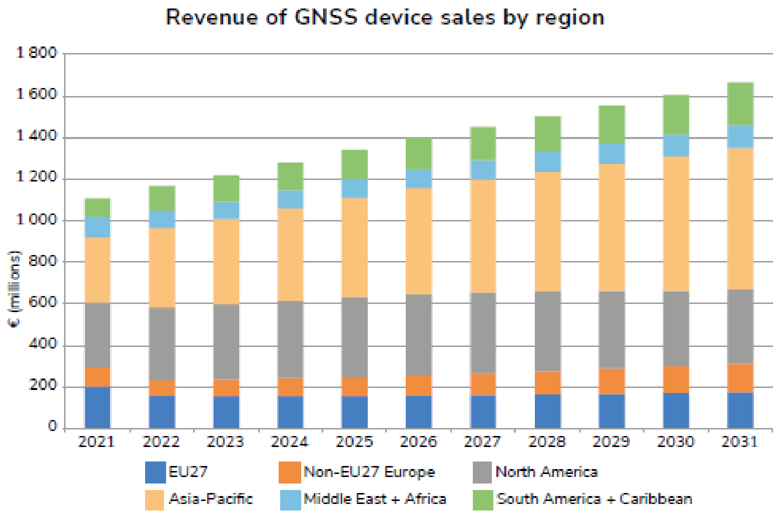


The graph does not consider impact of COVID-19 pandemic.

Revenue of GNSS device sales by application



Certified Electronic Conspicuity devices relying on the aircraft's integrated GNSS receiver are included within the PBN application.
GADSS Aircraft Tracking will either use the GNSS receiver quantified under Performance Based Navigation ,or Electronic Conspicuity – certified.
Earth Observation applications, and ATM systems timing and Infrastructure timing, are not yet quantified and are therefore not presented in this edition of the Market Report.



3.1.1 Key Market Trends

Though EUSPA Market Report [RD1] considers the key market trends related to aviation and drones closely linked to overcoming COVID-19 impacts and indirectly accelerating GNSS capabilities, the key trends to be recognised are:

- PBN modernisation
- Focus of European regulations on unlocking drones and Urban Air Mobility
- Increasing utilisation of earth observation in aviation.

3.1.2 GNSS Market Evolution

Push for new Alternative PNT

PBN is the foundation for enabling aircraft trajectories in the future that are optimised for the efficiency and environmental impact, with GNSS the key enabler. The evolution of navigation and surveillance applications, which will enable interoperability between manned aircraft and drones, is required. Future applications are therefore likely to lead to increased dependence on GNSS with associated demands for improved resilience and continuity to counteract the possibility of a loss of service.

In aviation, the GNSS landscape is evolving and moving steadily towards Dual Frequency Multi-Constellation (DFMC) supporting navigation and surveillance improving the resilience and integrity derived from dependence on multiple core constellations. In addition, aviation surveillance infrastructure increasingly utilises integrated GNSS, particularly for timing. From a GNSS standardisation perspective, this is well advanced, although not finalised, for manned aviation.

Traditional aviation has always operated with alternative technologies, particularly ground-based navigation aids (or self-contained airborne), in addition to GNSS. Whilst these technologies cannot deliver the performance equivalent to GNSS, particularly with DFMC, they do provide resilience.

With interoperability, new airspace users expect a continued push for rationalisation of historical alternative technologies in the future, there will be a need to maintain a spectrum and cost-efficient solution accessible to all, drones and manned aviation alike. Technologies such as the L-band Digital Aeronautical Communications System (LDACS) and 5G offer integrated positioning services, yet there is no clear solution that can meet the key performance requirements that GNSS delivers.

Advanced GNSS Operations for Helicopters and General Aviation

On 18th November 2020, EUSPA and EHA (the European Helicopter Association) hosted a workshop on the GNSS/EGNOS benefits for Helicopter Emergency Medical Services (HEMS) operations. This built on the increasing importance of GNSS to support helicopter operations operating in hostile environments, such as close to mountains or in valleys with poor connectivity to traditional infrastructure. GNSS provides HEMS with capabilities that improve the safety of the operations and enable an expedited rescue to the most suitable hospital for patients. Workshops such as this have helped the HEMS community become more aware of the operational benefits and technical requirements of GNSS.

In addition, the use of GNSS-based altitude can provide specific benefits for helicopter operations under particular conditions:

- GNSS-based altitude can be used instead of barometric altitude to improve altitude information reliability in low-level operations in areas where the local settings for barometric altitude (QNH) are not available or not reliable.
- Terrain Awareness Warning Systems (TAWS) and Synthetic Vision Systems (SVS) data is based on GNSS altitude. If the altitude displayed in the helicopter cockpit were GNSS-based instead of barometric, then all data would have the same reference and be coherent.
- At low speeds, the rotor flow can impact barometric sensors, which can lead to some bias on barometric altitude determination. On some helicopters, a hybridization of GNSS-based altitude with barometric altitude is already made to reduce noise and bias in the altitude value.

Overall drone market evolution by 2025

The global drone market will grow from €19.4 bn in 2020 to over €36.9 bn in 2025 at a CAGR of 13.8% (According to the Drone Market Report 2020). This huge growth will drive shipments of GNSS-capable drones to exceed 10 million units per year for most of this decade.

Nearly all drone use cases will continue to be operated outside of controlled airspace by Open or Specific category drones. Certified Electronic Conspicuity and Performance Based Navigation devices will be used for high-value applications, but by a relatively small population (compared to the overall drone market) of certified drones.

Important drone-related topics (network identification, electronic conspicuity and geo-awareness) are dealt with in EASA AMC and GM to Regulation (EU) 2021/664 on a regulatory framework for the U-space, Issue 1, 16 Dec 2022. Network identification explains the purpose of the network identification service for U-space and what information can be available. The objective of the geo-awareness service is described, how the quality of the geo-awareness information (its completeness, integrity, timeliness and availability) support UAS operators. With regard to e-conspicuity, three means for transmissions of position information are introduced.

Network identification requirement specifies, what kind of information supporting the traffic information service may be available Importance of this service is stressed out, with its complementing the direct network identification supporting authorities for security and privacy needs.

The requirement for manned aircraft operating in U-space airspace related to e-conspicuity and introduced by SERA.6005(c) means, that in case when such a flight is not controlled by the air traffic control service, it shall make itself electronically conspicuous continuously. A minimum position information message standard has been introduced, listing three possible means of the transmission: certified ADS-B out systems compliant with ICAO Annex 10, systems transmitting on SRD 860 frequency band and systems transmitting via standardised mobile telecommunication network services coordinated for aerial use in Europe.

Geo-awareness supports drone operators with provision of information on operational conditions and airspace constraints with the level of accuracy and other performance requirements for which it has been specified.

Applications such as critical infrastructure inspection and drone Delivery & eCommerce – which is predicted to be the largest market area by 2030 – are developing rapidly. These applications increase demand for Beyond Visual Line of Sight (BVLOS) missions classified as medium risk, which will fall under the Specific category. Such missions require a proportionate approach to safety and will require a design verification report. The designs will almost certainly include Electronic Conspicuity devices (based on one of the previous three solutions) to ensure awareness of other airspace users, and support U-space tracking by UTM systems.

In line with expectations stated in European Drones Outlook Study [RD26], there continues to be demand for drones in applications within agriculture, energy domain, public safety and security, e-commerce and delivery, mobility and transport. Growing is also utilisation of drones in media and mining and construction.

In the agriculture sector, long-range surveying allows remote sensing and long-range light-payload drones perform spraying of chemicals. In the energy sector, drones are used for maintenance and inspections, either local-site or long-range utility ones. When considering public safety and security, border security and maritime surveillance can be considered primary usage, contributing also to disaster relief, assistance to first response teams, identification of persons, tracking, etc.. E-commerce and delivery sectors have been already supported by drones, where delivery of medical materials and rescue equipment should be mentioned specifically. Self-driving capabilities of drones stand out in mobility sector. In other growing sectors, construction and mining benefit from surveying possibilities, routine tower inspections are performed in telecommunications and aerial views are widely used in real estate area. Academics and researchers utilise drones for observation of various subjects, from wildlife to geology.

Due to the rapid expansion of drone usage, regulatory aspects have gained more importance. National rules were replaced by a common EU regulation from July 2021. EU Regulations 2019/947 and 2019/945 formed the framework for the operation of civil drones, adopting a risk-based approach. Main categories considered for dividing drones into specific groups are the weight, the specifications and intended activity. Commission Implementing Regulations (EU) 2021/664, 2021/665 and 2021/666 set rules for operations in U-space airspace.

Urban Air Mobility

Urban Air Mobility (UAM) is a concept looking for ways to quickly and efficiently move people within cities in a safe and environmentally friendly manner. UAM transport networks will offer an alternative to congested city transport systems and will develop strong interfaces between city/region, drone, transport and urban planning communities. UAM is expected to debut in the coming years in big cities such as Paris and Singapore, according to Volocopter and Lilium, two European leaders in this market, but is not expected to emerge as a significant market until the 2030s.

Certification is an important aspect of introduction of UAM into operations. In June 2022, EASA published 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 [RD22]. It introduces amendments to existing EU aviation regulations and the creation of new ones to address issues of airworthiness and operational requirements.

As in most transportation modes, UAM strongly benefits from the GNSS services for positioning, but also from other services that are specifically tailored to drones applications: geo-fencing and geo-caging; e-identification (Drone navigation and guidance); and tracking (facilitated via Electronic Conspicuity). Maps that integrate EO data will provide up-to-date information about the distribution of dwellings and approximate population. This will help planning routes for UAM traffic to avoid densely populated areas and for developers to strategically plan infrastructure.

The Solution for EGNSS U-space Service (SUGUS) project, funded by the European Commission, organised a survey last year, whose results can be used as a valuable input to tailor the EGNSS Service Provision layer to specific drone missions' needs, allowing better mitigation of risks in complex operations like UAM, increasing safety and security.

3.1.3 EO Market Evolution

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

When it comes to the sale of EO data (worth €0.8 billion in 2031, 15% of global revenue), the top five of segments is made up of Urban Development and Cultural heritage, Agriculture, Insurance and Finance, Energy and Raw Materials as well as Consumer Solutions, Tourism and Health. Despite a relatively small market share in 2021 (i.e. 5% or €145 million), the Insurance and Finance segment – boosted by the growing use of parametric insurance products in the context of disaster resilience frameworks by commercial entities in areas with high exposure to extreme events – will increase its uptake of EO data and value-added services over the decade, pushing the Insurance and Finance segment to a forecasted €1 billion EO-enabled revenues by 2031 (constituting an 18% market share).

From a supply perspective, the EO market is jointly led by the United States of America and Europe with market shares of 42% and 41% respectively. Europe plays a leading role in the market of Analysis, Insights and Decision Support (the subset of value-added services closest to end users) with a 50% market share covering all segments, contributing to its overall market share above.

Although challenged by US companies in the mature Agriculture market and the growing Insurance and Finance segment, European companies lead the market across almost all other segments, excluding the Emergency Management and Humanitarian Aid segment (led by Asian companies with 52%) and the niche EO market of Road and Automotive (led by US companies with 77%). Based on the latest European Association of Remote Sensing Companies (EARSC) Industry Survey, SMEs and start-ups account for more than 93% of European EO companies, showcasing the importance of small companies for the European EO economy.

The global EO market of data and services, based on an analysis of over 100 applications, has been split across 16 segments (with Space being the sole segment unconnected with the EO market in this report). Despite having identified several EO applications across each segment, only 14 of these EO segments are currently quantified in terms of data and value-added service revenue streams as no quantifiable data was available for the Aviation and Drones and Rail segments.

In 2021, the global turnover across EO data and value-added services amounts to €2.8 bn. Over half of these global revenues (i.e. 55%) are generated by the top five segments, namely Urban Development and Cultural Heritage, Agriculture, Climate Services, Energy and Raw Materials, and Infrastructure. However, it is forecasted that the Insurance and Finance segment (i.e. €145 m and 5.2% in 2021) will realise substantial growth over the next decade and become the largest contributor to global EO revenues in 2031 (with €994 m and an 18.2% market share). By 2031, revenues of the global EO data and value-added services market will approach €5.5 bn.

The forecasted growth of EO data and value-added service revenues within the Insurance and Finance segment can mainly be attributed to an expected rapid uptake of solutions that support parametric insurance[1].

[1] Parametric insurance or index-based insurance is an innovative insurance product that offers pay-outs following pre-defined parameters and specific perils (e.g. droughts, floods). See Annex 3 for more information on Index production.

Insurance and Finance segment is expected to experience the fastest growth over the next decade. Segments in the darker zone are those which are projected to grow faster than others, while those in the lighter zone will experience slower growth. This can be explained by the degree of maturity of the segment. More mature market segments will experience smaller year-on-year growth than emergent markets in which the customer base is not yet well established. For instance, a mature segment such as Energy and Raw Materials has a slow and constant growth rate. Conversely, Insurance and Finance is a rapidly increasing segment with high growth rate.

The total revenues for **EO data** in 2021 accumulate to **€536 m** across all segments. From 2021, the EO data market will see a CAGR of 3.5% by 2031, resulting in **€797 m** total revenues. **The EO value-added services** market is considerably larger and accumulated globally a **total of €2.2 bn** in 2021 within the same scope of market segments. From 2021, the EO value-added services market will see a CAGR of 6.8%, resulting in **€4.7** bn total revenues by 2031.

European companies account **for half of the global Analysis, Insights & Decision Support market in 2019**. Companies in this market make use of EO data to provide information and intelligence to their clients seeking to solve complex geospatial challenges.

The European EO industry is the market leader in most market segments within this value chain category. In **Maritime and Inland Waterways, Fisheries and Aquaculture,** and **Aviation and Drones**, the European EO industry makes up for over 80% of the global market. The only segments in which European EO companies have a market share far below the European average are Rail (35%), Emergency Management and Humanitarian Aid (17%), and Road and Automotive (12%).

Europe accounts for 42% of the global Data Acquisition and Distribution market and 34% of the global Data Processing market in 2019.

Data acquisition and distribution companies supply commercial raw, unprocessed or pre-processed data. They include satellite, online platforms and data catalogues.

Data processing companies provide services used to process, calibrate, and analyse data, develop algorithms and build specific applications. The processing of data leads to change detection, mapping trends and the quantification of desired indicators on the Earth's surface.

3.2 Main User Communities

The user communities may be split based on various aspects. 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. 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 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, 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, researchers and start-ups:**
  - 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.

Subgroup	Description	Primary EO and GNSS needs and motivations to use apps	Primary applications		
			EO	Synergistic	GNSS
ANSP	ATM System Timing	Support of ground surveillance (Radar / A-SMGCS / MLAT) and ATM systems,			X
Airport	Aircraft Emission Measurement and Monitoring	Environmental contribution – emission control	X		X
ANSP / Airlines / Airports	Particulate Matter Monitoring	Monitoring of PM for flight planning	X		
USSP / ANSP	Drone Navigation	GNSS as a key navigation mean for drones			X
Drone operator	GNSS & EO data to minimise the ground risk class in the SORA process.	SORA		X	
Drone operator	EO (wind data) for checking the conformance within the intended corridor	Flight authorisation		X	
ANSP / Airlines / Airports / General Aviation	Performance Based Navigation (PBN)	Supporting PBN operations by precise positioning performance			X
General Aviation	VFR complement	Improved PNT services for uncertified applications including VFR navigation, situational awareness, flight tracking			X
Airlines	Aircraft Maintenance and Operation Optimisation	PM and atmosphere monitoring for flight planning considering impact of particulates on the airframe and the engines.	X		
Authorities	Monitoring terrain Obstacles near an Airport	Mapping of the CTR area around airport to provide information about terrain limitation to database providers	X		
ANSP / Airlines / Airports / General Aviation	Electronic Conspicuity	Improvement of situational awareness focusing on uncontrolled airspace.			X
Authorities	GADSS (Global Aeronautical Distress & Safety System)	Continuous reporting of position information with acknowledgement and remote beacon activation (flight and distress tracking)			X

3.3 Main Market Players

Main categories of market players in aviation and drones industry have been presented in EUSPA Market Report [RD1] addressing use of Galileo and EGNOS.

3.4 Aviation GNSS Value Chain

Across the aviation domain, there are several key players established in this mature market. New entrants to the aviation domain are few as the entry requirements are exceedingly high due to the regulatory and certification hurdles that need to be overcome. Thus the GNSS value chain is also well established with key actors that can be grouped under the following classifications:

- **GNSS receiver manufacturers:** The equipment manufacturers who build the GNSS receivers. The manufacturers can build the GNSS chipsets or integrate chipsets mass produced or from another system supplier. Examples include Thales Avionics, Honeywell and Garmin.
- **Aircraft manufacturers:** The aircraft manufacturers integrate the GNSS receivers and define the navigation performance of the aircraft based on the GNSS receivers and other airborne sensors. Examples here include Airbus, Boeing and Embraer.
- **Airlines and airspace users:** The airlines and other airspace users are the companies and private pilots that operate in the airspace utilizing the aircraft and avionics supplied by the aircraft manufacturer or fitted as an aircraft modification. Examples include KLM / Air France, Lufthansa Group or industry representatives such as IATA.
- **Air Traffic Management (ATM) service providers:** Provide services to airspace users and airlines that might be predicated on the availability of GNSS data. Generally, there is one ANSP per State which together are represented through trade body CANSO (Civil Air Navigation Services Organisation).
- **Aerodromes and infrastructure providers:** The aerodromes and other infrastructure providers support the operations of airlines and other airspace users and might publish procedures or rely on surveillance information based on GNSS. This would include all aerodromes that publish GNSS based instrument approach procedures.

