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EGNOS

EGNOS Safety of Life (SoL)

Service Definition Document

Issue 3.5

#EUSpace

DOCUMENT CHANGE RECORD

Revision	Date	Summary of changes
1.0	02/03/2011	First release of the document
2.0	28/06/2013	• 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.
2.1	19/12/2014	• 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.
2.2	07/04/2015	Figure 4-1 corrected and improvement of commitment maps visibility
3.0	22/09/2015	• 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.
3.1	26/09/2016	• New SoL commitment maps based on ESR241M • EGNOS Space Segment updated
3.2	28/09/2018	• 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
3.3	26/03/2019	• EGNOS Service Area extension to 72°N • New SoL commitment maps extended to 72°N • EGNOS service information updated
3.4	26/04/2021	• Updated magenta area • EGNOS service information updated
3.5	23/11/2023	• GSA becoming EUSPA • New SoL commitment maps including an updated magenta area • EGNOS service information updated

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The European Union Agency for the Space Programme
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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 service is compliant with the aviation requirements for Approaches with Vertical Guidance (APV-I) and Category I precision approaches[1], as defined by ICAO in Annex 10 [RD-1]. The operational use of the EGNOS SoL Service may require specific authorisation by the relevant authorities in the application sectors concerned.

The purpose of the "EGNOS SoL Service Definition Document" (EGNOS SoL SDD) is to give information on the EGNOS SoL Service.

The document describes the EGNOS system architecture and Signal-In-Space (SIS) characteristics, the SoL service 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 organisations[2] implementing EGNOS based procedures, receiver manufacturers, equipment integrators, airlines, operators, GNSS application developers and the final users of the EGNOS SoL Service.

The document also includes complementary high level information on GNSS concepts, the GPS Service, the EGNOS System/Services, the EGNOS Management structure and EGNOS interfaces with users, as well as the minimum performance characteristics of the EGNOS SoL Service.

This document is not intended to address EGNOS Open Service (OS) nor EDAS performance. Information about the EGNOS OS is available in a separate document called the "EGNOS Open Service – Service Definition Document" (EGNOS SDD OS – [RD-5]), whilst 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.

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

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

The minimum level of performance of the EGNOS SoL Service as specified in the EGNOS SoL SDD 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.

The EGNOS SoL 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 use, including liability, and its intended lifetime.
- Section 3 ("Description of the EGNOS System and EGNOS SoL Service Provision Environment") gives a brief overview of the EGNOS system, as well as its technical and organisational framework for EGNOS SoL service 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 Performance") describes the positioning Service offered to users by the EGNOS SoL Service and the minimum performance in the positioning domain.
- Appendix A contains fundamental information of the satellite navigation (GNSS) as complementary concepts for the rest of the documents.
- Appendix B describes the integrity concept used in EGNOS.
- Appendix C assesses the impact of the ionospheric activity on GNSS and in particular on SBAS systems.
- Appendix D presents EGNOS SoL Service 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 provides the achieved availability performances for EGNOS SoL Service.
- Appendix F presents relevant definitions.
- Appendix G provides the list of acronyms used in the document.

This document does not address the Open Service (OS) and the EGNOS Data Access Service (EDAS), which are described in separate dedicated Service Definition Documents.

2.2 Terms and Conditions of Use of EGNOS Safety of Life Service, Including Liability

2.2.1 SCOPE OF THE EGNOS SAFETY OF LIFE SERVICE COMMITMENT

The EGNOS Safety of Life service (further **"EGNOS SoL Service"**) 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 described here in the EGNOS SoL Service Definition Document (further **"EGNOS SoL SDD"**).

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.

2.2.2 WHO CAN USE THE EGNOS SOL SERVICE?

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.

At the date of EGNOS SoL SDD publication, only the aviation domain has specific service requirements, as well as certification and individual authorisation procedures developed and implemented.

In the EU[3], the EEA 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 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 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[4]. The EGNOS helpdesk (see section 3.2.2 for contact details) is available to clarify the steps to follow in this case.

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

- *Airspace user*s, as defined in the Single European Sky (SES) framework Regulation[5], equipped with an EGNOS certified receiver and located within the appropriate EGNOS SoL Service area corresponding to the phase of flight in which the EGNOS SoL Service 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).

3. 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.
4. 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.
5. 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.

DISCLAIMER OF LIABILITY

The European Union, as the owner of EGNOS system, the European Union Agency for the Space Programme (EUSPA)as EGNOS Programme manager and ESSP SAS, as EGNOS services provider, expressly disclaim all warranties of any kind (whether expressed or implied) to any party, other than Aviation Users specified under 2.2.2. above, and/or for any other use of the EGNOS SoL Service 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, EUSPA or ESSP SAS and its business partners shall create any such warranty.

By using the EGNOS SoL Service, the Aviation Users agree that neither the European Union nor EUSPA nor ESSP SAS shall 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.

Furthermore, no party shall be entitled to any claim against ESSP SAS and/or the European Union and/or the EUSPA if the damage is the result, or the consequence, of any of the following events:

- Use of EGNOS SoL Service beyond the conditions and limitations of use set forth in the EGNOS SoL SDD, it being understood that the use of EGNOS SoL 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 when a test message is broadcast (a Message Type 0 or a Message Type 0/2), or
- Use of the EGNOS SoL Service without required authorisation, or
- In case of a Force Majeure event.

- 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 Regulation[6], please refer to section 3.2.3 for further information.

Should any support from the EGNOS Service Provider be needed, these organisations can consult with the EGNOS helpdesk (see section 3.2.2 for contact details).

6. 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 can be used only upon signature of an EWA.

2.2.3 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. Before any use of the EGNOS SoL Service, all users should study this document in order 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 3.2.2 for contact details). Aviation Users may also contact their competent authority.

2.3 EGNOS SoL Service Description

The EGNOS SoL Service consists of signals for timing and positioning intended for most transport applications in different domains. Nevertheless, navigation operations based on the EGNOS SoL Service may require a specific authorisation, issued by the relevant authority, unless the authority, or applicable regulation, establishes that no such authorisation is required.

The SoL service is based on integrity data provided through the EGNOS satellite signals.

The main objective of the EGNOS SoL service is to support civil aviation operations down to LPV (Localiser Performance with Vertical guidance) minima. However, the SoL Service is also intended to support applications in a wide range of other domains such as maritime, rail and road.

2.4 EGNOS SoL Lifetime

The EGNOS Services are 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.

2.5 Reference Documents

RD	Document Title
[RD-1]	ICAO Standards and Recommended Practices (SARPS) Annex10 Volume I (Radio Navigation Aids) 6th edition of July 2006, including all amendments up to and including No 92
[RD-2]	RTCA MOPS DO 229 (Revisions C, D Change 1, E or F)
[RD-3]	GPS Standard Positioning Service Performance Standard – April 2020 5th Edition
[RD-4]	IS GPS 200 Revision K – NAVSTAR GPS Space Segment / Navigation User Interface – 6th May 2019
[RD-5]	EGNOS Service Definition Document – Open Service (OS SDD) https://egnos-user-support.essp-sas.eu/documents/egnos-open-service-sdd
[RD-6]	EGNOS Data Access Service – Service Definition Document (EDAS SDD) https://egnos-user-support.essp-sas.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	Document Title
[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 16th Edition
[RD-12]	The European Concept for GNSS NOTAM, V2.7 (Eurocontrol GNSS NOTAM CONOPS), 29th November 2011
[RD-13]	ICAO Standards and Recommended Practices (SARPS) Annex 6, Operation of Aircraft, Part I – International Commercial Air Transport – Aeroplanes, July 2022 12th 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[7]
[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

7. 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.

3 Description of the EGNOS System and EGNOS SoL Service Provision Environment

3.1 High Level Description of the EGNOS Technical Framework

3.1.1 OBJECTIVE OF EGNOS

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 safety critical applications, 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 position) 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 (i.e. ionospheric errors, satellite position/clock errors, etc.). 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 the view of this network of monitoring stations 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 for background information about the Satellite Navigation Concept.

3.1.2 EGNOS OVERVIEW

3.1.2.1 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:

- Open Service (OS), freely available to any user;
- Safety of Life (SoL) Service, that provides the most stringent level of signal-in-space performance to all Safety of Life user communities;
- 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..

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

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].

Safety of Life Service (SoL)

The main objective of the EGNOS SoL service is to support civil aviation operations down to Localiser Performance with Vertical Guidance (LPV) minima. At this stage, a detailed performance characterisation has been conducted only against the requirements expressed by civil aviation but the EGNOS SoL service might also be used in a wide range of other application domains (e.g. maritime, rail, road…) in the future. 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].

The EGNOS SoL Service has been available since March 2nd 2011 being this document the applicable SDD.

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

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[8] based on EDAS data to final customers.

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

3.1.2.2 EGNOS: The European SBAS

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 aviation, maritime, 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) and India (GPS Aided GEO Augmented Navigation –GAGAN). Analogous systems are under commissioning or deployment in other regions of the world (e.g. System of Differential Correction and Monitoring – SDCM in Russia, Korea Augmentation Satellite System – KASS in South Korea) or under investigation (e.g. BeiDou SBAS – BDSBAS in China, Southern Positioning Augmentation Network – SouthPAN in Australia and New Zealand, and SBAS for Africa – ANGA in Africa and Indian Ocean). The worldwide existing and planned SBAS systems are shown in Figure 3-1.

For additional information on the SBAS systems, the reader is invited to visit the following website: https://egnos-user-support.essp-sas.eu/european-gnss/what-gnss#Other-SBAS

In addition, EGNOS has plans to extend their service areas to neighbouring regions, thus paving the way for near global SBAS coverage.

