



PROGRAMME OF THE
EUROPEAN UNION



EGNOS Safety of Life (SoL) for Aviation

Service Definition Document

Issue 3.6

#EUSpace

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Scope of the EGNOS Safety of Life Service for Aviation Commitment

The EGNOS Safety of Life Service for Aviation comprises the provision of an augmentation signal to the Global Positioning System (GPS) Standard Positioning Service (SPS) with the specific committed performance and subject to the service limitations and disclaimers of liability described in this document.

Only minimum performance characteristics are included in the commitment even though the users can usually experience a better performance. These characteristics are expressed in statistical values under given assumptions.

The minimum level of performance of the EGNOS SoL Service for Aviation as specified in this document is obtained under the condition that compliance is ensured with:

- The main GPS SPS SIS characteristics and performance defined in the GPS ICD [RD-4], in SBAS MOPS Appendix B [RD-2] and in GPS SPS Performance Standard [RD-3] and;
- The receiver characteristics as described in sections 3 and 4.

Who can use the EGNOS SoL Service for Aviation?

In general, the EGNOS SoL Service is intended for most transport applications in different domains where lives could be endangered if the performance of the navigation system is degraded below specific accuracy limits without giving notice in the specified time to alert. This requires that the relevant authority of the particular transport domain determines specific requirements for the navigation service based on the needs of that domain, as well as certification procedures if necessary. In addition, the navigation operations based on the EGNOS SoL Service may require a specific authorisation, issued by the relevant authority, or the authority, or applicable regulation, may establish that no such authorisation is required.

The aviation domain has specific service requirements, as well as certification and individual authorisation procedures developed and implemented. Some of these particularities are described in this EGNOS SoL Service for Aviation SDD.

In the EU¹ and EFTA territories the requirements that apply for implementing an EGNOS based procedure are those set forth in the Single European Sky (SES) Regulation, and all related EU regulatory provisions applicable to the implementation of PBN operations. It is compulsory to comply with them in order to use EGNOS as defined in this document. In some specific areas such as the use of EGNOS at non-ATS environments, local regulations may complement these applicable provisions where appropriate.

EGNOS SoL Service for Aviation signal covers also territories outside the EU. However, authorising and safety oversight of the use of EGNOS in civil aviation outside the EU falls within the sole responsibility of the respective third country. ESP will support the operational use of EGNOS based procedures via the

¹ i.e. territory in which the Treaty on the Functioning of the European Union applies, as well as airspace where the EU member states apply Regulation (EC) No 551/2004.

signature of the EGNOS Working Agreement (EWA) provided that the level of safety at least equivalent to the Single European Sky requirements can be demonstrated by the interested parties on a case-by-case basis and that there is an agreement between the EU and the third country on the use of EGNOS SoL Service for Aviation². The EGNOS helpdesk (see section 3.4.2 for contact details) is available to clarify the steps to follow in this case.

The EGNOS SoL Service for Aviation is today provided for all phases of flight within the corresponding service area to aviation users (further “**Aviation Users**”) namely:

- *Airspace users*, as defined in the Single European Sky (SES) framework Regulation³, equipped with an EGNOS certified receiver and located within the appropriate EGNOS SoL Service for Aviation service area corresponding to the phase of flight in which the EGNOS SoL Service for Aviation is used.
- *Organisations implementing EGNOS based procedures responsible for the operational use of the respective procedure:*
 - Air navigation service providers (ANSP) (e.g. EGNOS based approaches down to LPV minima at ATS environments).
 - Aerodrome Operators (e.g. EGNOS based approaches at non-ATS environments).
 - Rotorcraft Operators (e.g. EGNOS based HEMS operations at non-ATS environments).
 - Any other organisation upon its competent authority approval.

When written agreements are required in the frame of the applicable Regulation⁴, please refer to section 3.4.3 for further information.

Should any support from the EGNOS SoL Service Provider be needed, these organisations can consult with the EGNOS helpdesk (see section 3.4.2 for contact details).

Obligations of the users to exercise due care

EGNOS is a complex technical system, and the users also have certain obligations to exercise due care in using the EGNOS SoL Service for Aviation. Before any use of the EGNOS SoL Service for Aviation, all users should study this document to understand whether and how they can use the service, as well as to familiarise themselves with the performance level and other aspects of the service they can rely on.

In case of doubt, the users and other parties should contact the EGNOS helpdesk (see section 3.4.2 for contact details). Aviation Users may also contact their competent authority.

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² There are EGNOS based operations already implemented and/or planned (through the corresponding EWA between ESSP and the Air Navigation Service Providers of those states) in the following non-EU states: Norway, Switzerland, Bailiwick of Guernsey, Bailiwick of Jersey, Iceland, Serbia, and Montenegro.

³ Regulation (EC) No 549/2004 of the European Parliament and of the Council of 10 March 2004 laying down the framework for the creation of the Single European Sky.

⁴ For some of these organisations, the signature of an EGNOS Working Agreement (EWA) is required according to the Single European Sky (SES) Regulation (Regulation (EC) 550/2004 Article 10.2 and Regulation (EU) 2017/373, ATM/ANS.OR.B.005 (f) and ATS.OR.525 (b)). In those cases, the EGNOS SoL Service for Aviation can be used only upon signature of an EWA.

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Disclaimer of liability

As the owner of EGNOS system, the European Union - including any of its institutions, offices or agencies, such as the European Commission, the European Union Agency for the Space Programme (EUSPA) as EGNOS Programme manager - and ESSP SAS, hereinafter referred to as ESSP, as certified EGNOS SoL Air Navigation Services Provider⁵, do not offer any warranties of any kind (whether expressed or implied) to any party with respect to the service subject of this Definition Document, other than Aviation Users specified under “Who can use the EGNOS SoL Service for Aviation?” above, and/or for any other use of the EGNOS SoL Service for Aviation including, but not limited to the warranties regarding availability, continuity, accuracy, integrity, reliability and fitness for a particular purpose or meeting the users’ requirements.

No advice or information, whether oral or written, obtained by a user from the European Union - including any of its institutions, offices, or agencies, such as the European Commission, EUSPA, and other entities acting on the basis of a contract or agreement with the European Union involved in the EGNOS SoL Service provision for Aviation - shall offer or commit to offering any such warranty and consequently, be held liable for committing to or offering any such warranty.

By using the EGNOS SoL Service for Aviation, the user accepts and agrees that the European Union - including any of its institutions, offices or agencies, such as the European Commission, EUSPA, and other entities acting on the basis of a contract or agreement with the European Union involved in the EGNOS SoL Service - shall not be held responsible or liable for any indirect, special or consequential damages including but not limited to, damages for interruption of business, loss of profits, goodwill or other intangible losses, resulting from the use of, misuse of, or the inability to use the EGNOS SoL Service for Aviation, other than in accordance with Article 340 of the Treaty on the Functioning of the European Union.

Furthermore, no party shall be entitled to any claim against the European Union - including any of its institutions, offices, or agencies, such as the European Commission, EUSPA, and other entities acting on the basis of a contract or agreement with the European Union involved in the EGNOS SoL Service for Aviation - if the damage is the result, or the consequence, of any of the following events:

- Use of EGNOS SoL Service for Aviation beyond the conditions and limitations of uses set forth in the EGNOS SoL Service for Aviation SDD, it being understood that the use of EGNOS SoL Service for Aviation by users other than Aviation Users constitutes a use beyond such conditions and limitations, or
- Use of equipment or receivers which are:
 - not fully compliant to MOPS (Minimum Operational Performance Standards for Global Positioning System/Wide Area Augmentation System Airborne Equipment) or
 - not certified or approved by the relevant competent authority, or
 - malfunctioning, or;
- Use of the EGNOS SoL Service for Aviation when a test message is broadcast (a Message Type 0 or a Message Type 0/2), or

⁵ According to regulation EU 2017/373

- Use of the EGNOS SoL Service for Aviation without required authorisation, or
- Use of the SOL corrections not broadcast by via EGNOS GEO satellites, or
- In case of a Force Majeure event.

EGNOS SoL Service for Aviation Lifetime

The EGNOS SoL Service for Aviation is intended to be provided for a minimum period of 20 years, as from its first declaration date, with 6 years advance notice in case of significant changes in the Services provided.

DOCUMENT CHANGE RECORD

REASON FOR CHANGE	ISSUE	DATE
First version of the document	1.0	02/03/2011
<ul style="list-style-type: none"> Update of the document including the improvements derived from the latest EGNOS system releases. Alignment with the latest versions of the EGNOS Open Service SDD and the EDAS SDD. 	2.0	28/06/2013
<ul style="list-style-type: none"> EGNOS system information updated. Update with new commitment maps for ESR2.3.2. Observed performance figures updated. EGNOS NOTAM proposals updated with current service level provided. New appendix D on the impacts of ionospheric activity on GNSS. 	2.1	19/12/2014
<ul style="list-style-type: none"> Figure 5 corrected and improvement of commitment maps visibility 	2.2	07/04/2015
<ul style="list-style-type: none"> Declaration of LPV-200 service level: Approach operations based on SBAS down to a minimum Decision Height not lower than 200 ft. EGNOS Space Segment updated as per EGNOS Service Notice #15. New NPA continuity map. Update of Appendix D with EGNOS Service Notice #13. 	3.0	22/09/2015
<ul style="list-style-type: none"> New SoL commitment maps based on ESR241M EGNOS Space Segment updated 	3.1	26/09/2016
<ul style="list-style-type: none"> New SoL commitment maps based on ESR241N Specific consideration of non-EU users Specific consideration of non-ATS users EGNOS system and service information update New Appendix D with EGNOS SLs vs PBN Navigation Specifications New Appendix E with EGNOS SoL achieved performances 	3.2	28/09/2018
<ul style="list-style-type: none"> EGNOS Service Area extension to 72°N New SoL commitment maps extended to 72°N EGNOS service information updated 	3.3	26/03/2019
<ul style="list-style-type: none"> Updated magenta area EGNOS service information updated 	3.4	26/04/2021
<ul style="list-style-type: none"> GSA becoming EUSPA New SoL commitment maps including an updated magenta area EGNOS service information updated 	3.5	23/11/2023
<ul style="list-style-type: none"> SDD title updated. New SoL for aviation commitment maps. EGNOS Service Provision scheme updated after the declaration of the EGNOS Safety of Life assisted service for Maritime Users (ESMAS). ICAO SARPS Annex 10 compliance information updated considering last published amendment. 	3.6	09/09/2024

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1 EXECUTIVE SUMMARY

The European Geostationary Navigation Overlay Service (EGNOS) provides an augmentation service to the Global Positioning System (GPS) Standard Positioning Service (SPS). Today, EGNOS augments GPS using the L1 (1575.42 MHz) Coarse/Acquisition (C/A) civilian signal function by providing correction data and integrity information for improving positioning, navigation and timing services over Europe. EGNOS will augment both GPS and Galileo in the future, using L1 and L5 (1176.45 MHz) frequencies.

The EGNOS Safety of Life (SoL) Service is provided openly and is freely accessible without any direct charge. It is tailored to safety-critical transport applications in various domains, in particular, the EGNOS Safety of Life (SoL) Service for Aviation is compliant with the aviation requirements for Approaches with Vertical Guidance (APV-I) and Category I precision approaches⁶, as defined by ICAO in Annex 10 [RD-1]. The operational use of the EGNOS SoL Service for Aviation may require specific authorisation by the relevant authorities in the application sectors concerned.

This "EGNOS SoL Service for Aviation Service Definition Document" (EGNOS SoL Service for Aviation SDD) provides information on the EGNOS SoL Service for Aviation. The document describes the EGNOS system architecture and Signal-In-Space (SIS) characteristics, the EGNOS SoL Service for Aviation performance, and provides information on the established technical and organisational framework for the provision of this service. It is intended to be of use to Air Navigation Service Providers (ANSPs), other organisations⁷ implementing EGNOS based procedures, receiver manufacturers, equipment integrators, airlines, operators, GNSS application developers and the final users of the EGNOS SoL Service for Aviation.

This document is not intended to address EGNOS SoL Service for other domains nor EGNOS Open Service (OS) nor EDAS performance.

- Information about the EGNOS Safety of Life assisted service for Maritime users (ESMAS) is available in a separate document called the "EGNOS Safety of Life assisted service for Maritime users (ESMAS) - Service Definition Document" (ESMAS SDD - [RD-21]).
- Information about EGNOS OS can be found in the "EGNOS Open Service - Service Definition Document" (EGNOS SDD OS - [RD-5]).
- Information regarding EDAS can be found in the "EGNOS Data Access Service (EDAS) - Service Definition Document" (EDAS SDD - [RD-6]).

This document will be updated in the future as required in order to reflect changes and improvements to the EGNOS SoL Service for Aviation.

⁶ LPV-200 enables approach procedures designed for 3D instrument approach operations Type A or Type B, as also stated in ICAO Annex 6.

⁷ Entities implementing the EGNOS based procedure while having the responsibility over its operational use. These are normally those organisations submitting the procedure to the competent authority requesting the operational approval.

2 INTRODUCTION

2.1 Purpose and scope of the document

The EGNOS Safety of Life Service for Aviation SDD (EGNOS SoL Service for Aviation SDD) presents the characteristics of the service offered to users by EGNOS Safety of Life (SoL) Service for Aviation highlighting the positioning performance currently available to suitably equipped users using both the GPS SPS broadcast signal and the EGNOS augmentation signals.

The EGNOS SoL Service for Aviation SDD comprises 6 main sections and 7 appendixes:

- Section 1 is an Executive Summary of the document.
- Section 2 (“Introduction”) defines the scope of the document and the relevant reference documentation. In addition, this section clarifies the terms and conditions of EGNOS SoL Service for Aviation use, including liability, and its intended lifetime.
- Section 3 (“Description of the EGNOS System and EGNOS SoL Service for Aviation Provision Environment”) gives a brief overview of the EGNOS system, as well as its technical and organisational framework for EGNOS SoL Service for Aviation provision.
- Section 4 (“EGNOS SIS”) introduces the EGNOS Signal In Space characteristics and performance in the range domain.
- Section 5 (“EGNOS Receivers”) briefly presents the certification context for aviation receivers.
- Section 6 (“EGNOS SoL Service for Aviation Performance”) describes the positioning Service offered to users by the EGNOS SoL Service for Aviation and the minimum expected performance in the positioning domain.
- Appendix A Satellite Navigation Concept contains fundamental information of the satellite navigation (GNSS) as complementary concepts for the rest of the documents.
- Appendix B EGNOS Integrity concept describes the integrity concept used in EGNOS.
- Appendix C Ionospheric activity and impact on GNSS assesses the impact of the ionospheric activity on GNSS and in particular on SBAS systems.
- Appendix D EGNOS SoL service for aviation levels/PBN navigation specifications presents EGNOS SoL Service for Aviation Levels versus the different PBN Navigation Specifications (NavSpecs), as defined in the PBN Manual [RD-15], in order to identify in which NavSpecs EGNOS is considered as an enabler.
- Appendix E EGNOS SoL service for aviation: achieved performances provides the achieved availability performances for EGNOS SoL Service for Aviation.
- Appendix F Definitions presents relevant definitions.
- Appendix G List of acronyms provides the list of acronyms used in the document.

This document does not address the EGNOS Safety of Life assisted service for Maritime users (ESMAS), Open Service (OS) nor the EGNOS Data Access Service (EDAS), which are described in separate dedicated Service Definition Documents.

2.2 Reference documents

RD	Document title
RD-1	ICAO Standards and Recommended Practices (SARPs) Annex 10 Volume I (Radio Navigation Aids)

	8th edition of July 2023 (which incorporates all amendments up to and including No 93)
RD-2	RTCA MOPS DO 229 (Revisions C, D Change 1, E or F)
RD-3	GPS Standard Positioning Service Performance Standard – April 2020 5 th Edition https://www.gps.gov/technical/ps/2020-SPS-performance-standard.pdf
RD-4	IS GPS 200 Revision N – NAVSTAR GPS Space Segment / Navigation User Interface – 22nd Aug 2022
RD-5	EGNOS Service Definition Document – Open Service (OS SDD) https://egnos.gsc-europa.eu/documents/egnos-open-service-sdd
RD-6	EGNOS Data Access Service – Service Definition Document (EDAS SDD) https://egnos.gsc-europa.eu/documents/egnos-data-access-service-sdd
RD-7	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
RD-8	REGULATION (EC) No 550/2004 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 10 March 2004 on the provision of air navigation services in the single European sky
RD-9	COMMISSION IMPLEMENTING REGULATION (EU) 2017/373 of 1 March 2017 laying down common requirements for providers of air traffic management/air navigation services and other air traffic management network functions and their oversight, repealing Regulation (EC) No 482/2008, Implementing Regulations (EU) No 1034/2011, (EU) No 1035/2011 and (EU) 2016/1377 and amending Regulation (EU) No 677/2011.
RD-10	EC/ESA/CNES User Guide for EGNOS Application Developers Ed. 2.0 – 15th December 2011
RD-11	ICAO Standards and Recommended Practices (SARPS) Annex 15 Aeronautical Information Services, July 2018 16 th Edition
RD-12	The European Concept for GNSS NOTAM, V2.7 (Eurocontrol GNSS NOTAM CONOPS), 29 th November 2011
RD-13	ICAO Standards and Recommended Practices (SARPS) Annex 6, Operation of Aircraft, Part I – International Commercial Air Transport – Aeroplanes, July 2022 12 th Edition
RD-14	ICAO Doc 8168, Aircraft Operations (PANS-OPS) Volume I — Flight Procedures Volume II — Construction of Visual and Instrument Flight Procedures Volume III – Aircraft Operating Procedures
RD-15	ICAO Doc 9613, Performance-based Navigation (PBN) Manual
RD-16	ICAO Doc 9849, Global Navigation Satellite System (GNSS) Manual
RD-17	COMMISSION REGULATION (EU) No 965/2012 Air Operations of 5 October 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
RD-18	CS-ACNS, Subpart C — Navigation (NAV), SECTION 1 — PERFORMANCE-BASED NAVIGATION (PBN) Subsection 5: Supplementary specifications for vertical navigation in final approach, Effective: 05/04/2022 ⁸
RD-19	FAA AC 20-138D - Airworthiness Approval of Positioning and Navigation Systems
RD-20	FAA AC 90-107 - Guidance for localizer performance with Vertical Guidance and Localizer

⁸ Subsection 5 sets out the certification specifications for systems that use either a barometric VNAV (BAROVNAV) or a GNSS space-based augmented source of vertical position (SBAS-VNAV) for procedures where vertical guidance is based on a published vertical path to LNAV/VNAV or LPV minima respectively.

RD-21	EGNOS Service Definition Document – EGNOS Safety of Life assisted service for Maritime users (ESMAS SDD) https://egnos.gsc-europa.eu/documents/egnos-safety-life-assisted-service-maritime-users-esmas
RD-22	IMO resolution A.1046 (27), 30 November 2011 https://wwwcdn.imo.org/localresources/en/KnowledgeCentre/IndexofIMOResolutions/Documents/A%20-%20Assembly/1046(27).pdf

Table 1: Reference documents

3 DESCRIPTION OF THE EGNOS SYSTEM AND EGNOS SOL SERVICE

3.1 EGNOS: the European SBAS

Satellite navigation systems are designed to provide a positioning and timing service over vast geographical areas (typically continental or global coverage) with high accuracy performance. However, a number of events (either internal to the system elements or external, due to environmental conditions) may lead to positioning errors that are in excess of the typically observed navigation errors. For a large variety of users, such errors will not be noticed or may have a limited effect on the intended application. However, for a number of user communities, they may directly impact the safety of operations. Therefore, there is an absolute need to correct such errors, or to warn the user in due time when such errors occur and cannot be corrected. For this reason, augmentation systems have been designed to improve the performance of existing global constellations.

EGNOS is a Satellite Based Augmentation System (SBAS). SBAS systems are designed to augment the navigation system constellations by broadcasting additional signals from geostationary (GEO) satellites. The basic scheme is to use a set of monitoring stations (at very well-known positions) to receive the navigation signals from core GNSS constellations that will be processed in order to obtain some estimations of these errors that are also applicable to the users (e.g. ionospheric errors and satellite position/clock errors). Once these estimations have been computed, they are transmitted in the form of “differential corrections” by means of a GEO satellite. Today, EGNOS augments GPS signals and will augment Galileo signal in the future.

Along with these correction messages which increase accuracy, some integrity data for the satellites that are in view of this network of monitoring stations and for the Ionospheric Grid Points visible from the service area are also broadcast, increasing the confidence that a user can have in the satellite navigation positioning solution.

The reader is invited to read Appendix A Satellite Navigation Concept for background information about the Satellite Navigation Concept.

EGNOS is part of a developing multi-modal inter-regional SBAS service, able to support a wide spectrum of applications in many different user communities, such as maritime, aviation, rail, road, agriculture.