3.5 Drones GNSS Value Chain

The GNSS value chain for drones is similar to that for manned aviation. In addition to component and receiver manufacturers and aerodromes and infrastructure operators, there are drone manufacturers and drone operators. UTM service providers are starting to play a significant role. The key players can be grouped as follows:

- **GNSS receiver manufacturers:** The main representatives in this group are generally mass market manufacturers that also provide chipset to other market segments. The main representatives in this group include Hexagon AB, Septentrio, u-blox, and Infineon.
- **Drone manufacturers:** These are the integrators that build and supply the drone for use by operators. There are several examples depending on drone configuration including fixed-wing drones (Airbus, Altavision, Delaire, Marques Aviation, etc.), multi-rotor drones (3D Robotics, DJI, Euphorix, Parrot, Yuneec), single-rotor drones (Babcock, Schiebel, Swiss Drones) and VTOL fixed wing (Aerovinci, Aiti, ATMOS UAV, Wingtra).
- **Drone Operators:** These are the companies that utilize the drones and rely on the performance of the GNSS chipsets and receivers to perform their mission. Examples here include Flying Basket, Manna, Topview.

- **U-Space Service Providers (USSP):** These will provide services to the drone operators which may include traffic alerting and monitoring. Representatives in this space include Unifly, Altitude Angel, and others that may be represented by the Global UTM Association (GUTMA).

3.6 Aviation and drones EO Value Chain

The aviation EO value chain is developing strongly linked with the manufacturer and maintenance of aerodromes. The main representatives of the EO value chain can be categorised as providers and users. While users fall just into several categories (air navigation service providers, airport planners, airports, flight planners and instrument flight procedure designers), providers can vary from infrastructure to data, platform, EO products and services and information providers. Some of them public offerings, while some represent user segments.

Out of infrastructure providers, AWS, Copernicus Dias, Google cloud, Intel Geospatial and Copernicus Collaborative Ground Segment stand out. Prominent data providers are Airbus, Blacksky, Copernicus Dias, Descartes labs, Maxar, Planet, Copernicus Sentinels, USGS/NASA Landsat and relevant in-situ networks. Copernicus Dias has been involved also in services of platform providers; other representatives are Bohannan Huston, Dares technology, Eisat Imagens de Satelite, flysom Holdings, Leonardo, Satellite Earthstar Geographics, Satellite Imaging and Skymap Global. Many of these companies belong also to EO products and services providers, we need to mention also Copernicus Services. Another standard function is being information providers.

4 POLICY, REGULATION AND STANDARDS

There are various stakeholders involved in aviation GNSS and EO regulatory segment, with their impact ranging from international to regional. This section does not specifically address EGNSS or EO regulation but rather focuses on relevant aviation regulation in context of these services. Specifically, for EO there is a lack of standardisation of geospatial datasets.

4.1 International organisations

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). The strategic objectives of ICAO are safety, air navigation capacity and efficiency, security and facilitation, economic development of air transport and environmental protection. ICAO works with the Convention's 191 participating Member States and industry groups to reach consensus on international civil aviation Standards and Recommended Practices (SARPs) and policies in support of a safe, efficient, secure, economically sustainable and environmentally responsible civil aviation sector. These SARPs and policies are used by ICAO Member States to ensure that their local civil aviation operations and regulations conform to global norms.

ITU: International Telecommunication Union is the UN specialised agency responsible for telecommunications, in particular for spectrum management and technical characteristics of systems. To ensure aviation safety the ITU allocates specific frequency bands for the use of aviation communication, navigation and surveillance systems. For navigation the reserved band is called ARNS (Aviation Radio Navigation Service).

IATA: The International Air Transport Association is the trade association for the world's airlines, representing some 290 airlines or 83% of total world air traffic. IATA supports many areas of aviation activity and helps formulate industry policy on critical aviation issues. IATA also sponsors projects and infrastructure in partnership with ICAO or local bodies to improve flight safety and ATM services in countries or areas with poor institutional/financial means.

Regional airlines associations: many organisations acting at continental or regional levels exist in order to promote the interest of regional airlines in their area of operation. Members of regional airlines associations may also be IATA members.

CANSO: the Civil Air Navigation Services Organisation groups a large number of air navigation service providers, civil aviation authorities and industrial actors. CANSO Members support over 85% of world air traffic and is a major ATM representative for all aspects pertaining to changes in the aviation systems. CANSO is organised in 5 regions, Africa, Asia-Pacific, Europe, Latin America-Caribbean and Middle-East.

4.2 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). In its regulator role the EC is assisted by EASA and EC Member States. The European Commission's activities in civil aviation fall within the responsibility of the Directorate-General Mobility and Transport.

EASA: The European Union Aviation Safety Agency created in 2002 that was initially competent for rule-making and aircraft type certification. Since 2008 EASA competencies have been extended to airports, Air Traffic Management and Air Navigation Services. EASA has now the competency for air operators' approval as well as personal (crews, air traffic controllers etc.) licensing. A large part of EASA's activity is dedicated to rule-making including the assistance to the European Commission for aviation EC regulations. EFTA Member States concluded specific agreements with EASA in order to follow EASA's regulations.

EUROCONTROL: The European Organisation for Air Navigation Safety created in 1963 with mission to harmonize Air Traffic Management in Europe for civil and military airspace users and to increase safety and efficiency while reducing environmental impact. EUROCONTROL has 41 Member States. EUROCONTROL conducts both operational activities (e.g. management of the Central Flow Management Unit, management of the Maastricht Air Traffic Control Centre) as well as research activities (SESAR).

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 civil aviation authorities: national CAAs have to implement ICAO recommendation (or to publish any deviation to these recommendations). In the EU and EFTA countries national CAAs implement the EC and EASA regulations and play a major role in the safety oversight as well as in approval of aviation organisations (aircraft and equipment manufacturers, maintenance and training organisations etc.)

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).

4.3 Regional bodies

Civil Aviation Commissions or Conference: The primary objective of these Commissions is to provide the civil aviation authorities of their Member States with a suitable framework within which to discuss and plan all the necessary measures for co-operation and co-ordination of civil aviation activities. These Commissions that do not have a regulatory competency are often specialized bodies of regional organisations and work in close cooperation with ICAO and aviation stakeholders:

- **ECAC**: European Civil Aviation Conference, created in 1955.
- **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.

4.4 Aviation standardisation organisations

EUROCAE and RTCA are the two main standardisation bodies for aviation equipment. These standards served as basis for equipment and aircraft certification.

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. Drones are specifically addressed by EUROCAE WG-105 UAS.

RTCA: founded in 1935; the Radio Technical Commission for Aeronautics, this non-profit organisation produces standards for equipment and systems. It cooperates with EUROCAE since 1963.

Aviation manufacturers also use engineering standards or guidelines from other standardisation bodies like ARINC and IEEE for equipment or SAE for guidelines for development of aircraft systems. Other standard development organisations relevant in the field of drones are: International Organization for Standardization, ISO/TC 20/SC 16 Unmanned aircraft systems[2] as well as ASTM[3].

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[2] https://www.iso.org/committee/5336224.html

[3] https://www.astm.org/

5 USER REQUIREMENTS ANALYSIS

This chapter provides a detailed analysis of user requirements pertaining to aviation and drones applications before describing the different roles and needs covered by GNSS and EO. From this application analysis the corresponding performance GNSS and EO requirements from a user perspective are ultimately identified.

From a high-level perspective, GNSS plays a critical role in the aviation segment especially to compute PVT (position, velocity and time). GNSS is also foreseen as the main navigation and surveillance tool for open and specific category of drones due to its high performance, light-weight and ubiquitous nature (for outdoors and open sky operations). In the aviation context, EO supports monitoring air quality focusing on particulates that have potential to impact operations eg sand or volcanic ash, but also assisting with asset monitoring of aerodromes and developments within close proximity to the aerodrome that have a potential to impact safety.

In the context of European GNSS solutions supporting aviation, EGNOS provides three services: EGNOS Open Service (OS), EGNOS Data Access Service (EDAS) and EGNOS Safety-of-Life (SoL) Service. In relation to Aviation and Drones, EGNOS can support drone missions by providing improved accuracy of the navigation during the mission. The most significant impending milestone is the implementation of EGNOS V3 Operations & Evolutions in 2028, which will augment not only GPS, but also Galileo, providing corrections on two frequencies.

This is complimentary to the core constellation services provided by Galileo offering a wide range of services: Open Service (OS), Search and Rescue Service (SAR), High Accuracy Service (HAS) and Public Regulated Service (PRS). Extensive work is being done to characterize Galileo OS performance for aviation in the frame of a formal Work Plan involving the European Space Agency (ESA), EUSPA and the European Commission (EC). The Galileo High Accuracy Service (HAS) will provide free-of-charge high-accuracy Precise Point Positioning (PPP) corrections up to two decimetres through the Galileo signal (E6-B) and by terrestrial means (Internet). Galileo Navigation Message Authentication (OS-NMA) is a new public and free-of-charge service, that provides users with an additional layer, so that to be reassured about the authenticity of the information received from Galileo satellites.

Table 1 below depicts the main applications making use of GNSS and/or EO technologies in aviation and drones. The list of applications is non-exhaustive and is expected to potentially grow and adapt according to the expected adoption of space technologies in the coming years and the innovations that should come with it. The current report being the first version of the aviation and drones report on User Needs and Requirements addressing EO in addition to GNSS, it is a living and evolving document that will periodically be updated and expanded by EUSPA in its next releases. In describing each of the applications, a simple categorisation is used to reflect the depth of information available in section 5:

- ● Application Type A: these applications correspond to those for which an in-depth investigation is presented and for which needs and requirements relevant to GNSS and/or EO have been identified and validated with the aviation and drones user community in either this or previous editions.
- ◐ Application Type B: these applications correspond to those not selected for in-depth investigation in the current version of this document, for which a partial specification of needs and requirements is provided, limited at this stage to the ones relevant to GNSS.
- ○ Application Type C: these applications correspond to EO-based applications, not selected for in-depth investigation in the current version of the document. A high-level description of the application is included considering that they will be further analysed and developed in next versions of the RURs.

While each one of the applications addressed in this document can benefit from GNSS and/or EO, the current issue the RUR does not cover in detail the needs and requirements of all applications. The applications that are explored in detail in this document have been selected following a prioritising based on stakeholder feedback on the usefulness of the applications, their maturity level and relevance to individual market trends and drivers. Other applications are foreseen to be covered in more detail in future versions of this RUR.

The table below maps the aviation and drone related applications to the three above-mentioned types. **The following** list of **applications and their** categorisation are **expected to evolve in the next versions of the document.**

Legend

EO only application
GNSS only application
Hybrid/synergetic application (combined use of EO and GNSS)

Table 1: Applications and depth of information

Subsegment	Application		Type of application / Level of Investigation	
Communications	Time synchronisation		C	○
	ATM system timing		C	○
Environmental Monitoring	Aircraft Emission Measurement and Monitoring		C	○
	Particulate Matter Monitoring		A	●
Navigation	Resilience requirements for a total PBN environment		A	●
	PBN Applications	RNAV / RNP for En-route and TMA	A	●
		RNP APCH (LNAV)	A	●
		RNP APCH (LNAV/VNAV)	A	●
		RNP APCH (LPV)	A	●
		RNP AR APCH	A	●
		A-RNP	C	○
		RNP 0.3	C	○
	GBAS CAT I		B	◐
	GBAS CAT II/III		C	○
	Precision approaches with AUTOLAND		C	○
	Transition from P-RNAV/RNP/RNP AR to LPV		C	○
	Transition from continuous descent approach (CDA) to LPV continuous descent approach		C	○
	Steep approach (5°) based on GNSS (EGNOS)		C	○
	PBN Approach procedures in simultaneous operations to instrument parallel runways (SOIR)		C	○
	VFR complement		B	◐
Operations Management	Aircraft Maintenance and Operation Optimisation		C	○
	Airport Asset Monitoring		C	○
	Monitoring Terrain Obstacles near an Airport		C	○
Surveillance	eConspicuity (e.g. ADS-B applications)		A	●
	Search and Rescue (GADSS)		C	◐
	Terrain awareness		C	○

Subsegment	Application	Type of application / Level of Investigation	
Weather services	Hazardous Weather Identification	C	○
Drones	Positioning for non-navigation functions	B	◐
	PBN Applications	A	●
	Mission planning	C	○
	SORA ground risk assessment	A	●
	Geo-awareness System	B	◐
	Geo identification System	C	○

Each EO-based "Type A" application will address the needs and requirements for potentially several operational scenarios. For each scenario, a table summarising the EO related needs and requirements is presented according to the template illustrated below in Table 2 which also explains the various inputs.

Table 2: Description of needs and requirements relevant to EO table[4]

ID	Identifier
Application	Application covered.
Users	Common users of the product/service.
User Needs	
Operational scenario	**Describes the operational scenario faced by the user, which requires a solution.**
Size of area of interest	Describes the area of interest (e.g. an airport is only interested in the area out to 45km from the reference point).
Scale	Describes the scale of interest (e.g. an airport is interested in all obstacles above 10m in height within the area).
Frequency of information	How often the user requires the information.
Other (if applicable)	Other user needs such as contextual information (weather data) or file formatting requirements.
Service Provider Offer	
What the service does	Description of the service that satisfies the user's needs.
How does the service work	(Technical) description of how the service works.
Service Provider Satellite EO Requirements	
Spatial resolution	Spatial resolution of the satellite imagery/data required by the service provider to realise the service.
Temporal resolution	Frequency of satellite data (revisit time) over the area of interest.
Data type / Spectral range	Type of data (e.g. RGB, SAR) and spectral range (if relevant).
Other (if applicable)	Other data requirements.
Service Inputs	
Satellite data sources	Type of required data and examples of operational satellites that can provide these data.
Other data sources	Other sources of data that the service provider uses to realise the service.

[4] See key EO performance parameters (detailed) definition in A.5.

5.1 Current GNSS/EO use and requirements per application

This section presents existing GNSS and EO requirements identified at the application level taking into account existing standards and specifications and user needs identified most recently with stakeholders through the UCP 2022.

It is noted that for GNSS, the key user requirements for manned aviation are already defined and are linked to increased availability, continuity and integrity as it has implications on safety. New user requirements are mostly coming from new users (i.e. the drones industry). Here, whilst there is no navigation performance specification for drones currently, there were identified that there is a need linked to several regulatory requirements, specifically: Reg. 2019/947 Article 11 (SORA), Reg. 2021/664 on the UAS flight authorisation service, and SC Light UAS – Medium Risk, Subpart F, requirements 2510, 2511 and 2529. The key GNSS requirements for RNP of drones operations in the specific category are linked to containment of the drone within a corridor along the desired flight path (DFP), constrained according to the Total System Error (TSE) limits. This implies that the desired flight path is aerodynamically and mechanically flyable and that autopilot behaviour based on GNSS derived PVT (position, velocity and time) is understood and considered.

In many ways, the use of EO data by aviation has been largely un-noticed with it forming a critical role within flight procedure design activities for several years. Ground features and geospatial data, (i.e. electronic terrain and obstacle data), are of key importance and are intended to be used in air navigation applications such as ground proximity warning systems, continency procedures, aircraft operating limitations analysis, flight simulators or synthetic vision systems. These are relevant for both manned and unmanned aviation.

In the following sections, the contribution from GNSS and EO is explored for each of the applications addressed in Table 1.

5.1.1 Communication

5.1.1.1 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.

5.1.1.2 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 requirement for the accuracy of this timing is linked to the above application.

5.1.2 Environmental monitoring

5.1.2.1 Aircraft Emission Measurement and Monitoring

This application reflects the growing push for aviation to enable monitoring of trace gas composition of the Earth's atmosphere at different altitudes to understand more accurately the impact Aviation has on the environment, climate change and human health.

During UCP 2022 a number of practical use cases of EO were presented noting that around 60%[5] of aviation's climate impact is caused by condensation trails, or contrails, almost double that of direct CO2 emissions from aircraft engines. Utilising EO data to update predictive models to optimise contrail prevention has been shown to avoid the indirect CO2 contributions. For example, in 2021, SATAVIA, Etihad Airways and Boeing proved the concept by conducting a ground-breaking commercial flight, the EY20 Sustainable Flight, that avoided over 64 tonnes of carbon dioxide equivalent (CO2e) via contrail prevention. Utilising post flight data from flights, the trajectory can be compared with models and EO observations of contrail development to validate models and ensure increase the climate benefits.