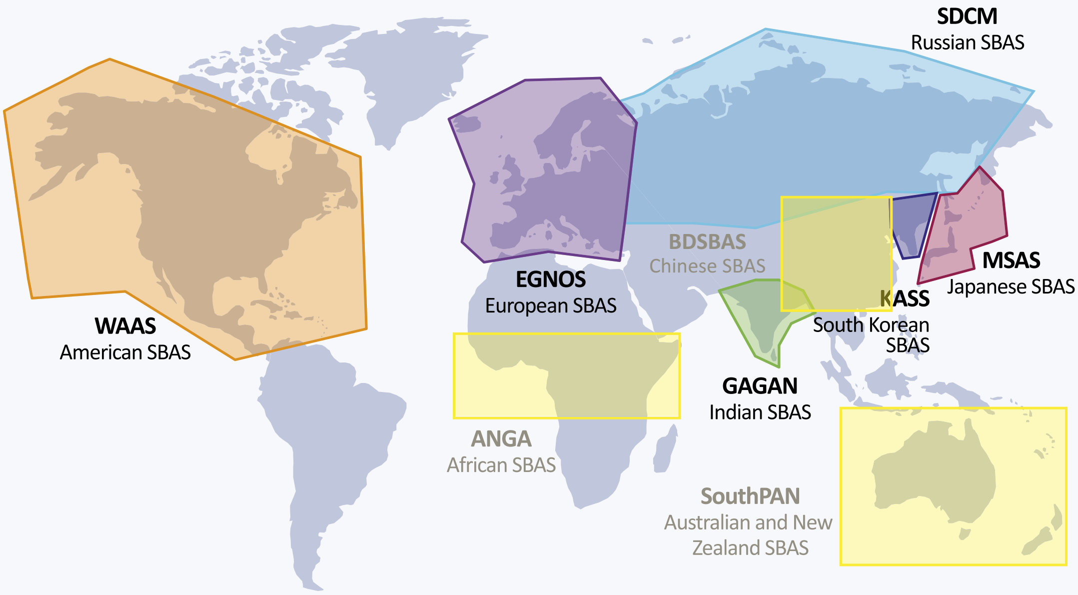
3.1.2.3 EGNOS Architecture

The EGNOS functional architecture is shown in Figure 3-2.

In order to provide its services to users equipped with appropriate receivers, the EGNOS system comprises two

8. Examples of potential applications that could be provided are: EGNOS pseudolites; provision of EGNOS services through RDS, DAB, Internet; accurate ionospheric delay/TEC maps; provision of performance data (e.g. XPL availability maps, GIVE maps, etc.); provision of EGNOS message files.

Figure 3-1 Existing and planned SBAS systems



main segments: the Space Segment, and the Ground Segment.

EGNOS Space Segment

The EGNOS Space Segment comprises 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 (see Table 3-1).

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, the others broadcasting 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 webpage (https://egnos-user-support.essp-sas.eu/).

It is intended that the EGNOS space segment will be replenished over time in order to maintain a similar 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 published (https://egnos-user-support.essp-sas.eu/new_egnos_ops/documents/field_gc_document_type/service-notices-87) and distributed.

Figure 3-2 EGNOS architecture

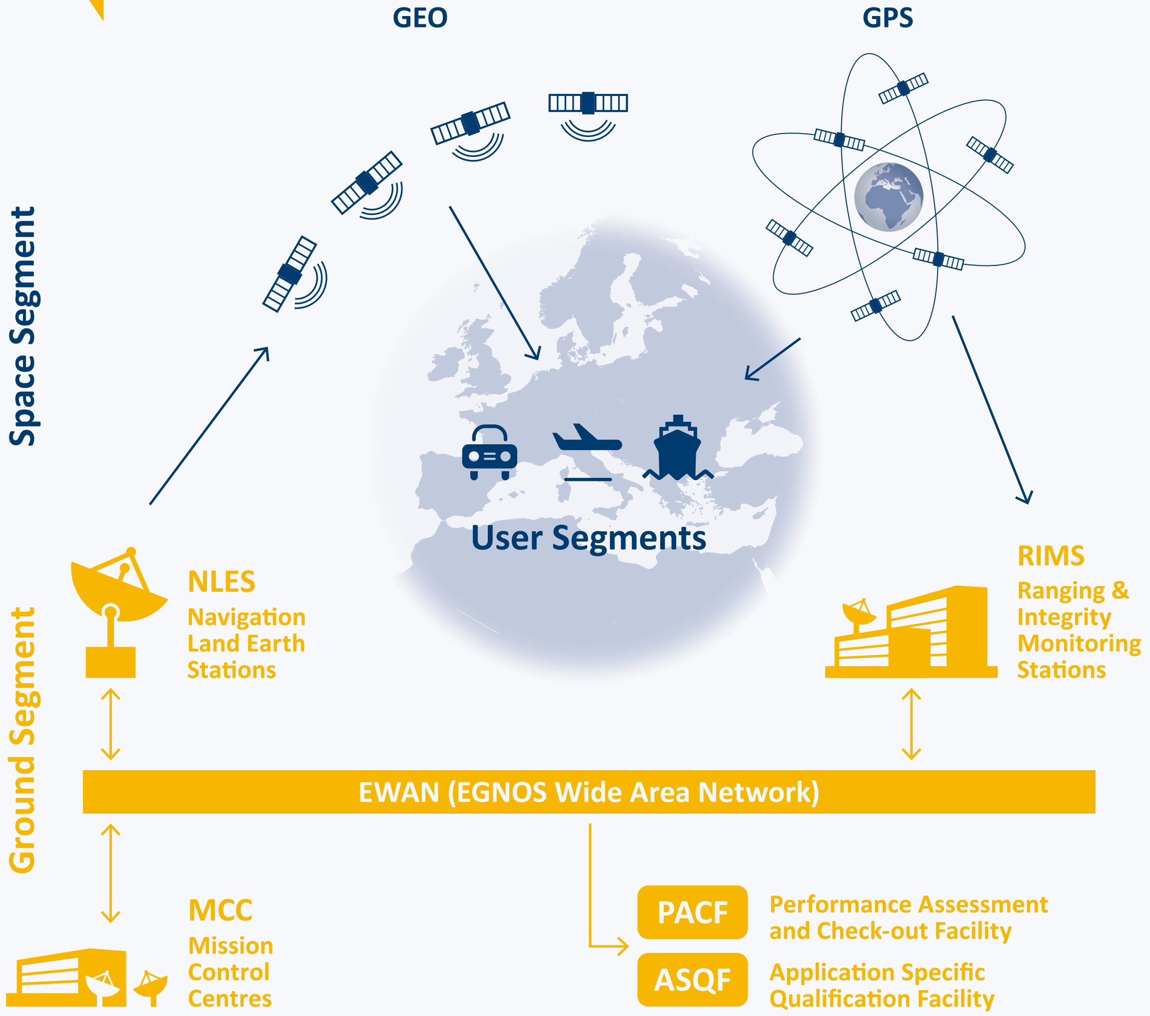


Table 3-1 GEOs used by EGNOS

GEO Name	PRN Number	Orbital Slot
ASTRA-5B	PRN 123	23.5 E
ASTRA SES-5	PRN 136	5 E
EUTELSAT 5 West B[9]	PRN 121	5 W

9. At the time of the publication of this document, EUTELSAT 5 West B is used for testing purposes and will broadcast Message Type 0 indicating it cannot be used for SoL applications by the certified receivers.

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.

• 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 37 RIMS sites located over a wide geographical area.

Figure 3-3 shows the geographical distribution of the deployed RIMS.

• 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.

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. These monitoring functions are tailored to the Safety of Life functions and will not be further detailed in this document.

• 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.

Figure 3-3 **EGNOS RIMS sites**

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:

- Select the CPF that broadcast the SBAS message
- Modules the message provided by the CPF
- Synchronizes the uplink signal with GPS time
- Send data to the GEO satellites

• **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.

3.2 EGNOS Organisational Framework

3.2.1 BODIES INVOLVED IN THE EGNOS PROGRAMME AND SERVICE DELIVERY

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

As per the Space Regulation [RD-7]:

- 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.

The European Satellite Services Provider (ESSP) SAS is the current EGNOS Services Provider within Europe, certified according to the Single European Sky (SES) regulation as Air Navigation Service Provider (ANSP). ESSP SAS provides the EGNOS OS, EDAS and SoL Service compliant with ICAO (International Civil Aviation Organization) Standards and Recommended Practices throughout the European Civil Aviation Conference (ECAC) region. ESSP SAS as EGNOS service provider 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.

3.2.2 HOW TO GET INFORMATION ON EGNOS AND EGNOS APPLICATIONS OR CONTACT THE SERVICE PROVIDER

A number of websites and e-mail addresses are made available by the EC, EUSPA, ESSP SAS and other organisations to provide detailed information on the EGNOS programme, the system status and system performance, as well as a number of useful tools. Table 3-2 below lists the main sources of information about EGNOS.

EGNOS SoL 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)-145/146 for details of both the fundamental GPS SPS service and EGNOS receiver equipment respectively. EGNOS also meets the ICAO Annex 10, 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.

3.2.3 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 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 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.