Similar SBAS systems, designed according to the same standard (i.e. SARPs [RD-1]), have already been commissioned by the US (Wide Area Augmentation System – WAAS), Japan (MTSAT Satellite based Augmentation System – MSAS), India (GPS Aided GEO Augmented Navigation – GAGAN) and Republic of Korea (Korea Augmentation Satellite System – KASS). Analogous systems are under commissioning or deployment in other regions of the world (e.g. System of Differential Correction and Monitoring – SDCM - in Russia, BeiDou SBAS – BDSBAS - in China, Southern Positioning Augmentation Network - SouthPAN - in Australia and New Zealand, and African Satellite Augmentation System – ANGA in Africa and Indian Ocean).

EGNOS provides services to European Union Member States (EU-MS), to EGNOS Programme participating States (Switzerland, Norway, Iceland) and to other countries with an agreement with the EU on the provision of EGNOS services. The worldwide existing and planned SBAS systems are shown in Figure 1.

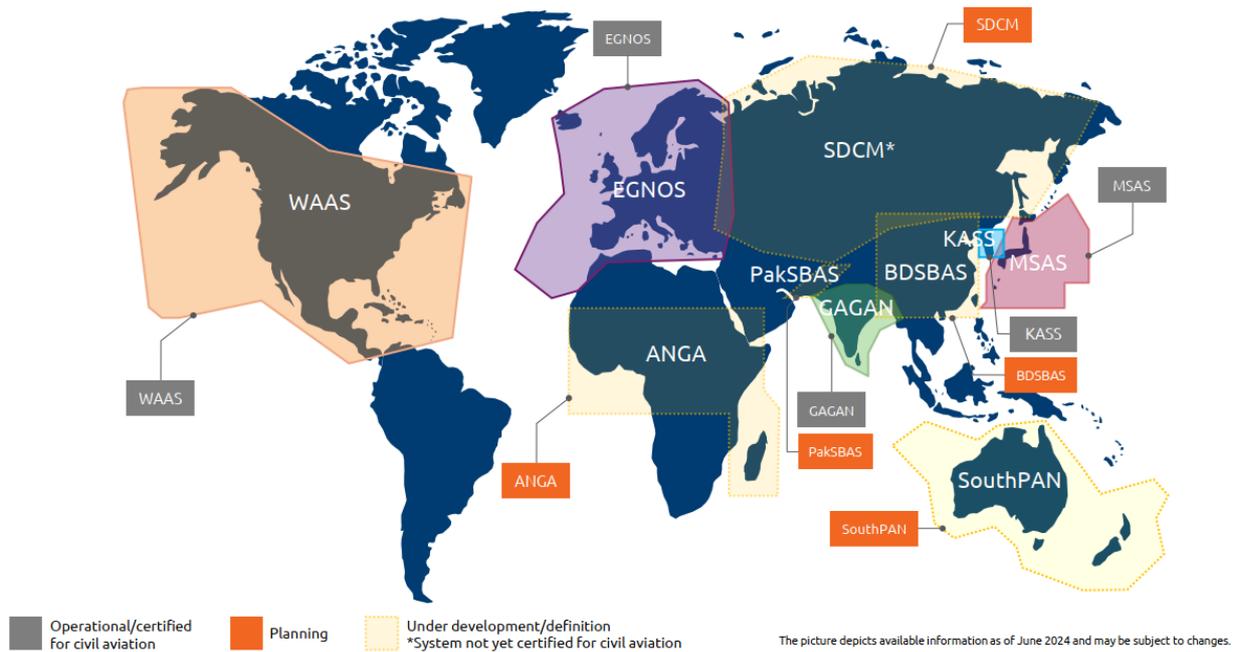


Figure 1: Existing and planned SBAS systems with indicative service areas⁹

3.2 EGNOS Services

EGNOS provides corrections and integrity information to GPS signals over a broad area centred over Europe and it is fully interoperable with other existing SBAS systems.

EGNOS provides three services:

- **Safety of Life (SoL) Service**, that provides the most stringent level of signal-in-space performance to all Safety of Life user communities, in particular for the aviation sector which is the service defined in this document, and for the maritime sector through the EGNOS Safety of Life assisted service for MAritime userS (ESMAS);
- **Open Service (OS)**, freely available to any user;
- **EGNOS Data Access Service (EDAS)** for users who require access to specific GNSS data streams for the provision of added-value services, professional applications, commercial products, R&D, etc.

SoL, ESMAS and OS services are transmitted by GEO SIS whereas EDAS is provided by internet access.

All these EGNOS services are available and granted throughout their respective service areas.

3.2.1 EGNOS Safety of Life (SoL) Service for Aviation

The main objective of the EGNOS SoL Service for Aviation is to support civil aviation operations down to Localiser Performance with Vertical Guidance (LPV) minima. In order to provide the SoL Service, the EGNOS system has been designed so that the EGNOS Signal-In-Space (SIS) is compliant to the ICAO SARPs for SBAS [RD-1].

Two EGNOS SoL Service for Aviation levels (NPA and APV-I) were declared with the first issue of the EGNOS SoL Service for Aviation SDD v1.0 in March 2011 and an additional one (LPV-200) was declared

⁹ Represented SBAS according to the SBAS service provider identifiers defined in the ICAO SARPs [RD-1].

with the EGNOS SoL SDD v3.0 in September 2015 enabling the following SBAS-based operations in compliance with requirements as defined by ICAO in Annex 10 [RD-1]:

- Non-Precision Approach operations and other flight operations supporting PBN navigation specifications other than RNP APCH, not only for approaches but also for other phases of flight.
- Approach operations with Vertical Guidance supporting RNP APCH PBN navigation specification down to LPV minima as low as 250 ft.
- Category I precision approach with a Vertical Alert Limit (VAL) equal to 35m and supporting RNP APCH PBN navigation specification down to LPV minima as low as 200 ft, and in accordance with the accuracy requirements presented in the Table 7 ensured through the corresponding system analysis.

The EGNOS SoL Service for Aviation has been available since March 2nd, 2011, being this document the applicable SDD, which defines a model for an aviation receiver bounding the local errors for an aircraft in flight. The receiver, based on this model, uses the EGNOS data to compute a high confidence bound on the residual error in the navigation solution (user level integrity) and compares it to a pre-established tolerance to determine whether the service can be used operationally or not within a limited geographical area, called the EGNOS service area. This high confidence bound together with the capacity to warn the user within a specific time (Time To Alert) is what has been defined as SBAS integrity (i.e., a measure of the trust that can be placed in the correctness of the information supplied by SBAS, including its ability to provide timely and valid warnings to the user (alerts).

3.2.2 EGNOS Safety of Life (SoL) Assisted Service for Maritime Users (ESMAS)

In an operational environment a vessel travels close to various obstacles for the GNSS signals: buildings, port infrastructure, other vessels or even bridges, that create multipath, interference or blockages of satellite signals. As such, the SBAS integrity model mentioned above is not valid for maritime applications. Current PVT user solutions usually rely on GNSS complemented by a variety of sensors and/or sensor fusion techniques to offer accuracy and a certain level of confidence in the position for safety purposes.

The ESMAS offers a service tailored to maritime users to enable marine navigation in harbour entrances, harbour approaches and coastal waters of the European Union Member States and EGNOS contributing countries (Iceland, Norway, and Switzerland) in line with IMO Resolution A.1046 [RD-22].

This service targets a large variety of users. It provides certain performance that the corrections being broadcast shall or shall not be used and up to which extent. Therefore, it increases the confidence that a user can have in the satellite SIS information. The receiver manufacturer will be responsible to combine this information with other sensor(s) to compute the navigation position and the associated confidence levels.

The ESMAS has been available since March 13th, 2024, and the corresponding SDD is [RD-21].

3.2.3 Open Service (OS)

The main objective of the EGNOS OS is to improve the achievable positioning accuracy by correcting several error sources affecting the GPS signals. The corrections transmitted by EGNOS contribute to mitigate the ranging error sources related to satellite clocks, satellite position and ionospheric effects. The other error sources (tropospheric effects, multipath and user receiver contributions) are local effects that cannot be corrected by a wide area augmentation system. Finally, EGNOS can also detect distortions affecting the signals transmitted by GPS and prevent users from tracking unhealthy or misleading signals.

The EGNOS OS is accessible in Europe to any user equipped with an appropriate GPS/SBAS compatible receiver for which no specific receiver certification is required.

The EGNOS OS has been available since 1st October 2009 and the corresponding SDD is [RD-5].

3.2.4 EGNOS Data Access Service (EDAS)

EDAS is the EGNOS terrestrial data service which offers ground-based access to EGNOS data in real time and also in a historical FTP archive to authorised users (e.g. added-value application providers). EDAS is the single point of access for the data collected and generated by the EGNOS ground infrastructure (RIMS and NLES) mainly distributed over Europe and North Africa.

EDAS users and/or application Providers will be able to connect to EDAS, and directly exploit the EGNOS products or offer added-value services based on EDAS data.

The EDAS service is available since July 26th 2012 and the corresponding SDD is [RD-6].

3.3 EGNOS Architecture

To provide its services to users equipped with appropriate receivers, the EGNOS system comprises three main segments: the Space Segment, the Ground Segment and the User Segment. EGNOS functional architecture is shown in Figure 2.

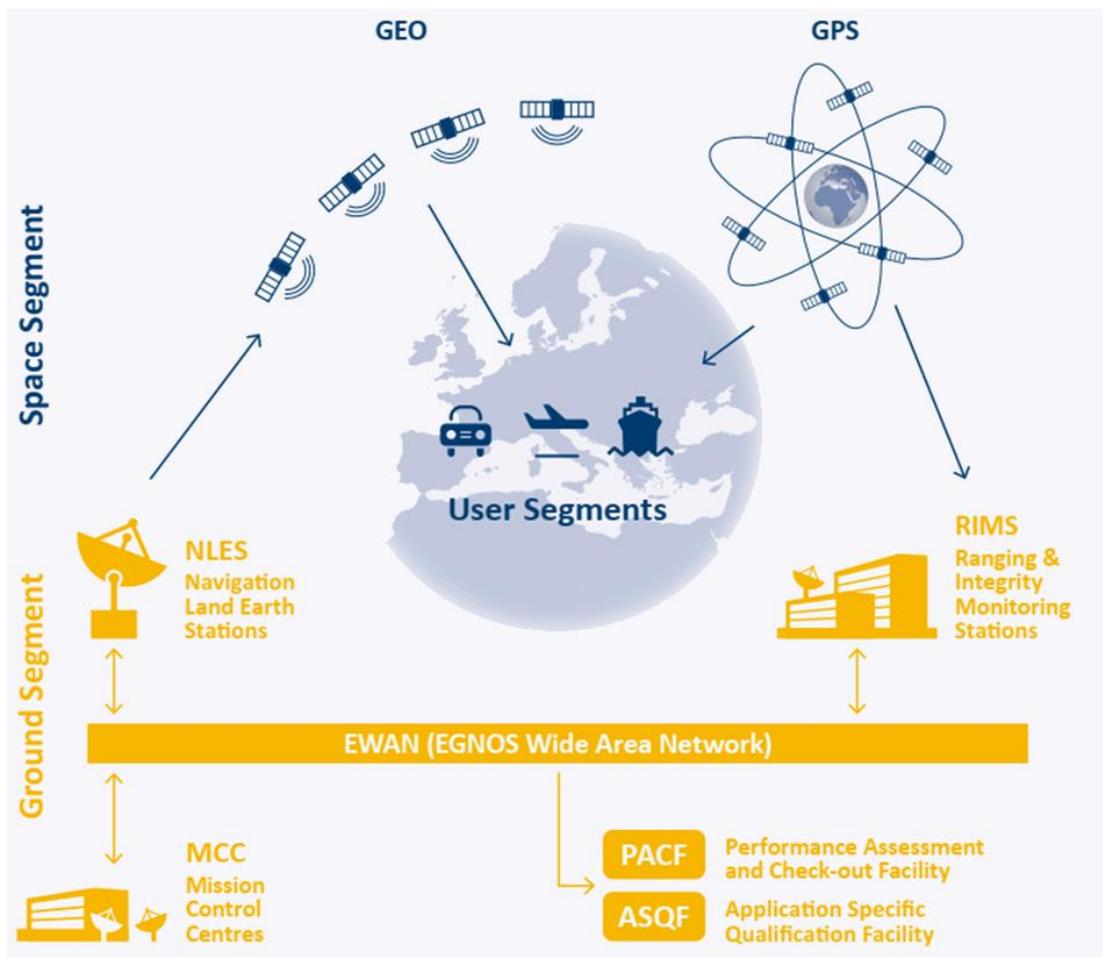


Figure 2: EGNOS architecture

3.3.1 EGNOS space segment

The EGNOS space segment comprises at least 3 geostationary (GEO) satellites broadcasting corrections and integrity information for GPS satellites in the L1 frequency band (1575.42 MHz). The configuration of the GEOs in operation does not change frequently but possible updates are nevertheless reported to users by the EGNOS Service Provider. At the date of publication, the 3 GEOs used by EGNOS are the following ones.

GEO Name	PRN Number	Orbital Slot
ASTRA-5B	PRN 123	23.5 E
ASTRA SES-5	PRN 136	5 E
EUTELSAT 5 West B ¹⁰	PRN 121	5 W

Table 2: GEOs used by EGNOS

This space segment configuration provides a high level of redundancy over the whole service area in case of a geostationary satellite link failure. The EGNOS operations are handled in such a way that, at any point in time, at least two of the GEOs broadcast an operational signal and the other one broadcasts a test signal. This secures a switching capability in case of interruption and ensures a high level of continuity of service.

The detailed configuration of operational and test satellites is reported in the EGNOS User Support webpage¹¹.

The EGNOS space segment is constantly replenished over time in order to maintain the required level of redundancy. The exact orbital location of future satellites may vary, though this will not impact the service offered to users. Similarly, different PRN code numbers may be assigned to future GEOs.

It is important to remark that these changes in the EGNOS GEO space segment are performed in a seamless manner without any interruption from an EGNOS user point of view and without compromising at any moment the EGNOS performances. For this purpose, and whenever there could be any relevant information complementing the SDD, an EGNOS Service Notice is published¹² and distributed.

3.3.2 EGNOS ground segment

The EGNOS Ground Segment comprises a network of Ranging Integrity Monitoring Stations (RIMS), two Mission Control Centres (MCC), two Navigation Land Earth Stations (NLES) per GEO, and the EGNOS Wide Area Network (EWAN) which provides the communication network for all the components of the ground segment.

Two additional facilities are also deployed as part of the ground segment to support system operations and service provision, namely the Performance Assessment and Checkout Facility (PACF) and the Application Specific Qualification Facility (ASQF), which are operated by the EGNOS Service Provider.

3.3.2.1 Ranging Integrity Monitoring Stations (RIMS)

The main function of the RIMS is to collect measurements from GPS satellites and to transmit these raw data every second to the Central Processing Facilities (CPF) of each MCC. The current RIMS network comprises 38 RIMS sites located over a wide geographical area described in Figure 3.

¹⁰ At the time of the publication of this document, EUTELSAT 5 West B is used for testing purposes and broadcasts Message Type 0 indicating it cannot be used for SoL applications by the certified receivers. This satellite will not be used in EGNOS OP until its qualification is completed.

¹¹ <https://egnos.gsc-europa.eu/>

¹² https://egnos.gsc-europa.eu/documents/field_gc_document_type/service-notices-87



Figure 3: EGNOS RIMS sites

3.3.2.2 Central Processing Facility (CPF)

The Central Processing Facility (CPF) is a module of the MCC that uses the data received from the network of RIMS stations to:

1. Elaborate clock corrections for each GPS satellite in view of the network of RIMS stations. These corrections are valid throughout the geostationary broadcast area (i.e. wherever the EGNOS signal is received).
2. Elaborate ephemeris corrections to improve the accuracy of spacecraft orbital positions. In principle, these corrections are also valid throughout the geostationary broadcast area. However, due to the geographical distribution of the EGNOS ground monitoring network, the accuracy of these corrections will degrade when moving away from the core of the EGNOS service area.

3. Elaborate a model for ionospheric errors over the EGNOS service area in order to compensate for ionospheric perturbations to the navigation signals.

These three sets of corrections are then broadcast to users to improve positioning accuracy.

In addition, the CPF estimates the residual errors that can be expected by the users once they have applied the set of corrections broadcast by EGNOS. These residual errors are characterised by two parameters:

- User Differential Range Error (UDRE): this is an estimate of the residual range error after the application of clock and ephemeris error correction for a given GPS satellite.
- Grid Ionospheric Vertical Error (GIVE): this is an estimate of the vertical residual error after application of the ionospheric corrections for a given geographical grid point.

These two parameters can be used to determine an aggregate error bounded by the horizontal and vertical position errors. Such information is of special interest for Safety of Life users but may also be beneficial to other communities needing to know the uncertainty in the position determined by the user receiver. More details on the EGNOS integrity concept can be found in Appendix B EGNOS Integrity concept.

Finally, the CPF includes a large number of monitoring functions designed to detect any anomaly in GPS and in the EGNOS system itself and is able to warn users within a very short timeframe (less than Time To Alert (TTA)) in case of an error exceeding a certain threshold.

3.3.2.3 Navigation Land Earth Stations (NLES)

The messages elaborated by the CPF are transmitted to the NLESs. The NLESs (two for each GEO for redundancy purposes) transmit the EGNOS message received by the CPF to the GEO satellites for broadcast to users and to ensure the synchronisation with the GPS signal.

The NLES are grouped by pairs, pointing to a Geostationary satellite. For each GEO, one NLES is active (broadcasts) and the other in Back-up mode.

The main functions of the NLES include:

- the selection of the CPF that broadcasts the SBAS message,
- the modulation of the message provided by the CPF,
- the synchronization of the uplink signal with GPS time,
- the transmission of the data to the GEO satellites,
- the real-time monitoring of the received signal from the GEO satellites to ensure is the one transmitted and within the expected power levels.

3.3.2.4 Central Control Facility (CCF)

The EGNOS system is controlled through a Central Control Facility (CCF) located in each of the Mission Control Centres. These facilities are manned on a 24/7 basis in order to ensure permanent service monitoring and control.

3.3.3 EGNOS user segment

The EGNOS user segment consists of the user equipment that processes the received signals from the GNSS satellites (EGNOS and GPS) and uses them to derive and apply position, time and integrity information. The equipment ranges from smartphones and handheld receivers, to sophisticated, specialized receivers used for high-end safety critical applications.

The particular user equipment for the EGNOS Safety of Life for Aviation is detailed in section 5.

3.4 EGNOS Organisational Framework

3.4.1 Bodies Involved in the EGNOS Programme and Service Delivery

The European Union (EU) is the owner of the EGNOS system.

As per the EU Space Regulation [RD-7]:

- The European Commission has the overall responsibility for the implementation of the EGNOS Programme, including for security and determines the priorities and long-term evolutions.
- The European Union Agency for the Space Programme (EUSPA) is in charge of the EGNOS exploitation and - according to the Financial Framework Partnership Agreement between the European Commission representing the European Union, EUSPA and ESA- acts as System Prime for the System in Operations for EGNOS, i.e. is responsible for maintenance changes and mid-term improvement of the System in operations.
- ESA is in charge of the System evolution and - according to the Financial Framework Partnership Agreement between the European Commission representing the European Union, EUSPA and ESA- acts as Design Authority, i.e. holds the technical responsibility of the system baseline, design integrity and consistency including for the System in Operations.

ESSP is the current EGNOS Service Provider within Europe for SOL Service for Aviation. It is certified according to the Single European Sky (SES) regulation as Air Navigation Service Provider (ANSP). ESSP also generates EGNOS Notice To Airmen (NOTAM) proposals to the appropriate Aeronautical Information Service providers within Europe that should validate and distribute the final Official EGNOS NOTAM.

3.4.2 How to Get Information on EGNOS and EGNOS Applications or Contact the Service Provider

Detailed information about the EGNOS programme, EGNOS system status, and EGNOS services performance can be found by accessing the sources listed in Table 3.