This is exactly the approach taken by SATAVIA which integrates numerical weather prediction modelling, EO data and global asset-tracking to provide high-resolution and easily accessible data to tactically avoid contrail generation. It is noted that predictions for the provision of contrail avoidance and measurements of moisture content supporting the possible formation of contrails is not required within ICAO documents.

To improve the predictions it is necessary to have access to high-resolution horizontal, vertical and timely data is of key importance for them to show, when a contrail formed, what area it covered, how sheared by wind it was, how it grew and ultimately what the lifetime of the contrail was. In this context, the EO data combined with in situ is essential for validating models to build the confidence, that the models can be used as the most appropriate tool to conduct post-flight analysis.

This example for contrail prediction is but one example of particulate monitoring. As is noted however, to provide full benefits, EO data coverage should be global. Vertical coverage needs to extend to all levels which can be affected, and in particular the enroute cruise levels above FL250. Aircraft cruising above FL290 are spaced by 1000 ft vertically and so to support flight planning and model predictions, the solution should have at least a vertical resolution of 1000 ft.

5.1.2.2 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 PM2.5 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 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

[5] https://www.sciencedirect.com/science/article/pii/S1352231020305689?via%3Dihub

(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. 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 concertation. 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 documentation is for offsets of 10-15NM [RD10]. 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 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 10-15NM.

Flight crew 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 <12hr validity. However, where the weather conditions are not expected to change significantly, the forecasts are sufficient out to 18 hours [RD31]. Therefore, the EO solution must be able to support a forecast valid for an 18hr timeframe after which a new forecast valid for a 18hr 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.

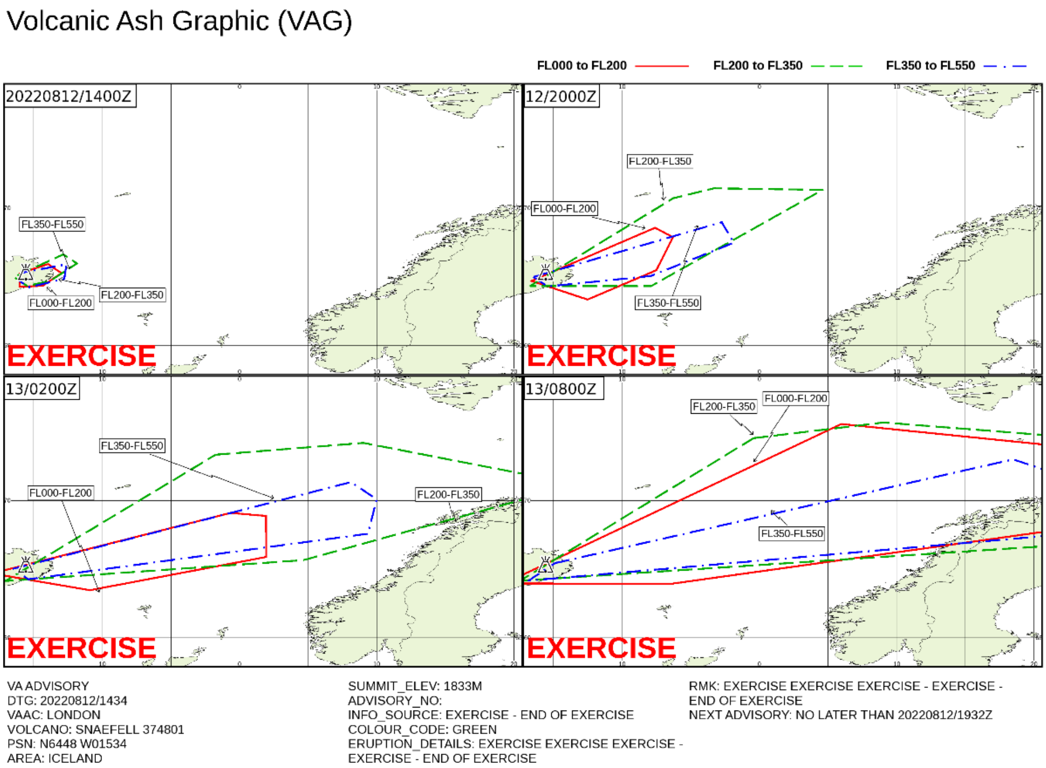


Figure 2: Example of volcanic ash graphic[6]

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

ID	EUSPA-EO-UR-AVI-0001
Users	World aviation Forecast centres, Volcanic Ash Advisory Centres, Flight planning software providers, Air Navigation Service Providers, Airlines and Business aviation users which might be operating on international flights
User Needs	
Operational scenario	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. Examples include: ▪ 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 taking into account contrail avoidance and balancing the competing contributions of winds, fuel burn and moisture levels supporting contrail development.
Size of area of interest	Global
Scale	1:250000 on the basis of the highest resolution VFR charts.
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 to achieve the regulatory minimum. Advantage should be taken of any additional information that can extracted and extend the information provided beyond that required as a regulatory minimum. All charting produces should support more granular representation than is currently provided (c.f. the IWXXM[7]).
Service Provider Offer	
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).
Service Provider Satellite EO Requirements	
Spatial resolution	Depending on the application. 10NM lateral grids for ash and sand and other non-water based particulates. Vertically, 1000ft layers between FL180 and FL450.
Temporal resolution	Data should be no older than 18 hrs. 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 (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

[7] http://schemas.wmo.int/iwxxm/2023-1RC1/

5.1.3 Navigation / Positioning

5.1.3.1 Resilience requirements for a total PBN environment

The Performance Based Navigation (PBN) is a modern 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 sensors. 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 preference of PBN approaches (LNAV/VNAV and LPV) and ILS CAT I network to be minimised (by 2030).

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, Table 3.7.2.4-1). 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 a business continuity requirements.

Typical operation	Accuracy horizontal 95% (Notes 1 and 3)	Accuracy vertical 95% (Notes 1 and 3)	Integrity	Time-to-alert	Continuity	Availability
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

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

The alert limits for these applications ae also specified in ICAO Annex 10 Vol I as follows:

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 4: GNSS signal in space alert limits – ICAO Annex 10 Vol I

According to the European Navaid Infrastructure Planning Handbook [RD21], 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 of GNSS signals and how to maintain ATM operations using only ground-based Navaids. 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, but while the flight crew will be the first to detect anomalies, there are no reports/mechanisms to report it (except to calling the ATC). However, 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. This could if achieved also enable approached below ILS CAT I minima which would be of interest, however, currently, EGNOS and Galileo both meet the required performance and therefore there are no additional requirements

DFMC (Dual Frequency Multi Constellation) provides extra robustness, but regardless the MON should be kept to support 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.

5.1.3.2 PBN Applications

There are several implementations of PBN applications that each have a different level of performance and are detailed in the following sections. Due to the recovery from the COVID-19 pandemic, airlines have expressed that implementation of PBN is not currently seen as a priority. Sustainability of the business models is seen as more of a priority before the focus can shift to addressing a better operating environment. A reason for this is the significant costs experienced by the airlines during the pandemic, and access to suitable funding mechanisms that might help with fleet equipage are seen as too complex – especially for smaller operators. This is despite the fact that adoption of PBN procedures using EGNOS gives the opportunity for new operations in remote locations (markets).

In the context of airports, the vulnerability to GNSS jamming is a concern. 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 mast space. Airports have not reported any plans to rationalise ILS regardless of category, although they are aware of the 2030 deadline.

5.1.3.2.1 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 navaids, are kept on some level and where feasible, as back-up systems for safety reasons.

Within PBN, RNAV and RNP applications are commonly characterized 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 is known as P-RNAV (Precision RNAV).

RNAV 5 is currently mandated in the European airspace, mostly above FL 95. It is also applicable in numerous non-European airspaces. In the near future, other PBN specifications will be mandated in the European Airspace by a PBN Implementing Rule currently under preparation at EC level after the EASA has conducted the regulatory process phases.

5.1.3.2.2 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.

5.1.3.2.3 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.

5.1.3.2.4 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 realized:

- 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 & larges airports), the main benefit is to allow CAT I instrument approach with no need for a ILS to that runway-end, that might be decommissioned. On such runway LPV200 will be implemented, meaning DH as low as 200 ft above the runway threshold obstacles permitting and RVR of 1800 ft. Complemented with EVS (Enhanced Vision System) it will be possible to operate with RVR of 1000 ft and even lower in the future.

Furthermore, deployment at non-instrument runways and VFR airports EGNOS improves flight safety and enables the provision of LPV to all runway ends without 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) will replace ILS CAT I, with ILS being reserved for CAT II/III.

SARPs for DFMC SBAS were approved by the ICAO Navigation Systems Panel in November 2020. The EUROCAE ED-259 - Minimum Operational Performance Standards for Galileo - Global Positioning System - Satellite-Based Augmentation System Airborne Equipment, was published in February 2019. The standard includes a complete definition of the DFMC SBAS message and will be supported by future editions of EGNOS.

This is being addressed within the development of EGNOS V3 and it should be noticed that EGNOS V3 includes options for the extension of the service area to Ukraine and Africa. The EUSPA is currently defining a programmatic study of EGNOS V3 over sub-Saharan Africa, funded by the EU-African Partnership programme.

5.1.3.2.5 RNP AR APCH ●

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.

5.1.3.2.6 A-RNP ○

The A-RNP specification, described in the ICAO PBN Manual, 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 are: RNAV 5, RNAV 1, RNAV 2, RNP 2, RNP 1 and RNP APCH.

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 1.0NM in steps of 0.1 NM).

5.1.3.2.7 RNP 0.3 ○

RNP 0.3 represents the same Advanced RNP philosophy but typically for helicopter operations. It's 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, RNP 0.3 navigation specification is also 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 (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 would be extended to manned VTOL capable aircraft (pilot onboard) once NPA 2022-06 is endorsed.

5.1.3.3 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, 4 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. This solution provides significant operational improvement for GBAS equipped users, leveraging SBAS global observation of ionospheric perturbations albeit is seen as an intermediate step to achieving CAT II/III noting also the PBN requirements on the deployment of EGNOS enabled procedures to CAT I minima.

5.1.3.4 GBAS CAT II/III ○

GBAS CAT I based on GPS is already in operation in some airports and CAT II/III based on GPS is under final stage of development and standardisation. According to SESAR Solution #55 — Precision approaches using GBAS CATII/III, their benefits start date is foreseen for 31 December 2025 and full-benefit date for 31 December 2035.

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.

5.1.3.5 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.

5.1.3.6 Transition from P-RNAV/RNP/RNP AR to LPV ○

An approach can be based on RNP APCH or RNP AR. RNP APCH has a performance requirement of 1NM (in the initial, intermediate and missed approach segments) and RNP AR down to 0.1NM.

SESAR project 5.6.3 studies the possibility to make a transition between RNP APCH or RNP AR to a final approach with an SBAS 3D guidance. Approaches with RF in the final segment or RF capability for RNP APCH can be studied. Also, EASA CS-ACNS and to AC 20-138D & AC 90-101A AR and PBN Manual do not allow a transition from RNP AR to LPV procedures based on SBAS since the vertical guidance in the final approach segment can only be supplied by barometric signal. 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".

5.1.3.7 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. The SESAR project studies how to combine CDA with SBAS final approach segments like LPV or APV.

5.1.3.8 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 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.

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

A new amendment is in progress to PANS-OPS and PANS-ATM (as well as SOIR Manual – ICAO DOC 9643-) in order to incorporate PBN approach procedures in SOIR. RNP APCH and/or RNP AR APCH navigation specification will be required and it is of paramount importance that, once the aircraft is established in the RNP AR APCH, no vertical separation will be required with the aircraft on parallel approach (currently it is necessary to keep at least a vertical separation of 1000 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.

5.1.3.10 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.

5.1.4 Operations Management

5.1.4.1 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.

5.1.4.2 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.

5.1.4.3 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.

5.1.5 Surveillance

5.1.5.1 eConspicuity (e.g. ADS-B)

Automatic Dependent Surveillance – Broadcast (ADS-B)[8] is defined by ICAO (Doc 4444) as a means by which aircraft, aerodrome vehicles and other objects can automatically transmit and/or receive data such as identification, position and additional data, as appropriate, in a broadcast mode via a data link.

ADS-B is a powerful enabler of the surveillance domain. In areas without radar coverage it allows significant cost reduction where implementing ground stations receiving ADS-B messages is feasible. Over oceanic and remote areas, it is not always the case and satellite telecom to relay ADS-B messages is necessary. To this end ITU WRC 2015 allocated a frequency band (1087.7-1 092,3 MHz) for the Aeronautical Mobile Satellite Service (AMSS) in order to allow world-wide flight tracking via ADS-B messages broadcast by aircraft, thus potentially serving navigation and SAR services. Many other air and ground aviation applications based on ADS-B are already developed or under development.

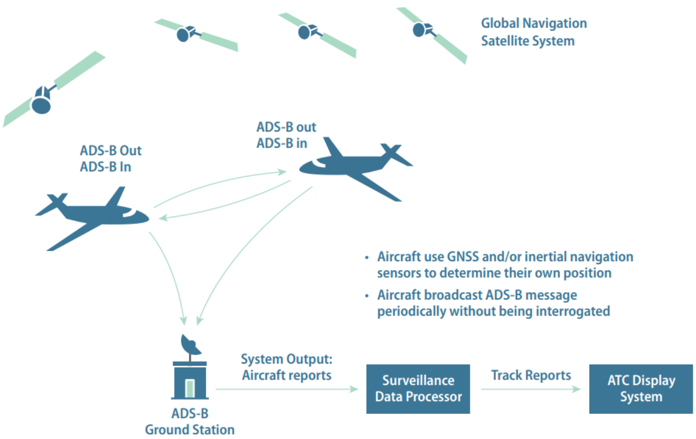


Figure 5: ADS-B Functional Architecture

The use of SBAS as a positioning source for ADS-B provides the same level of service as SSR (99.9% availability) that can allow in the future the reduction of SSR duplicity with new ADS-B infrastructure:

[8] ADS-B is one form of eConspicuity. This is a certified form and additional solutions exist (e.g. FLARM) which are not certified. The uncertified solutions are also dependent on GNSS for positioning. ADS-B performance specifications are well defined and are presented noting that the various levels of ADS-B GNSS performance requirements map also to performance needed by uncertified solutions.

Mode S SSR coverage duplicity is to be eliminated from Europe through the replacement of the required SSRs with ADS-B ground stations.

ADS-B is a surveillance technology which relies on aircraft-derived information for the provision of surveillance information to other airspace users (i.e. ATS units and/or aircraft's flight crews). As such, it is defined as a cooperative dependent surveillance (in opposition to secondary radar or multilateration systems, which are cooperative, but independent, surveillance sensors).

The ADS-B operation application determines the navigation system that can be used for that specific application. In practice GNSS is the only one that can currently match the required performance.

Some ADS-B In and Out applications are already in service in some airspace (e.g. ADS-B In Trail Procedure –ITP- over the North Atlantic Ocean) and new application deployments are under consideration in SESAR, knowing that RTCA/EUROCAE standards are already published in EASA CS-ACNS issue 4, Subpart D, Section 4 1090 MHz Extended Squitter ADS-B. GNSS user requirements for these applications are listed in chapter 6.

5.1.5.2 Search and Rescue (GADSS) ◐

After the recent aircraft losses in the ocean (flights AF447 and MH370) ICAO recognized 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 that recommendation was included in EASA AIR OPS with requirements for flight tracking. These regulations aimed at preventing the following problems:

- 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 of the last 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 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 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 lasted 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; and Post Flight Localization and Recovery. Aircraft Tracking is enabled through the on-board GNSS equipment (either the PBN or Electronic Conspicuity device), whilst the other components are provided by Emergency Locator Transmitters.

After the Amendment 39 to ICAO Annex 6, 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.

5.1.5.3 Terrain awareness

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

- Ground Proximity Warning System (GPWS): this system is a safety net based on the radio altimeter providing alarms to the crew. It appeared in the 70's. 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 defined) are mandatory for aircraft of more than 5700 kg and with more than 9 seats as well as for helicopters of more than 3175 kg and 9 seats for IFR operations.

5.1.6 Weather services

At the UCP 2022 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 CO_2, NO_x/CH_4/Ozone, Particulate Matter (nvPM, vPM, UFP) or SO_x;
- 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.

It is clear, that aviation has an impact on climate change, but it is important to realise, that climate change as well poses significant and increasing risks to aviation in the years ahead. Recently published EUROCONTROL study on climate change risks for European aviation assesses, how existing weather trends have impacted aviation in recent years, factoring in climate change impacts that are 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.

5.1.6.1 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 UAM, it focuses on the identification of wind and micro turbulence in low level altitude in highly built areas. This leads a reduction in the number of safety incidents and increased flight efficiency.