Table 3-2 Where to find information about EGNOS

Topic	Organisation	Web/contact details
EGNOS Programme EC institutional information about the EGNOS Programme	EC	http://ec.europa.eu/growth/sectors/space/egnos/
What is EGNOS?	EUSPA	https://www.euspa.europa.eu/european-space/egnos/what-egnos
EGNOS User Support EGNOS user support website website is the main source of information for EGNOS OS/SoL and EDAS users on EGNOS/EDAS status and performance, system description, historical and real time services performances, forecasts, applicable documentation, FAQs, etc.	ESSP	http://egnos-user-support.essp-sas.eu/
EGNOS Helpdesk The helpdesk is accessible on-line through the website and also by e-mail and by phone. It is the direct point of contact for any question related with the EGNOS OS/SoL and EDAS system, its performance and applications.	ESSP	https://egnos-user-support.essp-sas.eu/helpdesk +34 911 236 555 egnos-helpdesk@essp-sas.eu
EGNOS Service provider activity ESSP official reporting of the service provider activities, news etc.	ESSP	http://www.essp-sas.eu
EGNOS certified receivers EASA mailbox for any question related to service difficulties or malfunctions of EGNOS certified receivers.	EASA	egnos@easa.europa.eu
EGNOS Working Agreements (EWA) Formalization between ESSP and a specific organisation for introducing EGNOS procedures.	ESSP	EGNOS-working-agreement@essp-sas.eu

The EWA includes:

- EWA contractual document: The agreement itself containing contractual liability with two annexes:
  - EWA Annex 1: Including the "ESSP SAS SoL Service Commitment" as stated in this EGNOS SoL SDD. It also includes reference to contingency coordination between ESSP and the organisation.
  - Annex 2: Including the "Service Arrangements" defined between the ESSP and the organisation implementing Performance Based Navigation (PBN) procedures based on EGNOS, covering all identified applicable requirements, namely:
    - NOTAM Proposal Origination: Outlining the terms and conditions under which the ESSP SAS 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 3.2.4).
    - EGNOS Data Recording: Describing the proposal of the ESSP SAS in order to provide GNSS data to organisation. To this purpose, the detailed data, format, storing time, time to provide these data and procedures are described.
    - Collaborative Decision Making (CDM): Defining clear working relationships between ESSP SAS and organisation describing organisation involvement in the ESSP SAS decision making process whenever any decision could lead to a material impact on the service provided.

The EGNOS SoL users of other than aviation domains should refer to their sectorial laws and regulations.

All EWA related information / discussions will be managed by ESSP SAS through the dedicated focal points (see section 3.2.2 for contact information).

The updated information concerning the EGNOS implementation status can be found in the EGNOS user support website: https://egnos-user-support.essp-sas.eu/resources-tools/lpv-procedures-map

3.2.4 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 Declaration date), the ESSP, as the EGNOS Services Provider, 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 3-4 shows the EGNOS NOTAM proposal service in the overall NOTAM lifecycle and depict the NOTAM process until the reception to the end users.

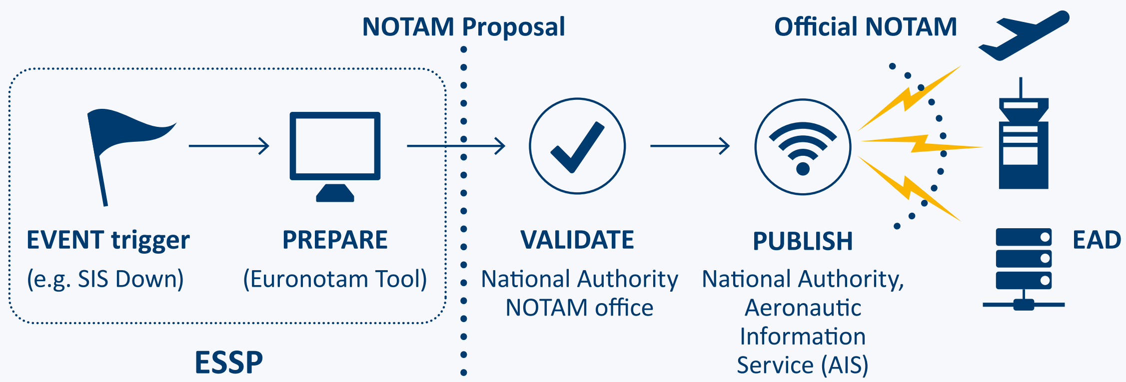
The terms and conditions under which the ESP provides EGNOS NOTAM proposals to any national NOTAM Offices (NOFs) providing Aeronautical Information Services (national AIS provider) are detailed within the corresponding EGNOS Working Agreement (EWA) to be established between the ESP and the particular organisation implementing EGNOS based operations (see section 3.2.3).

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 (7D/H24).

Figure 3-4 ESSP 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)[10]. 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 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 4-1 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 ICAO SARPs [RD-1][11] and RTCA SBAS MOPS [RD-2].

Table 4-1 EGNOS SIS transmitted MTs

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[12]
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
9[13]	GEO ranging function parameters	EGNOS GEO satellites orbit information (ephemeris)

10. An EGNOS L1 message is currently broadcast 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].
11. 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 ICAO SARPs for SBAS [RD-1].
12 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 to [RD-9].
13. MT 9 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 ICAO SARPs as an option. This is indicated by a special bit coding of the Health and Status parameter broadcast in MT 17. 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 a_{Gf0} & a_{Gf1} parameters in MT 9, are permanently set to zero.

Message Type	Contents	Purpose
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	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

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 (ITRS[14]) which is a geocentric system of

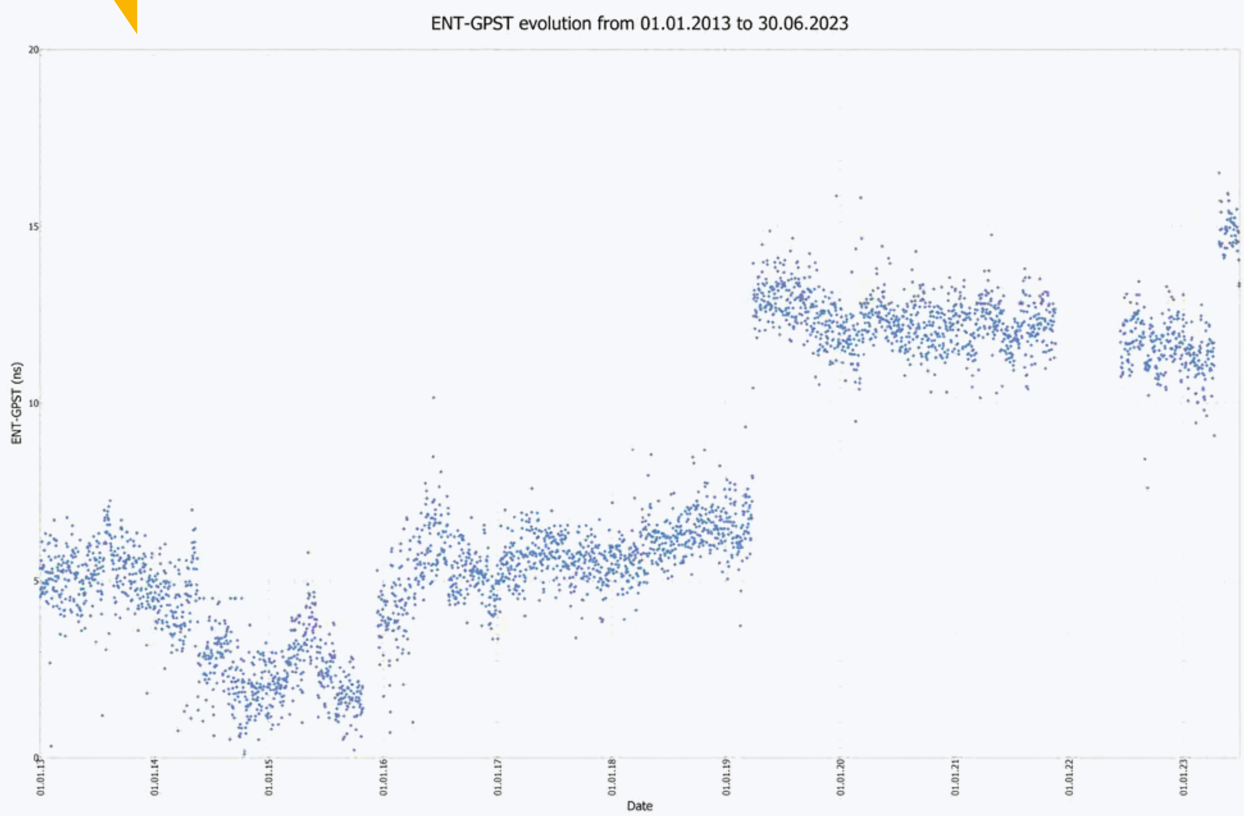
14. Detailed information on ITRS (concepts, realisation, materialization ...) can be found on the official website: https://itrf.ign.fr/en/

coordinates tied to the surface of the Earth and in which the unit distance is consistent with the International System of Units (SI[15]) definition of the metre. The ITRS is maintained by the International Earth Rotation and Reference Systems Service (IERS[16]) 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 (IGS[17]) 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 off-set 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).

Figure 4-1 **ENT GPS time offset evolution (Period January 13 – June 23)**



15. Information on the International System of Units (SI) can be obtained from https://www.bipm.org/en/
16. Information on IERS can be obtained from http://www.iers.org/
17. Information on IGS can be obtained from http://www.igs.org/

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 4-1:

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 5-1 summarises the main characteristics of the EGNOS equipment operational classes:

Table 5-1 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

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 SDD.

More information about EGNOS receivers for aviation can be found in the official EGNOS User Support website (see section 3.2.2).

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 certified equipment. An ETSO certified 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 certified equipment that is fully compliant with the standards and that is certified for use by the competent authority.

It should also be considered that ETSO certificates 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.

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 authority[18] (as defined in [RD-17]).

Table 5-2 lists the existing ETSOs related to the hardware required for SBAS operations:

Table 5-2 Existing ETSOs and hardware requirements for SBAS operations

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

18. 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 Performance

6.1 EGNOS SoL Service Description and Characteristics

The EGNOS SoL Service 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 is offered are described in section 2.2 above.

The EGNOS SoL Service is accessible to any user equipped with an EGNOS receiver as described in Section 5 within the EGNOS SoL Service 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 5.1.[19] 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 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.

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.

6.2 EGNOS SoL Service 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 6-1:

6.3 EGNOS SoL Minimum Service Performance Characteristics

The EGNOS SoL 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. The EGNOS SoL for areas beyond the region defined by this line is not ensured in the absence of an agreement since the EGNOS SoL shall

19. Performance of SBAS avionics could be impacted in case of an erroneous setting of GPS SVs to “do not use” (UDREI=15) in the EGNOS message because, 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. An erroneous setting of all GPS SV to “Do not use” for more than 1 minute would be considered as a Critical Safety Event in the operation of the service (and reported to the competent authority as such).