Topic	Description and Web/contact details
EGNOS Programme	European Commission institutional information about the EGNOS Programme http://ec.europa.eu/growth/sectors/space/egnosp/
What is EGNOS	General information related to EGNOS Programme. https://www.euspa.europa.eu/european-space/egnosp/what-egnosp/
EGNOS User Support Website and Helpdesk	EGNOS user support website is the main source of information for EGNOS OS and EGNOS SoL aviation users: EGNOS OS and EGNOS SoL Service for Aviation status and performance, system description, historical and real time services performance, forecasts, EGNOS OS and EGNOS SoL Service for Aviation applicable documentation, FAQs, etc. The helpdesk is accessible on-line through the website and also by e-mail and by phone (24/7). It is the direct point of contact for any question related with the EGNOS OS and EGNOS SoL Service for Aviation, including performance and applications. https://egnosp.gsc-europa.eu/ helpdesk@egnosp.gsc-europa.eu Helpdesk line: +34 911 236 555
EGNOS Safety of Life assisted service for Maritime users and	ESMAS User support Website is the main source of information for ESMA and EDAS status and performance, system description,

EDAS User Support Website and Helpdesk	historical and real time services performance, forecasts, applicable documentation, FAQs, etc. The helpdesk is accessible on-line through the website and also by e-mail and by phone (24/7). It is the direct point of contact for any question related with the EDAS and ESMAS service, including performance and applications. https://edas-maritime.gsc-europa.eu/helpdesk@edas-maritime.gsc-europa.eu Helpdesk line: +34 911 236 555
EGNOS Service Provider activity	ESSP official reporting of the service provider activities, news, etc. http://www.essp-sas.eu
EGNOS certified receivers	EASA mailbox for any question related to service difficulties or malfunctions of EGNOS certified receivers egnos@easa.europa.eu
EGNOS Working Agreements (EWA)	Formalization between ESSP and a specific organization for introducing EGNOS procedures. EGNOS-working-agreement@essp-sas.eu
EGNOS app	Direct point of contact for any question related with the EGNOS system, its performance and applications.  https://itunes.apple.com/app/egnos/id1346540596?ls=1&mt=8  https://play.google.com/store/apps/details?id=com.essp.egnosapp

Table 3: Where to find information about EGNOS

EGNOS SoL for Aviation SDD readers are also invited to refer to the GPS SPS PS [RD-3] and European Aviation Safety Agency (EASA) European Technical Standard Order (ETSO)-C145/C146 & C196 for details of both the fundamental GPS SPS service and EGNOS receiver equipment respectively. EGNOS also meets the ICAO Annex 10¹³, Standards and Recommended Practices (SARPs) for Global Navigation Satellite System (GNSS) Satellite Based Augmentation System (SBAS), [RD-1], except for the continuity requirements where some waivers exist as detailed in section 6.3.1.4 for NPA service level, in section 6.3.2.5 for APV-I service level and in section 6.3.3.5 for LPV-200 service level.

3.4.3 EGNOS Working Agreement

As foreseen in the Single European Sky (SES) regulatory requirements (see [RD-8] and [RD-9]), an EGNOS Working Agreement (EWA) is required to be signed between the EGNOS SoL Service Provider and the ANSP implementing EGNOS based operations.

When there is no ANSP providing ATS services but an organisation implementing an EGNOS based operation, if required by the relevant competent authority, the EGNOS SoL Service for Aviation can be used only upon signature of an EWA. The signature of this EWA between that organisation and the ESP can be also required by the organisation implementing an EGNOS based operation itself, as part of the approval process of the corresponding operation

The overall objective of the EGNOS Working Agreement is to formalise the operational and technical baseline between the ESP and the specific organisation, as well as the required operational interfaces, in order to support the EGNOS based operation.

The EWA includes:

¹³ With the exceptions specified in the footnotes 16 and 20.

- EWA contractual document: The agreement itself containing contractual liability with two annexes:
 - EWA Annex 1: Including the “EGNOS Service Provider Service Commitment” as stated in this EGNOS SoL Service for Aviation SDD. It also includes reference to contingency coordination between the Service Provider and the organisation.
 - Annex 2: Including the “Service Arrangements” defined between the Service Provider and the organisation implementing Performance Based Navigation (PBN) procedures based on EGNOS, covering all identified applicable requirements, namely:
 - NOTAM Proposals: Outlining the terms and conditions under which the Service Provider will provide EGNOS NOTAM Proposals to the NOFs of the organisation providing Aeronautical Information Services (AIS) under the scope of a signed EWA (see section 3.4.4).
 - GNSS Data Recording: Describing the proposal of the Service Provider in order to provide GNSS data to the organisation. To this purpose, the detailed data, format, storing time, time to provide these data and procedures are described.
 - Collaborative Decision Making: Defining clear working relationships between the Service Provider and the organisation describing organisation involvement in ESSP decision making process whenever any decision could lead to a material impact on the service provided.

All EWA related information / discussions will be managed by the SoL Service Provider through the dedicated focal points (see section 3.4.2 for contact information).

The updated information concerning the EGNOS implementation status can be found in the EGNOS user support website: <https://egnos.gsc-europa.eu/resources-tools/lpy-procedures-map>.

3.4.4 EGNOS NOTAM Proposals Generation

A NOTAM (Notice to Airmen) is a notice issued to alert pilots of potential hazards along a flight route that could affect the safety of the flight.

The objective of the EGNOS NOTAM Proposal generation is to:

- Predict Service Level outages at given locations.
- Create and format the corresponding NOTAM Proposals into an ICAO format [RD-11] and according to the European Concept for GNSS NOTAM [RD-12] to ease the validation process to be performed by the NOF (NOTAM Offices).
- Distribute the NOTAM Proposals to the concerned NOFs through the AFTN network.

The need for a NOTAM service when implementing SBAS based procedures is clearly stated by the ICAO SARPs ([RD-11]). Apart from establishing the NOTAM service as a key element in the implementation of SBAS based procedures, the ICAO SARPs also lay down the applicable recommendations for this kind of service, in terms of notification timeliness.

Since the 2nd of March 2011 (EGNOS SoL Service for Aviation Declaration date), ESSP is providing the EGNOS NOTAM Proposals service, through the corresponding national AIS provider, for any EGNOS based procedure published. Hence, the ESP acts as data originator in the EGNOS NOTAM generation chain. In particular, the ESP provides NOTAM Proposals to the corresponding national NOTAM Offices (AIS provider) of the concerned States, which are responsible for the validation and publication of NOTAMs for end users.

Please note that, apart from the EGNOS NOTAM Proposals, there is no other EGNOS operational status information provided, which is fully in line with the applicable concept of operations; specifically, and according to ICAO Annex 10 Volume I, 3.7, there is no EGNOS operational status information provided to aerodrome control towers and units providing air traffic services.

Figure 4 shows the EGNOS NOTAM Proposal service in the overall NOTAM lifecycle and depict the NOTAM process until the reception to the end users.

The terms and conditions under which the ESP provides EGNOS NOTAM Proposals to any national NOTAM Offices (NOFs) providing Aeronautical Information Services (national AIS provider) are detailed within the corresponding EGNOS Working Agreement (EWA) to be established between the ESP and the particular organisation implementing EGNOS based operations (see section 3.4.3). The agreement includes the EGNOS NOTAM Proposals services as one of the main enablers for the EGNOS based procedures implementation.

Since January 1st, 2014, the EGNOS NOTAM Proposals service is (so called Service Level 4) based on:

- NOTAMs resulting from:
 - GNSS scheduled events notified minimum 72 hours in advance.
 - GNSS (EGNOS and GPS) unscheduled events notified within 2 hours (24/7)

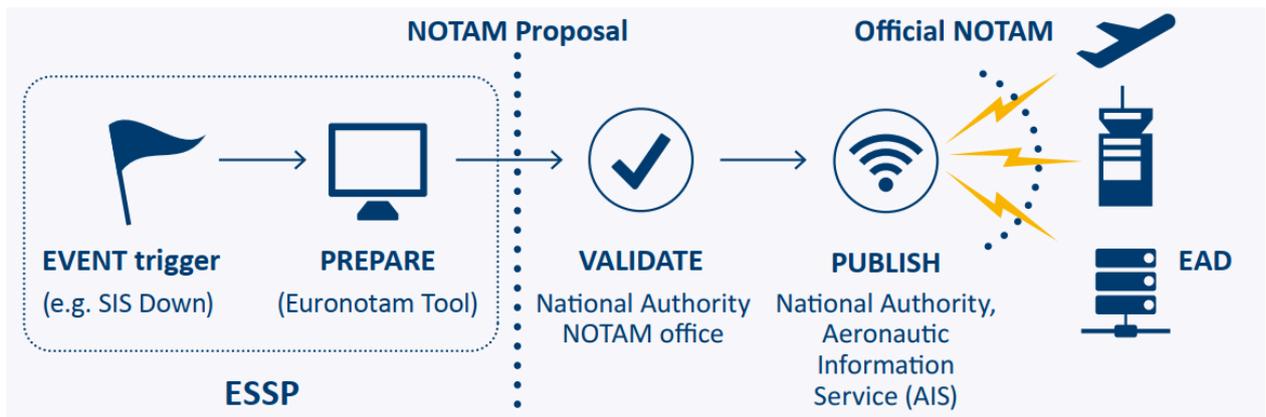


Figure 4: NOTAM Proposal service within the NOTAMs life cycle

4 EGNOS SIS

4.1 EGNOS SIS Interface Characteristics

The EGNOS Signal In Space format is compliant with the ICAO SARPs for SBAS [RD-1]. This section provides an overview of the EGNOS SIS interface characteristics, related to carrier and modulation radio frequency (section 4.1.1) and structure, protocol and content of the EGNOS message (section 4.1.2).

4.1.1 EGNOS SIS RF Characteristics

The EGNOS GEO satellites transmit right-hand circularly polarised (RHCP) signals in the L band at 1575.42 MHz (L1)¹⁴. The broadcast signal is a combination of a 1023-bit PRN navigation code of the GPS family and a 250 bits per second navigation data message carrying the corrections and integrity data elaborated by the EGNOS ground segment.

The EGNOS SIS RF characteristics are compliant with the corresponding values defined in the ICAO SARPs [RD-1].

4.1.2 EGNOS SIS Message Characteristics

The EGNOS SIS Navigation Data is composed of a number of different Message Types (MT) as defined in the SBAS standard.

Table 4 describes the MTs that are used by EGNOS and their purpose.

The format and detailed information on the content of the listed MTs and their use at SBAS receiver level are given in the ICAO SARPs [RD-1]¹⁵ and RTCA SBAS MOPS [RD-2].

Message Type	Contents	Purpose
0	Don't Use (SBAS test mode)	Discard any ranging, corrections, and integrity data from that PRN signal. Used also during system testing.
1	PRN Mask	Indicates the slots for GPS and EGNOS GEO satellites provided data ¹⁶
2-5	Fast corrections	Range corrections and accuracy
6	Integrity information	Accuracy-bounding information for all satellites in one message
7	Fast correction degradation factor	Information about the degradation of the fast term corrections

¹⁴ An EGNOS L1 message is currently broadcast as well by the EGNOS GEOs through the civil frequency L5 (1176.45 MHz). This signal does not have any impact for Safety of Life users, who are limited to the use of the L1 frequency as defined in RTCA SBAS MOPS [RD-2]. This represents a deviation with respect to the ICAO SARPs [RD-1], in which it is required that each frequency is used to broadcast its specific message. It is expected that future versions of EGNOS will solve this non-compliance [RD-1].

¹⁵ Note that ESSP, as EGNOS Service Provider, continuously monitors that SBAS messages broadcast by all SBAS visible from the EGNOS Service Area are compliant with the format specifications defined in the ICAO SARPs for SBAS RD-1].

¹⁶ EGNOS provides corrections for all operational/healthy GPS satellites included in this PRN mask. The introduction of Block III satellites is done under specific Competent Authority review following the process in accordance with [RD-9].

9 ¹⁷	GEO ranging function parameters	EGNOS GEO satellites orbit information (ephemeris)
10	Degradation parameters	Information about the correction degradation upon message loss
12	SBAS network Time/UTC offset parameters	Parameters for synchronisation of EGNOS Network time with UTC
17	GEO satellite almanacs	EGNOS GEO satellites almanacs ¹⁸
18	Ionospheric grid point masks	Indicates for which geographical point ionospheric correction data is provided
24	Mixed fast/long-term satellite error corrections	Fast-term error corrections for up to six satellites and long-term satellite error correction for one satellite in one message.
25	Long-term satellite error corrections	Corrections for satellite ephemeris and clock errors for up to two satellites
26	Ionospheric delay corrections	Vertical delays/accuracy bounds at given geographical points
27	EGNOS service message	Defines the geographic region of the service
63	Null message	Filler message if no other message is available

Table 4: EGNOS SIS transmitted MTs

4.2 EGNOS Time and Geodetic Reference Frames

Strictly speaking, the time and position information that are derived by an SBAS receiver that applies the EGNOS corrections are not referenced to the GPS Time and the WGS84 reference systems as defined in the GPS Interface Specification. Specifically, the position coordinates and time information are referenced to separate reference systems established by the EGNOS system, namely the EGNOS Network Time (ENT) timescale and the EGNOS Terrestrial Reference Frame (ETRF). However, these specific EGNOS reference systems are maintained closely aligned to their GPS counterparts and, for the vast majority of users, the differences between these two time/terrestrial reference frames are negligible.

4.2.1 EGNOS Terrestrial Reference Frame – ETRF

EGNOS was initially designed to fulfil the requirements of the aviation user community as specified in the ICAO SBAS SARPS [RD-1]. [RD-1] establishes the GPS Terrestrial Reference Frame, WGS84, as the terrestrial reference to be adopted by the civil aviation community.

The EGNOS Terrestrial Reference Frame (ETRF) is an independent realisation of the International Terrestrial Reference System (ITRS¹⁹) which is a geocentric system of coordinates tied to the surface of the Earth and in which the unit distance is consistent with the International System of Units (SI²⁰) definition of the metre.

¹⁷ MT9 is broadcast with some information about the orbital position of the broadcasting EGNOS GEO satellite. At this stage, the EGNOS system does not support the Ranging function which is described in the ICAO SARPs as an option. This is indicated by a special bit coding of the Health and Status parameter broadcast in MT17. In particular, GEO satellite position broadcast in both MT9 and MT17 are set to fixed position (x, y, z), and GEO position rate of change in MT9 & MT17, as well as GEO acceleration and aGf0 & aGf1 parameters in MT9, are permanently set to zero.

¹⁸ Regarding MT17 GEO satellite almanacs, there is a deviation to the specifications in the ICAO SARPs [RD-1], which requires that a SBAS service provider use MT17 to broadcast the almanac of all the GEOs of the same system. Currently, the MT17 broadcast by the EGNOS operational GEOs only include the operational GEOs almanacs, while the MT17 broadcast by the test GEO only includes the test GEO almanac. This deviation does not represent any impact for Safety of Life Users.

¹⁹ Detailed information on ITRS (concepts, realisation, materialization ...) can be found on the official website: <https://itrf.ign.fr/en/>

²⁰ Information on the International System of Units (SI) can be obtained from <https://www.bipm.org/en/>

The ITRS is maintained by the International Earth Rotation and Reference Systems Service (IERS²¹) and is the standard terrestrial reference system used in geodesy and Earth research. Realizations of ITRS are produced by the IERS under the name International Terrestrial Reference Frames (ITRF). Several realizations of the ITRS exist, being ITRF2014 the last one.

In order to define the ETRF, the ITRF2000 coordinates and velocities of the RIMS antennas are estimated using space geodesy techniques based on GPS data. Precise GPS ephemeris and clock corrections produced by the International GNSS Service (IGS²²) are used to filter the GPS data collected over several days at each RIMS site and to derive the antenna coordinates and velocities with geodetic quality. This process is repeated periodically (at least once per year) in order to mitigate the degradation of the ETRF accuracy caused by the relative drift between the two reference frames.

The ETRF is periodically aligned to the ITRF2000 in order to maintain the difference between the positions respectively computed in both frames below a few centimetres. The same can be said about the WGS84 (WGS84(G1150) aligned to ITRF2000). Conversion of ETRF data into WGS84(G1150) is obtained by applying the offset that exists at a certain epoch between the ETRF and the ITRF2000 to the ITRF2000 to WGS84(G1150) frame. Note that currently these last two reference frames are almost equivalent (offsets minor than 2cm).

This means that, for the vast majority of applications, it can be considered that the positions computed by an EGNOS receiver are referenced to WGS84 and can be used with maps or geographical databases in WGS84.

4.2.2 EGNOS Network Time: ENT – GPS Time consistency

The time reference used by EGNOS to perform the synchronisation of the RIMS clocks is the EGNOS Network Time (ENT). The ENT timescale is an atomic timescale that relies on a group of atomic clocks deployed at the EGNOS RIMS sites. The EGNOS CPFs compute the ENT in real time, using a mathematical model which processes timing data collected from a subset of the RIMS clocks.

The ENT is continuously steered towards GPS Time (GPST) by the EGNOS Ground Control Segment and the relative consistency between the two timescales is maintained at the level of tens of nanoseconds as observed in Figure 5:

²¹ Information on IERS can be obtained from <http://www.iers.org/>

²² Information on IGS can be obtained from <http://www.igs.org/>

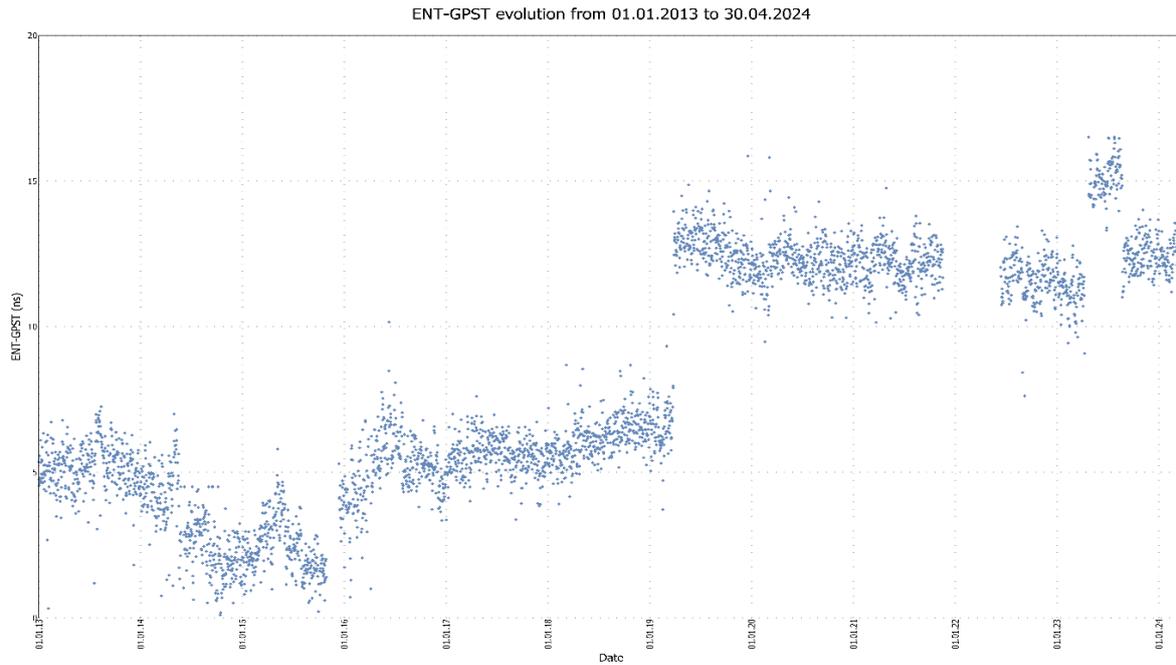


Figure 5: ENT GPS time offset evolution (Period 01/01/2013 - 30/04/2024)

All satellite clock corrections computed by the EGNOS Ground Segment and transmitted to the EGNOS users are referenced to the ENT timescale. Moreover, the offset between ENT and UTC is broadcast in the EGNOS navigation message. Applying EGNOS corrections on GPS measurements, a precise time and navigation solution referenced to ENT is obtained. Therefore, the assessment of the time difference between ENT and UTC is a key issue for time users.

Despite the high level of consistency between the ENT and GPST timescales, EGNOS users are advised not to combine uncorrected GPS measurements (i.e. those referenced to GPST) and GPS measurements which have been corrected using EGNOS parameters (i.e. those referenced to ENT), when computing a navigation solution. Indeed, this approach might noticeably degrade the accuracy of the solution (by up to 10 to 20 metres). EGNOS users who want to combine GPS measurements referenced to different timescales should account for an additional unknown corresponding to the time offset between the two-time references in the receiver navigation models.

5 EGNOS RECEIVERS

5.1 EGNOS Receivers for Aviation

Since the SBAS standards have been initially derived to meet the stringent navigation performance requirements applicable to civil aviation approach and landing operations, the reference SBAS receiver standards have also been developed by the civil aviation community. These standards are called SBAS Minimum Operational Performance Standards (MOPS) and are published by the Radio Technical Commission for Aeronautics (RTCA) under the reference DO-229 [RD-2]. This receiver standard has been designed by and for the aviation community and therefore supports both horizontal and vertical navigation and implements a large number of features aimed at ensuring the integrity of the derived position.

This standard identifies different classes of user receivers depending on the intended operations. Table 5 summarises the main characteristics of the EGNOS equipment operational classes:

Operational Class	Phases of Flight
Class 1	Oceanic and domestic en-route, terminal, approach (LNAV), and departure operation
Class 2	Oceanic and domestic en-route, terminal, approach (LNAV, LNAV/VNAV), and departure operation
Class 3	Oceanic and domestic en-route, terminal, approach (LNAV, LNAV/VNAV, LP, LPV), and departure operation
Class 4	Equipment that supports only the final approach segment operation

Table 5: EGNOS equipment operational classes

For EGNOS, the minimum performance levels assume equipage with a class 1 receiver (for NPA service level) or class 3 receiver (for APV-I and LPV-200 service levels) under the conditions in terms of number of satellites in view for a fault-free receiver as indicated in section 6.

For non-aviation SoL users, alternative EGNOS message processing may be implemented, deviating from the DO-229 MOPS standard [RD-2]. However, the EGNOS system performance has not been characterised for such a receiver configuration and therefore the performance experienced by such receivers is likely to deviate from that described in the EGNOS SoL Service for Aviation SDD.