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

5.1.7 Drones

5.1.7.1 Positioning for non-navigation functions

Integration of surveillance capabilities will be needed for drones as the number of simultaneous operations increase and begin mixing with manned aviation. A move to a requirement for electronic conspicuity (e.g. ADS-B) as a means of surveillance would enable interoperability with manned aviation but will be limited by frequency congestion as traffic numbers of both manned and drone traffic increase. Since the GNSS derived position velocity and time (PVT) is intrinsic to this information broadcasted as part of any electronic conspicuity solution, its performance becomes critical. This is addressed specifically within industry standards ED-279 and ED-280 covering functional hazard assessments and safety linked to external services and infrastructure requirements from Specific Operations Risk Assessment (SORA) and Operational Safety Objectives (OSOs).

The UAS elements identified as having a major impact in case of failure include the navigation of the flight path, the provision of traffic data (e.g. eConspicuity, DAA) and the provision of emergency functions (e.g. FTS, Emergency Recovery). This places requirements on the navigation system linked to reducing single points of failure, multiple information sources, authentication of GNSS services or requirements on system monitoring, to have timely and accurate information about status of the different systems.

Documents dealing with this system are the AMC/GM to Regulation (EU) 2021/664 on a regulatory framework for the U-space, Network identification service, ASTM F3411-19 'Standard Specification for Remote ID and Tracking', Draft AMC and GM to Regulation (EU) 2021/666 amending Regulation (EU) No 923/2012 as regards requirements for manned aviation operating in U-space airspace and AMC1 SERA.6005 Requirements for communications, SSR transponder and electronic conspicuity in U-space airspace.

Manufacturers and industry through the standardisation bodies are developing specifications that support operations of drones within

In addition, surveillance applications (such as ADS-B) will be needed to support the self-deconfliction and separation of drones operating in autonomous or automatic modes especially in Beyond Visual Line of Sight (BVLOS) situations. However, most of the unmanned operations are expected in Class G airspace where most of the general aviation operates and therefore the equipage level of ADS-B will be essential for achieving desired interoperability.

In April 2020, The European Commission published a regulation (EU) 2020/587 that mandates aircraft with a maximum take-off mass exceeding 5,700 kg to be compliant with Mode S. The ADS-B mandate in the United States is much more intransigent and as of January 2020, aircraft are required to have a certified ADS-B system. Unlike the European mandate, in US the use of ADS-B is linked to the airspace, not the aircraft (e.g. MTOM).

Surveillance applications may also exist that are beyond the applications in the air but depend more on terrestrial solutions (e.g. LTE, 5G) which in turn have requirements on GNSS timing. These are already in development and are foreseen to enable some of the key elements of the Unmanned Traffic Management (UTM) development by NASA or U-space as proposed by the European Commission.

5G and LTE seem to be a better solution for missions at urban canyons and low altitudes, where the space signal may be obstructed. On the other hand, the commercial networks cannot provide the benefits of closed aviation spectrum and cyber security concerns may arise. Due to a number of application and devices, there might be problems with aviation spectrum available to support all unmanned operations and most likely aviation spectrum will be used for safety critical unmanned operations like personal transportation and the rest of low-risk applications will be based on commercial spectrum.

Another means of increasing the performance of drone navigation and positioning is the use of DFMC receivers since as the primary navigation sensor GNSS is directly correlated with drone flight safety for drones. In this perspective, EGNSS can support drone operations with:

- Full geometric altimetry approach for UAS-UAS vertical reference enhanced with Galileo HAS, without the need of additional ground infrastructure for U-space airspace operations.
- Enhancement of payload final products with Galileo HAS without the need to place and survey Ground Control Points.
- Galileo OSNMA in combination with other technologies (Blockchain) could pave the way to a new class of U-space services enabled by EGNSS for legal protection and customer accreditation.

Furthermore, operators have emphasised the need for a Common Altitude Reference System (CARS) to ensure all operators (including manned aviation) set altitude consistently since the altitude for drone missions is usually reported as “above the take-off position”. A need to pair this with an EO derived DSM precise enough to plan operations that should also be authorised and managed (e.g. AIRAC cycles) by the competent national authority to ensure single source of truth for all systems connected has also been expressed. This would enable consistent planning and coordination of operations between various U-space Service Providers (USSPs).

5.1.7.2 PBN applications

The advent of new drone applications that enable operations beyond line of sight increases the need for a high performance navigation system that supports both mission requirements and the airspace in which the drone will operate. The navigation system might take as input the position (PVT) data as described in the previous application, but needs to consider the complete system performance of the drone. This is akin to the Performance Based Navigation (PBN) requirements of manned aviation which take into account the position information accuracy and the accuracy of the aircraft guidance system to place the aircraft where planned. The difference between where the drone is planned to be and where it actually is, is termed Total System Error (TSE) and consists of the Flight Technical Error (FTE), the Path Definition Error (PDE) and the Navigation System Error (NSE). The FTE determines how accurately the drone can fly the proposed path, and the NSE describes how the difference between where the drone thinks it is (laterally and vertically) and where it actually is. PDE occurs when the path defined in the navigation database does not correspond to the desired path, i.e. the path expected to be flown over the ground.

With the technology uptake and regulatory developments drones are being used more frequently than ever. Most operators are especially interested in BVLOS operations which can provide wide range of benefits. Urban Air Mobility flights are also expected to grow in numbers and U-space service providers (USSPs) will soon face challenges in accommodating unmanned traffic into relatively small and limited airspace safely and efficiently. With rising traffic RNP routes will most likely emerge in short timescales which express differing levels of navigation performance for drones depending on the mission that will have different expectations in terms of NSE.

Navigation requirements for drones currently presuppose the existence of GNSS and carriage of receivers, either as standalone or integrated with IRS/INS systems, is currently available. However, not all the applications for which drones may be deployed are yet determined as the platform opens up new possibilities for constant exploitation. In line with the principles behind PBN, a minimum required navigation performance will be required that takes into account the systems used by the drone and the overall positional performance of the drones GNSS sensors.

Background work undertaken by EUSPA has proposed a minimum NSE that supports the typical operations that would be undertaken. This builds on the work that is previously undertaken and which was consulted in previous User Consultation Platforms placing requirements dependent on the area in which the drone will operate (urban, non-urban). Considering the requirements of the missions, and the differences between fixed-wing and rotary-wing operations, the following table summarises the NSE requirements based on GNSS. The context in which this is applied is described further in the following section.

Table 3: Nav equipment (GNSS receiver) performance requirements for Drone en-route PBN[9]

Operation	Hor (m) NSE(95%)	Ver (m) NSE(95%)	Integrity[10]	TTA (s)	Alert limits (m)	Continuity	Availability
SAIL 3	3 - 8	4 - 13	1 -1E-4 /h	1 – 3	HAL: 25 -27 (fixed wing) 10 - 14 (rotary) VAL: 12 - 22 (fixed wing) 7 - 23 (rotary)	1 - 1E-4 /h	0.9999
SAIL 4	3 - 8	4 - 13	1 -1E-5 /h	1 - 3	HAL: 25 -27 (fixed wing) 10 - 14 (rotary) VAL: 12 - 22 (fixed wing) 7 - 23 (rotary)	1 - 1E-4 /h	0.9999
NOTE: *The performance characteristics presented in this table are sufficient to deliver navigation performance equivalent to a RNP 26/16 m for fixed wing and RNP 12/14 m for rotorcraft due to improved FTE for rotorcraft*							

5.1.7.3 Mission planning

Digital Surface Model (DSM), could help with the mission planning for all UAS flight operations including open, specific and certified. As of current regulation, the maximum ceiling for unmanned operations in open category is 120m AGL (above ground level).

Drone operators participating at the UCP want to be able to resolve heights of features similar to those required around an aerodrome (see. ICAO Annex 15 Area 2). However, ICAO Annex 15 paragraph 3.2.2 requires the resolution of the provided data to be commensurate with the actual data accuracy. So accuracy is dependent on the area of operation. Industry guidance for general aviation within Eurocae ED-98c provides a requirement that the horizontal and vertical accuracies should be 5m and 3m respectively. As an Area 2 guidance, for drones this can be considered when not within the immediate landing site. For the landing site, the requirements for Area 4 are considered more appropriate and place a requirement horizontally of 2.5m and vertically of 1m. All these are at 90% confidence levels. Considering that the

[9] Figures in the table are under discussion and consolidation. Performance requirements are inclusive of SiS, receiver performance and the navigation database

[10] Assumption for the integrity requirement of the navigation system, $IR < \frac{10^{-(SAIL+1)}}{flight\ hour}$

drone needs to be able to navigate sufficiently well to avoid the population, buildings and other restricted areas as defined within the SORA, these proposed accuracies similar to the navigation performance requirements derived for drones previously.

There is also a need for monitoring anthropologic changes using EO a satellite to detect unauthorised building constructions which create otherwise unknown physical obstacles which could risk the drone operation. This is especially relevant in the context of operations beyond the visual line of sight (BVLOS) of the pilot. Currently, the monitoring of development is possible, but the resolution is too low.

The temporality of the data need to be defined as per the AIRAC cycle defined within ICAO Annex 15, it is proposed that the data should be refreshed every 28 days to ensure that the data can be relied for flight planning purposes when also considering possible links to the use of existing Air Traffic Services (ATS) that may be provided in airspace within which the drone will be operating.

Synopsis of requirements:

Spatial resolution shall be at least 5m horizontally and 3m vertically at a EU level for all obstacles and terrain. Obstacles including natural features such as mountains, cliffs and man-made features such as buildings, telecommunication towers, water towers and anything >10m above the terrain base. Within urban environments, to enable this requirement is extended to allow for operations close to buildings and landing on buildings of 2.5m horizontally and 1m vertically.

5.1.7.4 SORA ground risk assessment

Disclaimer: This report does not consider the proposed evolution of ground risk assessment in the SORA 2.5 that was issued for public consultation at the end of 2022.

Regulatory context

Drone operators under the requirements of (EU) 2019/947, utilising EASA specific category drones are required to identify the risks of the operational environment, geographical area and, in particular, to the overflown population. The way in which this is required to be executed is through a Specific Operations Risk Assessment (SORA)[11] 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 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 and rules for Certified category operations are being developed under an EASA Notice of Proposed Amendment NPA 2022-06. 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, elevation of operation, 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 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 operation. As a part of ground risk assessment, an Intrinsic Ground Risk Class

[11] http://jarus-rpas.org/content/jar-doc-06-sora-package

(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 recently published EUROCAE document ED-301 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. This relationship between the navigation performance and the EO data supporting the application of the SORA process needs to be considered.

Existing solutions to assess sparsely populated areas

SORA 2.0 requires distinguishing between sparsely and non-sparsely populated areas. However, it does not explicitly specify or guide the operator on the appropriate population density thresholds, spatial resolutions or other criteria for data and methods. As a result, operators employ a variety methods and data sources assess if an area is sparsely populated or not. These are:

- Visual interpretation of optical orthomosaics from various sources with Google Earth/Maps ortho-imagery being among the more popular. Resolutions of 0.5m and below allow for interpretation of land use/cover with decent thematic accuracy. Key challenges are manual, time-consuming process and non-deterministic, variable result due to subjective, non-standardised nature of human photo-interpretation.
- Population density maps from national statistical and/or geospatial offices (examples in Spain, France, Switzerland). These are usually based on census data.
- Providers of regional/global population settlement layers such as Copernicus Human Settlement layer, Oakridge National Laboratory Landscan global human settlement layers. These products come at resolutions of 100-1000m grids. GHSL has residential/non-residential mapping and estimates of diurnal and seasonal variation (at 1000m grid).
- Land use/cover maps from national geospatial offices or pan-European products such as Copernicus Corine Land Cover, Copernicus Urban Atlas are used rarely as they do not provide a direct population density estimate. Estimation population density from LCLU class is a little explored possibility in the context of SORA.
- High fidelity population data from mobile operators or other smartphone tracking based technologies is seen as promising by EASA and others, but no operational use was discovered yet.

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. Although the data needs to be calibrated and independently validated in order to make the model trustworthy for the approving authorities, it has several advantages – increased spatio-temporal fidelity, use of open domain data i.e. independence from mobile networks, which pose a number of challenges including high cost, security and privacy risks.

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. 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 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 meters was deemed sufficient during the UCP 2022. An increase in the resolution of population density maps would lead to higher variance in population density figures and hence higher ground risk scores with the max risk approach in current version of SORA.

Whilst it is difficult to measure population density directly via Earth Observation, it is possible to merge EO data with other sources. Processed EO data can highlight residential and commercial buildings, open spaces, green spaces, bodies of water, residential and industrial zones and transport and critical infrastructure as a consolidated dataset. EO data and other sources can be overlaid and used by the operator as part of their SORA methodology.

ID	EUSPA-EO-UR-AVI-0002
Users	Air Navigation Service Providers / U-space Service Providers, Drone operators, Regulators
User Needs	
Operational scenario	Operations of specific category drones are required to undertake a Specific Operations Risk Assessment (SORA) (v2.0) which requires the drone operator to assess the risks of the operation and understand the areas impacted during the mission (e.g. risk of physical harm to uninvolved people and critical infrastructure). This results in different operators undertaking the SORA utilising different approaches.
Size of area of interest	It is proposed that the focus of this service should be European to ensure a consistency of the information which underpins flight planning decisions by the operators from the application of the SORA methodology.
Scale	Depending on the operation but at a level of 1:25000 or lower
Frequency of information	Updated every 28 days[12]
Other (if applicable)	-
Service Provider Offer	
What the service does	The service will provide a risk classification of area of operation at the time of the expected drone mission. The use of the EO enabled SORA application allows automatic assignment of risk based on a standardised and repeatable methodology utilising a European wide dataset.
How does the service work	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.
Service Provider Satellite EO Requirements	
Spatial resolution	10-30m GSD for population density data.
Temporal resolution	The data should be updated every 28 days
Data type / Spectral range	SAR, VS stereo photogrammetry
Other (if applicable)	Ability to identify geographical features based on use and type such as: residential and commercial buildings, open spaces, green spaces, bodies of water, residential and industrial zones, transport and other critical infrastructure.

[12] Population data as indicated is expected to be required on a real time basis going forward.

	Population data at grid sizes of 10-30m to support overlay with geographic features.
Service Inputs	
Satellite data sources	Sentinel 1, and Sentinel 2, Copernicus Contributing Missions
Other data sources	Copernicus services products including CEMS Global Human Settlement layer, Urban Atlas, Corine Land Cover, other building and land use databases, mobile phone and network data

5.1.7.5 Geo-awareness System

The concept of geofencing is a solution originally proposed by the drone industry to ensure containment of the drone within a pre-defined area. This is now being applied more widely as a means of ensuring that drones:

- remain within a defined piece of airspace;
- are unable to operate when within a restricted piece of airspace (e.g. at or near and aerodrome).

The implemented geofence could be a simple cube or a more complex geometric shape which fits more with the airspace in which the drone is operating and could extend for tens of kilometres as a containment area – for example to support power line inspections. Geofencing is one of the main U-space tools. There is currently no standard on the performance expected from geofencing or whether this should vary depending on the airspace or traffic environment in which the drone is operating.

Regulations to be considered are EASA Implementing Regulation (EU) 2019/947, EASA Delegated Regulation (EU) 2019/945, U-space regulatory package (Regulations (EU) 2021/664, (EU) 2021/665 and (EU) 2021/666), NPA Notice of Proposed Amendment 2021-14; Development of acceptable means of compliance and guidance material to support the U-space regulation and EUROCAE ED-269 MOPS for Geofencing.

Within the regulation proposed by Opinion 01/2018 the concept of 'geo-fencing' is being replaced by 'geo-awareness' to better reflect the nature of the requirement already presented in NPA2017- 05. This differs in that it places the onus on the drone operator to be aware of airspace limitations and the 'geo-awareness' supports the drone operator in this role. The main difference between geofencing and geo-awareness is that while geofencing actively prevents drone from flying into restricted area, geo-awareness feeds information and warns pilot in case of restricted area proximity. The need to determine position and velocity as part of a 'geo-awareness' function are expected to lead to demands for performance that require robust integration of various navigation sensors. It is expected that EGNOS and Galileo (with user authentication available) will provide added value.

5.1.7.6 Geo-identification System

Geo-identification is a function enabling the "network remote identification" service as defined in U-space [U-space services IMR], i.e. the service allowing the identification of a drone operator from a drone in operation (in line with the global scope of registry (ICAO) & eIDAS - Regulation (EU) No 910/2014). The identification provides access to the information stored in the registry based on an identifier emitted electronically by the drone. The identification service includes the localisation of the drones (position and time stamp). For more detail, AMC/GM to Regulation (EU) 2021/664 on a regulatory framework for the U-space proposes acceptable means of compliance and guidance material related to article 9 covering the geo-awareness service.

The ability of the geo-identification system to provide the position information needed is dependent on the performance of the drone's geo-awareness system. Specifications for the geo-identification system are detailed within ASTM F3411-19 'Standard Specification for Remote ID and Tracking'.