Table 6-1 SoL service performance requirements (ICAO)

	Accuracy		Integrity				Continuity	Availability
Typical operation	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	$1 - 1x10^{-7}$/h	5 min	7.4 km (4 NM)	N/A	$1 - 1x10^{-4}$/h to $1 - 1x10^{-8}$/h	0.99 to 0.99999
En-route (continental)					3.7 km (2 NM)	N/A		
En-route, Terminal	0.74 km (0.4 NM)	N/A	$1 - 1x10^{-7}$ /h	15 s	1.85 km (1 NM)	N/A	$1 - 1x10^{-4}$/h to $1 - 1x10^{-8}$/h	0.99 to 0.99999
Initial approach, Intermediate approach, Non-precision approach (NPA), Departure	220 m (720 ft)	N/A	$1 - 1x10^{-7}$ /h	10 s	556 m (0.3 NM)	N/A	$1 - 1x10^{-4}$/h to $1 - 1x10^{-8}$/h	0.99 to 0.99999
Approach operations with vertical guidance (APV-I)	16.0 m (52 ft)	20 m (66 ft)	$1 - 2x10^{-7}$ in any approach	10 s	40 m (130 ft)	50 m (164 ft)	$1 - 8x10^{-6}$ 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)	$1 - 2x10^{-7}$ in any approach	6 s	40 m (130 ft)	35.0 m to 10.0 m (115 ft to 33ft)	$1 - 8x10^{-6}$ per 15 s	0.99 to 0.99999

Note 1: For Category I precision approaches with Vertical Alert Limit (VAL) higher than 10m, 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) < 10^{-7}/150s*
2. *In degraded conditions: Probability (VNSE > 15m) < 10^{-5}/150s*

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.

Table 6-2 EGNOS SoL Service performance values

		Accuracy		Integrity		Continuity	Availability
		Horizontal Accuracy 95%	Vertical Accuracy 95%	Integrity	Time-To-Alert (TTA)		
Performance	**NPA**	220 m	N/A	1 – 1x10^{-7}/h	Less than 6 seconds	<1 –1x10^{-3} per hour in most of ECAC <1 – 2.5x10^{-3} per hour in other areas of ECAC	0.999 in all ECAC
	APV-I & LPV200[21]	3 m[21]	4 m[20]	1 – 2x10^{-7} / approach		<1 – 1x10^{-4} per 15 seconds in the core of ECAC 1 – 5x10^{-4} per 15 seconds in most of ECAC landmasses	0.99 in most of ECAC landmasses
Comment		Accuracy values at given locations are available at: https://egnos-user-support.essp-sas.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	

be provided as a priority on the territory of all Member States geographically located in Europe.

EGNOS SoL Service performance is summarized in Table 6-2 and detailed in following sections.

6.3.1 NPA – NON PRECISION APPROACH[22]

The performance commitment for NPA covers other phases of flight (en-route, terminal or other RNPs (RNP0.3 being the minimum supported)) using EGNOS for lateral guidance only.

6.3.1.1 Accuracy

The EGNOS accuracy, as reflected in Table 6-2, is compliant with the accuracy requirements specified in Table 6-1 for NPA inside the EGNOS service area.

6.3.1.2 Integrity

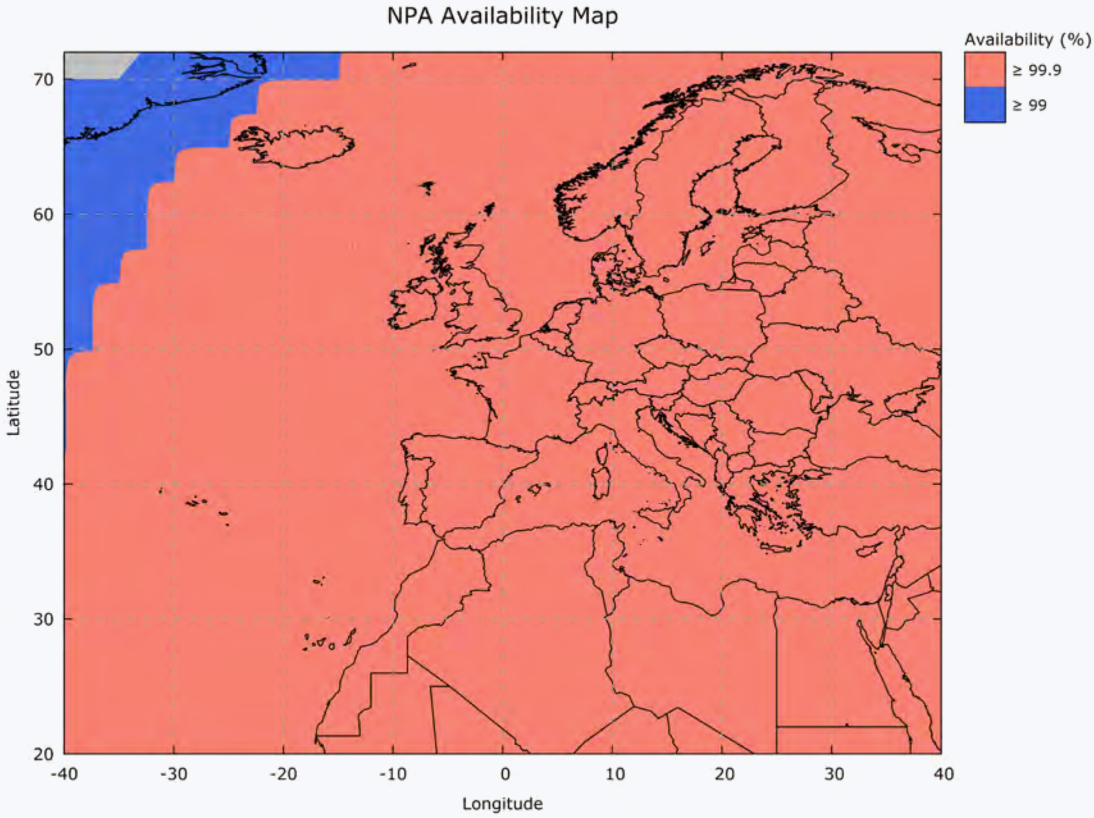
The EGNOS integrity, as reflected in Table 6-2, is compliant with the integrity requirements specified in Table 6-1 for NPA.

6.3.1.3 Availability

Figure 6-1 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 6-1, is met. These values

20. 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
21. Values committed inside the APV-I & LPV-200 99% availability areas
22. 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 6-1 **EGNOS NPA availability**



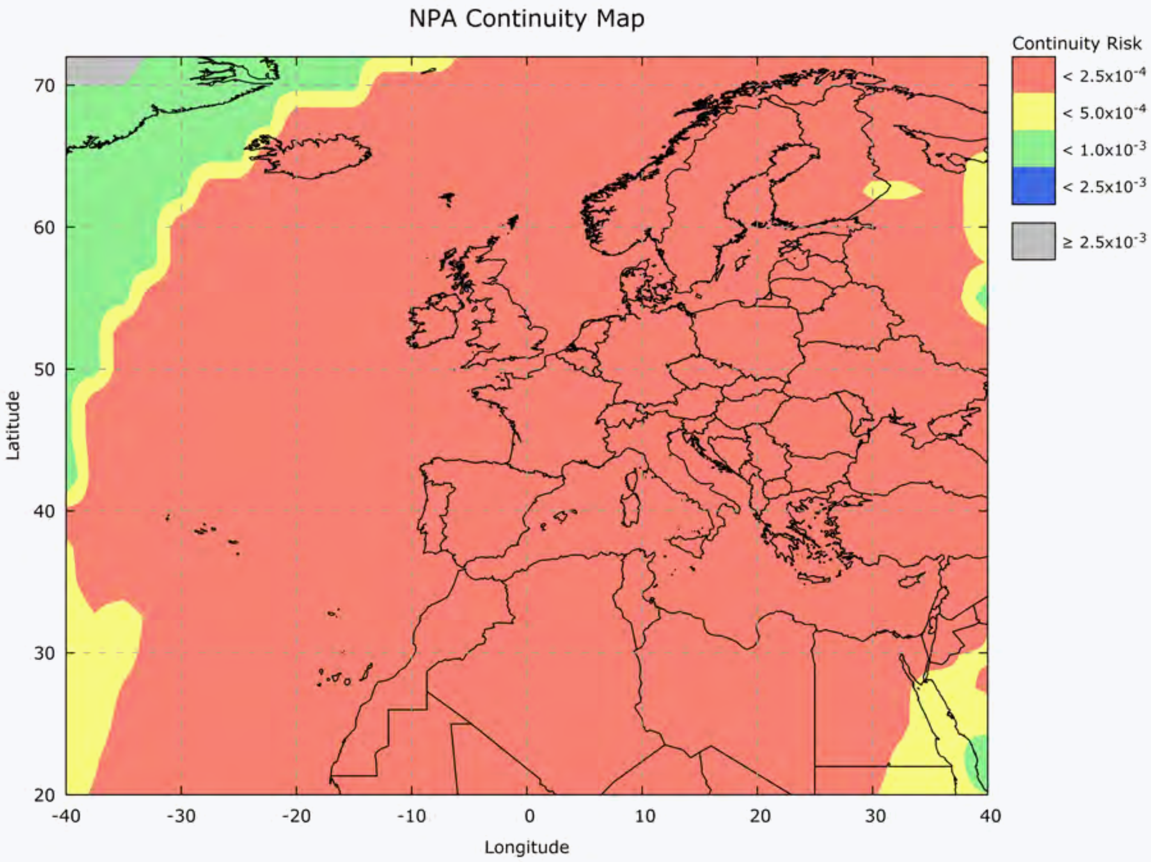
correspond to the performance measured by a fault-free receiver using all GPS satellites in view over a period of one month, using all the operational EGNOS GEOs.

6.3.1.4 Continuity

Figure 6-2 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.