More information about EGNOS receivers for aviation can be found in the official EGNOS User Support website (see section 3.4.2).

5.2 Receiver & Avionics Certification

According to the intended operation, EASA material providing implementing guidance is available in [RD-18]. This material includes airworthiness criteria such as equipment qualification and functional criteria, airworthiness compliance for installation, as well as operational criteria.

The equipment qualification recommended in EASA material refers to ETSO (European-TSO) equipment. An ETSO authorised piece of hardware (receiver, antenna, etc.) has been demonstrated to have been designed, tested, and manufactured in compliance with the applicable standards. It is recalled that the ETSO approval process is just a way that the equipment manufacturer chooses to demonstrate compliance with the standards; it is not the unique method. Therefore, it is possible to find non-ETSO authorised equipment that is fully compliant with the standards and that is authorised for use by the competent authority.

It should also be considered that ETSO authorizations refer only to the equipment itself (avionics and related hardware) and not the installation within the aircraft. The user/operator should follow the guidance provided in the applicable EASA material in order to ensure that the approval for the avionics installation by the aircraft manufacturer includes all the proper elements.

Receivers authorised following FAA regulation with an issued Technical Standard Order (TSO) can also benefit from the EGNOS SoL Service for Aviation. A TSO is a minimum performance standard for specified materials, parts, and appliances used on civil aircraft. When authorised to manufacture a material, part, or appliances to a TSO standard, this is referred to as TSO authorization. Receiving a TSO authorization is both design and production approval. A separate FAA approval is required to install the equipment on an aircraft.

Given an airworthy installation and functions compliant with the requirements in the applicable EASA material, it is important to highlight that for some specific operations (such as RNP AR and RNP0.3 as defined in [RD-15]) an operational approval has to be obtained from the competent authority²³ (as defined in [RD-17]).

Table 6 lists the existing ETSOs and TSOs related to the hardware required for SBAS operations:

ETSO	TSO	EQUIPMENT
ETSO-C144a	TSO-C144a	Passive Airborne Global Navigation Satellite System (GNSS) Antenna
ETSO-C145e A1	TSO-C145e	Airborne Navigation Sensors Using the Global Positioning System Augmented by the Satellite Based Augmentation System.
ETSO-C146e A1	TSO-C146e	Stand Alone Airborne Navigation Equipment Using the Global Positioning System Augmented by the Satellite Based Augmentation System.
ETSO-C190	TSO-C190	Active Airborne Global Navigation Satellite System (GNSS) Antenna
ETSO-C196b	TSO-C196b	Airborne Supplemental Navigation Sensors for Global Positioning System Equipment Using Aircraft-Based Augmentation

Table 6: Existing ETSOs and TSOs and hardware requirements for SBAS operations

²³ Aircraft with an existing airworthiness approval (according to [RD-19] and [RD-20] as indicated in the EASA Easy Access Rules for [RD-17] or CS-ACNS [RD-18]) do not require an additional approval for LPV-200, unless the Aircraft Flight Manual (AFM) includes a specific limitation stating that the DH cannot be lower than a certain threshold.

6 EGNOS SOL SERVICE FOR AVIATION PERFORMANCE

6.1 EGNOS SoL Service for Aviation Description and Characteristics

The EGNOS SoL Service for Aviation has been available from March 2nd, 2011. It consists of signals for timing and positioning, provided openly which are freely accessible and without any direct charge. Terms and conditions of use under which the EGNOS SoL Service for Aviation is offered are described in section 2.2 above.

The EGNOS SoL Service for Aviation is accessible to any user equipped with an EGNOS receiver as described in section 5 within the EGNOS SoL Service for Aviation area as referred to in section 6.3. The minimum performance reported in this section is the performance that can be experienced when using receiving equipment compliant with RTCA MOPS DO229 Class 3 specifications as described in section 5.1²⁴. It also assumes GPS characteristics/performance as mentioned in section 2.1 and a clear sky environment with no obstacle masking satellite visibility at angles greater than 5° above the local horizontal plane.

The EGNOS SoL Service for Aviation is compliant with the aviation requirements for Approach with Vertical Guidance (APV-I) and Category I precision approach as defined by ICAO in Annex 10 [RD-1], except for specific deviations noted within section 6.3 but is also intended to support applications in other SoL domains.

The “minimum” performance figures shown in this section take into account a number of abnormal system states or non-typical environmental conditions that can statistically be expected to occur during the lifetime of the system. These types of characterisation are considered to provide valuable and complementary insights into EGNOS service performance for receiver manufacturers, for GNSS application developers and for end users of the EGNOS SoL Service for Aviation.

The performance reported in this document is the one that can be obtained with the version of EGNOS currently in operation. It is the objective that future versions will deliver, as a minimum, an equivalent level of performance. The SDD will be updated whenever necessary.

²⁴ The performance of SBAS avionics is impacted by the erroneous setting of GPS SVs to “do not use” (UDREI=15) in the EGNOS message as, depending on the DO-229 version, it could deny the use of the GPS+RAIM/FDE functions (i.e. affected GPS SV might be removed from navigation solution). This could have significant impact in some flight operations, such as when conducting missed approach procedures. The failure case where EGNOS would erroneously set all GPS SV to “Do not use” for more than 1 minute is considered as a Critical Safety Event in the operation of the service (and reported to the competent authority as such).

6.2 EGNOS SoL Service for Aviation Performance Requirements

The EGNOS system has been designed to support different types of civil aviation operations. Requirements for each type of operation have been issued by [RD-1] and are summarised in Table 7:

Typical operation	Accuracy		Integrity				Continuity	Availability
	Horizontal Accuracy 95%	Vertical Accuracy 95%	Integrity	Time-To-Alert (TTA)	Horizontal Alert Limit (HAL)	Vertical Alert Limit (VAL)		
En-route (oceanic/continental low density)	3.7 km (2.0 NM)	N/A	$1 - 1 \times 10^{-7} / \text{h}$	5 min	7.4 hm (4NM)	N/A	$1 - 1 \times 10^{-4} / \text{h}$ to $1 - 1 \times 10^{-8} / \text{h}$	0.99 to 0.99999
En-route (continental)					3.7 km (2NM)	N/A		
En-route, Terminal	0.74 km (0.4 NM)	N/A	$1 - 1 \times 10^{-7} / \text{h}$	15 s	1.85 km (1NM)	N/A	$1 - 1 \times 10^{-4} / \text{h}$ to $1 - 1 \times 10^{-8} / \text{h}$	0.99 to 0.99999
Initial approach, Intermediate approach, Non-precision approach (NPA), Departure	220 m (720 ft)	N/A	$1 - 1 \times 10^{-7} / \text{h}$	10 s	556 m (0.3 NM)	N/A	$1 - 1 \times 10^{-4} / \text{h}$ to $1 - 1 \times 10^{-8} / \text{h}$	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	40 m (130 ft)	50 m (164 ft)	$1 - 8 \times 10^{-6}$ per 15 s	0.99 to 0.99999
Category I precision approach	16.0 m (52 ft)	6.0 m to 4.0 m (20 ft to 13 ft)	$1 - 2 \times 10^{-7}$ in any approach	6 s	40 m (130 ft)	35.0 m to 10.0 m (115 ft to 33 ft)	$1 - 8 \times 10^{-6}$ per 15 s	0.99 to 0.99999

Table 7: SoL Service for Aviation performance requirements (ICAO)

Note 1: For Category I precision approaches with Vertical Alert Limit (VAL) higher than 10m, the ICAO SARPs ([RD-1]) defines the following acceptable mean to manage the risks of collision and unsafe landing due to Navigation System Error (NSE) in the visual segment:

1. In nominal conditions: Probability (VNSE > 10m) <math>< 10^{-7}/150s</math>
2. In degraded conditions: Probability (VNSE > 15m) <math>< 10^{-5}/150s</math>

The degraded or system-failure conditions are those affecting either the core constellations or the GNSS augmentation under consideration. This probability is to be understood as the combination of the occurrence probability of a given failure with the probability of detection for applicable monitor(s). Typically, the probability of a single fault is large enough that a monitor is required to satisfy this condition. The nominal or fault-free conditions are those different from the degraded ones.

6.3 EGNOS SoL Service for Aviation Minimum Service Performance Characteristics

The EGNOS SoL Service for Aviation minimum performance characteristics are described below for accuracy, integrity, availability, and continuity. This minimum performance is conservative since it has been derived to take account of a number of degraded conditions or abnormal environmental conditions that could be experienced throughout the lifetime of the system.

The region in which the service availability or continuity will be actively pursued by the Programme are the landmasses inside the perimeter defined by the magenta line in the availability and continuity maps presented in sections 6.3.2 and 6.3.3. This region includes EU member states and third countries with an agreement with the EU for the use of the EGNOS SoL Service for Aviation. The EGNOS SoL Service for Aviation for areas beyond the region defined by this line is not ensured in the absence of an agreement since the EGNOS SoL Service for Aviation shall be provided as a priority on the territory of all Member States geographically located in Europe.

EGNOS SoL Service for Aviation performance is summarized in Table 8 and detailed in following sections.

		Accuracy		Integrity		Continuity	Availability
		Horizontal Accuracy 95%	Vertical Accuracy 95%	Integrity	Time-To-Alert (TTA)		
Performance	NPA	200 m	N/A	$1 - 1 \times 10^{-7} / h$	Less than 6 seconds	<math>< 1 - 1 \times 10^{-3}</math> per hour in most of ECAC <math>< 1 - 2.5 \times 10^{-3}</math> per hour in other areas of ECAC	0.999 in all ECAC
	APV-I & LPV-200 ²⁵	3 m ²⁶	4 m	$1 - 2 \times 10^{-7} / \text{approach}$		<math>< 1 - 1 \times 10^{-4}</math> per 15 seconds in the core of ECAC	0.99 in most of ECAC landmasses

²⁵ For LPV-200, additional requirements are established:

- Probability of having a VNSE greater than 10 meters is lower than 10^{-7} per approach in nominal conditions
- Probability of having a VNSE greater than 15 meters is lower than 10^{-5} per approach in degraded conditions

²⁶ Values committed inside the APV-I & LPV-200 corresponding 99% availability areas

						1 – 5x10 ⁻⁴ per 15 seconds in most of ECAC landmasses	
Comment	Accuracy values at given locations are available at: https://egnos.gsc-europa.eu/ For LPV-200 new accuracy requirements imposed by ICAO Annex 10 ([RD-1]) see section 6.3.3.2			N/A		See sections 6.3.1.3, 6.3.2.4 and 6.3.3.4 for detailed availability maps. See sections 6.3.1.4, 6.3.2.5 and 6.3.3.5 for detailed continuity maps.	

Table 8: SoL Service for Aviation performance values

6.3.1 NPA – Non-Precision Approach²⁷

The performance commitment for NPA covers other phases of flight (en-route, terminal or other RNP) (RNPO.3 being the minimum supported)) using EGNOS for lateral guidance only.

6.3.1.1 Accuracy

The EGNOS accuracy, as reflected in Table 8, is compliant with the accuracy requirements specified in Table 7 for NPA inside the EGNOS service area.

6.3.1.2 Integrity

The EGNOS integrity, as reflected in Table 8, is compliant with the integrity requirements specified in Table 7 for NPA.

6.3.1.3 Availability

Figure 6 provides the minimum availability performance that can be expected from EGNOS for NPA (not considering RAIM). The area in red is where the 99.9% availability requirement, specified in Table 7, is met. These values correspond to the performance measured by a fault-free receiver using all GPS satellites in view over a period of one month, using all the operational EGNOS GEOs.

²⁷ Even if it is recommended by RTCA MOPS 229 to use ionospheric corrections if they are available, the NPA performance results provided in this document consider that the ionospheric correction applied for this navigation mode is the GPS model, which represents a conservative approach.

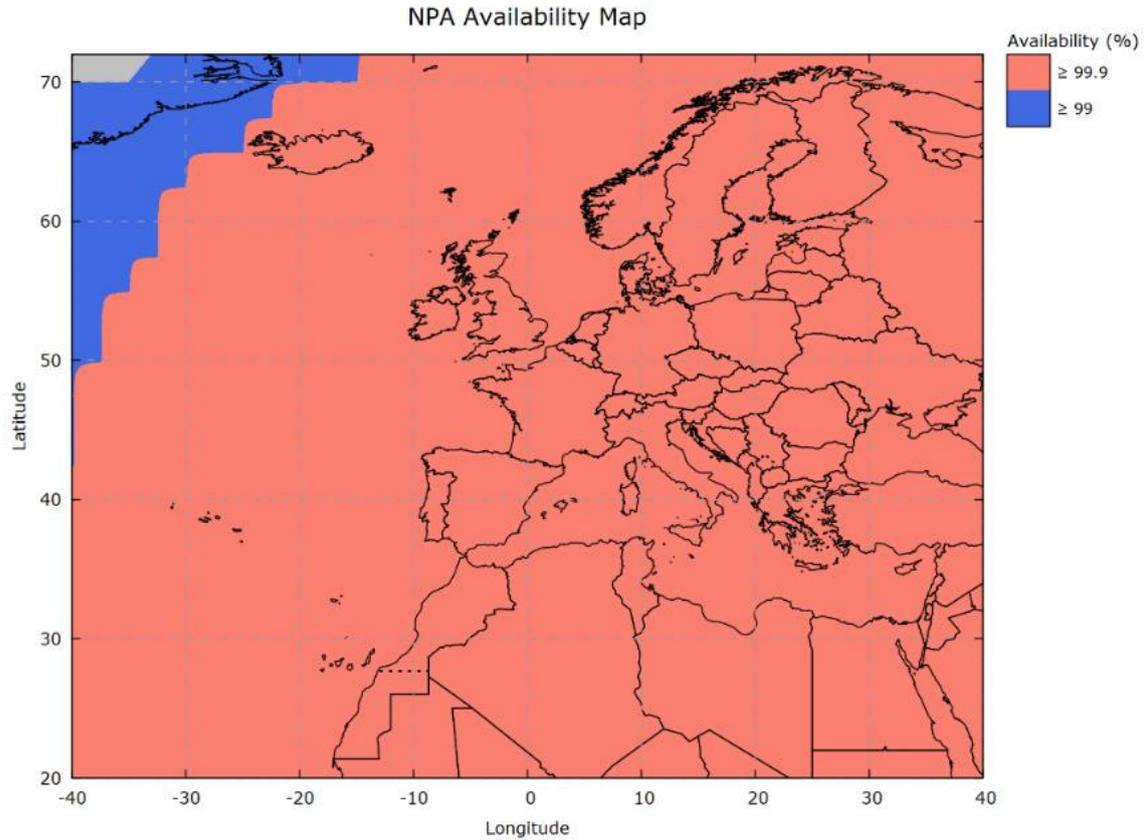


Figure 6: EGNOS NPA availability

6.3.1.4 Continuity

Figure 7 provides the commitment on the minimum continuity performance that can be expected from EGNOS for NPA (not considering RAIM). These values correspond to the expected performance measured by a fault-free receiver using all GPS satellites in view over a period of one month, using all the operational EGNOS GEOs.

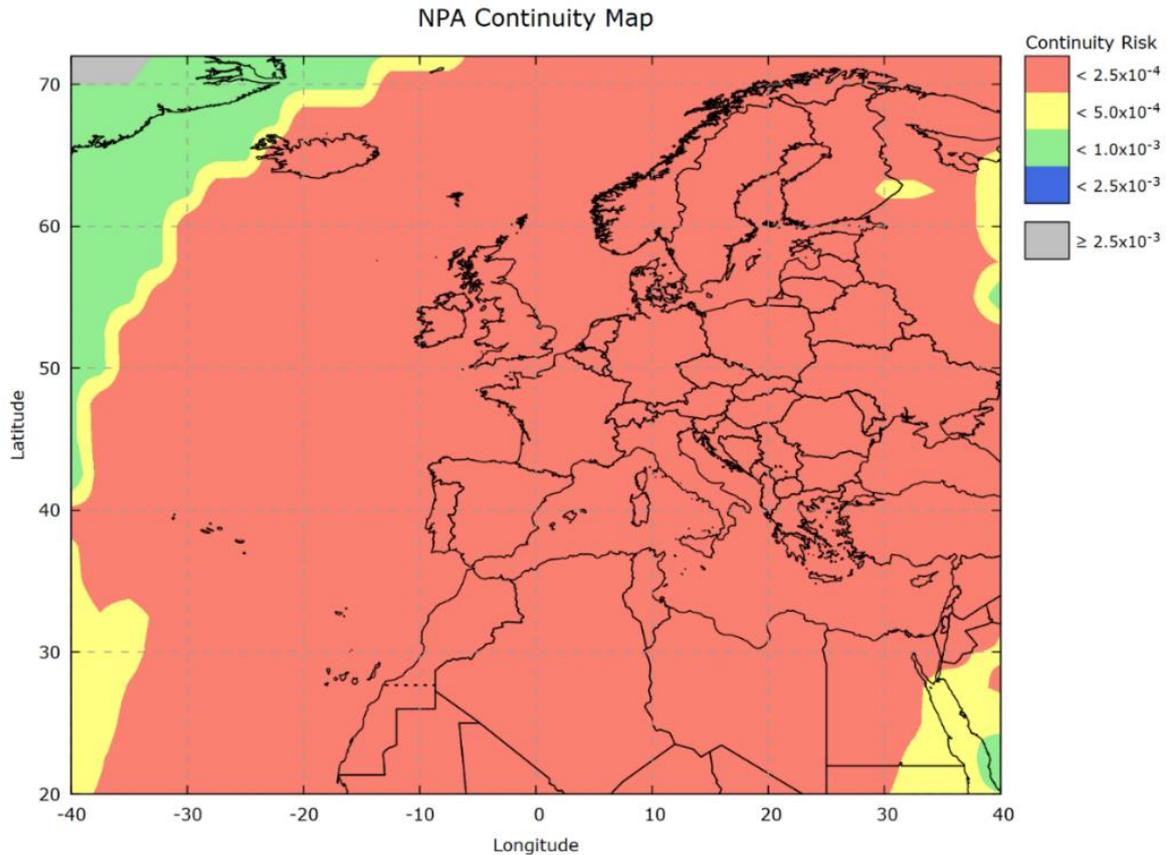


Figure 7: EGNOS NPA continuity²⁸

The minimum continuity risk performance is less than 1×10^{-3} per hour in most of ECAC 96 Flight Information Regions (FIRs). It should be noted that the regions of continuity risk smaller than 1×10^{-3} /hour are relatively sensitive to the scenario and models used to compute the minimum EGNOS SoL Service for Aviation area. Such a minimum performance is not compliant to ICAO requirements for NPA as described in Table 7.

These values are however considered as sufficient to start the EGNOS use in civil aviation. Indeed, the ICAO SARPs [RD-1] include interpretative material stating that when the continuity performance objective is not achieved by a given system, it is still possible to allow the publication of procedures based on the given system. In this case, local air navigation authorities shall define, if necessary, measures to mitigate the risks of an operational nature²⁹. Moreover, the Performance-based Navigation (PBN) Manual [RD-17] already includes special considerations when GNSS is the main or sole positioning source³⁰.

²⁸ In order to observe the minimum NPA continuity performance shown in the map (5×10^{-4}), at least 6 months of data needs to be evaluated due to the discrete nature of discontinuity events.

²⁹ Annex 10, of the Chicago Convention, Attachment D, 3.4.3.4: "For those areas where the system design does not meet the average continuity risk specified in the SARPs, it is still possible to publish procedures. However, specific operational mitigations should be put in place to cope with the reduced continuity expected. For example, flight planning may not be authorised based solely on a GNSS navigation means with such a high average continuity risk".

³⁰ ICAO Doc 9613, Performance-based Navigation (PBN) Manual, Chapter 3 Safety Assessment Considerations, 3.4.1 Failure of Navaid Environment, 3.4.1.2 "When GNSS is planned to be the main or sole positioning source, consideration needs to be given to the impact of loss of navigation capability, not to just a single aircraft, but to a predetermined population of aircraft in a specified airspace".