5.2 Limitations of GNSS and EO

The GNSS limitations, as outlined in previous RUR, are linked to following key areas:

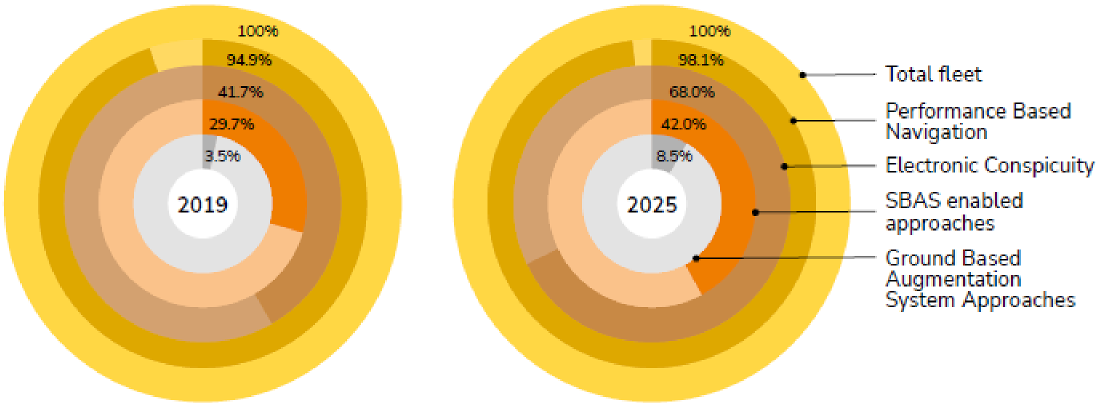
- **Power consumption** – Devices with high power consumption significantly decrease the range of drones and therefore put further challenges on operations' planning. The use of GNSS onboard drones should be optimised in terms of required precision and power consumption of the GNSS solution. Whilst the level of power consumption from the GNSS receiver is nevertheless significantly less than the power required for flight, depending on aircraft configuration there can be a link between aircraft control power and that utilised by the GNSS element.
- **Availability in challenging environments** – Drones flying in shielded areas eg urban canyons may experience a signal loss due to an obstructed view of satellites when flying at very low level. This results from poor geometry, signal blockage and / or multipath. Complementing GNSS with mobile networks like 4G or 5G is currently being explored as a mitigating solution as they are capable to provide sufficient user capacity and data exchange speeds. However, which this can be a factor of the environment, good airmanship and proper planning by the drone pilot would be expected to be the principle mitigation means as the drone should not be placed in an environment such as this.
- **Susceptibility to multipath** - Multipath effect is caused by a fact, that the signal arrives at the antenna by multiple paths, not just one direct path. This depends mostly on the surrounding environment of the antenna and the satellite geometry. Though there are many methods available to mitigate its impact, it still remains a major source of navigational errors, especially for satellites at low elevation angle. As previous, placing the drone in an environment in which there is likely to be multipath would be considered poor airmanship. Proper planning in advance of the flight would be expected to be the principle mitigation to avoiding this.
- **Jamming and spoofing of GNSS signals** – Jamming and spoofing of GNSS signal is a well-known issue for manned aviation. It can be caused unintentionally eg a lorry driver using jamming device to avoid highway tolling or as malicious act directed at aircraft or airport. If an aircraft on PBN approach detects GNSS failure it results in missed approach inferring further indirect costs for delay or even diversion. OS-NMA authentication service as another layer will help to ensure the signal integrity (in the case of spoofing).

The EO may present strong benefits to aviation and drones across multiple areas. However, with the current performance it only provides limited benefits. The shortcomings are mainly linked to:

- **Spatial resolution** – While EO system provides sufficient resolution for larger regions, more precision is required to support short drone flights (under 10km). Atmospheric and climate data currently provide a resolution of 1 degree (equal to 10km per data point) which is not sufficient to support drone flights taking into account most of the operators are not able to perform BVLOS flights longer than 10km.
- **Temporal resolution** (revisiting cycles) – While atmospheric data are captured with sufficient temporal resolution, land monitoring data are update every six years. Use cases using land use or even digital height of buildings for their mission planning or risk assessment might need much more frequent revisiting cycles.
- **Time to data upload** – Using climate data for post-mission assessments may require quicker data processing. In some cases, the process may take up to three months.

5.3 Prospective use of GNSS and EO

5.3.1 GNSS capabilities as a proportion of total civil aviation fleet



Due to the COVID-19 pandemic, air traffic dropped by more than 65% compared to 2019 and worldwide the aircraft fleet is expected to have shrunk by 15% in 2021 compared to 2020. Based on recent numbers published by EUROCONTROL, number of flights in Europe in July 2022 remains 13% down comparing to July 2019, with only business aviation reporting higher traffic than in July 2019. Some aircraft have been switched to transporting cargo in a desperate attempt to avoid bankruptcy by their operators. This impact is expected to last for some years with the net effect that there may be fewer shipments but an increase in GNSS capabilities within the fleet as older, non-upgraded aircraft will be retired to save costs. Due to the pandemic, major key players in the GNSS Chips & Modules market are witnessing fluctuation in demand, which is altering market trends, potential opportunities and consumer preferences. The figure above illustrates how this change is expected to impact fleet capabilities, especially in relation to Localiser Performance with Vertical Guidance (LPV) and SBAS which see a significant increase over the period in response to COVID-19.

GNSS is essential in aviation, and the technical developments are targeted to support specific problems. However, as the ubiquity of GNSS in aviation across Communication, Navigation and Surveillance (CNS) increases, so too does the requirement to improve across all areas. This section presents some of the more recent developments and focus areas from a CNS perspective.

5.3.2 GNSS capabilities as a proportion of the drone fleet

The use of GNSS receivers is core to the functionality of the drone. Without a GNSS receiver, the majority of drones would not be able to operate as only high end drones make use of the navigation aids also used by manned aviation. Given this functional requirement all drones have as a minimum GPS reception.

The use of mass market chipsets within drone navigation units does however afford a faster adoption of new capabilities than within manned aviation. For example, the use of Galileo signals by the drone community is accelerating and the use of the Galileo High Accuracy Service and Open Service Network Message Authentication are expected to accelerate demand for these more advanced chipsets.

5.3.3 Dual Frequency Multi-Constellation progress in navigation

The GBAS Approach Service Type D (GAST D), which allows Cat-III precision approaches to less than 100ft decision height, is fully standardised and validated for GPS L1 signals. Furthermore, a dedicated ICAO ad-hoc group is defining the future DFMC GBAS concept, which takes benefit from dual-frequency signals and multiple constellations such as GPS and Galileo, in order to enhance the robustness of GBAS approach service and even explore new GBAS services. The ICAO DFMC GBAS Concept Paper is expected by the end of 2022.

As of today, it is expected that the GNSS Manual (ICAO Doc 9849) will update to accommodate GAST-F in 2024 and that ICAO Standards And Recommended Practices for GBAS GAST F would be written around 2030.

GBAS GAST F or GBAS DFMC is seen as the future of GBAS and will enable greater robustness against ionosphere disturbances as well as against Radio Frequency Interference (RFI), as it will work with two frequencies and offer reversion modes. This version of GBAS is also the one that has been indicated by the European Commission as supporting the CAT III deployment incorporating also the use of Galileo through the DFMC capabilities.

The ICAO Navigation System Panel (NSP) approved new Standards and Recommended Practices for the use of EGNOS and Galileo in November 2020. This is an important milestone in SBAS DFMC Standardisation for EGNOS and Galileo but also for European aviation. Indeed, DFMC SBAS opens up new possibilities for air transportation but also more resilience for users against RFI.

In the U-space and UAM area EUSPA has supported numerous trials of drones equipped with EGNOS as well as Galileo through its EGNSS4RPAS, GAUSS, REALITY and other projects. Manned aircraft are expected to be outnumbered by all kinds of drones, employed for everything from weather and environmental monitoring to personalised delivery services. The traditional person-based air traffic control model will need to evolve to accommodate such a shift, based on automated monitoring, traffic management and collision avoidance. In Europe, this highly automated version of air traffic control is termed U-space.

GNSS performance requirements supporting drone operations are being developed globally. Eurocae WG-105 within Europe is developing Minimum Operational Performance Specifications (MOPS) for Detect and Avoid (DAA) in Very Low Level (VLL) airspace.

SBAS's safety-of-life service is essential to making this happen, moving from today's situation — where drones are limited to specific air corridors and line-of-sight operations — to let them roam freely but safely in busy airspace and built-up areas.

5.3.4 Electronic Conspicuity has an important role in surveillance

Electronic Conspicuity is an umbrella term for technologies that provide self-reporting of position from an aircraft to other aviation actors. Electronic Conspicuity 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). 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 U-space and manned aviation, but GNSS positioning 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) (1090MHz and UAT), Flight Alarm (FLARM), LTE/5G, 802.11 and the new ADS Light operating on the SRD860 frequency band raising questions on interoperability.

ADS-B implementation, both airborne equipage and ground infrastructure, continues toward full integration in the ATM environment. Since December 2020, new aircraft are required to be ADS-B equipped with a transition period till June 2023 for retro-fit. At European level, users would like to improve cost-efficiency through rationalisation of the surveillance infrastructure, including the decommissioning of CNS facilities and to improve the aviation spectrum efficiency. GNSS will become more critical as this step progresses.

Final version of the EASA technical specification for transmissions using SRD860 frequency band is expected to be ready in 2022. Possibility of usage of the mobile telephony depends on coordination amongst European telecommunication regulators. Results of the EASA feasibility study show, that it would be possible to complete these activities in 2022.

5.3.5 Increased focus on monitoring aviation emissions

There is an increasing push for aviation to become more environmentally friendly. Whilst particular complaints in the vicinity of aerodromes might focus on noise, it is the emissions and the level of fuel burn that are predominantly being addressed, particularly at European level (based on [RD27]) where commercial airlines are subject to the emissions charging scheme. Airport expansion plans in recent years have also been subject to restrictions on movement or night curfews as pressure builds on limiting the impacts of aviation.

Drones are one area where there is significant development and interest due to the electrification of flight and the consequent ‘zero’ emissions in comparison to traditional aviation. EO can provide a monitoring source for the effects of aircraft emissions at different flight levels, or in areas in which air pollution is at or approaching legal limits.

Indeed, Copernicus Atmosphere Monitoring Service (CAMS) provides consistent and quality-controlled information related to air pollution and health, solar energy, greenhouse gases and climate forcing everywhere in the world. The three core product areas of CAMS are products to monitor the current situation, provide forecasts for the next few days and tools to explore the data further and support the user in using the data. Specific examples of the use of CAMS include estimating global fire emissions & long-range transport of Canadian wildfire emissions to Europe or forecasts of aerosol in the North Atlantic region that experiences long-range transport of pollution from multiple sources and source regions. Data used for near real-time analyses, forecasts and reanalyses of a wide range of atmospheric pollutants at the global and European regional scale are available on Atmosphere Data Store (ADS). It is planned that CAMS will consolidate all atmospheric data and information about the climate into Climate and Atmosphere Datastore (CADS).

Notably, CAMS could be used to help the Volcanic Ash Advisory Centres (VAAC) forecast volcanic ash clouds dispersion trajectories. This would enhance flight safety in case an aircraft flies in the vicinity of volcanic ash. In addition, the CAMS products include analyses/re-analyses of greenhouse gases (carbon dioxide, methane, and nitrous oxide), having the ability to monitor these compositions in a number of layers at different altitudes. Therefore, the European Commission has already completed some studies [RD24], [RD25] into the feasibility of the CAMS system being used to monitor air pollution at different altitudes. This would be of great interest to better understand the impact of aviation on the environment.

An example of a practical application of CAMS data is Assist [13] (Aircraft Support & Maintenance Services) which uses atmospheric datasets obtained from CAMS to compute three key indicators of atmospheric conditions: abrasion, clogging and corrosion. With these data, Assist can provide indicators to help airlines and manufacturers to save costs thanks to precise monitoring of aeroplanes’ exposure to harmful particles. This allows airlines to build their maintenance plans around the expected damage.

The Copernicus Land Monitoring Service (CLMS) provides geographical information on land cover and its changes, land use, vegetation state, water cycle and Earth's surface energy variables to a broad range of users in Europe and across the World in the field of environmental terrestrial applications. CLMS is divided into four main components: Global, Pan-European, Local and Imagery and reference data. CLMS might also enable the monitoring of precise localisation and the size of terrain and obstacles that surround an airport. This is of particular relevance to procedure designers when designing and publishing specific procedures for the airport, and to the general integrity and safety of the airport. Both these factors are essential enablers for PBN and the exploitation of GNSS for navigation purposes.

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[13] https://atmosphere.copernicus.eu/cams-data-assist-airline-maintenance

Given the long lifecycle of airport development projects in general, the use of EO data would allow easy access to reliable, up-to-date information throughout a project lifecycle thanks to high-frequency revisits. With the relevance already established for applications linked to volcanic ash evolution monitoring, infrastructure monitoring, orographic and aeronautical cartography data the use of applications related to air quality monitoring is expected to remain a hot topic since meeting aviation's climate goals cannot be achieved without technological and digital innovation. To tackle this area, Sentinel 5 has features to allow monitoring of concentration of gas such as ozone (O_3) profile, columns of sulphur dioxide (SO_2), nitrogen dioxide (NO_2), carbon monoxide (CO) and dioxide (CO_2), methane (CH_4) and many others.

5.3.6 Sustainable and smart mobility - Green airports

Mobility within Aviation targets the application of innovative digital and satellite-based solutions, including new tools and traffic optimisation mechanisms for multimodal access, passenger and freight flows into, out of and between airports, facilitating airport access and reducing traffic to/ from cities or other nodes.

As transport systems become more integrated, aviation is expected to increasingly interface with other public transport links. Links with GNSS and EO are expected to become more critical. This is not just through the ambitions of the Green Deal, but also linked to the exploitation of increased automation and PBN procedures to improve the efficiency of aircraft operations arriving and departing at each aerodrome. Optimising flows with the better sharing of information between airports and airspace users is a focus of R&D within SESAR.

5.3.7 The importance of timing on optimising operations

The exploitation of GNSS timing as a reference source for timing and synchronisation processes is fundamental for critical infrastructure like telecommunication networks, energy distribution grids, financial markets and commercial aviation systems and networks. In the case of aviation, optimising the traffic flows also comes down to timing, as does synchronisation of information about flights. This information can be shared between users to cut down on flight times and reduce delays, diminishing the environmental impact. GNSS time is used for:

- positioning and timing for on-board navigation purposes;
- timing and synchronisation for datalink communications (on-board to ground and vice-versa); and
- timing and synchronisation for ground systems used for Air Traffic Control (ATC), communication networks, airspace surveillance, and airport logistics coordination.

5.3.8 Updated Aviation and Drones applications

Previous market reports provided data broken down by airspace user group. In this edition, data is presented by GNSS application. These applications are used by different airspace user groups in both manned aviation and drones. Definitions of each application are provided in Annex 3. Not all applications appear in the charts:

- ATM systems timing and Infrastructure timing are not yet quantified.
- GADSS Aircraft Tracking uses either the Performance Based Navigation system and on-board satellite communications, or can be collected by satellites that detect the aircraft with MTOM of more than 27 tonnes according to [RD23].
- Earth Observation applications are not yet quantified.

6 USER REQUIREMENTS SPECIFICATION

The chapter provides a synthesis of the user requirements described in section 5.1 respectively on GNSS in section 6.1 and on EO in section 6.2. The content of this section is updated, completed and expanded by EUSPA based on the results of further investigations discussed and validated in the frame of the UCP.