The minimum continuity risk performance is less than 1x10-3 per hour in most of ECAC 96 Flight Information Regions (FIRs). It should be noted that the regions of continuity risk smaller than 1x10-3/hour are relatively sensitive to the scenario and models used to compute the minimum EGNOS SoL service area. Such a minimum performance is not compliant to ICAO requirements for NPA as described in Table 6-1. These values are however considered as sufficient to start the EGNOS use in civil aviation. Indeed, ICAO SARPs include interpretative material

Figure 6-2 EGNOS NPA continuity[23]



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 nature[24]. Moreover the Performance-based Navigation (PBN) Manual [RD-17] already includes special considerations when GNSS is the main or sole positioning source[25].

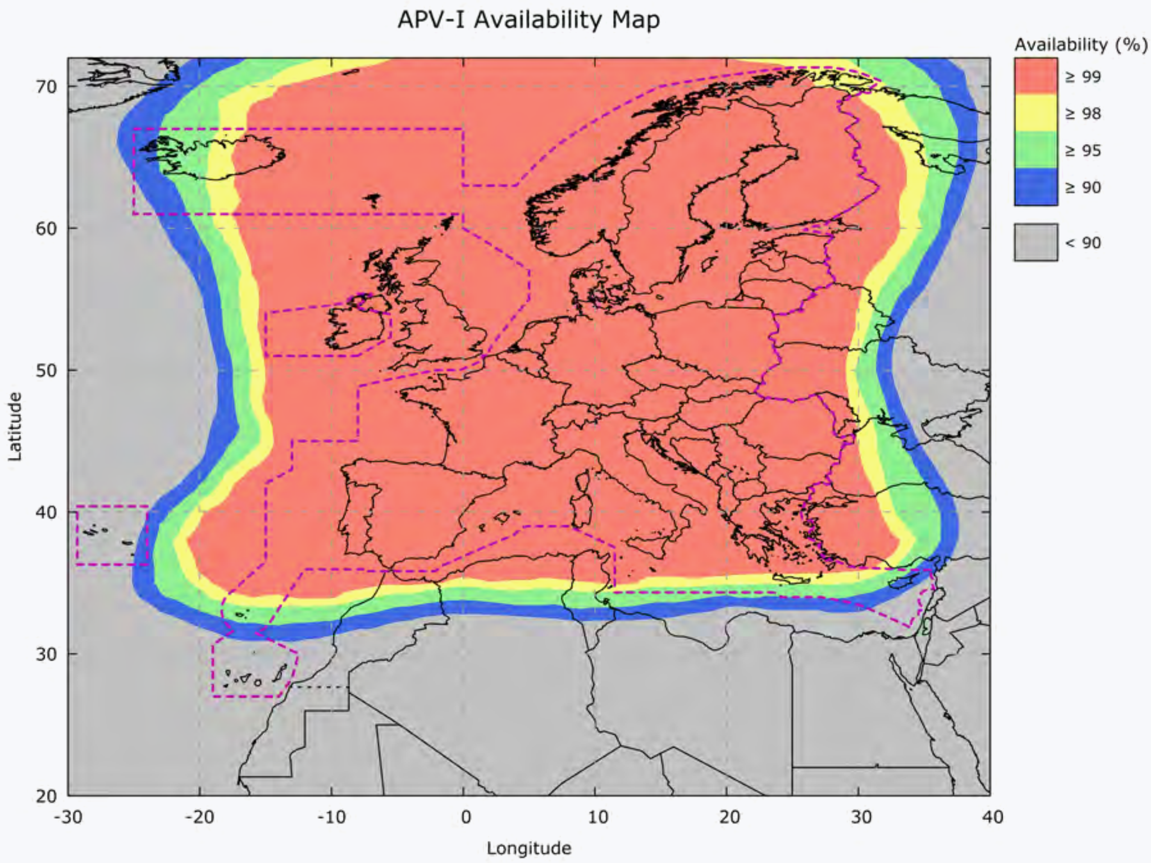
6.3.2 APV-I – APPROACH WITH VERTICAL GUIDANCE

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 rep-

23. In order to observe the minimum NPA continuity performance shown in the map (5x10-4), at least 6 months of data needs to be evaluated due to the discrete nature of discontinuity events.
24. 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".
25. 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".*

Figure 6-3 **EGNOS APV-1 availability**



resent 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 3-3, in section 3.1.2.3. 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 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 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 an 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 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-user-support.essp-sas.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 6-2. The EGNOS system is therefore compliant with the accuracy requirements specified in Table 6-1 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 6-2, is compliant with the integrity requirements specified in Table 6-1 for APV-I.

6.3.2.4 Availability

Figure 6-3 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 6-1, 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.

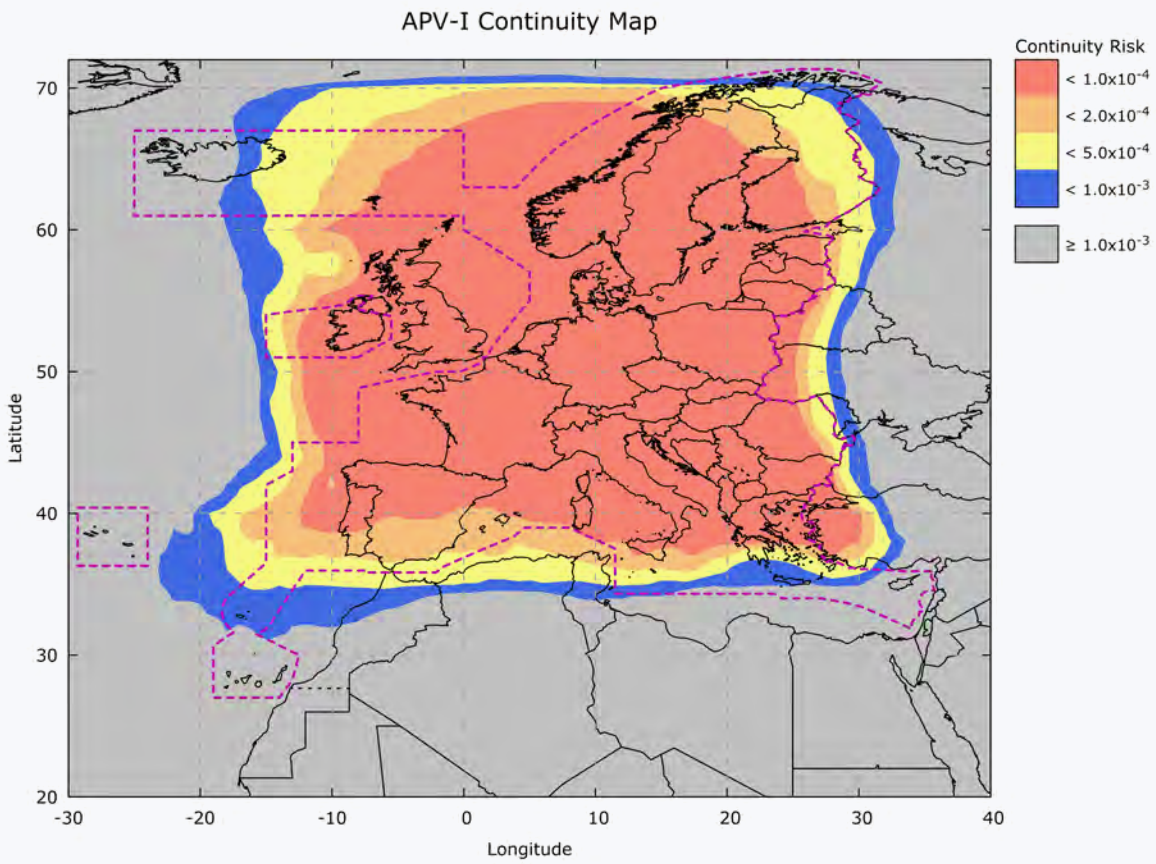
6.3.2.5 Continuity

Figure 6-4 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.

The minimum continuity risk performance is less than 10-4 per 15 seconds in core part of ECAC landmasses, and less than 5x10-4 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 6-1 (8x10-6 per 15 seconds). These values are however considered as sufficient to start the EGNOS use in civil aviation. Indeed, ICAO SARPs 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

Figure 6-4 **EGNOS APV-1 continuity**



mitigate the risks of an operational nature[26]. Moreover the Performance-based Navigation (PBN) Manual [RD-17] already includes special considerations when GNSS is the main or sole positioning source[27].

6.3.3 LPV-200

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 xPL < xAL 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.