6.3.2 APV-I – Approach with vertical guidance

6.3.2.1 Assumptions for the Definition of the Commitment Maps

The APV-I availability and continuity maps presented in the following sections have been elaborated on the basis of the results observed during several months of observation of EGNOS performances. These maps represent the minimum level of performances which can be expected under similar conditions to those under which these performance maps have been computed. These conditions, which refer to both the internal status of the system (number of RIMS used, number of GEOs, etc.) and the external conditions (GPS constellation status, environmental conditions, etc.), are detailed hereafter:

- EGNOS RIMS configuration: the number and location of the EGNOS RIMS corresponds to those presented in Figure 3, in section 3.3. Those stations which appear as part of the TEST platform or under deployment have not been considered for the definition of the commitments.
- EGNOS GEOs configuration: The EGNOS space segment assumed for the preparation of the maps consists of two operational GEOs. The use of at least two GEOs by the SBAS receiver secures a switching capability in case of interruption and ensures a high level of continuity of service.
- GPS satellite constellation (PRN mask): The number of usable GPS satellites assumed for the definition of the maps corresponds to all the satellites identified in the EGNOS PRN mask, as broadcasted in the SBAS Message Type 1. During the observation period the number of GPS PRNs identified in the EGNOS mask has been 31 GPS satellites.
- Environmental conditions: The observations used for the generation of the maps cover a period of none or moderated ionospheric activity. Under high ionospheric activity or geomagnetic storm periods (caused by sudden eruptions of the Sun), GNSS/SBAS users, in particular EGNOS SoL Service for Aviation users, can experience residual ionospheric effects owing to increased ionospheric variability impossible to be effectively modelled and corrected, which can cause reduced navigation performance (see Appendix C Ionospheric activity and impact on GNSS for further details). The methodology used for the definition of the maps filters out data coming from days with abnormally high ionosphere activity; this is achieved by discarding days with a planetary A index (Ap) higher than 30 and by discarding the outliers of the analysed data. The Ap index is one of the most commonly used indicator to quantify and classify the ionospheric and geomagnetic conditions during a time period. An Ap index of 30 or greater indicates unusually high local geomagnetic storm conditions.

The consequence of the presented assumptions and methodology is that the actual performance experienced by a user at a particular moment may differ from the one presented in the following sections, owing in particular to the uncontrollable variability of the external conditions such as GPS constellation status or environmental conditions (see Appendix C Ionospheric activity and impact on GNSS for further details). The users in the border of the service area may be more affected.

The EGNOS Service Provider, is continuously monitoring and analysing the impact caused by these conditions that may be experienced by the EGNOS users so that, whenever there could be a degraded situation expected to be maintained over the time, an EGNOS Service Notice is published (https://egnos.gsc-europa.eu/documents/field_gc_document_type/87) and distributed.

6.3.2.2 Accuracy

APV-I horizontal and vertical accuracy performances are detailed in Table 8. The EGNOS system is therefore compliant with the accuracy requirements specified in Table 7 for Approach operations with vertical guidance (APV-I) inside the availability service area defined in section 6.3.2.4.

6.3.2.3 Integrity

The EGNOS integrity, as reflected in Table 8, is compliant with the integrity requirements specified in Table 7 for APV-I.

6.3.2.4 Availability

Figure 8 provides the minimum availability performance that can be expected from EGNOS for APV-I. The area in red represents the area where the 99% availability requirement, specified in Table 7, is met and other colours represent other availability requirements (yellow – 98%, green – 95% and blue – 90%). These values correspond to the expected performance measured by a fault-free receiver using all satellites in view over a period of one month, using all the operational EGNOS GEOs.

For the sake of a proper interpretation of the APV-I availability map, please see the details in section 6.3.2.1 concerning the methodology used for the map generation.

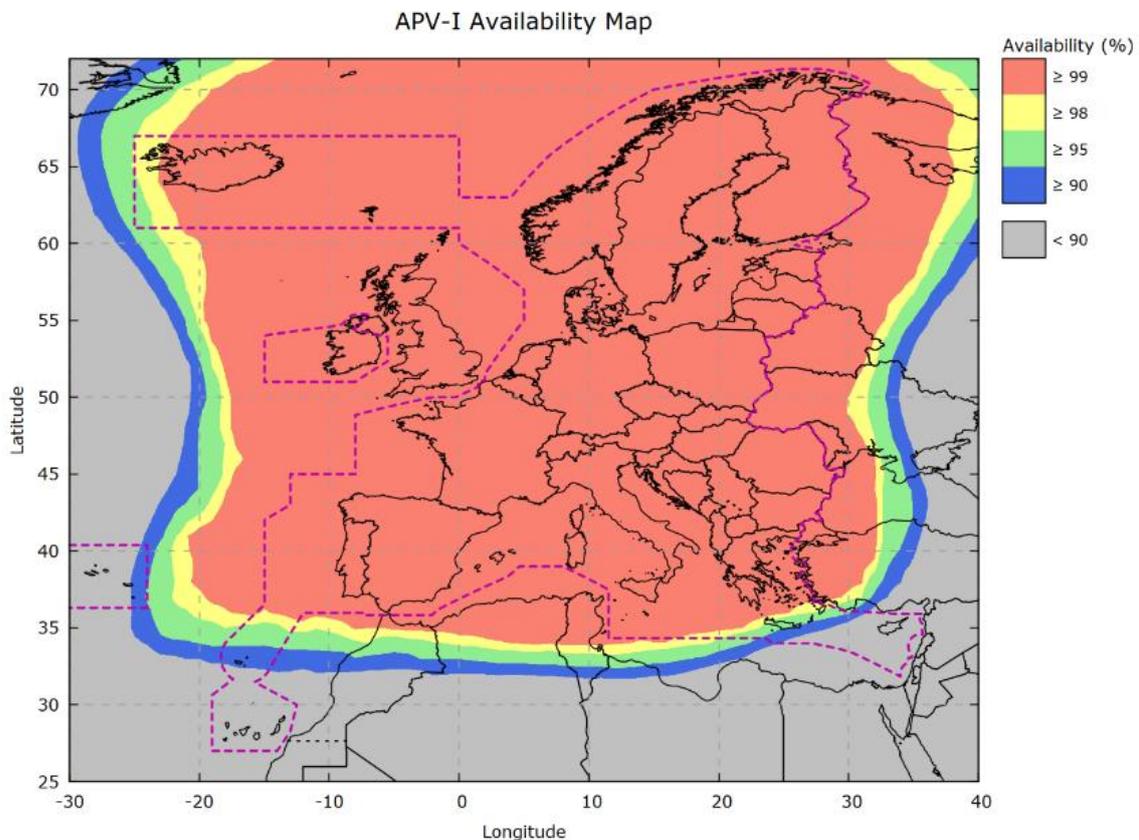


Figure 8: EGNOS APV-I availability

6.3.2.5 Continuity

Figure 9 provides the minimum continuity performance that can be expected from EGNOS for APV-I. These values correspond to the expected performance measured by a fault-free receiver using all satellites in view, over a period of one month, using all the operational EGNOS GEOs.

For the sake of a proper interpretation of the APV-I continuity map, please see the details in section 6.3.2.1 concerning the methodology used for the map generation.

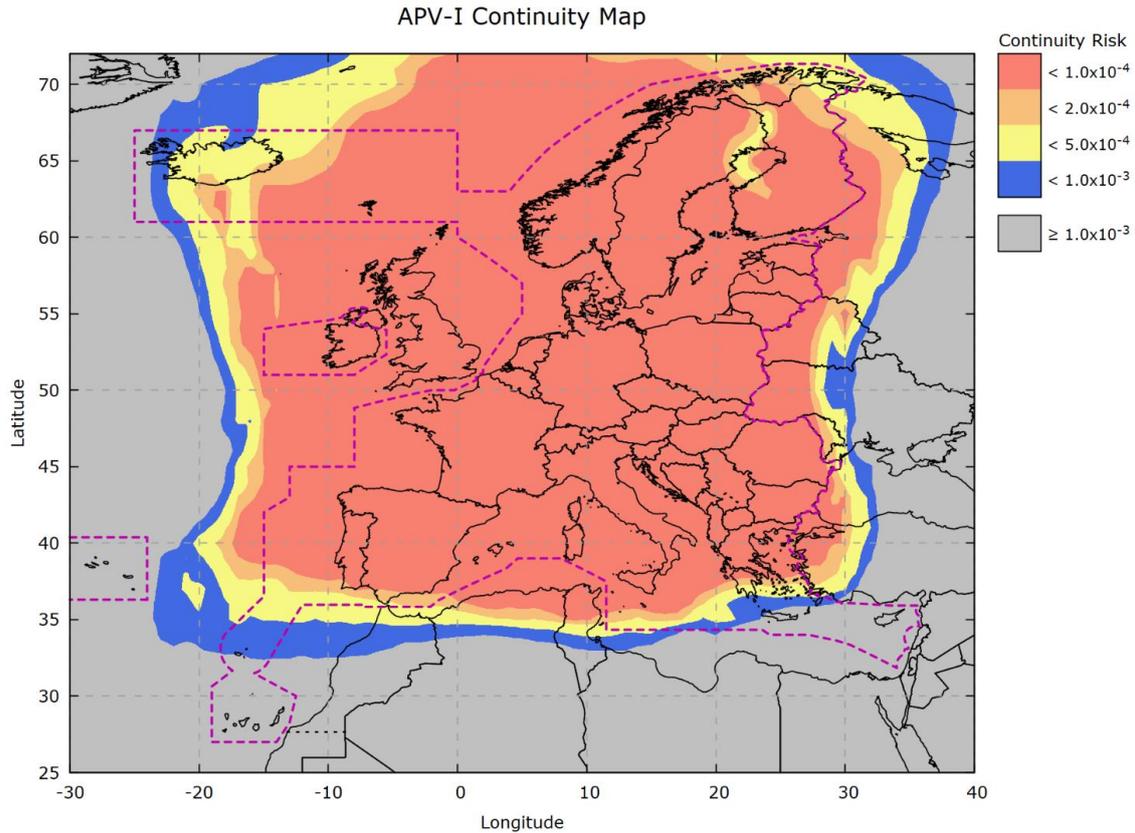


Figure 9: EGNOS APV-I continuity

The minimum continuity risk performance is less than 10^{-4} per 15 seconds in core part of ECAC landmasses, and less than 5×10^{-4} per 15 seconds in most of ECAC landmasses. There are however some regions with a risk of over 10^{-3} per 15 seconds. Such a minimum performance is not compliant to ICAO requirements for APV-I as described in Table 7 (8×10^{-6} per 15 seconds). These values are however considered as sufficient to allow the EGNOS use in civil aviation. Indeed, the ICAO SARPs [RD-1] include interpretative material stating that when the continuity performance objective is not achieved by a given system, it is still possible to allow publishing procedures based on the given system. In this case, local air navigation authorities shall define, if necessary, measures to mitigate the risks of an operational nature³¹. Moreover, the Performance-based Navigation (PBN) Manual [RD-17] already includes special considerations when GNSS is the main or sole positioning source³².

³¹ Annex 10 of the Chicago Convention, Attachment D, 3.4.3.4: "For those areas where the system design does not meet the average continuity risk specified in the SARPs, it is still possible to publish procedures. However, specific operational mitigations should be put in place to cope with the reduced continuity expected. For example, flight planning may not be authorised based solely on a GNSS navigation means with such a high average continuity risk".

³² ICAO Doc 9613, Performance-based Navigation (PBN) Manual, Chapter 3 Safety Assessment Considerations, 3.4.1 Failure of Navaid Environment, 3.4.1.2 "When GNSS is planned to be the main or sole positioning source, consideration needs to be given to the impact of loss of navigation capability, not to just a single aircraft, but to a predetermined population of aircraft in a specified airspace".

6.3.3 LPV-200 – Localizer Performance with Vertical Guidance Approach Down to a Decision Height not Lower than 200 ft

6.3.3.1 Assumptions for the Definition of the Commitment Maps

See section 6.3.2.1.

Note that, for the computation of LPV-200 availability, two new requirements in addition to $x_{PL} < x_{AL}$ are defined regarding the probability that the VNSE exceeds 10 m in nominal system operation conditions, set to 10^{-7} /per approach, and 15 m in degraded system operation conditions, set to 10^{-5} /per approach.

These LPV-200 requirements relative to the maximum VNSE probability are novel with respect to APV-I. It is to be noted that the hazard severity of an incompliance of the requirement $VNSE > 15$ m in degraded conditions is formally considered major from a safety point of view as explained by ICAO in Annex 10 [RD-1].

These new requirements are also considered in the LPV-200 continuity map. Therefore, the EGNOS system is compliant with these accuracy requirements inside the LPV-200 commitment maps curves defined in sections 6.3.3.4 and 6.3.3.5. The service is not provided outside those areas.

6.3.3.2 Accuracy

LPV-200 horizontal and vertical accuracy performances are detailed in Table 8. The EGNOS system is therefore compliant with the accuracy requirements specified in Table 7 for Category I precision approach with a Vertical Alert Limit of 35m inside the availability service area defined in Section 6.3.3.4.

6.3.3.3 Integrity

The EGNOS integrity is compliant with the integrity requirements specified in Table 7 for Category I precision approach.

6.3.3.4 Availability

Figure 10 provides the minimum availability performance that can be expected from EGNOS for LPV-200. The area in red represents the area where the 99% availability requirement, specified in Table 7, is met and other colours represent other availability requirements (yellow - 98%, green - 95% and blue - 90%). These values correspond to the expected performance measured by a fault-free receiver using all satellites in view over a period of one month, using all the operational EGNOS GEOs.

For the sake of a proper interpretation of the LPV-200 availability map, please see the details in section 6.3.3.1 concerning the methodology used for the map generation.

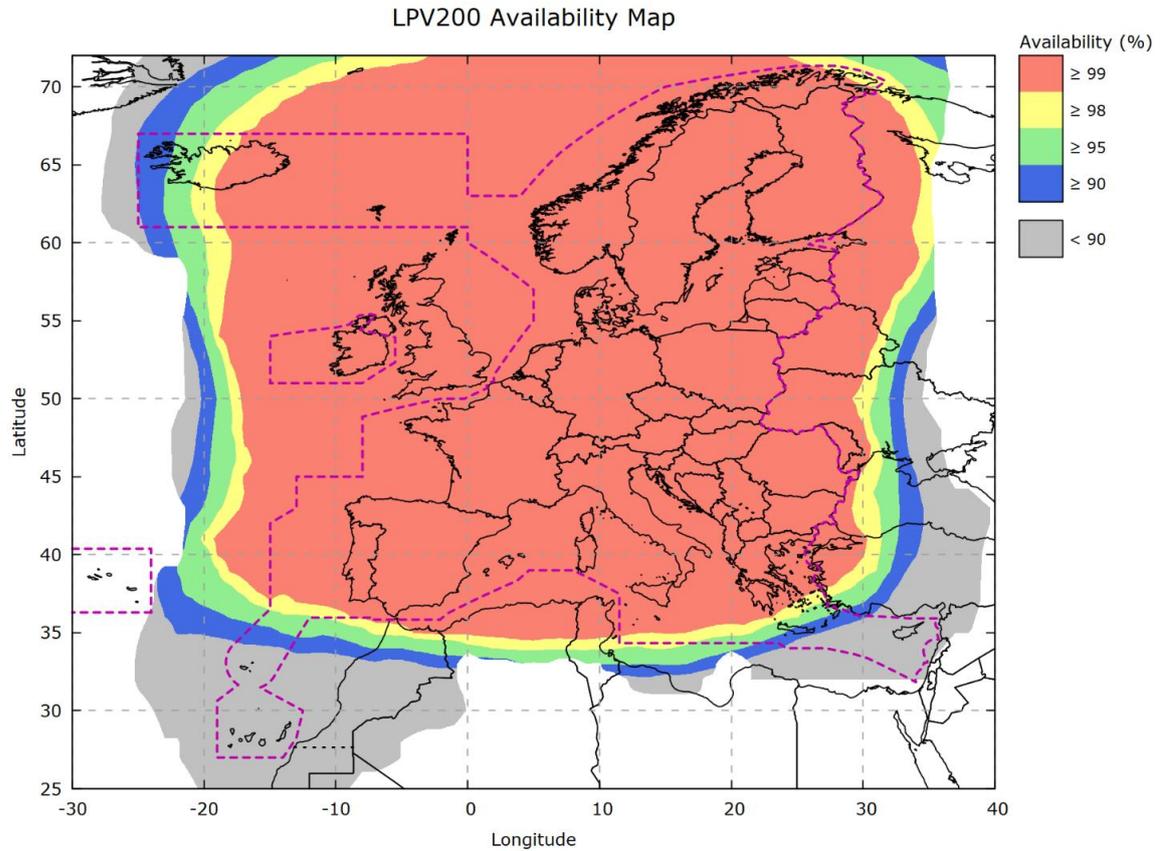


Figure 10: EGNOS LPV-200 availability³³

6.3.3.5 Continuity

Figure 11 provides the minimum continuity performance that can be expected from EGNOS for LPV-200. These values correspond to the expected performance measured by a fault-free receiver using all satellites in view, over a period of one month, using all the operational EGNOS GEOs.

³³ Service is not provided outside the coloured areas due to the non-compliance in those regions with the accuracy requirements imposed to LPV-200 service level. See more details in section 6.3.3.1

For the sake of a proper interpretation of the LPV-200 continuity map, please see the details in section 6.3.3.1 concerning the methodology used for the map generation.

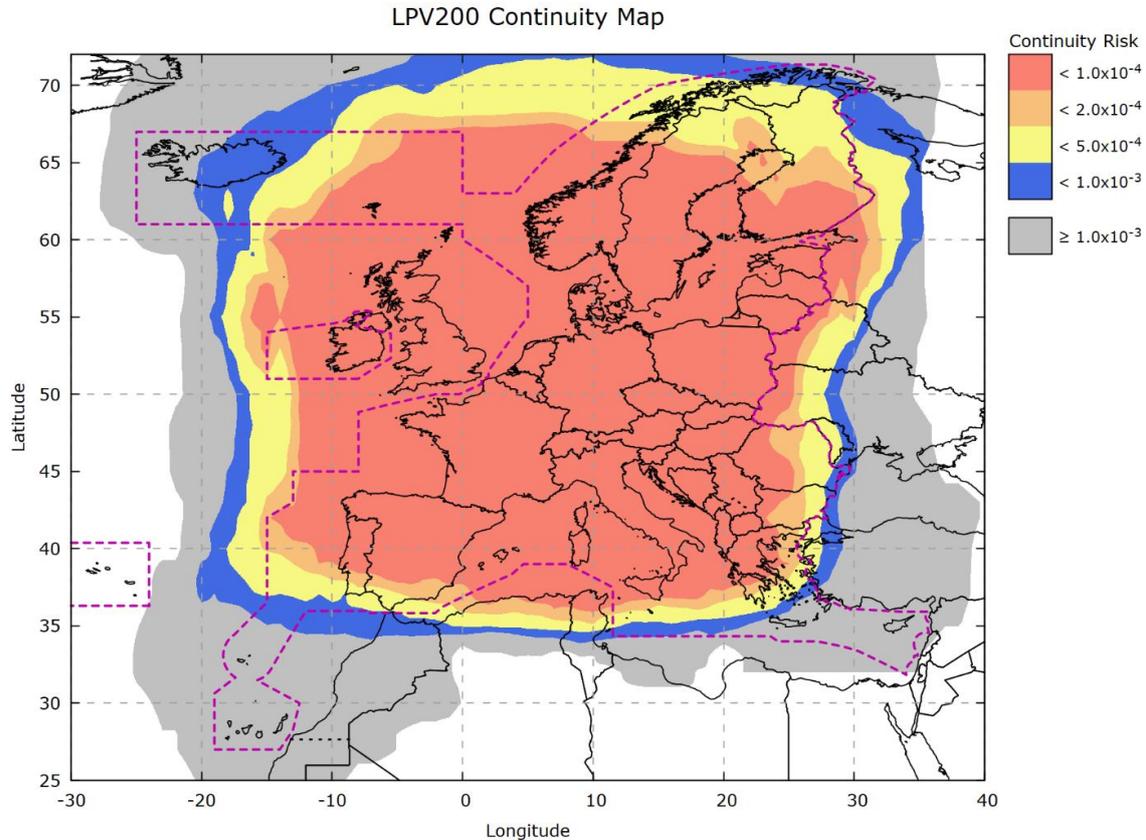


Figure 11: EGNOS LPV-200 continuity³⁴

The minimum continuity risk performance is less than 10^{-4} per 15 seconds in core part of ECAC landmasses, and less than 5×10^{-4} per 15 seconds in most of ECAC landmasses. There are however some regions with a risk of over 10^{-3} per 15 seconds. Such a minimum performance is not compliant to ICAO requirements for Category I precision approach as described in Table 7 (8×10^{-6} per 15 seconds). These values are however considered as sufficient to allow the EGNOS use in civil aviation. Indeed, the ICAO SARPs [RD-1] include interpretative material stating that when the continuity performance objective is not achieved by a given system, it is still possible to allow publishing procedures based on the given system. In this case, local air navigation authorities shall define, if necessary, measures to mitigate the risks of an operational nature³⁵. Moreover, the Performance-based Navigation (PBN) Manual [RD-17] already includes special considerations when GNSS is the main or sole positioning source³⁶.

³⁴ Service is not provided outside the coloured areas due to the non-compliance in those regions with the accuracy requirements imposed to LPV-200 service level. See more details in section 6.3.3.1

³⁵ Annex 10 of the Chicago Convention, Attachment D, 3.4.3.4: "For those areas where the system design does not meet the average continuity risk specified in the SARPs, it is still possible to publish procedures. However, specific operational mitigations should be put in place to cope with the reduced continuity expected. For example, flight planning may not be authorised based solely on a GNSS navigation means with such a high average continuity risk".

³⁶ ICAO Doc 9613, Performance-based Navigation (PBN) Manual, Chapter 3 Safety Assessment Considerations, 3.4.1 Failure of Navaid Environment, 3.4.1.2 "When GNSS is planned to be the main or sole positioning source, consideration needs to be given to the impact of loss of navigation capability, not to just a single aircraft, but to a predetermined population of aircraft in a specified airspace".