6.1 Synthesis of GNSS User Requirements

6.1.1 Navigation

6.1.1.1 Resilience requirements for a total PBN environment

Table 4: GNSS resilience requirements for a total PBN environment

Id	Description	Type	Source
EUSPA-GN-UR-AVI-2110	The PBN solution shall enable a minimum horizontal accuracy (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 (Table 3.7.2.4-1) ICAO PBN Manual RTCA and EUROCAE GNSS receiver MOPS (EU) 2018/1048 Airspace usage requirements and PBN operating procedures (EU) 2021/116 Establishment of Common Project One
EUSPA-GN-UR-AVI-2120	The PBN solution shall enable a minimum vertical accuracy (95%) of 6 to 4 m.	Performance (Vertical Accuracy)	
EUSPA-GN-UR-AVI-2130	The PBN solution shall provide an alert within 10 sec 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 (Horizontal Alert Limit and Time to Alert)	
EUSPA-GN-UR-AVI-2140	The PBN solution shall provide an alert within 10 sec if the Vertical Protection Level computed by the system exceeds the Vertical Alert Limit of 50 m.	Performance (Vertical Alert Limit and Time to Alert)	
EUSPA-GN-UR-AVI-2150	The GNSS signal in space[14] shall ensure an integrity performance of 1-1x10-7 per hour or better.	Performance (Integrity)	
EUSPA-GN-UR-AVI-2160	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-2170	The GNSS signal in space shall provide a continuity performance of 1-1x10-4 to 1-1x10-8/h or better.	Performance (Continuity)	

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

Id	Description	Type	Source
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

6.1.1.2 PBN Applications

6.1.1.2.1 RNP / RNAV for En-Route and Terminal operations

Table 5: 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%) of 2 NM. (NSE 2σ)	Performance (Horizontal Accuracy)	ICAO Annex 10 ICAO PBN Manual RTCA and EUROCAE GNSS receiver MOPS
EUSPA-GN-UR-AVI-0020	The PBN solution shall provide an alert within 5mn 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 (Horizontal Alert Limit and Time to Alert)	
EUSPA-GN-UR-AVI-0030	The GNSS signal in space shall ensure an Integrity performance of 1-1x10-7 per hour or better.	Performance (Integrity)	
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 1-1x10-4 to 1-1x10-8 per hour or better.	Performance (continuity)	

Table 6: 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%) of 0.4 NM	Performance (Horizontal Accuracy)	ICAO Annex 10 ICAO PBN Manual RTCA and EUROCAE GNSS receiver MOPS
EUSPA-GN-UR-AVI-0070	The PBN solution shall provide an alert within 15 sec if the Horizontal Protection Level computed by the system exceeds the Horizontal Alert Limit of 1 NM.	Performance (Horizontal Alert Limit and Time to Alert)	
EUSPA-GN-UR-AVI-0080	The GNSS signal in space shall ensure an integrity performance of 1-1x10-7 per hour or better.	Performance (Integrity)	
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)	
EUSPA-GN-UR-AVI-0100	The GNSS signal in space shall provide a continuity performance of 1-1x10-4 to 1-1x10-8/h or better.	Performance (continuity)	

Table 7: 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 ICAO PBN Manual RTCA and EUROCAE GNSS receiver MOPS
EUSPA-GN-UR-AVI-0120	The PBN solution shall provide an alert within 10 sec 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 (Horizontal Alert Limit and Time to Alert)	
EUSPA-GN-UR-AVI-0130	The GNSS signal in space shall ensure an integrity performance of 1-1x10-7 per hour or better.	Performance (Integrity)	
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)	
EUSPA-GN-UR-AVI-0150	The GNSS signal in space shall provide a continuity performance of 1-1x10-4 to 1-1x10-8/h or better	Performance (continuity)	

6.1.1.2.2 RNP APCH (LNAV)

Table 8: Requirements for RNP APCH (LNAV) 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 ICAO PBN Manual RTCA and EUROCAE GNSS receiver MOPS
EUSPA-GN-UR-AVI-0170	The PBN solution shall provide an alert within 10 sec if the Horizontal Protection Level computed by the system exceeds the Horizontal Alert Limit of 0.3 NM	Performance (Horizontal Alert Limit and Time to Alert)	
EUSPA-GN-UR-AVI-0180	The GNSS signal in space shall ensure an Integrity performance of 1-1x10-7 per hour or better.	Performance (Integrity)	
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 1-1x10-4 to 1-1x10-8/h or better	Performance (continuity)	

6.1.1.2.3 RNP APCH (LNAV/VNAV)

Table 9: Requirements for RNP APCH (LNAV/VNAV) 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
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 40m.	Performance (Horizontal Alert Limit and Time to Alert)	ICAO PBN Manual RTCA and EUROCAE GNSS receiver MOPS
EUSPA-GN-UR-AVI-0250	The GNSS signal in space shall ensure an Integrity performance of 1-1x10-7/h or better.	Performance (Integrity risk)	
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 1-1x10-4/h to 1 - 1x10-8/h 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)	

6.1.1.2.4 RNP APCH LPV

Table 10: Requirements for RNP APCH LPV200 operations – GNSS

Id	Description	Type	Source
EUSPA-GN-UR-AVI-9991	The PBN solution shall enable a minimum horizontal accuracy (HNSE, 95%) of 16 m.	Performance (Horizontal Accuracy)	ICAO Annex 10
EUSPA-GN-UR-AVI-9992	The PBN solution shall enable a minimum vertical accuracy (VNSE, 95%) of 4 m.	Performance (Vertical Accuracy)	ICAO Annex 10, Table 3.7.2.4-1 I
EUSPA-GN-UR-AVI-9993	The PBN solution shall provide an alert within 6 s if the HPL computed by the system exceeds the HAL of 40 m.	Performance (Horizontal Alarm Limit and Time to Alert)	ICAO PBN Manual
EUSPA-GN-UR-AVI-9994	The PBN solution shall provide an alert within 6 s if the VPL computed by the system exceeds the VAL of 35 m.	Performance (Vertical Alarm Limit and Time to Alert)	RTCA and EUROCAE GNSS receiver MOPS
EUSPA-GN-UR-AVI-9995	The GNSS signal in space shall ensure an Integrity performance of 1 - 2x10-7 in any approach (150 s) or better.	Performance (Integrity)	
EUSPA-GN-UR-AVI-9996	The GNSS signal in space shall provide an availability of 0.99 to 0.99999 of the time.	Performance (availability)	
EUSPA-GN-UR-AVI-9997	The GNSS signal in space shall provide a continuity performance of 1 - 8x10-6 per 15 s or better.	Performance (continuity)	

Table 11: Requirements for RNP APCH LPV operations – GNSS

Id	Description	Type	Source
EUSPA-GN-UR-AVI-0280	The PBN solution shall enable a minimum horizontal accuracy (95%) of 16 m.	Performance (Horizontal Accuracy)	ICAO Annex 10 ICAO PBN Manual RTCA and EUROCAE GNSS receiver MOPS
EUSPA-GN-UR-AVI-0290	The PBN solution shall enable a minimum vertical accuracy (95%) of 20 m.	Performance (Vertical Accuracy)	
EUSPA-GN-UR-AVI-0300	The PBN solution shall provide an alert within 10 sec if the Horizontal Protection Level computed by the system exceeds the Horizontal Alert Limit of 40 m.	Performance (Horizontal Alert Limit and Time to Alert)	
EUSPA-GN-UR-AVI-0310	The PBN solution shall provide an alert within 10 sec if the Vertical Protection Level computed by the system exceeds the Vertical Alert Limit of 50 m.	Performance (Vertical Alert Limit and Time to Alert)	
EUSPA-GN-UR-AVI-0320	The GNSS signal in space shall ensure an Integrity performance of 1-2x10-7 in any approach or better.	Performance (Integrity risk)	
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 1-8x10-6 per 15 sec or better.	Performance (continuity)	

6.1.1.2.5 RNP AR APCH operations

Table 12: Requirements for RNP AR APCH 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. **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.**	Performance (Horizontal Accuracy)	ICAO Annex 10 ICAO Annex 10, Table 3.7.2.4-1 I ICAO PBN Manual RTCA and EUROCAE GNSS receiver MOPS
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)	
EUSPA-GN-UR-AVI-0460	The GNSS signal in space shall ensure an Integrity performance of 1 - 2x10-7 in any approach (150 s) or better.	Performance (Integrity)	
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)	
EUSPA-GN-UR-AVI-0480	The GNSS signal in space shall provide a continuity performance of 1-1x10-4 1 to 1 - 1x10-8/h or better.	Performance (continuity)	

6.1.1.3 GBAS CAT I ◑

Table 13: 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 ICAO Annex 10, Table 3.7.2.4-1 I ICAO PBN Manual RTCA and EUROCAE GNSS receiver MOPS
EUSPA-GN-UR-AVI-0500	The nav. solution shall enable a minimum vertical accuracy (VNSE, 95%) of 4 m.	Performance (Vertical Accuracy)	
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)	
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)	
EUSPA-GN-UR-AVI-0530	The nav. solution shall ensure an Integrity performance of 1 - 2x10-7 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 - 8x10-6 per 15 s or better.	Performance (continuity)	

6.1.1.4 VFR complement ◑

Table 14: 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, Chapter 3, 3.7.2.4
EUSPA-GN-UR-AVI-2220	The system shall provide an integrity of 1 – 1x10-7/h or higher	Performance (Integrity)	
EUSPA-GN-UR-AVI-2230	The system shall provide time-to-alert of 5min or lower	Performance (Time to alert)	
EUSPA-GN-UR-AVI-2240	The system shall provide a continuity of 1 – 1x10-4/h or better	Performance (Continuity)	
EUSPA-GN-UR-AVI-2250	The system shall provide availability of 0.99 or better	Performance (Availability)	

6.1.2 Surveillance

6.1.2.1 eConspicuity (e.g. ADS-B)

6.1.2.1.1 ADS-B Airport (APT)

Table 15: Requirements for ADS-B Airport (APT) – GNSS

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
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 1x10-4/h or lower.	Performance (Integrity)	
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/h or better	Performance (Continuity)	

6.1.2.1.2 ADS-B ATSA - Airborne Situational Awareness (AIRB)

Table 16: Requirements for ADS-B ATSA – Airborne Situational Awareness (AIRB) – GNSS

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)	

6.1.2.1.3 ADS-B ATSA – Visual Separation in Approach

Table 17: Requirements for ADS-B ATSA – Visual Separation in Approach – GNSS

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
EUSPA-GN-UR-AVI-0939	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/h or lower.	Performance (Integrity)	
EUSPA-GN-UR-AVI-0950	The system shall provide a velocity accuracy of 10 m/s.	Performance (Velocity)	

6.1.2.1.4 ADS-B ATSA SURF – Surface Traffic Awareness

Table 18: Requirements for ADS-B ATSA SURF – Surface traffic Awareness – GNSS

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/h or lower.	Performance (Integrity)	

6.1.2.1.5 ADS-B ITP (In Trail Procedure)

Table 19: Requirements for ADS-B ITP (In Trail Procedure) – GNSS

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 1x10-5/h or lower.	Performance (Integrity)	
EUSPA-GN-UR-AVI-0990	The system shall provide a velocity accuracy of 10 m/s.	Performance (Velocity)	

6.1.2.1.6 ADS-B Non Radar Airspace (NRA 3 NM separation)

Table 20: Requirements for ADS-B Non Radar Airspace (NRA 3 NM separation) – GNSS

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 EUROCAE ED 126 and ED 102A RTCA DO 303 and DO 260B
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 1x10-5/h or lower.	Performance (Integrity)	
EUSPA-GN-UR-AVI-0690	The system shall provide a continuity of 1 - 2x10-4/h or better.	Performance (Continuity)	

6.1.2.1.7 ADS-B Non Radar Airspace (NRA 5 NM separation)

Table 21: Requirements for ADS-B Non Radar Airspace (NRA 5 NM separation) – GNSS

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 EASA CS-ACNS FAA AC 20-165A EUROCAE ED 126 RTCA DO 303
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 1x10-5/h or lower.	Performance (Integrity)	
EUSPA-GN-UR-AVI-0650	The system shall provide a continuity of 1 - 2x10-4/h or better.	Performance (Continuity)	

6.1.2.1.8 ADS-B Radar Airspace (Independent and parallel Approach)

Table 22: Requirements for ADS-B Radar Airspace (Independent and parallel Approach) – GNSS

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
EUSPA-GN-UR-AVI-080	The system shall implement a Horizontal Alarm Limit of 0.2 NM.	Performance (Integrity)	
EUSPA-GN-UR-AVI-0860	The system shall provide an integrity risk (SDA) of 1x10-5/h or lower.	Performance (Integrity)	

6.1.2.1.9 ADS-B Radar Airspace (RAD < 2.5 NM separation)

Table 23: Requirements for ADS-B Radar Airspace (RAD < 2.5 NM separation) – GNSS

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
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 1x10-5/h or lower.	Performance (Integrity)	
EUSPA-GN-UR-AVI-0830	The system shall provide a Source Integrity Level (SIL) of 1x10-7/h or lower.	Performance (Integrity)	

6.1.2.1.10 ADS-B Radar Airspace (RAD 3 NM separation)

Table 24: Requirements for ADS-B Radar Airspace (RAD 3 NM separation) – GNSS

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 FAA AC 20-165A EUROCAE ED 126 and ED 102A RTCA DO 303 and DO 260B
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 1x10-5/h or lower.	Performance (Integrity)	
EUSPA-GN-UR-AVI-0780	The system shall provide a Source Integrity Level (SIL) of 1x10-7/h or lower.	Performance (Integrity)	
EUSPA-GN-UR-AVI-0790	The system shall provide a velocity accuracy of 10 m/s	Performance (Velocity accuracy)	

6.1.2.1.11 ADS-B Radar Airspace (RAD 5 NM separation)

Table 25: Requirements for ADS-B Radar Airspace (RAD 5 NM separation) – GNSS

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 FAA AC 20-165A EUROCAE ED 126 and ED 102A RTCA DO 303 and DO 260B
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 1x10-5/h or lower.	Performance (Integrity)	
EUSPA-GN-UR-AVI-0730	The system shall provide a Source Integrity Level (SIL) of 1x10-7/h or lower.	Performance (Integrity)	
EUSPA-GN-UR-AVI-0740	The system shall provide a velocity accuracy of 10 m/s	Performance (Velocity accuracy)	

6.1.2.2 Search and Rescue (GADSS)

Table 26: 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
EUSPA-GN-UR-AVI-1110	C/S Second Generation 406Mhz distress beacons ELT (DT) • 2D: accuracy <= 30 m, (95%) • Altitude, accuracy <=50 m (95%)	Performance (accuracy)	C/S T.018, Issue 1– Revision 10, Nov 2022
EUSPA-GN-UR-AVI-1120	Galileo RLS enabling ELT remote activation from the ground offering the possibility to localize in-flight a non-cooperative aircraft	Functionality	EUROCAE MASPS for Aircraft ELT RLS- work in progress (KOM held in April 2018)
EUSPA-GN-UR-AVI-1130	For ELT(DT)s the value of the repetition period shall be: • 5 seconds + 0.0 / - 0.2 seconds during the first 120 seconds after beacon activation; • 10 seconds + 0.0 / - 0.2 seconds between 120 seconds and 300 seconds after beacon activation; and • after the first 300 seconds after beacon activation until the beacon is deactivated, the period shall be randomised around a mean value of 28.5 seconds, so that time intervals between transmissions are randomly distributed on the interval 27.0 to 30.0 seconds.	Performance	C/S T.001, Issue 4 – Revision 10, Nov 2022

6.1.3 Drones

6.1.3.1 Positioning for non-navigation functions

Table 27: Requirements for Drones: Positioning for non-navigation functions - GNSS

Id	Description	Type	Source
EUSPA-GN-UR-AVI-2310	The system shall provide a minimum Horizontal Navigation System Error [HNSE] (95%) of 1-3m	Performance (Horizontal Accuracy)	Report on Aviation User Needs and Requirements EUSPA-MKD-AV-UREQ-250287, Annex 7: Updates following the User Consultation Platform 2020 SA-MKD-AV-MOM-246179
EUSPA-GN-UR-AVI-2320	The system shall provide a minimum Vertical Navigation System Error [VNSE] (95%) of 1.5 – 4.5m	Performance (Vertical Accuracy)	
EUSPA-GN-UR-AVI-2330	The system shall achieve a minimum continuity of TBC	Performance (Continuity)	
EUSPA-GN-UR-AVI-2340	The system shall provide a minimum Integrity performance of 1-1E-4 per flight	Performance (Integrity)	

Id	Description	Type	Source
EUSPA-GN-UR-AVI-2350	The system shall provide a minimum Time to Alert (TTA) of 3 – 4s	Performance (TTA)	
EUSPA-GN-UR-AVI-2360	The system shall provide a minimum Horizontal Alert Limit (HAL) of 3 – 10m	Performance (Integrity	
EUSPA-GN-UR-AVI-2370	The system shall provide a minimum Vertical Alert Limit (VAL) of 4.5 – 15m	Performance (Integrity)	
EUSPA-GN-UR-AVI-2380	The system shall provide a minimum Time to First Fix (TTFF) of 30s	Performance (Signal Acquisition)	
EUSPA-GN-UR-AVI-2390	The system shall provide a minimum position update rate of 0.1s	Performance (Update rate)	

6.1.3.2 PBN applications

Table 28: Requirements for Drones: PBN applications - GNSS

Id	Description	Type	Source
EUSPA-GN-UR-AVI-2410	The Navigation system shall provide a minimum Horizontal navigation accuracy per the following: - SAIL 3: 3-8m - SAIL 4: 3-8m	Performance (Horizontal Accuracy)	EUSPA Analysis
EUSPA-GN-UR-AVI-2420	The Navigation system shall provide a minimum Vertical navigation accuracy per the following: - SAIL 3: 4-13m - SAIL 4: 4-13m	Performance (Vertical Accuracy)	
EUSPA-GN-UR-AVI-2430	The Navigation system shall have a minimum integrity performance of 1-1x10-4/h or better	Performance (Integrity)	
EUSPA-GN-UR-AVI-2440	The Navigation system shall have a minimum Time to Alert in the event of integrity failure of 1-3s	Performance (Time to Alert)	
EUSPA-GN-UR-AVI-2450	The Navigation system shall have a minimum alert limit depending on the application as per the following: - HAL: o 25-27m (fixed wing) o 10-14m (rotary) - VAL: o 12-22 (fixed wing) o 7-23 (rotary)	Performance (Alert limits)	
EUSPA-GN-UR-AVI-2460	The Navigation system shall have a minimum continuity performance of 1-1x10-4/h or better	Performance (Continuity)	
EUSPA-GN-UR-AVI-2470	The Navigation system shall provide an availability of 99.99% of the time.	Performance (Availability)	