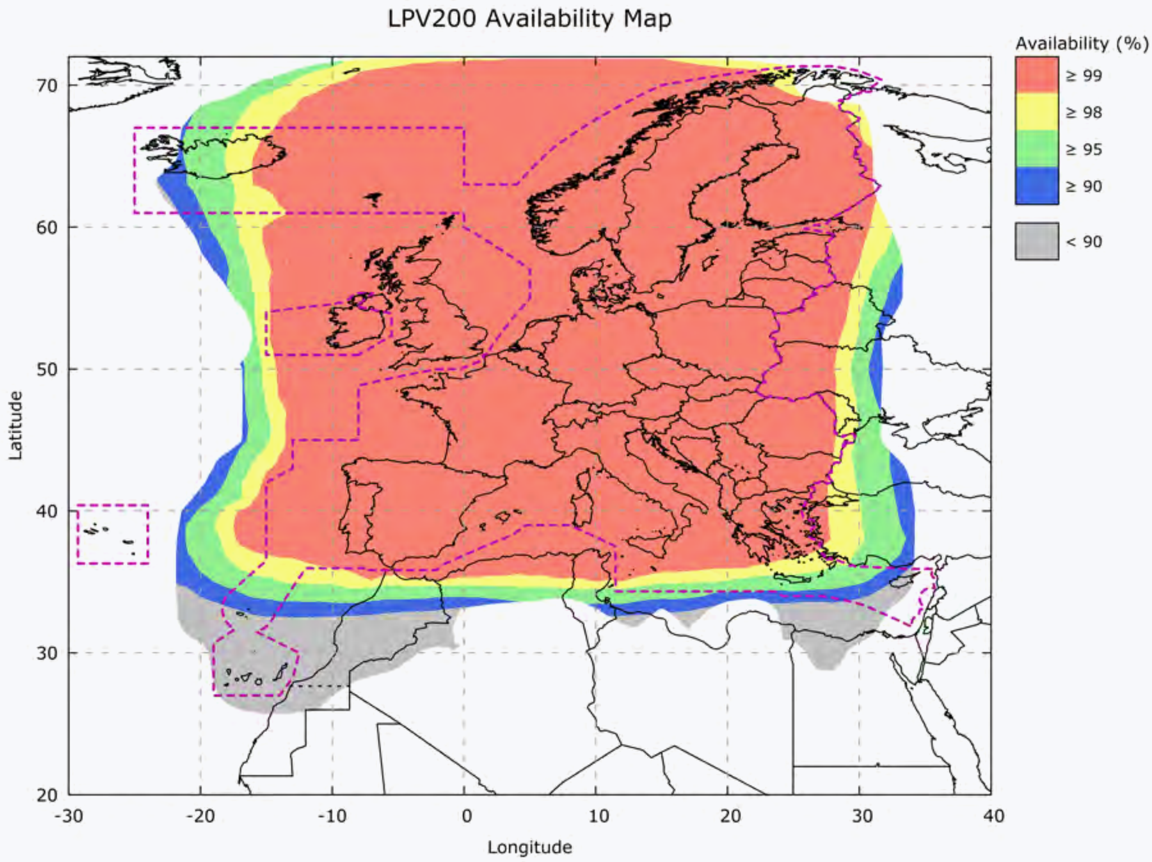
These LPV-200 requirements relative to the maximum VNSE probability are novel with respect to APV-I. It is to be noted that the hazard severity of an incompliance of the requirement VNSE>15 m in degraded conditions is formally considered major from a safety point of view as explained by ICAO in Annex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

These new requirements are also considered in the LPV-200

26. 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".

27. 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"*.

Figure 6-5 EGNOS LPV-200 availability[28]



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 6-2. The EGNOS system is therefore compliant with the accuracy requirements specified in Table 6-1 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 6-1 for Category I precision approach.

6.3.3.4 Availability

Figure 6-5 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 6-1, 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

28. 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

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.

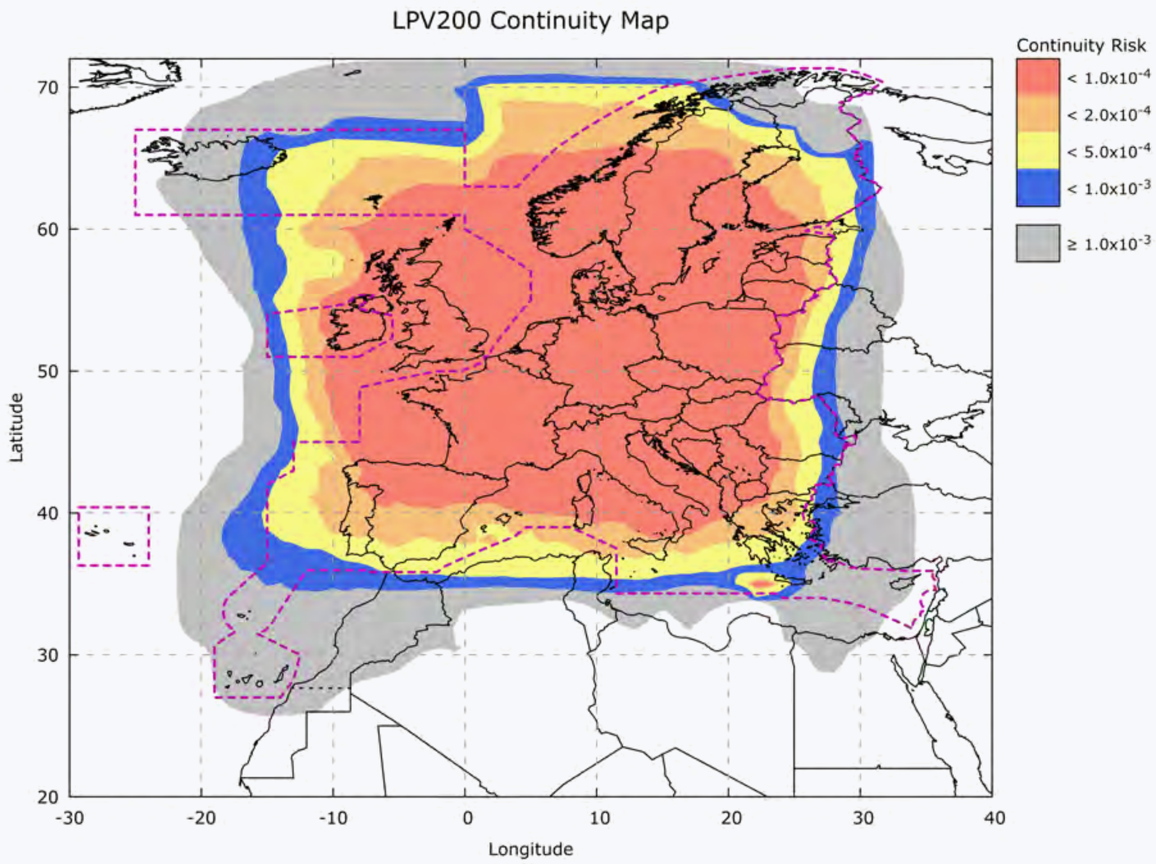
6.3.3.5 Continuity

Figure 6-6 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.

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.

The minimum continuity risk performance is less than 10-4 per 15 seconds in core part of ECAC landmasses, and less than 5x10-4 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

Figure 6-6 **EGNOS LPV-200 continuity[29]**



29. 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

compliant to ICAO requirements for Category I precision approach as described in Table 6-1 (8x10-6 per 15 seconds). These values are however considered as sufficient to start the EGNOS use in civil aviation. Indeed, ICAO SARPs 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 nature[30].

Moreover the Performance-based Navigation (PBN) Manual [RD-17] already includes special considerations when GNSS is the main or sole positioning source[31].

6.4 EGNOS SoL Service Limitations

In the vast majority of cases, the EGNOS SoL Service 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 always guaranteed. The most common causes for such abnormal behaviour are listed below in Table 6-3.

Table 6-3 EGNOS SoL limitations

Root Cause	Most Likely Symptoms
Broadcasting delays As explained in section 3.1.2.3, 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.	**EGNOS SoL Service Not immediately available** 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.
GPS or EGNOS Signal Attenuation 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	**Degraded Position Accuracy** 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.

30. 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".
31. 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"*.

Root Cause	Most Likely Symptoms
EGNOS Signal Blockage 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. At any latitude, it may happen that, in an urban environment, the EGNOS signals are not visible for some time.	**Degraded Position Accuracy After Some Time** 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.
Local Multipath 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.	**Degraded Position Accuracy** 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.
Local Interference 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. 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. In most cases, national agencies are in charge of detecting and enforcing the lawful use of spectrum within their national boundaries.	**Degraded Position Accuracy or Complete Loss of Service** 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). 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.
Ionospheric Scintillation 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.	**Degraded Position Accuracy** 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. In cases when the EGNOS signal is lost, the impact will be similar to the one described for "EGNOS signal blockage" above.
Degraded GPS Core Constellation 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.	**Degraded EGNOS SoL Service Performance** In such a case, the EGNOS SoL 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.

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 inferred[32].

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 (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

32. 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.

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 Schriver 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 is the most demanding among the EGNOS SoL Service levels whereas alert limits for APV-I are more demanding than for NPA). See Table 6-1 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:

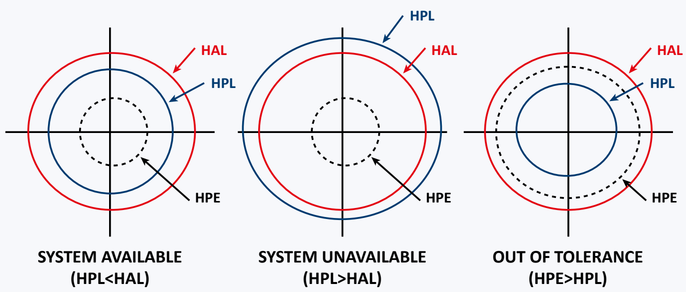
- HPE > HPL or,
- VPE > VPL (in absolute value)

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 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 B-1 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.

Figure B-1 **Possible situations when navigating with EGNOS**



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].

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.

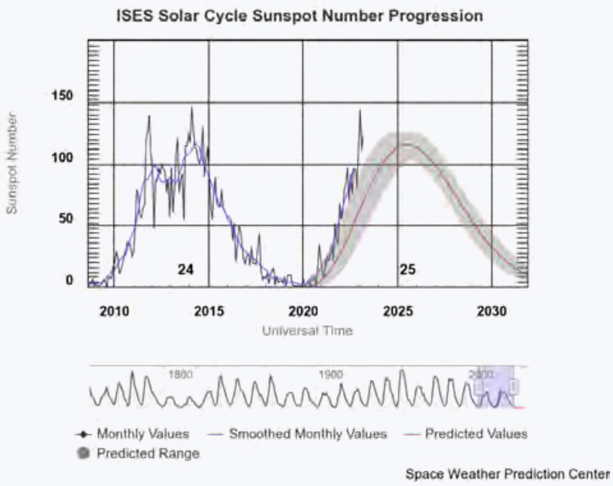
In the case of SBAS systems, the SBAS receivers inside the corresponding service area use the SBAS ionospheric corrections, which are derived from real-time ionospheric delay measurements. The SBAS ground system obtains these measurements from a network of reference stations and uses them to estimate 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 C-1). 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 C-1 SSN progression from NOAA/SWPC



The dependence of SBAS system performance on the ionosphere variations was especially noticeable during the period of solar activity increase in 2014 when EGNOS and the other GNSS/SBAS systems were affected. 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 geomagnetic activity or ionospheric storms when the ionosphere 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 North of Europe during periods with very high geomagnetic activity. The month of February 2014 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 C-2 presents the daily LPV performance[33] achieved by EGNOS on two particular degraded days, February 19th (nominal degraded case) and 27th (highly degraded case).