6.4 EGNOS SoL Service for Aviation Limitations

In the vast majority of cases, the EGNOS SoL Service for Aviation will be available and will provide performance in line with or beyond the minimum performance levels described in the previous sections of this document (section 6.3.1 for NPA service level, section 6.3.2 for APV-I service level and section 6.3.3 for LPV-200 service level). However, in a limited number of situations, users may experience non-nominal navigation performance levels. In all these cases, the integrity is not compromised. The most common causes for such abnormal behaviour are listed below in Table 9.

Root Cause	Most Likely Symptoms
<p>Broadcasting delays</p> <p>As explained in section 3.3, one of the functions of EGNOS is to elaborate a model of the ionosphere and to broadcast this model to users so that they can correct the related errors. When using the SBAS standard, the reception of all the parameters that are necessary to build such a model may take up to 5 minutes to be received, depending on the receiver. Therefore, the full positioning accuracy may not be reached as soon as the receiver is turned on.</p>	<p>EGNOS SoL Service for Aviation is not immediately available</p> <p>The receiver does not immediately use EGNOS to compute a navigation solution and therefore the position accuracy improvement is not available until a few minutes after the receiver is turned on.</p>
<p>GPS or EGNOS Signal Attenuation</p> <p>The receiver power level of GPS and EGNOS signals is extremely low. Using satellite navigation under heavy foliage or in an in-door environment will weaken further the signals up to a point where the receiver will either lose lock of such signals or have a very degraded performance.</p>	<p>Degraded Position Accuracy</p> <p>The position solution may demonstrate instability with higher error dispersion than usual. It may also be affected by sudden jumps when satellites are lost due to excessive attenuation. The performance of the receiver in such a difficult environment may be improved with a high-quality receiver and antenna design.</p>
<p>EGNOS Signal Blockage</p> <p>The EGNOS signals are broadcast by two geostationary satellites. This ensures some level of redundancy in case a satellite link is lost due to shadowing by a close obstacle (e.g. local orography or buildings). In addition, when moving North to high latitudes, the geostationary satellites are seen lower on the user's horizon and therefore are more susceptible to masking.</p> <p>At any latitude, it may happen that, in an urban environment, the EGNOS signals are not visible for some time.</p>	<p>Degraded Position Accuracy After Some Time</p> <p>The effect of losing the EGNOS signal (on both GEOs) on the receiver will be equivalent to reverting to a GPS-only receiver. The navigation solution will still be available but will demonstrate a degraded accuracy since no clock ephemeris or ionospheric corrections will be available to the user receivers. However, such degradation will not be instantaneous since the SBAS standard has been designed to cope with temporary signal blockages. The exact time the receiver can continue to provide good accuracy in case of the loss of signal depends on the receiver design.</p>
<p>Local Multipath</p> <p>In urban environments, the GPS and EGNOS signals will be prone to reflections on nearby objects (building, vehicles...). This may cause significant errors which cannot be corrected by the EGNOS system due to their local nature.</p>	<p>Degraded Position Accuracy</p> <p>The navigation solution will tend to meander around the true position and may demonstrate deviations of a few tens of metres. This effect will have a greater impact on static users or in those users moving at slow speed. High-quality receiver and antenna design is able to attenuate the effect of multipath in some specific conditions.</p>

<p>Local Interference</p> <p>GPS and EGNOS use a frequency band that is protected by the International Telecommunication Union (ITU). However, it is possible that in some specific locations, spurious transmissions from services operating in adjacent or more remote frequency bands could cause harmful interference to the satellite navigation systems.</p> <p>Such events can be intentional (jamming, spoofing) or unintentional and they are usually localised for ground users, but this may affect a wider area for airborne users.</p> <p>In most cases, national agencies are in charge of detecting and enforcing the lawful use of spectrum within their national boundaries.</p>	<p>Degraded Position Accuracy or Complete Loss of Service</p> <p>Depending on the level of interference, the effect on the user receiver may be a degradation of the position accuracy (unusual noise level affecting the positioning) or a total loss of the navigation service in case the interfering signals preclude the tracking of navigation signals, even if certified receivers are expected to be designed and tested in order to be capable of operating satisfactorily in typical interference conditions (refer to [RD-2] Appendix C Ionospheric activity and impact on GNSS).</p> <p>The detection, mitigation, and control of potential spurious transmissions from services operating in frequency bands that could cause harmful interference and effects to the satellite navigation systems (degrading the nominal performances) is under the responsibility of local authorities.</p>
<p>Ionospheric Scintillation</p> <p>Under some circumstances due to solar activity and in some specific regions in the world (especially for boreal and subtropical latitudes), ionospheric disturbances (called scintillation) will affect the GPS and EGNOS navigation signals and may cause the complete loss of these signals for a short period of time.</p>	<p>Degraded Position Accuracy</p> <p>The position solution may be affected when satellite tracking is lost due to scintillation. If the number of tracked satellites drops seriously, a 3-dimensional position may not be available. Eventually, the navigation service may be completely lost in case less than 3 satellites are still tracked by the user receiver.</p> <p>In cases when the EGNOS signal is lost, the impact will be similar to the one described for “EGNOS signal blockage” above.</p>
<p>Degraded GPS Core Constellation</p> <p>The GPS constellation is under continuous replenishment and evolution. On rare occasions, it may happen that the basic GPS constellation (as described in the GPS SPS PS [RD-3]) becomes temporarily depleted and that it does not meet the GPS SPS PS commitment.</p>	<p>Degraded EGNOS SoL Service for Aviation Performance</p> <p>In such a case, the EGNOS SoL Service for Aviation performance can be degraded. The performance experienced by the receiver may be worse than the minimum performance indicated in section 6.3.1 for NPA service level, section 6.3.2 for APV-I service level and section 6.3.3 for LPV-200 service level.</p>

Table 9: EGNOS SoL Service for Aviation limitations

APPENDIX A SATELLITE NAVIGATION CONCEPT

Satellite Navigation (GNSS) is a technique whereby mobile and static users can determine their position based on the measurement of the distance (range) between a number of orbiting satellites and the user receiver. Each satellite of the constellation broadcasts periodic signals that can be used by the user equipment to precisely determine the propagation time between the satellite signal transmission and the satellite signal reception by the receiver. This propagation time can easily be converted into a distance since, at a first approximation, the signals travel in space at a constant speed (the speed of light). Each satellite also continuously broadcasts all information (so-called ephemeris) necessary to determine the exact position of the satellite at any point in time.

Knowing the spacecraft position and the distance from that particular satellite, the user position is known to be somewhere on the surface of an imaginary sphere with a radius equal to that distance. If the position of and distance to a second satellite is known, the user/aircraft must be located somewhere on the circumference of the circle of where the two spheres intersect. With a third and fourth satellite, the location of the user can be inferred³⁷.

A GNSS receiver processes the individual satellite range measurements and combines them to compute an estimate of the user position (latitude, longitude, altitude, and user clock bias) in a given geographical coordinate reference frame.

The estimation of the satellite-to-user range is based on the measurement of the propagation time of the signal. A number of error sources affect the accuracy of these measurements:

- **Satellite clocks:** any error in the synchronisation of the different satellite clocks will have a direct effect on the range measurement accuracy. These errors are similar for all users able to view a given satellite.
- **Signal distortions:** any failure affecting the shape of the broadcast signal may have an impact on the propagation time determination in the user receiver.
- **Satellite position errors:** if the spacecraft orbits are not properly determined by the system's ground segment, the user will not be able to precisely establish the spacecraft location at any given point in time. This will introduce an error when computing the user position. The size of the error affecting the range measurements depends on the user's location.
- **Ionospheric effects:** The ionosphere is an ionised layer of the atmosphere located a few hundred kilometres above the surface of the Earth. When transiting through the ionosphere, the satellite navigation signals are perturbed, resulting in range measurement errors. The size of the error will depend on the level of solar activity (peaks in the solar activity occur on approximately an 11-year cycle) and on the satellite elevation above the horizon. For a low elevation satellite (5° above the horizon), the error affecting the measurement is about 3 times larger than the error affecting a satellite seen at the zenith.
- **Tropospheric effects:** The troposphere is the lower part of the atmosphere where most weather phenomena take place. The signal propagation in this region will be affected by specific atmospheric conditions (e.g. temperature, humidity...) and will result in range measurement errors. The size of the error will also depend on the satellite elevation above the horizon. For a low elevation satellite

³⁷ Based on this principle (called triangulation), the location of a receiver could theoretically be determined using the distances from only 3 points (satellites). However, in reality, the determination of a location requires in addition an estimate of the "unknown" receiver clock bias. This necessitates an additional (4th) range measurement.

(5° above the horizon), the error affecting the measurement is about 10 times larger than the error affecting a satellite seen at the zenith.

- Reflections: When propagating towards the user receiver, navigation signals are prone to reflections from the ground or nearby objects (buildings, vehicles...). These reflected signals combine with the direct signals and introduce a bias in the range measurements made by the user receiver, denoted as multipath error.
- Thermal noise, Interference and User receiver design: the navigation signals have an extremely low power level when they reach the user receiver. The range measurements made by the receiver will therefore be affected by ambient noise and interfering signals, and among other sources of disturbances, the accuracy of such measurements will also depend on the quality of the user receiver design.

When trying to characterise the overall range measurement errors, all error sources described above are aggregated and a unique parameter is used called the User Equivalent Range Error (UERE). The UERE is an estimate of the uncertainty affecting the range measurements for a given satellite.

When computing its position, the user receiver combines the range measurements from the different satellites in view. Through this process, the individual errors affecting each range measurement are combined which results in an aggregate error in the position domain. The statistical relationship between the average range domain error and the position error is given by a factor that depends on the satellite geometry; this factor is named DOP (Dilution Of Precision).

One of the GNSS constellations is named Global Positioning System (GPS). The GPS is a space-based radio-navigation system owned by the United States Government (USG) and operated by the United States Air Force (USAF). GPS provides positioning and timing services to military and civilian users on a continuous worldwide basis. Two GPS services are provided: the Precise Positioning Service (PPS), available primarily to the armed forces of the United States and its allies, and the Standard Positioning Service (SPS) open to civil users (further information can be found on <https://www.gps.gov/technical>). The GPS Signal In Space characteristics are defined in the GPS ICD [RD-4].

The GPS SPS performance characteristics are defined in the GPS SPS Performance Standards (GPS SPS PS) [RD-3].

Other satellite navigation constellations are being deployed that are currently not augmented by EGNOS. In particular, the European Galileo constellation is meant to be augmented by subsequent versions of EGNOS.

The GPS architecture

In order to provide its services, the GPS system comprises three segments: the Control, Space, and User Segment. The Space and Control segments are briefly described below.

The Space Segment comprises a satellite constellation. The GPS baseline constellation comprises 24 slots in 6 orbital planes with four slots in each plane. The baseline satellites occupy these slots. Any surplus GPS satellites that exist in orbit occupy other locations in the orbital planes. The nominal semi-major axis of the orbital plane is 26,559.7 km. The signals broadcast by the GPS satellites are in the L-band carriers: L1 (1575.42 MHz) and L2 (1227.6 MHz). Each Satellite broadcasts a pseudo-random noise (PRN) ranging signal on the L1 carrier.

The Operational Control System (OCS) includes four major subsystems: a Master Control Station, a backup Master Control Station, a network of four Ground Antennas, and a network of globally distributed Monitoring Stations. The Master Control Station is located at Schriever Air Force Base, Colorado, and is operated on a continuous basis (i.e. 24h, 7 days a week, all year); it is the central control node for the GPS satellite constellation and is responsible for all aspects of the constellation command and control.

APPENDIX B EGNOS INTEGRITY CONCEPT

Integrity is a measure of the trust which can be placed in the correctness of the information supplied by a given system. Integrity includes the ability of a system to provide timely and valid warnings to the user (alerts) when the system must not be used for the intended operation (or phase of flight).

The integrity service of ICAO compliant GNSS systems may currently be provided by the three normalised augmentations known under the terms ABAS (Airborne Based Augmentation System), GBAS (Ground Based Augmentation System) and SBAS (Satellite Based Augmentation System). There are several SBAS systems deployed around the world (WAAS in North America, MSAS in Japan and EGNOS in Europe) and others under development. EGNOS (and the other SBAS) augments GPS by providing integrity information and corrections through geostationary satellites.

The EGNOS integrity concept relies on the use of a network of ground reference stations which receive data from the GPS satellites and compute integrity and correction data. This information is uploaded to the EGNOS geostationary satellites which then relay this information to EGNOS receivers through the EGNOS SIS. The EGNOS receivers acquire and apply this data to determine the integrity and improve the accuracy of the computed navigation solution. Therefore, the SBAS integrity service should protect the user from both:

- Failures of GPS satellites (drifting or biased pseudoranges) by detecting and excluding faulty satellites through the measurement of GPS signals with the network of reference ground stations
- Transmission of erroneous or inaccurate differential corrections. These erroneous corrections may in turn be induced from either:
 - undetected failures in the ground segment,
 - processing of reference data corrupted by the noise induced by the measurement and algorithmic process.

The EGNOS ground system, using the measures taken from the observation of the GPS constellation through its dedicated network of reference ground stations provides separate corrections and bounds to the satellite ephemeris errors, clock errors and ionospheric errors.

The SBAS integrity concept is based on the following definitions:

- **Integrity risk:** the probability that the position error is larger than the alert limit defined for the intended operation and the user is not warned within the time to alert (TTA).
- **Integrity Event:** Occurs when the Navigation System Error is greater or equal to the corresponding Protection Level for the corresponding service level (e.g. APV-I) and the receiver does not trigger an alert within the Time To Alert (TTA).
- **Alert Limit:** the error tolerance not to be exceeded without issuing an alert (SARPS definition). There is a Horizontal Alert Limit (HAL) and a Vertical Alert Limit (VAL) for each operation (i.e.: alert limits for LPV-200 are the most demanding among the EGNOS SoL Service for Aviation levels whereas alert limits for APV-I are more demanding than for NPA). See Table 7 for the HAL and VAL values.
- **Protection levels [RD-2]:**
 - The **Horizontal Protection Level (HPL)** is the radius of a circle in the horizontal plane, with its centre being at the true position, which describes the region which is assured to contain the indicated horizontal position (RTCA MOPS).
 - The **Vertical Protection Level (VPL)** is the half-length of a segment on the vertical axis with its centre being at the true position, which describes the region which is assured to contain the indicated vertical position (RTCA MOPS).

In other words, the HPL bounds the horizontal position error with a confidence level derived from the integrity risk requirement. Similarly, the VPL bounds the Vertical Position Error.

- **Time To Alert (TTA):** The maximum allowable time elapsed from the onset of the navigation system being out of tolerance until the user equipment enunciates the alert.
- **“Out of tolerance”:** The out of tolerance condition is defined as a horizontal error exceeding the HPL or a vertical error exceeding the VPL.
 - The horizontal error is referred to as HPE (Horizontal Position Error),
 - The vertical error is referred to as VPE (Vertical Position Error).

Therefore, an out of tolerance event occurs when one of both following events occurs:

- $HPE > HPL$ or,
- $VPE > VPL$ (in absolute value)

The EGNOS integrity concept can be summarised as follows, from a user point of view:

- The user calculates the navigation solution and its associated protection levels. The protection levels should be understood as a conservative estimate of the user position error (typically for a confidence level of 10^{-7}) that is assumed to be a Gaussian function. As the user is unable to measure the real position error, the user will rely on this upper boundary of the real error to assess the system integrity.
- Then, the computed protection levels are compared to the alert limits defined for the intended operation, and if the protection levels are larger than the corresponding alert limits, the system becomes unavailable (the performance level provided by the system at that time is not sufficient to ensure the safety of the intended operation). On the contrary, if the computed protection levels are smaller than the alert limits defined for the intended operation, the system is declared available as the safety of the operation is ensured.

Figure 12 clarifies the concepts above and their physical interpretation. The figure depicts the situations that a SBAS user may experience; in this case, the horizontal plane has been chosen for the diagram, but the reasoning would be equivalent for the vertical one.

Please note that in the first two situations shown above, the system is working properly, as EGNOS provides a correct bound to the position error, and the safety of the user is ensured. Note that the system is expected to be declared available most of the time. In the third case, the error is not properly bounded by EGNOS ($HPE > HPL$), and safety issues could arise if the error is larger than the alert limits defined for the intended operation. The probability of this situation is minimal by design, enabling EGNOS to meet the integrity requirements of Category I precision approach, APV-I and NPA operations. A detailed description of how the Protection Levels are computed by EGNOS can be found on Appendix J of the RTCA SBAS MOPS [RD-2].

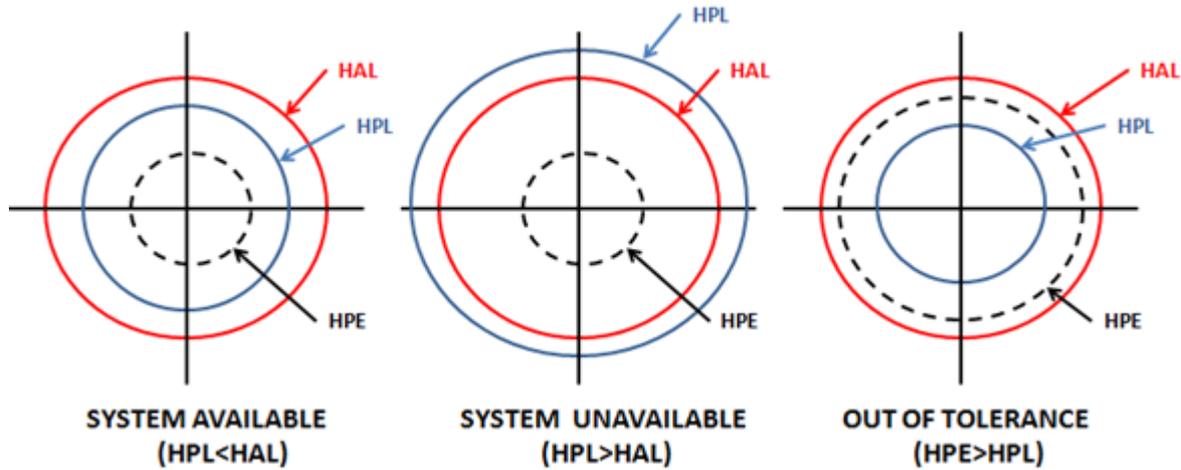


Figure 12: Possible situations when navigating with EGNOS

APPENDIX C IONOSPHERIC ACTIVITY AND IMPACT ON GNSS

Appendix C.1 Ionosphere and GNSS

Ionosphere is one of the main error sources in Global Navigation Satellite Systems (GNSS) error budget. The ionosphere is a highly variable and complex region of the upper atmosphere ionized by solar radiations and therefore containing ions and free electrons. The negatively charged free electrons and ions affect the propagation of radio signals and in particular, the electromagnetic satellite signals. Its dispersive nature makes the ionospheric refractive index different from unity. The structure of the ionosphere is continually varying in response to changes in the intensities of solar radiations: as solar radiation increases, the electron density in the ionosphere also increases. The ionosphere structure is also affected and disturbed by changes in the magnetic field of the Earth resulting from its interaction with the solar wind and by infrequent high-energy particles ejected into space during powerful solar eruptions such as coronal mass ejections and solar flares.

The ionospheric effects on satellite signals must be properly accounted for in the GNSS positioning process in order to obtain reliable and accurate position solutions. A large number of models and methods for estimating the ionospheric signal delay have been developed. The most widely used model is probably the Klobuchar model. Coefficients for the Klobuchar model are determined by the GPS control segment and distributed with the GPS navigation message to GPS receivers where the coefficients are inserted into the model equation and used by receivers for estimation of the signal delay caused by the ionosphere.

In the case of SBAS systems, the SBAS receivers inside the corresponding service area use the SBAS ionospheric corrections, which are derived from real-time ionospheric delay measurements. The SBAS ground system obtains these measurements from a network of reference stations and uses them to estimate the vertical delays and associated integrity bounds at the ionospheric grid points (IGPs), of a standardized ionospheric grid located 350 km above the surface of the Earth ([RD-1]). The user equipment uses the SBAS grid information to compute a vertical delay and vertical integrity bound for each line of sight to a satellite; then applies a standardized “obliquity factor” to account for the angle at which the line of sight pierces the ionospheric grid.

Appendix C.2 Impact of the ionospheric activity on GNSS

The GNSS signal delay as direct effect of ionosphere is always present and varies in size; however, it is generally well modelled and can be estimated to an extent that makes GNSS/SBAS usable. During periods with increased ionospheric activity or geomagnetic storms (caused by sudden eruptions of the Sun), GNSS/SBAS users can experience residual ionospheric effects owing to a high ionosphere variability impossible to be effectively modelled and corrected, which can reduce navigation performance at user level. The increase in the residual ionospheric effects implies a higher error over-bounding (this is, higher protection level) and in case this higher over-bounding exceeds the maximum value for the intended operation (this is, alert limit) the service availability for such operation is impacted.