6.1.3.3 Geo-awareness System

Table 29: Requirements for Drones: Geo-awareness System – GNSS

Id	Description	Type	Source
EUSPA-GN-UR-AVI-2510	The system shall provide a minimum Horizontal Navigation System Error [HNSE] (95%) of 1-3m	Performance (Horizontal Accuracy)	Report on Aviation User Needs and Requirements EUSPA-MKD-AV-UREQ-250287, Annex 7: Updates following the User Consultation Platform 2020 SA-MKD-AV-MOM-246179
EUSPA-GN-UR-AVI-2520	The system shall provide a minimum Vertical Navigation System Error [VNSE] (95%) of 1.5 – 4.5m	Performance (Vertical Accuracy)	
EUSPA-GN-UR-AVI-2530	The system shall achieve a minimum continuity of 1-1x10-4/h or better	Performance (Continuity)	
EUSPA-GN-UR-AVI-2540	The system shall provide a minimum Integrity performance of 1-1E-4 per flight	Performance (Integrity)	
EUSPA-GN-UR-AVI-2550	The system shall provide a minimum Time to Alert (TTA) of 3 – 4s	Performance (TTA)	
EUSPA-GN-UR-AVI-2560	The system shall provide a minimum Horizontal Alert Limit (HAL) of 3 – 10m	Performance (Integrity	
EUSPA-GN-UR-AVI-2570	The system shall provide a minimum Vertical Alert Limit (VAL) of 4.5 – 15m	Performance (Integrity)	
EUSPA-GN-UR-AVI-2580	The system shall provide a minimum Time to First Fix (TTFF) of 30s	Performance (Signal Acquisition)	
EUSPA-GN-UR-AVI-2590	The system shall provide a minimum position update rate of 0.1s	Performance (Update rate)	

6.2 Synthesis of EO User Requirements

6.2.1 Particulate Matter Monitoring for flight planning

Table 30: EO for PM monitoring for flight planning

ID	Application	Users	User Needs					Service Provider Offer		Service Provider Satellite EO Requirements				Service Inputs	
			Operational Scenario	Size of Area of Interest	Scale	Frequency of Information	Other (if applicable)	What the service does	How does the service work	Spatial Resolution	Temporal Resolution	Data Type / Spectral Range	Other (if applicable)	Satellite Data Sources	Other Data Sources
EUSPA-EO-UR-AVI-0001	Particulate Matter Monitoring for flight planning	World aviation Forecast centres, Volcanic Ash Advisory Centres, Flight planning software providers, Air Navigation Service Providers, Airlines and Business aviation users which might be operating on international flights	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. Examples include: - 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.	Global	1:250000 on the basis of the highest resolution VFR charts.	Every three hours to support flight planning activities. Can be supported by modelling forecasts with validation based on actual historical measurements.	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 to achieve the regulatory minimum. Advantage should be taken of any additional information that can extracted and extend the information provided beyond that required as a regulatory minimum (c.f. the IWXXM[15]). All charting products should support more granular representation than is currently provided.	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.	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).	Depending on the application. 10NM lateral grids for ash and sand and other non-water based particulates. Vertically, 1000ft 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	Other requirements as per ICAO Annex 3 (e.g. time stamped in UTC)	Sentinel-3, Sentinel-5P and weather observation satellites	Volcano data; satellite-based, ground-based and aircraft observations; weather forecast models and dispersion models

[15] http://schemas.wmo.int/iwxxm/2023-1RC1/

6.2.2 SORA ground risk assessment

Table 31: EO for SORA ground risk assessment

ID	Application	Users	User Needs					Service Provider Offer		Service Provider Satellite EO Requirements				Service Inputs	
			Operational Scenario	Size of Area of Interest	Scale	Frequency of Information	Other (if applicable)	What the service does	How does the service work	Spatial Resolution	Temporal Resolution	Data Type / Spectral Range	Other (if applicable)	Satellite Data Sources	Other Data Sources
EUSPA-EO-UR-AVI-0002	SORA ground risk assessment	Air Navigation Service Providers / U-space Service Providers, Drone operators, Regulators	Operations of specific category drones are required to undertake a Specific Operations Risk Assessment (SORA) (v2.0) which requires the drone operator to assess the risks of the operation and understand the areas impacted during the mission (e.g. risk of physical harm to uninvolved people and critical infrastructure). This results in different operators undertaking the SORA utilising different approaches.	Europe	Depending on the operation but at a level of 1:25000 or lower	Updated every 28 days (Population data as indicated is expected to be required on a real time basis going forward)	-	The service will provide a risk classification of area of operation at the time of the expected drone mission. The use of the EO enabled SORA application allows automatic assignment of risk based on a standardised and repeatable methodology utilising a European wide dataset.	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.	10-30m GSD for population density data	All datasets within the service should be updated every 28 days	SAR, VS stereo photogrammetry	Ability to identify geographical features based on use and type such as: residential and commercial buildings, open spaces, green spaces, bodies of water, residential and industrial zones, transport and other critical infrastructure. Population data at grid sizes of 10-30m to support overlay with geographic features.	Sentinel 1, and Sentinel 2, Copernicus Contributing Missions	Copernicus services products including CEMS Global Human Settlement layer, Urban Atlas, Corine Land Cover, other building and land use databases, mobile phone and network data

7 ANNEXES

A.1 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 aviation and drones 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: takes into account the receiver performance and the user's environment. Values vary greatly according to the specific use cases and services used.

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

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

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).

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).

A.2 Definition of key EO performance parameters

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

Spatial resolution relates to the level of detail that can be retrieved from a scene. In the case of a satellite image, which consists of an array of pixels, it corresponds to the smallest feature that can be detected on the image. A common way of characterising the spatial resolution is to use the Ground Sample Distance (GSD) which corresponds to the distance measured on the ground between the centres of two adjacent pixels. Thus, a spatial resolution of 1 meter means that each pixel represents a 1 by 1 meter area on the ground.

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).

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).

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.3 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
AEA	Association of European Airlines
AFCAC	African Civil Aviation Commission
AIR OPS	A short cut designation of (EU) No 965/2012
AMC	Acceptable Means of Compliance
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
ARINC	Aeronautical Radio, Incorporated
A-RNP	Advanced-RNP
ARNS	Aviation Radio Navigation Service
ARP	Aerospace Recommended Practice
ASA	Aircraft Surveillance Applications
ASECNA	Agency for Aerial Navigation Safety in Africa and Madagascar
A-SMGCS	Advanced-Surface Movement Guidance and Control System
ATC	Air Traffic Control
ATM	Air Traffic Management
ATS	Air Traffic System
ATSA	Air Traffic Situational Awareness
AWO	All Weather Operations
BVLOS	Beyond Visual Line of Sight
CAGR	Compound Annual Growth Rate
CAMS	Copernicus Atmosphere Monitoring Service
CANSO	Civil Air Navigation Services Organisation
CAT	Commercial Air Transport
CAT (I/II/II)	Category of precision approach operation
CLMS	Copernicus Land Monitoring Service
CNS	Communication, Navigation and Surveillance

Acronym	Definition
COPUOS	Committee on the Peaceful Uses of Outer Space
COSPAS-SARSAT	Russian acronym - Search and Rescue Satellite-Aided Tracking
CSD	UN Commission on Sustainable Development
CS-ETSO	Certification Specifications - European Technical Standard Orders
CTR	Control Zone
CVR	Cockpit Voice Recorder
DFMC	Dual Frequency Multi-Constellation
DME	Distance Measuring Equipment
EARSC	European Association of Remote Sensing Companies
EAS	Europe Air Sports
EASA	European Union Aviation Safety Agency
EBAA	European Business Aviation Association
EC	European Commission
ECAC	European Civil Aviation Conference
EFTA	European Free Trade Association
EGNOS	European Geostationary Navigation Overlay Service
EGNSS	European Global Navigation Satellite System
EGPWS	Enhanced Ground Proximity Warning System
EHA	European Helicopter Association
ELT	Emergency Locator Transmitter
EO	Earth Observation
ERAA	European Regions Airline Association
EUROCAE	European Organisation for Civil Aviation Equipment
EUSPA	European Union Agency for the Space Programme
EVS	Enhanced Vision System
FDMA	Frequency Division Multiple Access
FDR	Flight Data Recorder
FTE	Flight Technical Error
GA	General Aviation
GADSS	Global Aeronautical Distress and Safety System
GAGAN	GPS Aided GEO Augmented Navigation
GBAS	Ground Based Augmentation System
GEO	Group on Earth Observations
GLONASS	Global Orbiting Navigational Satellite System
GM	Guidance Material

Acronym	Definition
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
H-ARAIM	Horizontal ARAIM
HAS	High Accuracy Service
HEMS	Helicopter Emergency Medical Services
HLSC	High-Level Safety Conference
IADC	Inter-Agency Space Debris Coordination Committee
IAOPA	International Aircraft Owners and Pilots Association
IATA	International Air Transport Association
ICAO	International Civil Aviation Organisation
IEEE	Institute of Electrical and Electronics Engineers
IFR	Instrument Flight Rules
ILS	Instrument Landing System
ISO	International Standards Organization
ITU	International Telecommunication Union
ITP	In- Trail Procedure (ADS-B application)
JARUS	Joint Authorities for Rulemaking on Unmanned Systems
LAAS	Local Area Augmentation System
LACAC	Latin American Civil Aviation Commission
LDACS	L-band Digital Aeronautical Communications System
LNAV/VNAV	Lateral/Vertical Navigation
LPV	Localiser Performance with Vertical Guidance
LVC	Low Visibility Conditions
MASPS	Minimum Aircraft System Performance Specifications
MLS	Microwave Landing System
MMR	Multi-Mode Airborne Receiver
MON	Minimum Operating Network
MOPS	Minimum Operational Performance Specifications
MSAS	MTSAT Satellite Augmentation System
MTOM	Maximum Take-off Mass
NCC	Non-commercial operations with complex motor-powered aircraft
NM	Nautical Mile

Acronym	Definition
NPA	Non-Precision Approach
NRA	Non-Radar Airspace
NSP	Navigation System Panel
ORO	Organisational Requirements for Air Operations
OS NMA	Open Service Navigation Message Authentication
PBN	Performance Based Navigation
PDE	Path Definition Error
PM	Particulate Matter
PNT	Position, Navigation and Time
PVT	Position, Velocity and Time
QNH	Question Nil Height, atmospheric pressure at nautical height
RAD	RADAR Airspace
RADAR	Radio Detection and Ranging
RLS	Return Link Service
RNAV	Area Navigation
RNP	Required Navigation Performance
RNP AR	Required Navigation Performance Authorisation Required
RTCA	Radio Technical Commission for Aeronautics
RUR	Report on User needs and Requirements
SAE	Society of Automotive Engineers
SAIL	Specific Assurance and Integrity Level
SAR	Search And Rescue
SARPs	Standards and Recommended Practices
SBAS	Satellite-Based Augmentation System
SESAR	Single European Sky ATM Research
SID	Standard Instrument Departure Route
SORA	Specific Operations Risk Assessment
SPO	Specialised Operations
SSR	Secondary Surveillance Radar
SUGUS	Solution for EGNSS U-space Service
SVS	Synthetic Vision Systems
TAWS	Terrain Awareness Warning Systems
TMA	Terminal Manoeuvring Area
TSE	Total System Error
UAM	Urban Air Mobility
UCP	User Consultation Platform

Acronym	Definition
USSP	U-space service provider
UTM	Unmanned Traffic Management
VAAC	Volcanic Ash Advisory Centres
VFR	Visual Flight Rules
WAAS	Wide Area Augmentation System

A.4 Relevant documents related to GNSS

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<tr><td rowspan="6">ICAO SARPs</td><td>Annex 4 Aeronautical Charts</td></tr>
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<tr><td>Annex 10 Aeronautical Telecommunications - Volume I - Radio Navigational Aids
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<tr><td>Annex 14 Aerodromes</td></tr>
<tr><td>Annex 15 Aeronautical Information Services</td></tr>
<tr><td rowspan="6">Other ICAO publications</td><td>ICAO Doc 10054 ICAO Manual Location of Aircraft in Distress and Flight Recorder Data Recovery 2019</td></tr>
<tr><td>Global Navigation Satellite System (GNSS) Manual, ICAO Doc 9849 Second Edition – June 2013, Note: there is an Advance Third Edition – 2017 (unedited)</td></tr>
<tr><td>Aircraft Operations – Volume 1 Flight Procedures ICAO Doc 8168 6th Edition, 2018</td></tr>
<tr><td>Aircraft Operations – Volume 2 Construction of Visual and Instrument Flight Procedures ICAO Doc 8168 7th Edition, 2020</td></tr>
<tr><td>Procedures for Air Navigation services – ATM ICAO Doc 4444 16th Edition, 2016</td></tr>
<tr><td>Performance-based Navigation (PBN) Manual, ICAO Doc 9613, Fourth Edition –2013</td></tr>
<tr><td rowspan="4">EU Regulations and EASA Competencies</td><td>Commission Implementing Regulation (EU) 2021/664 On a regulatory framework for the U-space 22 April 2021</td></tr>
<tr><td>Commission Implementing Regulation (EU) 2021/665 Amending Implementing Regulation (EU) 2017/373 as regards requirements for providers of air traffic management/air navigation services and other air traffic management network functions in the U-space airspace designated in controlled airspace 22 April 2021</td></tr>
<tr><td>Commission Implementing Regulation (EU) 2021/666 Amending Regulation (EU) No 923/2012 as regards requirements for manned aviation operating in U-space airspace 22 April 2021</td></tr>
<tr><td>Regulation (EU) 2021/116 on the establishment of the Common Project One supporting the implementation of the European Air Traffic Management Master Plan provided for in Regulation (EC) No 550/2004 of the European Parliament and of the Council, amending Commission Implementing</td></tr>
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Documents	
	Regulation (EU) No 409/2013 and repealing Commission Implementing Regulation (EU) No 716/2014 01 February 2021
	Commission Implementing Regulation (EU) 2020/746 Amending Implementing Regulation (EU) 2019/947 as regards postponing dates of application of certain measures in the context of the COVID-19 pandemic 4 June 2020
	Commission Implementing Regulation (EU) 2020/639 Amending Implementing Regulation (EU) 2019/947 as regards standard scenarios for operations executed in or beyond the visual line of sight 12 May 2020
	Regulation (EU) No 2019/945 On unmanned aircraft systems and on third-country operators of unmanned aircraft systems 12 March 2019
	Regulation (EU) No 2019/947 On the rules and procedures for the operation of unmanned aircraft 24 May 2019
	Regulation (EU) 2018/1048 laying down airspace usage requirements and operating procedures concerning performance-based navigation 18 July 2018
	Regulation (EU) No 139/2014 Aerodromes 12 Feb 2014
	Regulation (EU) No 6/2013 Amending Regulation (EC) No 216/2008 of the European Parliament and of the Council on common rules in the field of civil aviation and establishing a European Aviation Safety Agency, and repealing Council Directive 91/670/EEC, Regulation (EC) No 1592/2002 and Directive 2004/36/EC 8 January 2013
	Regulation (EU) No 965/2012 Laying down technical requirements and administrative procedures related to air operations pursuant to Regulation (EC) No 216/2008 of the European Parliament and of the Council 5 October 2012
	Regulation (EU) No 748/2012 Laying down implementing rules for the airworthiness and environmental certification of aircraft and related products, parts and appliances, as well as for the certification of design and production organisations 3 August 2012
	Regulation (EC) No 1108/2009 Amending Regulation (EC) No 216/2008 in the field of aerodromes, air traffic management and air navigation services and repealing Directive 2006/23/EC 21 October 2009
	Regulation (EC) No 690/2009 Amending Regulation (EC) No 216/2008 of the European Parliament and the Council on common rules in the field of civil aviation and establishing a European Aviation Safety Agency, and repealing Council Directive 91/670/EEC, Regulation (EC) No 1592/2002 and Directive 2004/36/EC 30 July 2009
	Regulation (EC) No 216/2008 On common rules in the field of civil aviation and establishing a European Aviation Safety Agency, and repealing Council Directive 91/670/EEC, Regulation (EC) No 1592/2002 and Directive 2004/36/EC 20 February 2008