As it can be observed, several regions in the North of Europe were affected during February 19th. The case of February 27th is especially relevant owing to the size of the area impacted (this is, with SoL service availability below 99%) by the degradations. 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.

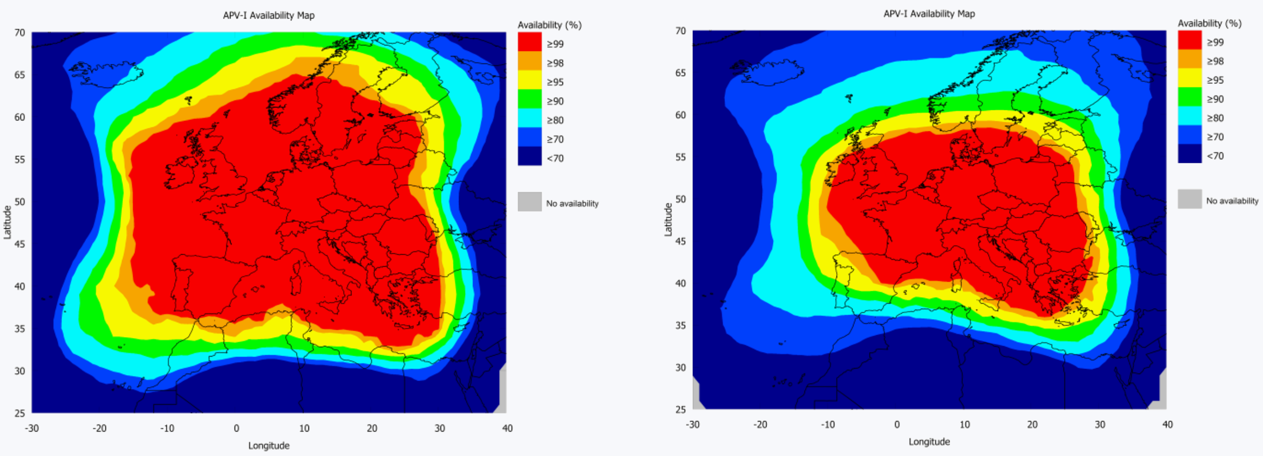
Nonetheless it is worth noting that, even in such degraded scenario, during these periods of time the SoL Service Availability in the most impacted areas (North and South-West) within the SoL SDD commitment area was close to 94% (from the 1st February to the 31st March 2014).

It must be noted that in the coming years, this SBAS performance's behaviour is expected to be observed again, in a more frequent way, due to the mentioned solar activity increase. That increase is linked to the solar cycle#25, which is being more active than initial predictions.

Additionally it should be highlighted that the ionospheric events in case of impact on GNSS/SBAS-based operations

33. 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%.

Figure C-2 EGNOS LPV performance results on 19th (left) and 27th (right) February 2014



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.

Appendix C.3 Improvement and robustness achieved by EGNOS

EUSPA, ESA and ESSP SAS are advancing towards a deeper understanding of the effects of ionosphere at user performance level in order to improve the EGNOS system behaviour towards ionospheric disturbances, make it more robust and provide a better service to the EGNOS users. An improved level of stability concerning ionosphere effects estimation was achieved after the deployment of the EGNOS 2.3.1i in August 2012. EGNOS system release 2.3.2, deployed in October 2013, increased the robustness of EGNOS against this kind of events. The EGNOS system release ESR 2.4.1M provided even further robustness to these ionospheric events. At Programme Level, the EGNOS 2.4.2.B release, which will enter into service before the end of 2023, will provide additional robustness against these degradations. It is also to 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 C-3 and Figure C-4).

It must be noted that this behaviour is limited to periods in which the ionosphere presents an important activity, what is specially high during the spring and autumn periods, presenting a better stability during the summer and winter periods. To illustrate this, the following maps (Figure C-5 and Figure C-6) show, respectively, the measured APV-I Availability during the period from February to mid-May 2014 ("spring period") and from mid-may until the first week of September ("summer period").

Figure C-3 EGNOS APV-I availability on 12th September 2014 with ESR 2.3.2 (left) ESR 2.4.1M (right)

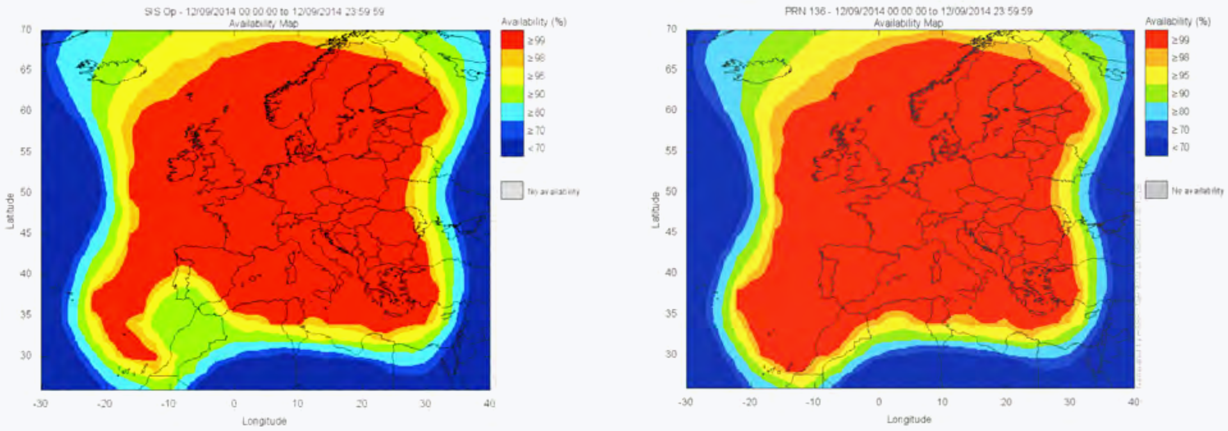
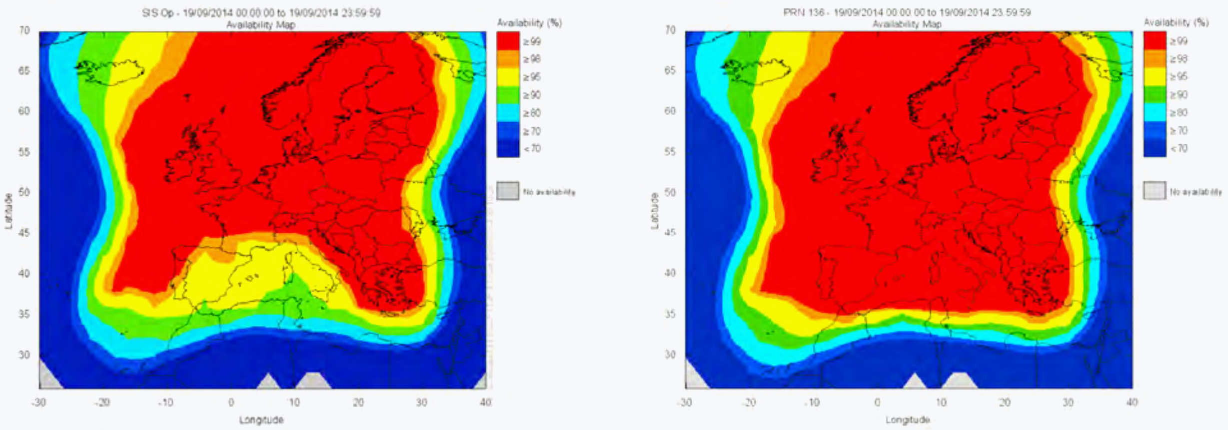


Figure C-4 EGNOS APV-I availability on 19th September 2014 with ESR 2.3.2 (left) ESR 2.4.1M (right)



As observed, during the 2014 summer period, the coverage, in terms of LPV performance, presented better results, in particular in the North and Southwest of Europe.

ESSP SAS, 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-user-support.essp-sas.eu/documents/field_gc_document_type/87) and distributed.

Particularly, the EGNOS Working Agreements (EWA) signed between ESSP 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 ESSP SAS to the impacted EWA signatories, providing the corresponding performance reports and distributing the corresponding NOTAM proposals when required.

Figure C-5 EGNOS LPV availability during "spring" (left) and "summer" (right) periods