The current solar cycle#25 started in December 2019. The solar cycle is the periodic change in the Sun's activity (including changes in the levels of solar radiation and ejection of solar material) and appearance (visible in changes in the number of sunspots, flares, and other visible manifestations) with a typical duration of eleven years. The number of sunspots (SSN) is one of the main parameters to monitor the ionosphere behaviour (Figure 13). In solar cycle#24 a first maximum of number of sunspots was reached in 2012 and a

second relative maximum, higher than the first one, was reached in 2014. The activity continued afterwards with a decreasing trend, and with cycle#25 once again rising up.

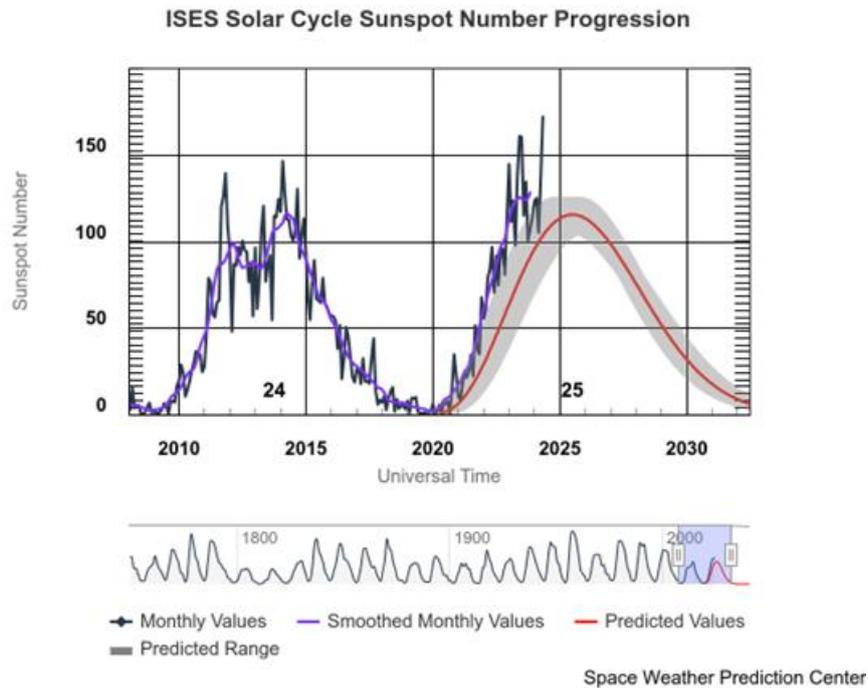


Figure 13: SSN progression from NOAA/SWPC

The dependence of SBAS system performance on the ionosphere variations is especially noticeable during the period when the solar activity increases. SBAS systems estimate ionospheric delays assuming a bidimensional behaviour of the ionosphere (no height), which is valid in a nominal situation, but which is not accurate in case of high solar activity or geomagnetic storms when the ionosphere presents high spatial gradients and behaves as a 3-dimensional body (whose properties change with the height). This is considered as an intrinsic limitation of single frequency SBAS systems.

This link between EGNOS performance and solar activity is particularly clear in the case of performance degradations observed in the South of Europe. Performance degradation is also observed in the North during periods with high geomagnetic activity. The month of October 2023 represented a very clear case of a period with a high number of ionospheric events impacting the performance of EGNOS and other SBAS systems. As an example, Figure 14 presents the daily LPV performance³⁸ achieved by EGNOS on two particular degraded days, the 11th of October 2023 (degraded case due to solar activity) and the 21st of October 2023 (highly degraded case due to geomagnetic activity).

As it can be observed, the South of Europe was affected during the 11th of October as a consequence of the increase of the solar activity. The case of the 21st of October shows an additional degradation in the North of ECAC due to the impact of a geomagnetic storm. From the users' perspective, the impact of these performance degradations resulted in unavailability of the corresponding service level at specific areas and during limited periods of time.

It must be noted that in the coming years, during the rap up of the current solar cycle 25, this SBAS performance's behaviour is expected to be observed again. That increase is linked to the solar cycle#25, which is being more active than initial predictions.

³⁸ EGNOS LPV availability is measured as the percentage of time the Horizontal Protection Level (HPL) and VPL (Vertical Protection Level) is below the Horizontal Alarm Limit (HAL) and Vertical Alarm Limit (VAL). HAL is 40m and VAL is 50m for LPV. The International Civil Aviation Organization (ICAO) requirement specifies that availability must be over 99%.

Additionally, it should be highlighted that the ionospheric events in case of impact on GNSS/SBAS-based operations cannot be currently notified to users in advance. Even if the possibility of predicting that kind of phenomenon, using space weather forecasts, to potentially alert users is still under investigation, the high impact for the SBAS users shows the clear need of understanding the mechanisms involved in this process.

It is of high importance to emphasize that independently of the presence of some EGNOS performance degradations linked to ionosphere in terms of Availability, Accuracy or Continuity, no associated integrity event (this is, navigation position error exceeds alarm limit for a given operation and the system does not alert the pilot in a time less than the time to alert) has been detected in the whole service area.

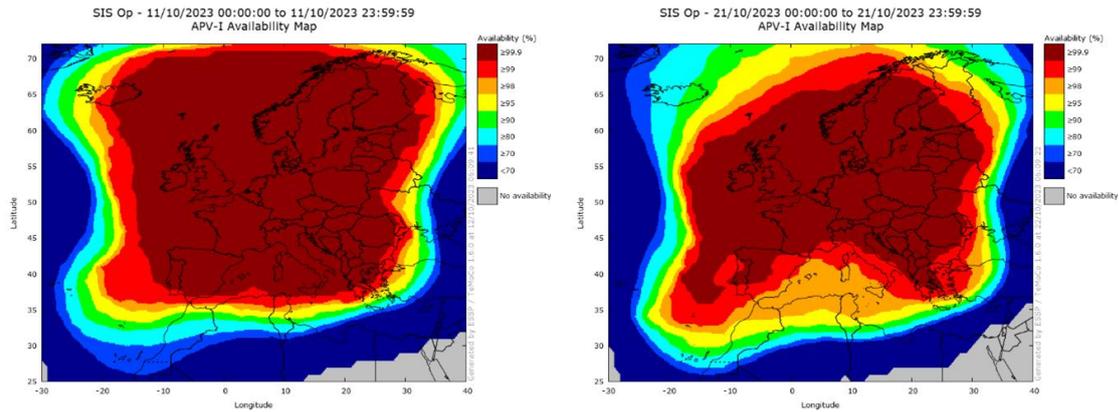


Figure 14: EGNOS LPV performance results on 11th (left) and 21st (right) October 2023

Appendix C.3 Improvement and robustness achieved by EGNOS

EGNOS Programme is advancing towards a deeper understanding of the effects of ionosphere at user performance level to improve the EGNOS system behaviour towards ionospheric disturbances, make it more robust and provide a better service to the EGNOS users. The increase of the robustness of EGNOS to the solar activity has been an objective of the EGNOS program with the aim of improving service performance. During the last years, this improvement in the service performance has been observed, showing since November 2023 a quite significant increase in the robustness against these kind of degradations. It must be noted that the impact of the Solar Cycle will be removed with the introduction of EGNOS V3 in the coming years for dual frequency users.

As an example, see the following figures (Figure 15 and Figure 16).

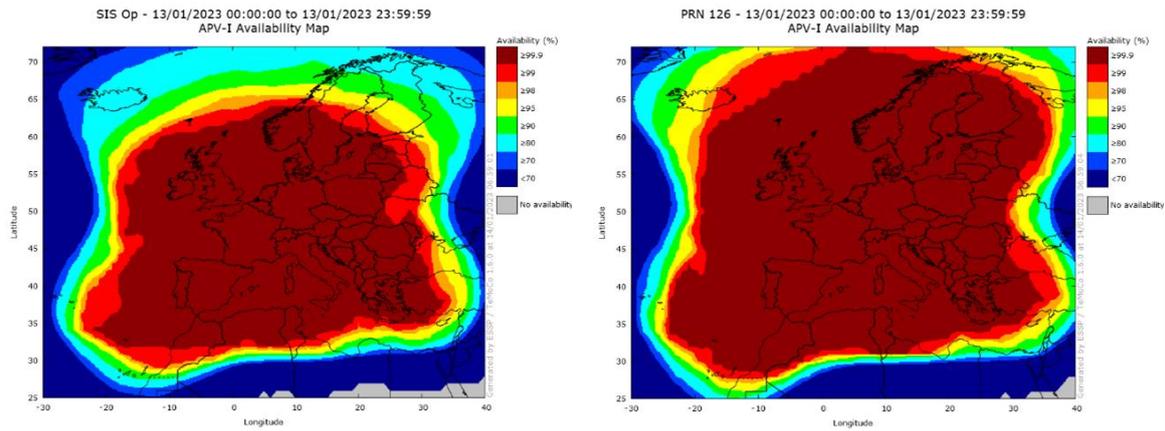


Figure 15: - EGNOS APV-I availability on 13th January 2023 without (left) and with (right) current EGNOS ionospheric robustness

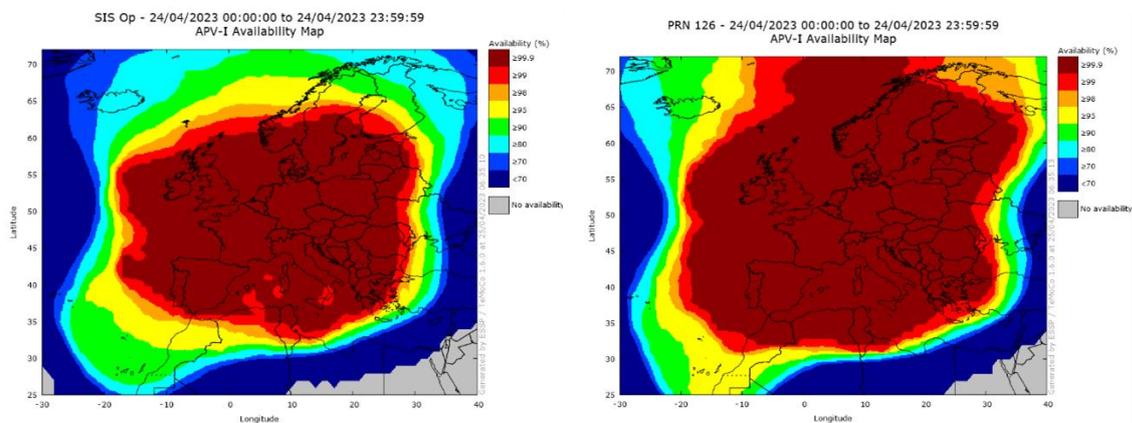


Figure 16: EGNOS APV-I availability on 24th April 2023 without (left) and with (right) current EGNOS ionospheric robustness

ESSP, as the EGNOS Service Provider, is continuously analysing the impact which could be faced by the different EGNOS users' communities. Whenever there is any relevant information (complementary to the different SDDs) related to this matter that could be of interest for the users, an EGNOS Service Notice is published (https://egnos.gsc-europa.eu/documents/field_gc_document_type/87) and distributed.

Particularly, the EGNOS Working Agreements (EWA) signed between the Service Provider and the different organisations responsible for the implementation of the EGNOS-based procedures includes commitment with regards to contingency communications. Whenever any degraded situation, which cause is expected to be maintained or that could potentially be reproduced (causing a similar impact) in the short term, is identified the corresponding contingency communications will be distributed by the Service Provider to the impacted EWA signatories, providing the corresponding performance reports and distributing the corresponding NOTAM proposals when required.

APPENDIX D EGNOS SOL SERVICE FOR AVIATION LEVELS/PBN NAVIGATION SPECIFICATIONS

The following presents the EGNOS SoL Service for Aviation Levels versus the different PBN NavSpecs, to have a clear view of which NavSpecs EGNOS is considered as an enabler.

User Operations	EGNOS SoL Service for Aviation Levels									
	NPA								APV-I	LPV-200
Performance Requirements Annex 10 - Vol I - Chapter 3 Table 3.7.2.4-1:	PBN Navigation Specifications									
	RNAV 10**	RNAV 5*	RNAV 2*	RNAV 1*	RNP 4**	RNP 2*	RNP 1*	RNP 0.3	RNP APCH* 3D, Type A***	RNP APCH* 3d, Type B***
- En-route	X	X	X	X	X	X		X		
-En-route -Terminal		X	X	X			X	X		
-Initial Approach - Intermediate Approach -Non-precision Approach (NPA) - Departure				X			X	X		
- Approach Operations with vertical guidance (APV-I)									X	
- Category I precision approach										X

Table 10: EGNOS SoL Service for Aviation Levels vs PBN NavSpecs

(*) Navigation specifications addressed by A-RNP.

(**) They are included for completion purposes, but SBAS is not considered as an enabler for RNAV 10 / RNP 4 being their intended use is for oceanic routes. Nevertheless, both can be flown with EGNOS information in the receiver if available and the requirements for both NavSpecs will be met.

(***) According to ICAO Annex 6, [RD-13].

APPENDIX E EGNOS SOL SERVICE FOR AVIATION: ACHIEVED PERFORMANCES

This appendix complements the information provided in section 6, where EGNOS SoL Service for Aviation performance requirements (section 6.2) and minimum service performance characteristics (section 6.3) are presented and specified.

The following figures provide the EGNOS SoL Service for Aviation achieved availability from 01/07/2023 to 30/04/2024 based on the information broadcast by the EGNOS operational GEOs during that period. Two different EGNOS system versions were operational during the period. A version with improved performance entered into service in November 2023.

The archived performances have been good although significant underperformance have been observed over the north and the south of the Service Area, in particular before the improved EGNOS version was operational.

The information on the EGNOS SoL Service for Aviation performance (for the NPA, APV-I and LPV-200 Service Levels) is anyway made available and updated in the EGNOS User Support website (<https://egnos.gsc-europa.eu>), and recurrently reported through the EGNOS Monthly Performance reports.

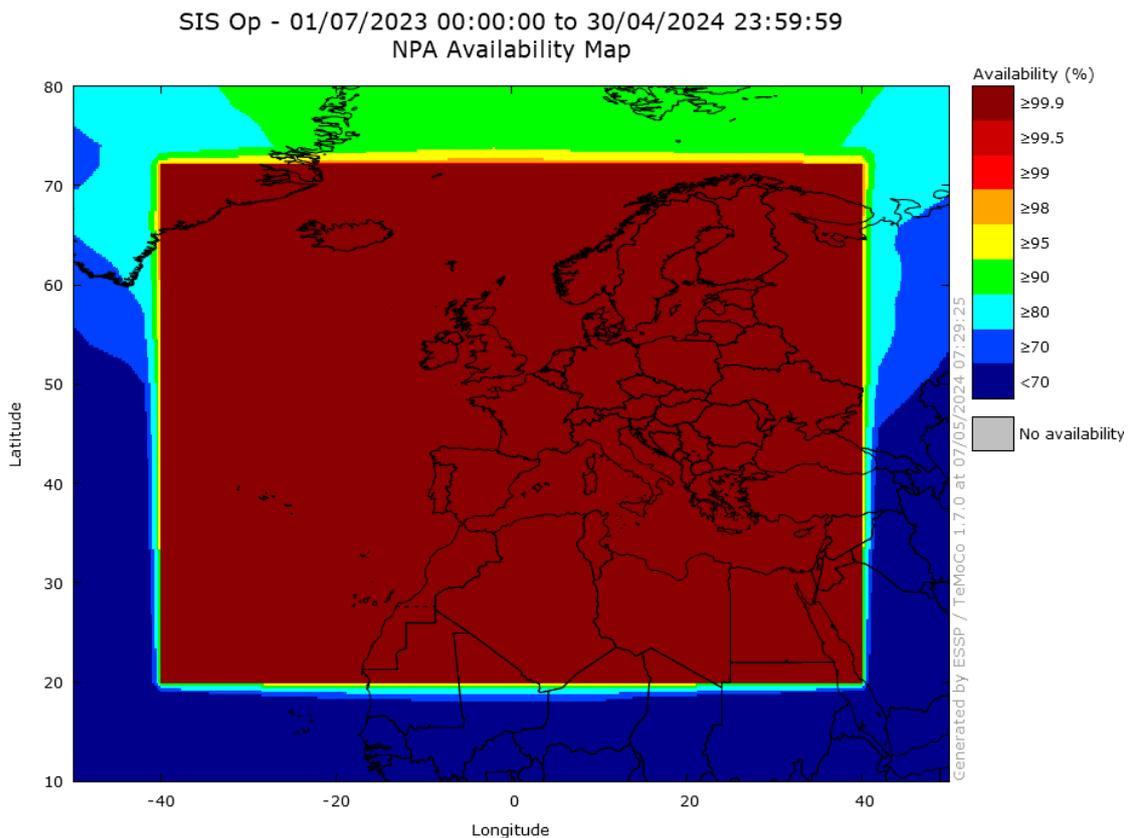


Figure 17: NPA availability from 01/07/23 to 30/04/24

SIS Op - 01/07/2023 00:00:00 to 30/04/2024 23:59:59
APV-I Availability Map

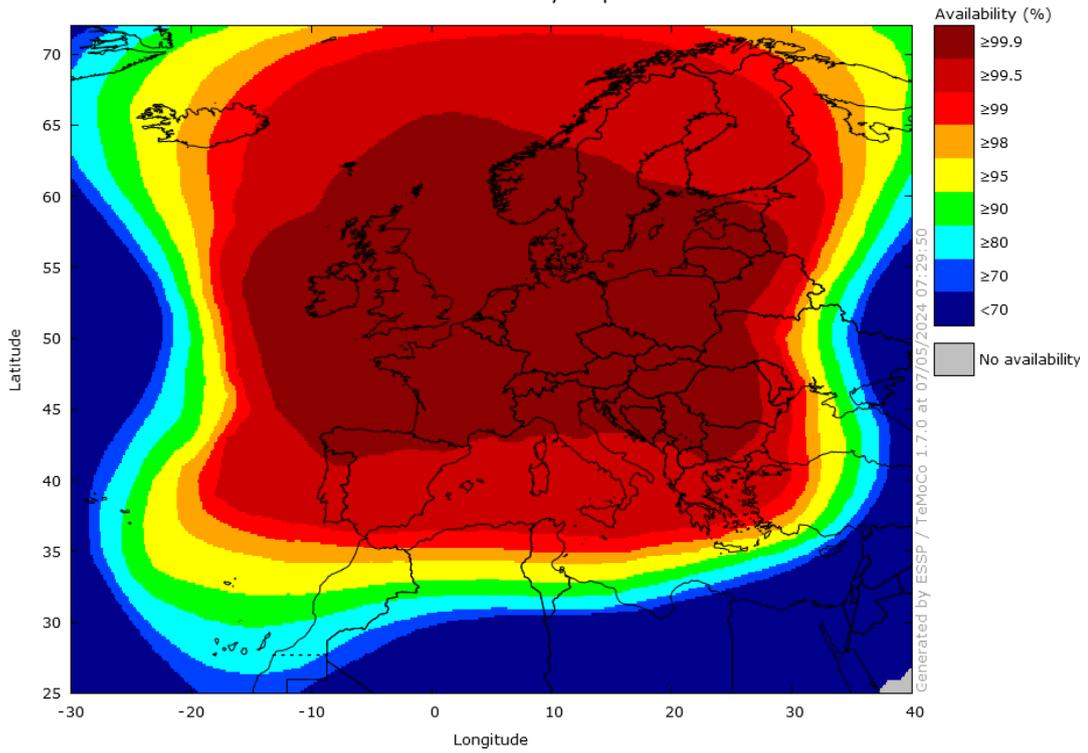


Figure 18: APV-I availability from 01/07/23 to 30/04/24

SIS Op - 01/07/2023 00:00:00 to 30/04/2024 23:59:59
LPV200 Availability Map

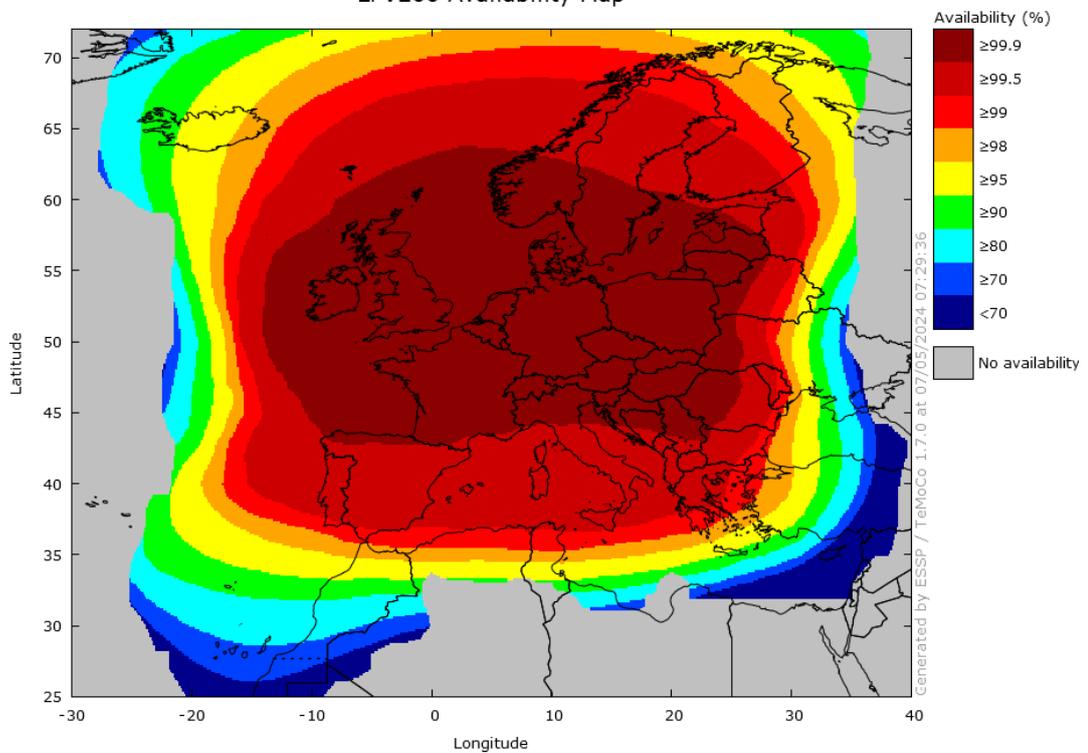


Figure 19: LPV-200 availability from 01/07/23 to 30/04/24

APPENDIX F DEFINITIONS

Accuracy: GNSS position error is the difference between the estimated position and the actual position. For an estimated position at a specific location, the probability should be at least 95 per cent that the position error is within the accuracy requirement. (ICAO SARPS).