Documents	
SES Regulations and Implementing Rules	Commission Implementing Regulation (EU) No 716/2014 On the establishment of the Pilot Common Project supporting the implementation of the European Air Traffic Management Master Plan 27 June 2014
	Regulation (EU) No 691/2010 Laying down a performance scheme for air navigation services and network functions and amending Regulation (EC) No 2096/2005 laying down common requirements for the provision of air navigation services 29 July 2010
	Regulation (EC) No 552/2004 On the interoperability of the European Air Traffic Management network 10 March 2004
	Regulation (EC) No 551/2004 On the organisation and use of the airspace in the Single European Sky 10 March 2004
	Regulation (EC) No 550/2004 On the provision of air navigation services in the Single European Sky 10 March 2004
	Regulation (EC) No 549/2004 Laying down the framework for the creation of the Single European Sky 10 March 2004
Certification Specification or Airworthiness Codes	Annex to ED Decision 2015/018/R CS-23 / Amendment 4 15 July 2015
	Annex to ED Decision 2015/019/R CS-25 / Amendment 17 15 July 2015
	Annex I to ED Decision 2013/031/R CS-ACNS / Initial Issue 17 December 2013
	Annex to ED Decision 2013/015/R CS-LSA / Amendment 1 29 July 2013
	Annex to ED Decision 2012/021/R CS-29 / Amendment 3 11 December 2012
	Annex to ED Decision 2009/009/R CS-22 / Amendment 2 5 March 2009
	Annex to ED Decision 2003/10/RM CS-ETSO / Initial Issue 24 October 2003
	Annex to ED Decision 203/006/R CS-AWO / Initial Issue 17 October 2003
Acceptable Means of Compliance	ED Decision 2003/012/RM AMC20 (13 separated amendments since initial issue in 2003) General Acceptable Means of Compliance for Airworthiness of Products, Parts and Appliances 5 November 2003
CS-ETSO	Easy Access Rules for European Technical Standard Orders (CS-ETSO) (Amendment 14) CS-ETSO November 2018
	ETSO C115c Airborne area navigation equipment flight management system (FMS) using multi-sensor inputs 12 July 2013
	ETSO C161a Ground-Based Augmentation System Very High Frequency Data Broadcast Equipment 5 July 2012
	ETSO-C196a Airborne Supplemental Navigation Sensors for Global Positioning System Equipment Using Aircraft-Based Augmentation 5 May 2012
	ETSO C144a Passive airborne GNSS antenna 21 December 2010

Documents	
	ETSO C145c Airborne Navigation Sensors Using the Global Positioning System Augmented by the Satellite-Based Augmentation System 21 December 2010
	ETSO C146c Stand-Alone Airborne navigation Equipment Using the Global Positioning System Augmented by the Satellite-Based Augmentation System 21 December 2010
	ETSO-C190 Active Airborne Global Navigation Satellite System (GNSS) Antenna 21 December 2010
EASA Technical Regulations for Operational Approval	Annex to Decision 2016/020/R AMC and GM to Part-SPA – Amendment 3 29 July 2016
Aeronautical Standards for GNSS Equipment	RTCA DO-384 Minimum Operational Performance Standards (MOPS) for GNSS Aided Inertial Systems December 2020
	RTCA/DO-317 Minimum Operational Performance Standards (MOPS) for Aircraft Surveillance Applications (ASA) System 01 June 2020
	RTCA DO-373 MOPS for GNSS Airborne Active Antenna Equipment for the L1/E1 and L5/E5a Frequency Bands June 2018
	RTCA DO-368 Minimum Operational Performance Standards for GPS/GLONASS (FDMA + antenna) L1-only Airborne Equipment July 2017
	RTCA DO-229F Minimum Operational Performance Standards (MOPS) for Global Positioning System/Satellite-Based Augmentation System Airborne Equipment 11 June 2020
	EUROCAE WG-98 MASPS ED-237 Criteria to Detect In-flight Aircraft Distress Events to Trigger Transmission of Flight Information 2016
	EUROCAE ED-75E Minimum Aviation System Performance Standards: Required Navigation Performance for Area Navigation, June 2022
	RTCA DO-236 Minimum Aviation System Performance Standards: Required Navigation Performance for Area Navigation Change 1 23 September 2014
	RTCA/DO-260B Minimum Operational Performance Standards for 1090 MHz Extended Squitter Automatic Dependent Surveillance – Broadcast (ADS-B) and Traffic Information Services – Broadcast, with Supplement 1, December 17, 2020, 13 December 2011
	RTCA-DO 316 Minimum Operational Performance Standards for Global Positioning System / aircraft-Based augmentation System Airborne Equipment April 2009
	RTCA-DO-235 Assessment of Radio Frequency Interference Relevant to the GNSS L1 Frequency Band March 2008

Documents	
	RTCA DO-301 Minimum Operational Performance Standards for Global Navigation Satellite System (GNSS) Airborne Active Antenna Equipment for the L1 Frequency Band December 2006
	RTCA-DO-292 Assessment of Radio Frequency Interference Relevant to the GNSS L5/E5A Frequency Band July 2004
	EUROCAE ED-88 MOPS for Multi-Mode Airborne Receiver (MMR) including ILS, MLS and GPS used for Supplemental Means of Navigation August 1997
	RTCA DO-228 Minimum Operational Performance Standards for Global Navigation Satellite Systems (GNSS) Airborne Antenna Equipment October 1995
	RTCA DO-208 Minimum Operational Performance Standards for Airborne Supplemental Navigation Equipment Using Global Positioning System (GPS) 21 September 1993
GLONASS Receiver Specifications	KT-229 MOPS-229 Airborne equipment of satellite navigation (AESN) – 4th Edition March 2011
	KT-229 MOPS-229 GNSS/SBAS Airborne Navigation Equipment March 2011
GBAS Standards	EUROCAE ED-114A MOPS for a Ground-Based Augmentation System (GBAS) ground facility to support CAT I approach and landing March 2013
	RTCA DO-253C Minimum Operational Performance Standards for GPS Local Area Augmentation System Airborne Equipment December 2008
	RTCA DO-246D GNSS-Based Precision Approach Local Area Augmentation System (LAAS) – Signal-in-Space Interface Control Document (ICD) December 2008
	RTCA DO-245A Minimum Aviation System Performance Standards for Local Area Augmentation System (LAAS) September 2004
Other Standards Applicable to GNSS Equipment	COSPAS-SARSAT C/S T.001 Issue 4 and T.007 Issue 5 Specification for COSPAS-SARSAT 406 MHz distress beacons and type approval November 2022
	COSPAS-SARSAT C/S T.018 Issue 1, Revision 10 Specification for Second-Generation Cospas-Sarsat 406-MHz November 2022
	EUROCAE ED-14G with Change1 Environmental Conditions and Test Procedures for Airborne Equipment January 2015
	EUROCAE ED-12C Software considerations in Airborne Systems and Equipment certification December 2012 Software Considerations in Airborne Systems and Equipment Certification Corrigendum 1 15 February 2021
	EUROCAE ED-109A Software Integrity Assurance Considerations for Communication, Navigation, Surveillance and Air Traffic Management (CNS/ATM) Systems January 2012 Software Integrity Assurance Considerations for CNS/ATM Systems - with Corrigendum 1 February 2021

Documents	
	RTCA DO-178C Software considerations in Airborne Systems and Equipment certification December 2011 Software considerations in Airborne Systems and Equipment certification – Errata 1 16 February 2021
	RTCA DO-278A Software Integrity Assurance Considerations for Communication, Navigation, Surveillance and Air Traffic Management (CNS/ATM) Systems December 2011
	RTCA DO-248C Supporting Information for DO-178 C and DO-287 A December 2011
	EUROCAE ED-79A Guidelines for Development of Civil Aircraft and Systems December 2010
	RTCA DO-160G Environmental Conditions and Test Procedures for Airborne Equipment August 2010
	RTCA DO-254 Design Assurance Guidance for Airborne Electronic Hardware April 2000
	EUROCAE ED-80 Design Assurance Guidance for Airborne Electronic Hardware April 2000
	ARP 4761 Guidelines and Methods for Conducting the Safety Assessment Process on Civil Airborne Systems and Equipment December 1996
	EUROCAE ED-301 Guidelines for the Use of Multi-GNSS Solutions for UAS Specific Category - Low Risk Operations SAIL I & II *Note: to be published in September 2022*
Other relevant documents and references	EASA Opinion No 1/2020 High-level regulatory framework for the U-space 13 March 2020
	ToR RMT.0230 Introduction of a regulatory framework for the operation of unmanned aircraft systems and for urban air mobility in the European Union aviation system 22 April 2021
	The Interoperable Global Navigation Satellite Systems Space Service Volume; United Nations Office for Outer Space Affairs [16] Second Edition (relevant for GNSS and EO)
	Commission Regulation (EU) No 1178/2011 of 3 November 2011 laying down technical requirements and administrative procedures related to civil aviation aircrew pursuant to Regulation (EC) No 216/2008 of the European Parliament and of the Council
	EASA Study on the societal acceptance of Urban Air Mobility in Europe
	EASA concept for regulation of Unmanned Aircraft Systems (UAS) operations in the 'certified' category and Urban Air Mobility - Issue 3.0
	EASA Drone Collision Task Force

[16] https://www.unoosa.org/

A.5 Relevant documents related to EO

Documents	
International Space Law	Registration Convention 1976
	Liability Convention 1972
	Outer Space Treaty 1967
International Environmental Law	UN CSD Principles of International Law of Sustainable Development 1995
	UN Environment Programme Principles
	Rio Declaration on Environment and Development (Rio Declaration) 1992
	Declaration of the UN Conference on the Human Environment (Stockholm Declaration) 1972
Soft Law Mechanisms and Other Relevant Guidelines & Initiatives	UN COPUOS Guidelines for the Long-term Sustainability of Outer Space Activities: ▪ UN COPUOS, Terms of reference, methods of work and workplan of the Working Group on the Long-Term Sustainability of Outer Space Activities of the Scientific and Technical Subcommittee (2021) ▪ UN COPUOS, Guidelines for the long-term sustainability of outer space activities (2019) ▪ UN COPUOS, Space Debris Mitigation Guidelines of the Committee on the Peaceful Uses of Outer Space (2010)
	IADC Statement on Large Constellations of Satellites in Low Earth Orbit 2021
	UN General Assembly Resolution 75/36 on Reducing space threats through norms, rules and principles of responsible behaviours 2020
	ISO 24113: Space systems – Space debris mitigation requirements 2019
	IADC Space Debris Mitigation Guidelines 2007
	Principles Relating to Remote Sensing of the Earth from Outer Space 1986
	The Charter on Cooperation to Achieve the Coordinated Use of Space Facilities in the Event of Natural or Technological Disasters (Disaster Charter)
International Telecommunications Union Constitution, Convention, and Radio Regulations	ITU Article 44 CC Use of the Radio-Frequency Spectrum and of the Geostationary Satellite and Other Satellite Orbits
	ITU-R S.1003.2 (12/2010) on the Environmental protection of the GSO
EU Regulations	REGULATION (EU) 2021/696 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 28 April 2021 establishing the Union Space Programme and the European Union Agency for the Space Programme and repealing Regulations (EU) No 912/2010, (EU) No 1285/2013 and (EU) No 377/2014 and Decision No 541/2014/EU

A.6 Reference Documents

Id.	Reference	Title	Date
[RD1]	EUSPA Market Report	EUSPA EO and GNSS Market Report (*Issue 7*)	Jan. 2022
[RD2]	GNSS Technology Report	GSA GNSS Technology Report (*Issue 3*)	Sept. 2020
[RD3]	ICAO Annex 10 Vol I	Annex 10 - Aeronautical Telecommunications - Volume I - Radio Navigational Aids	July 2006
[RD4]	ICAO PBN Manual	ICAO Performance-based Navigation (PBN) Manual (Third Edition)	2008
[RD5]	RTCA and EUROCAE GNSS receiver MOPS		June 2020
[RD6]	(EU) 2019/1048 Airspace usage requirements and PBN operating procedures	Commission Implementing Regulation (EU) 2019/1048	2019
[RD7]	(EU) 2021/116 Establishment of Common Project One	COMMISSION IMPLEMENTING REGULATION (EU) 2021/116	Feb 2021
[RD8]	PBN Handbook No. 4	European Navaid Infrastructure Planning Handbook including Minimum Operational Network (MON)	May 2021
[RD9]	UCP2020		
[RD10]	ICAO Doc 4444	Procedures for Air Navigation Services – Air Traffic Management	2016
[RD11]	ICAO Annex 2	Rules of the Air - 2005	2016
[RD12]	ICAO Annex 11	Air Traffic Services (2018)	2020
[RD13]	ICAO Doc 9613	PBN Manual	2012
[RD14]	SESAR JU – U-space	A report of the consolidated SESAR U-space research and innovation results	2020
[RD15]	JARUS External Consultation WG-SRM "SORA Annex A"		
[RD16]	Project GREy		
[RD17]	EUROCAE ED 163	Safety and Performance and Interoperability Requirements Document for ADS-B Airport Surface Surveillance Application (ADS-B-APT)	2010
[RD18]	EUROCAE ED 160 RTCA DO 314	Safety and Performance and Interoperability Requirements Document for Enhanced Visual Separation on Approach (ATSA-VSA)	2008
[RD19]	EASA CS ACNS	Certification Specification Airborne Communications, Navigation and Surveillance	April 2022
[RD20]	Report on Aviation User Needs and Requirements EUSPA-MKD-AV-UREQ-250287, Annex 7: Updates following the User Consultation Platform 2020 SA-MKD-AV-MOM-246179	Report on Aviation User Needs and Requirements EUSPA-MKD-AV-UREQ-250287, Annex 7: Updates following the User Consultation Platform 2020 SA-MKD-AV-MOM-246179	
[RD21]	European Navaid Infrastructure Planning Handbook	European Navaid Infrastructure Planning Handbook including Minimum Operational Network (MON) PBN HANDBOOK No. 4	May 2021
[RD22]	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

Id.	Reference	Title	Date
[RD23]	Consolidated AMC & GM to Annex IV (Part-CAT)	Acceptable Means of Compliance (AMC) and Guidance Material (GM) to Annex IV Commercial air transport operations [Part-CAT] of Commission Regulation (EU) 965/2012 on air operations	March 2018
[RD24]	EU policy on air quality: Implementation of selected EU legislation	EU policy on air quality: Implementation of selected EU legislation European Implementation Assessment https://www.europarl.europa.eu/RegData/etudes/STUD/2021/654216/EPRS_STU(2021)654216_EN.pdf	January 2021
[RD25]	Potential use of CAMS modelling results in air quality mapping under ETC/ATNI	Potential use of CAMS modelling results in air quality mapping under ETC/ATNI Eionet Report – ETC/ATNI 2019/17	May 2020
[RD26]	European Drones Outlook Study	European Drones Outlook Study Unlocking the value for Europe	November 2016
[RD27]	EU Directive including aviation in the EU ETS	DIRECTIVE 2008/101/EC OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 19 November 2008 amending Directive 2003/87/EC so as to include aviation activities in the scheme for greenhouse gas emission allowance trading within the Community	November 2008
[RD28]	FAA AC 20-165A	Airworthiness approval of Automatic Dependent Surveillance – Broadcast (ADS-B) Out systems in aircraft.	July 2012
[RD29]	EUROCAE ED 126 / RTCA DO 303	Safety and Performance and Interoperability Requirements Document for ADS-B-NRA Application	2006
[RD30]	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
[RD31]	ICAO Annex 3	Meteorological Service for International Air Navigation	2018

EUSPA Mission Statement

The mission of the European Union Agency for the Space Programme (EUSPA) is defined by the EU Space Programme Regulation. EUSPA's mission is to be the user-oriented operational Agency of the EU Space Programme, contributing to sustainable growth, security and safety of the European Union.

Its goal is to:

- Provide long-term, state-of-the-art safe and secure Galileo and EGNOS positioning, navigation and timing services and cost-effective satellite communications services for GOVSATCOM, whilst ensuring service continuity and robustness;
- Communicate, promote, and develop the market for data, information and services offered by Galileo, EGNOS, Copernicus and GOVSATCOM;
- Provide space-based tools and services to enhance the safety of the Union and its Member States. In particular, to support PRS usage across the EU;
- Implement and monitor the security of the EU Space Programme and to assist in and be the reference for the use of the secured services, enhancing the security of the Union and its Member States;
- Contribute to fostering a competitive European industry for Galileo, EGNOS, and GOVSATCOM, reinforcing the autonomy, including technological autonomy, of the Union and its Member States;
- Contribute to maximising the socio-economic benefits of the EU Space Programme by fostering the development of a competitive and innovative downstream industry for Galileo, EGNOS, and Copernicus, leveraging also Horizon Europe, other EU funding mechanisms and innovative procurement mechanisms;
- Contribute to fostering the development of a wider European space ecosystem, with a particular focus on innovation, entrepreneurship and start-ups, and reinforcing know-how in Member States and Union regions.
- As of July 2023, EUSPA will take the responsibility for the Programme's Space Surveillance Tracking Front Desk operations service.

The European Union Agency for the Space Programme: linking space to user needs.

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