Approach Procedure with Vertical guidance: A performance-based navigation (PBN) instrument approach procedure designed for 3D instrument approach operations Type A. (ICAO SARPS).

Depending on the type of APV procedure, vertical guidance can be provided from GNSS augmentation system such as SBAS (or possibly Galileo in the future) or a barometric reference.

- **APV Baro-VNAV:** An approach with barometric vertical guidance flown to the LNAV/VNAV Decision Altitude/Height. A vertically guided approach can be flown by modern aircraft with VNAV functionality using barometric inputs. Most Boeing and Airbus aircraft already have this capability meaning that a large part of the fleet is already equipped. Airworthiness approval material is available from EASA [RD-18]. Regulation [RD-17] by the European Commission can be consulted as reference.
- **APV SBAS:** An approach with geometric vertical and lateral guidance flown to the LPV Decision Altitude/Height. It is supported by satellite-based augmentation systems such as WAAS in the US and EGNOS in Europe to provide lateral and vertical guidance. The lateral guidance is equivalent to an ILS localizer and the vertical guidance is provided against a geometrical path in space rather than a barometric altitude. Airworthiness approval material is available from EASA [RD-18]. Regulation [RD-17] by the European Commission can be consulted as reference.

Area navigation (RNAV): A method of navigation which permits aircraft operation on any desired flight path within the coverage of station-referenced navigation aids or within the limits of the capability of self-contained aids, or a combination of these.

Availability: The availability of GNSS is characterised by the proportion of time during which reliable navigation information is presented to the crew, autopilot, or other system managing the flight of the aircraft. (ICAO SARPS).

Continuity: Continuity of service of a system is the capability of the system to perform its function without unscheduled interruptions during the intended operation. It relates to the capability of the navigation system to provide a navigation output with the specified accuracy and integrity during the specified procedure, assuming that it was available at the start of the operation. (ICAO SARPS).

Decision altitude (DA) or decision height (DH): A specified altitude or height in a 3D instrument approach operation at which a missed approach must be initiated if the required visual reference to continue the approach has not been established. (ICAO SARPS)

ECAC: Consists of the envelope of all FIRs of ECAC96 member States (including Canary Islands FIR) and the oceanic control areas of Reykjavik, Swanwick and Santa Maria. The ECAC landmass comprises the landmass region of ECAC member states, including ECAC islands (e.g. Canary Islands), and is indicated in Figure 20.

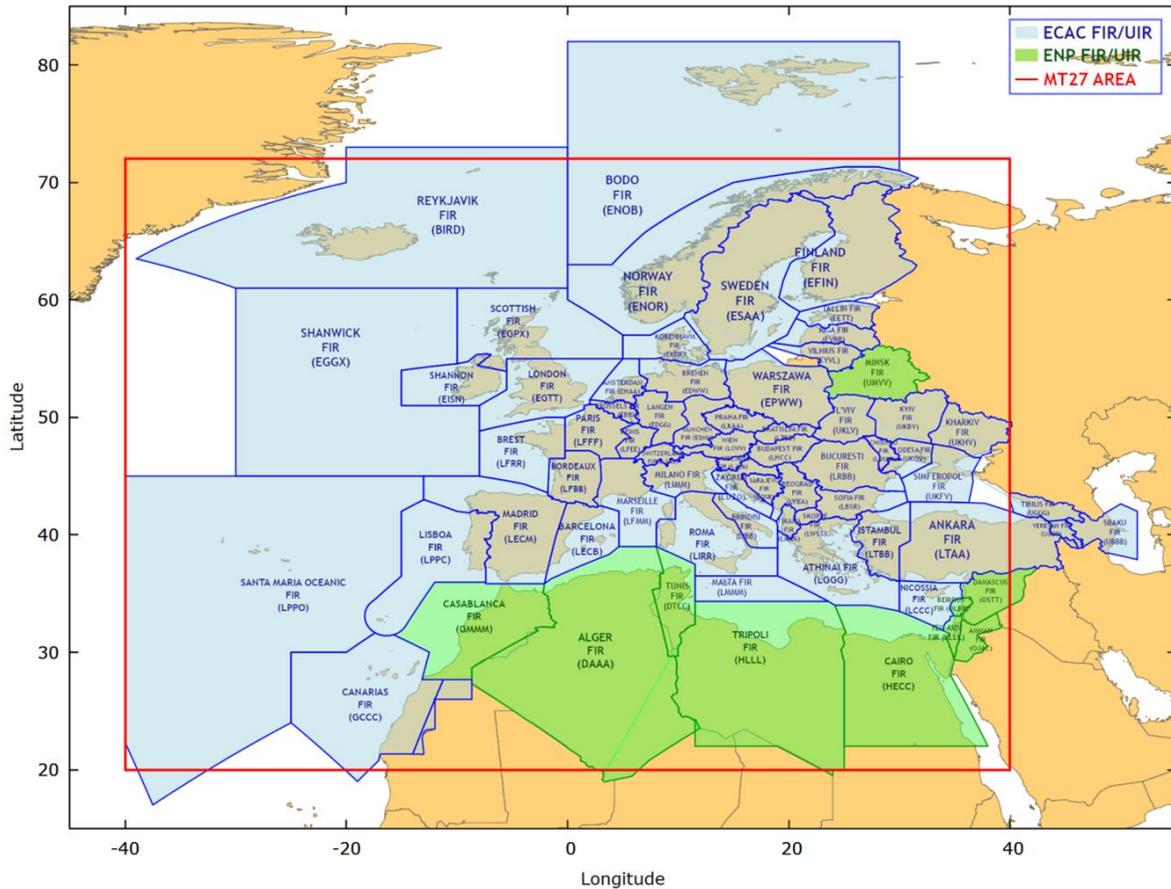


Figure 20: ECAC 96 FIRs and EGNOS service Area (in red)

EGNOS Service Area: Geographic region defined in the EGNOS Service Message MT27 which is limited in the North by 72 degrees latitude (72° N), in the South by 20 degrees latitude (20° N), in the East by 40 degrees longitude (40° E), and in the West by 40 degrees longitude (40° W).

EGNOS SoL Service for Aviation Area: as part of the EGNOS Service Area, the concept of EGNOS SoL Service for Aviation Area³⁹ can be defined for each SoL Service for Aviation level (i.e. NPA, APV-I and LPV-200) by the corresponding commitment maps. Therefore, any reference to EGNOS SoL Service for Aviation Area should be associated to a specific SoL Service for Aviation level. The EGNOS SoL Service for Aviation Area is always contained in the EGNOS Service Area.

End/Final User: The aviation user in possession of the certified receiver (§5) using the EGNOS Signal-In-Space for flying a previously approved operation based on EGNOS and more generally for other domains any user with an EGNOS-compatible receiver.

On the contrary, the term “User” is typically used alone to refer to organisations in the context of section 2.2.2.

Fault-free receiver: The fault-free receiver is assumed to be a receiver with nominal accuracy and time-to-alert performance. Such a receiver is assumed to have no failure affecting the integrity, availability, and continuity performance. (ICAO SARPS)

³⁹ This concept is defined according to the ICAO Annex 10 Service Area definition: “The service area shall be a defined area within an SBAS coverage area where SBAS meets the signal-in-space requirements and supports the corresponding approved operations.”

Fault Detection and Exclusion (FDE): FDE is a receiver processing scheme that autonomously provides integrity monitoring for the position solution, using redundant range measurements. The FDE consists of two distinct parts: fault detection and fault exclusion. The fault detection part detects the presence of an unacceptably large position error for a given mode of flight. Upon the detection, fault exclusion follows and excludes the source of the unacceptably large position error, thereby allowing navigation to return to normal performance without an interruption in service.

Hazardously Misleading Information (HMI): Information that persists beyond the allowable TTA causing the errors in the position solution output by an EGNOS enabled receiver to exceed the user's particular tolerance for error in the current application.

Instrument approach operations: An approach and landing using instruments for navigation guidance based on an instrument approach procedure. There are two methods for executing instrument approach operations: (ICAO SARPS)

- a two-dimensional (2D) instrument approach operation, using lateral navigation guidance only; and
- a three-dimensional (3D) instrument approach operation, using both lateral and vertical navigation guidance.

Note. — *Lateral and vertical navigation guidance refers to the guidance provided either by:*

- a) *a ground-based radio navigation aid; or*
- b) *computer-generated navigation data from ground-based, space-based, self-contained navigation aids or a combination of these.*

Instrument approach procedure (IAP): A series of predetermined manoeuvres by reference to flight instruments with specified protection from obstacles from the initial approach fix, or where applicable, from the beginning of a defined arrival route to a point from which a landing can be completed and thereafter, if a landing is not completed, to a position at which holding, or en-route obstacle clearance criteria apply. Instrument approach procedures are classified as follows (ICAO SARPS):

- **Non-precision approach (NPA) procedure**
- **Approach procedure with vertical guidance (APV)**
- **Precision approach (PA) procedure**

Instrument approach operation types: Instrument approach operations shall be classified based on the designed lowest operating minima below which an approach operation shall only be continued with the required visual reference as follows (ICAO SARPS):

- a) **Type A:** a minimum descent height or decision height at or above 75 m (250 ft); and
- b) **Type B:** a decision height below 75 m (250 ft). Type B instrument approach operations are categorized as:
 1. **Category I (CAT I):** a decision height not lower than 60 m (200 ft) and with either a visibility not less than 800 m or a runway visual range not less than 550 m;
 2. **Category II (CAT II):** a decision height lower than 60 m (200 ft) but not lower than 30 m (100 ft) and a runway visual range not less than 300 m;
 3. **Category IIIA (CAT IIIA):** a decision height lower than 30 m (100 ft) or no decision height and a runway visual range not less than 175 m;
 4. **Category IIIB (CAT IIIB):** a decision height lower than 15 m (50 ft) or no decision height and a runway visual range less than 175 m but not less than 50 m; and
 5. **Category IIIC (CAT IIIC):** no decision height and no runway visual range limitations.

Integrity: Integrity is a measure of the trust that can be placed in the correctness of the information supplied by the total system. Integrity includes the ability of a system to provide timely and valid warnings to the user (alerts) when the system must not be used for the intended operation (or phase of flight). (ICAO SARPS).

Minimum descent altitude (MDA) or minimum descent height (MDH): A specified altitude or height in a 2D instrument approach operation or circling approach operation below which descent must not be made without the required visual reference. (ICAO SARPS)

Misleading Information (MI): Information causing the errors in the position solution output by an EGNOS enabled receiver to exceed the protection levels.

Navigation mode: According to RTCA MOPS [RD-2], the navigation mode refers to the equipment operating to meet the requirements for a specific phase of flight. The navigation modes for MOPS C are: oceanic/remote, en-route, terminal, non-precision approach, and precision approach (including LNAV/VNAV). The navigation modes for MOPS D⁴⁰ are: oceanic/remote, en-route, terminal, and approach (including LNAV, LNAV/VNAV, LP and LPV). The main differences and equivalences in terminology are summarised in Table 11.

Notice to Airmen (NOTAM): A notice containing information concerning the establishment, condition or change in any aeronautical facility, service, procedure or hazard, the timely knowledge of which is essential to personnel concerned with flight operations. NOTAM are issued by Aeronautical Information Services (AIS) when there is not sufficient time to publish information and incorporate it into the Aeronautical Information Publication (AIP) or for changes of short duration.

Non-precision approach (NPA) procedure: An instrument approach procedure designed for 2D instrument approach operations Type A. (ICAO SARPS)

Note. — Non-precision approach procedures may be flown using a continuous descent final approach (CDFA) technique. CDFAs with advisory VNAV guidance calculated by on-board equipment (see PANS-OPS (Doc 8168), Volume I, Part I, Section 4, Chapter 1, paragraph 1.8.1) are considered 3D instrument approach operations. CDFAs with manual calculation of the required rate of descent are considered 2D instrument approach operations. For more information on CDFAs, refer to PANS-OPS (Doc 8168), Volume I, Part I, Section 4, Chapter 1, paragraphs 1.7 and 1.8.

Precision approach (PA) procedure: An instrument approach procedure based on navigation systems (ILS, MLS, GLS and SBAS CAT I) designed for 3D instrument approach operations Type A or B. (ICAO SARPS).

Receiver Autonomous Integrity Monitoring (RAIM): RAIM is an algorithm used in a GPS receiver to autonomously monitor the integrity of the output position/time solution data. There are many different RAIM algorithms. All RAIM algorithms operate by evaluating the consistency of redundant measurements.

Navigation mode	Requirements for	In MOPS C	In MOPS D
En-route and terminal	-	Section 2.1.2	Section 2.1.2
Approach	LNAV	LNAV does not exist (see NPA - Section 2.1.3)	Section 2.1.3 (see LNAV)
	LNAV/VNAV	Section 2.1.4 (This mode covers APV-I service)	Section 2.1.4
	LPV and LP	Does not exist	Section 2.1.5

Table 11: RTCA MOPS C&D terminology differences for navigation mode

Service Level (namely NPA, APV-I, LPV-200): The capability of the EGNOS Safety of Life Service for Aviation to comply with the performance requirements needed for a specific operation, namely:

- **NPA** service level which enables 2D instrument approach operation Type A and other flight operations than approaches based on SBAS in compliance with the Signal-in-Space performance requirements specified in ICAO Annex 10 for NPA / Departure, En-route / Terminal, and En-route operations.

⁴⁰ These navigation modes also correspond to MOPS E.

- **APV-I** service level which enables 3D instrument approach operation Type A based on SBAS in compliance with Signal-in-Space performance requirements specified in ICAO Annex 10 for Approach operations with vertical guidance (APV-I).
- **LPV-200** service level which enables 3D instrument approach operation Type A or B based on SBAS in compliance with Signal-in-Space performance requirements with a Vertical Alert Limit (VAL) equal to 35m (equivalent to ILS CAT I).

Service Volume: The service volume is defined to be those regions which receive the navigation service with the required level of availability.

Time-to-Alert (TTA): See Appendix B EGNOS Integrity concept.

APPENDIX G LIST OF ACRONYMS

The following table provides the definition of the acronyms used in this document.

ACRONYM	DEFINITION	ACRONYM	DEFINITION
ABAS	Airborne Based Augmentation System	ITU	International Telecommunications Union
AC	Advisory Circular	KNASS	Korea Augmentation Satellite System
AFM	Aircraft Flight Manual	LNAV	Lateral NAVigation
AFTN	Aeronautical Fix Telecommunication Network	LP	Localiser Performance
AIP	Aeronautical Information Publication	LPV	Localizer Performance with Vertical guidance
AIS	Aeronautical Information Service	MCC	Mission Control Centre
AMC	Accepted Means of Compliance	MDA/H	Minimum Descent Altitude / Height
ANSP	Air Navigation Service Provider	MI	Misleading Information
APCH	APproaCH	MLS	Microwave Landing System
APV	APproach with Vertical guidance	MOPS	Minimum Operational Performance Standards
AR	Authorization Required	MSAS	MTSAT Satellite-based Augmentation System
A-RNP	Advanced RNP	MT	Message Type
ASQF	Application Specific Qualification Facility	MTSAT	Multi-functional Transport Satellite
ATS	Air Traffic Services	NLES	Navigation Land Earth Station
C/A	Coarse/Acquisition	NM	Nautical Mile
CAT I/II/III	Category I/II/III	NOAA	National Oceanic and Atmospheric Administration
CCF	Central Control Facility	NOF	NOTAM Office
CDFA	Continuous Descent Final Approach	NOTAM	Notice to Airmen
CDM	Collaborative Decision Making	NPA	Non-Precision Approach
CPF	Central Processing Facility	NSE	Navigation System Error
CS-ACNS	Certification Specification – Airborne Communications, Navigation and Surveillance	OCS	Operational Control System
DAB	Digital Audio Broadcast	OS	Open Service
DA/H	Decision Altitude/Height	PA	Precision Approach
DOP	Dilution of Precision	PACF	Performance and Check-out Facility
EASA	European Aviation Safety Agency	PANS-OPS	Procedures for Air Navigation Services – Aircraft OPerationS
EC	European Commission	PPS	Precise Positioning Service
ECAC	European Civil Aviation Conference	PRN	Pseudo-Random Number
EDAS	EGNOS Data Access Service		

ACRONYM	DEFINITION	ACRONYM	DEFINITION
EEA	European Economic Area	PS	Performance Standard
EFTA	European Free Trade Association	PVT	Position Velocity and Timing
EGNOS	European Geostationary Navigation Overlay Service	RAIM	Receiver Autonomous Integrity Monitoring
EMEA	Europe, Middle East, and Africa	RD	Reference Document
ENT	EGNOS Network Time	RDS	Radio Data System
ESA	European Space Agency	RF	Radio Frequency
ESMAS	EGNOS Safety of Life assisted service for MAritime userS	RHCP	Right Hand Circularly Polarised
ESR	EGNOS System Release	RIMS	Range and Integrity Monitoring Station
ESSP	European Satellite Services Provider	RNAV	Area Navigation
ESP	EGNOS Service Provider	RNP	Required Navigation Performance
ETRF	EGNOS Terrestrial Reference Frame	RTCA	Radio Technical Commission for Aeronautics
ETSO	European Technical Standard Orders	SARPs	Standards and Recommended Practices
EU	European Union	SAS	Société par Actions Simplifiée
EUSPA	European Union Agency for the Space Programme	SBAS	Satellite-Based Augmentation System
EWA	EGNOS Working Agreement	SDCM	System of Differential Correction and Monitoring
EWAN	EGNOS Wide Area Network	SDD	Service Definition Document
FAA	Federal Aviation Administration	SES	Single European Sky
FAQ	Frequently Asked Questions	SI	International System of Units
FDE	Fault Detection and Exclusion	SIS	Signal-In-Space
FIR	Flight Information Region	SL	Service Level
FTP	File Transfer Protocol	ITRS	International Telecommunications Union
GAGAN	GPS Aided GEO Augmented Navigation	SoL	Safety of Life
GBAS	Ground Based Augmentation System	SPS	Standard Positioning Service
GEO	Geostationary Satellite	SSN	SunSpot Number
GIVE	Grid Ionospheric Vertical Error	SWPC	Space Weather Prediction Centre
GLS	GNSS Landing System	TEC	Total Electron Content
GNSS	Global Navigation Satellite System	TSO	Technical Standard Orders
GPS	Global Positioning System	TTA	Time-to-Alert
GPST	GPS Time	UDRE	User Differential Range Error
HAL	Horizontal Alert Limit	UERE	User Equivalent Range Error
HMI	Hazardously Misleading Information	US	United States
HPE	Horizontal Position Error	USAF	United States Air Force
HPL	Horizontal Protection Level	USG	United States Government
IAP	Instrument Approach Procedure	UTC	Coordinated Universal Time

ACRONYM	DEFINITION		
ICAO	International Earth Rotation and Reference System Service	VAL	Vertical Alert Limit
ICD	Interface Control Document	VNAV	Vertical NAVigation
IERS	International Earth Rotation and Reference Systems Service	VNSE	Vertical Navigation System Error
IGP	Ionospheric Grid Point	VPE	Vertical Position Error
IGS	International GNSS Service	VPL	Vertical Protection Level
ILS	Instrument Landing System	WAAS	Wide Area Augmentation System
IMO	International Maritime Organization	WGS84	World Geodetic System 84 (GPS Terrestrial Reference Frame)
IS	Interface Specification	YSR	Yearly System Release
ITRF	International Terrestrial Reference Frame		

Table 12: List of acronyms

More information on the European Union is available on the Internet (<http://europa.eu>).

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