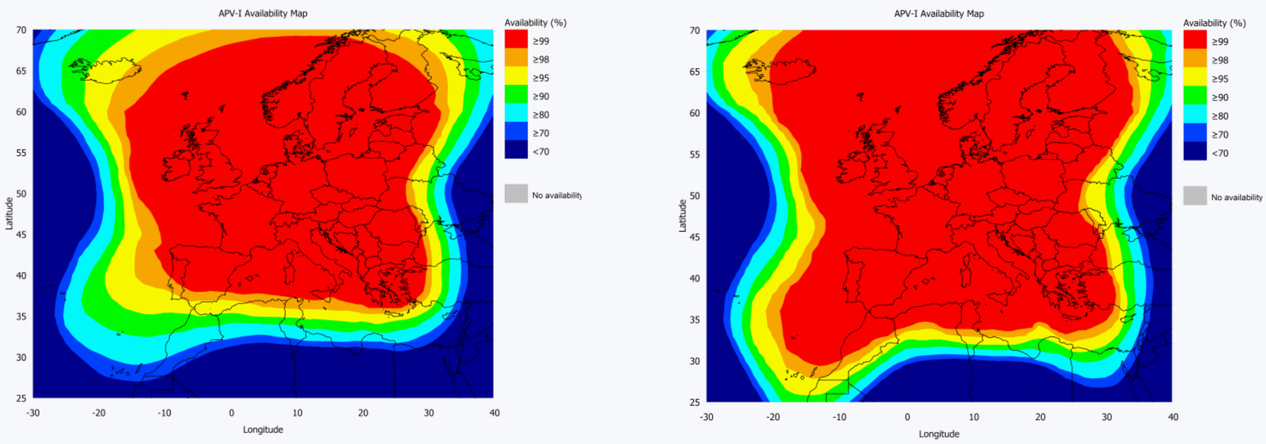
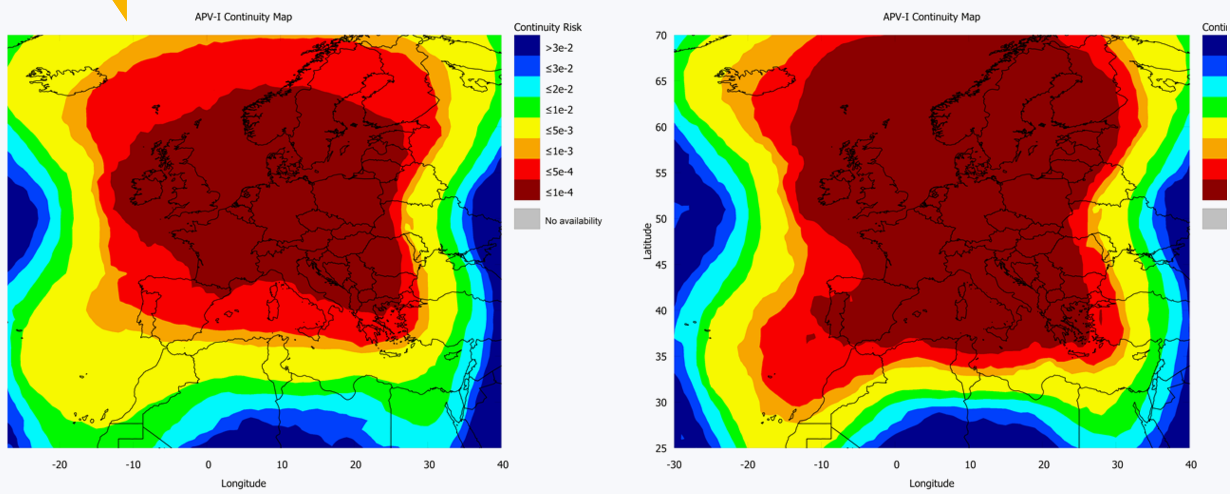


Figure C-6 EGNOS LPV continuity during "spring" (left) and "summer" (right) periods



Appendix D – EGNOS SoL service levels / PBN navigation specifications

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

Table D-1 EGNOS SoL Service Levels vs PBN NavSpecs

DOMAIN	USER OPERATION	EGNOS SoL Service Levels									
		NPA								APV-I	LPV-200
AVIATION	Performance Requirements Annex 10 – Vol I – Chapter 3 Table 3.7.2.4-1:	PBN Navigation Specification									
		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

(*) 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: achieved performances

This appendix complements the information provided in section 6, where EGNOS SoL service 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 achieved availability from 1 January 2022 to 30 June 2023 based on the information broadcast by the EGNOS operational GEOs during that period.

Figure E-1 NPA Availability from 01/01/22 to 30/06/23

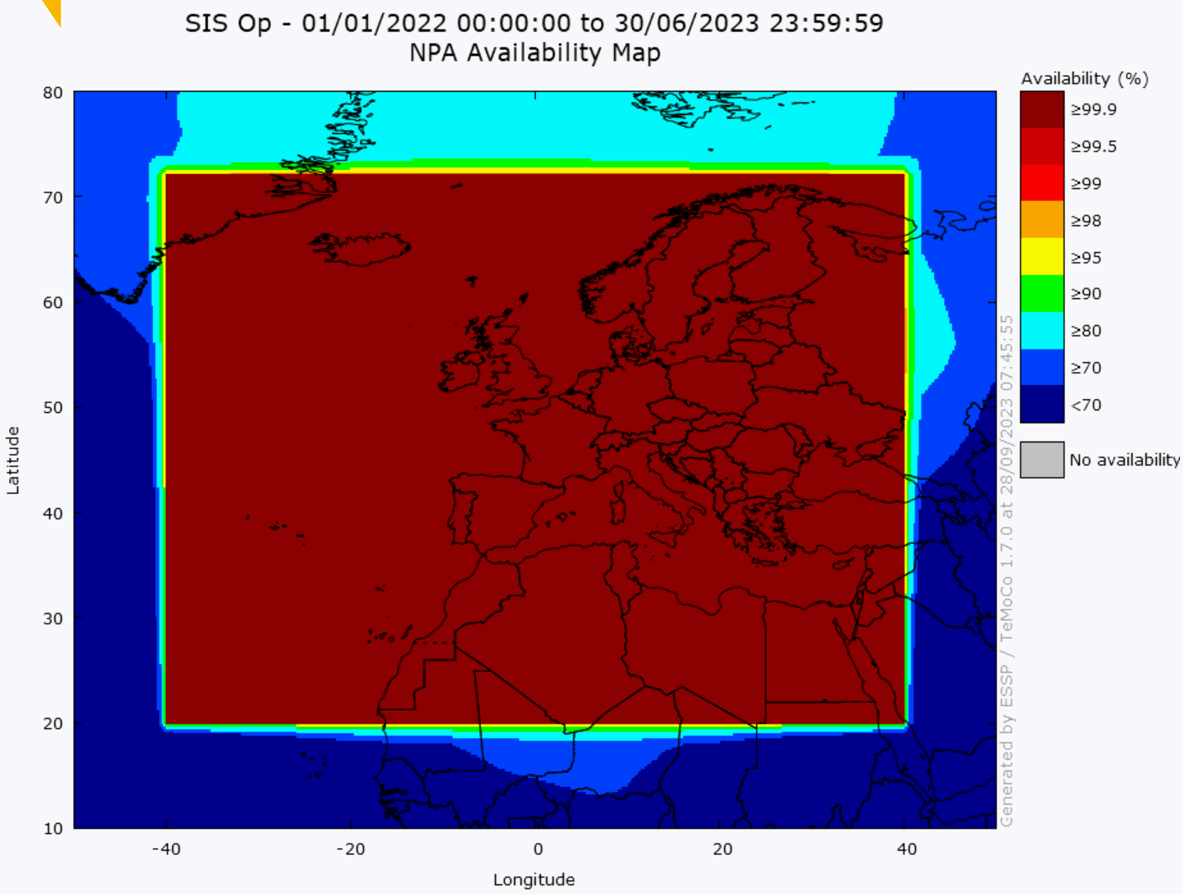


Figure E-2 APV-I Availability from 01/01/22 to 30/06/23

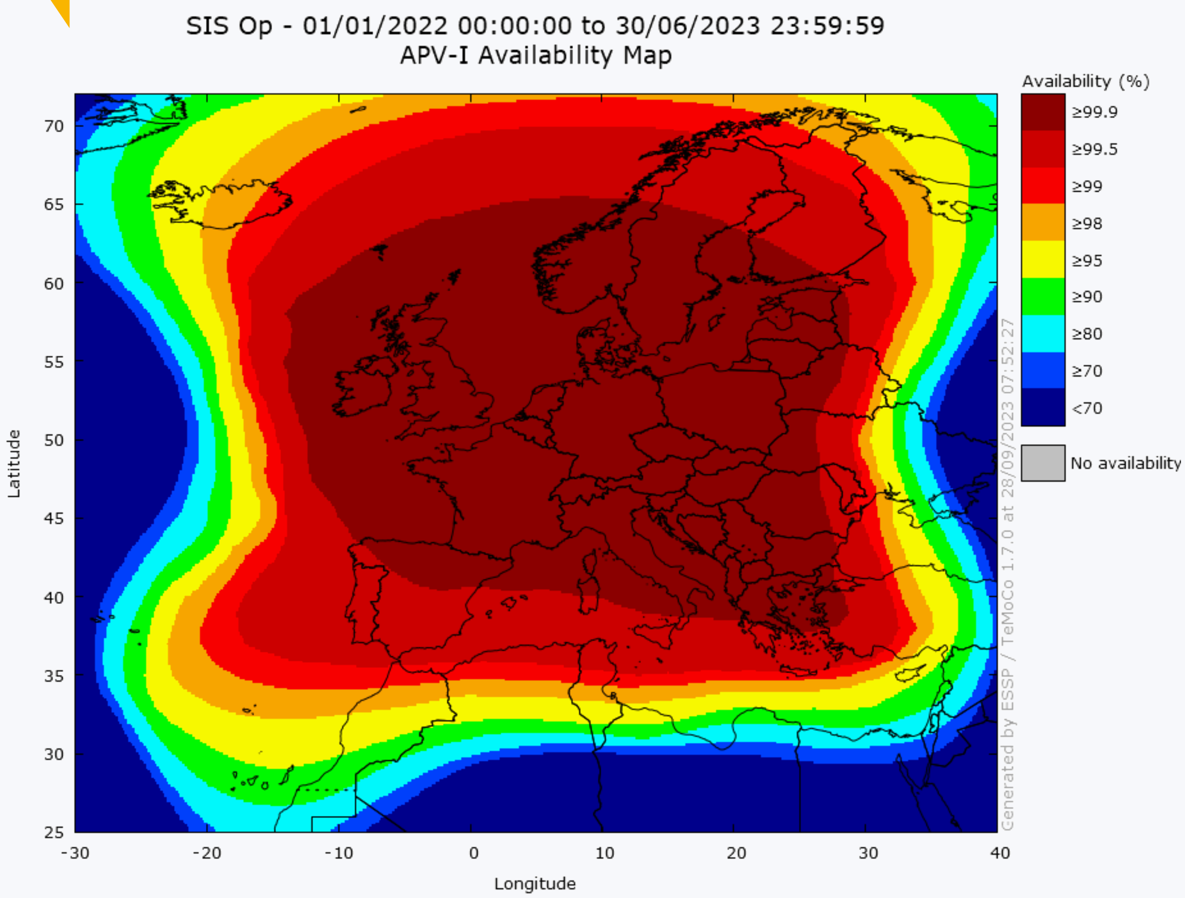
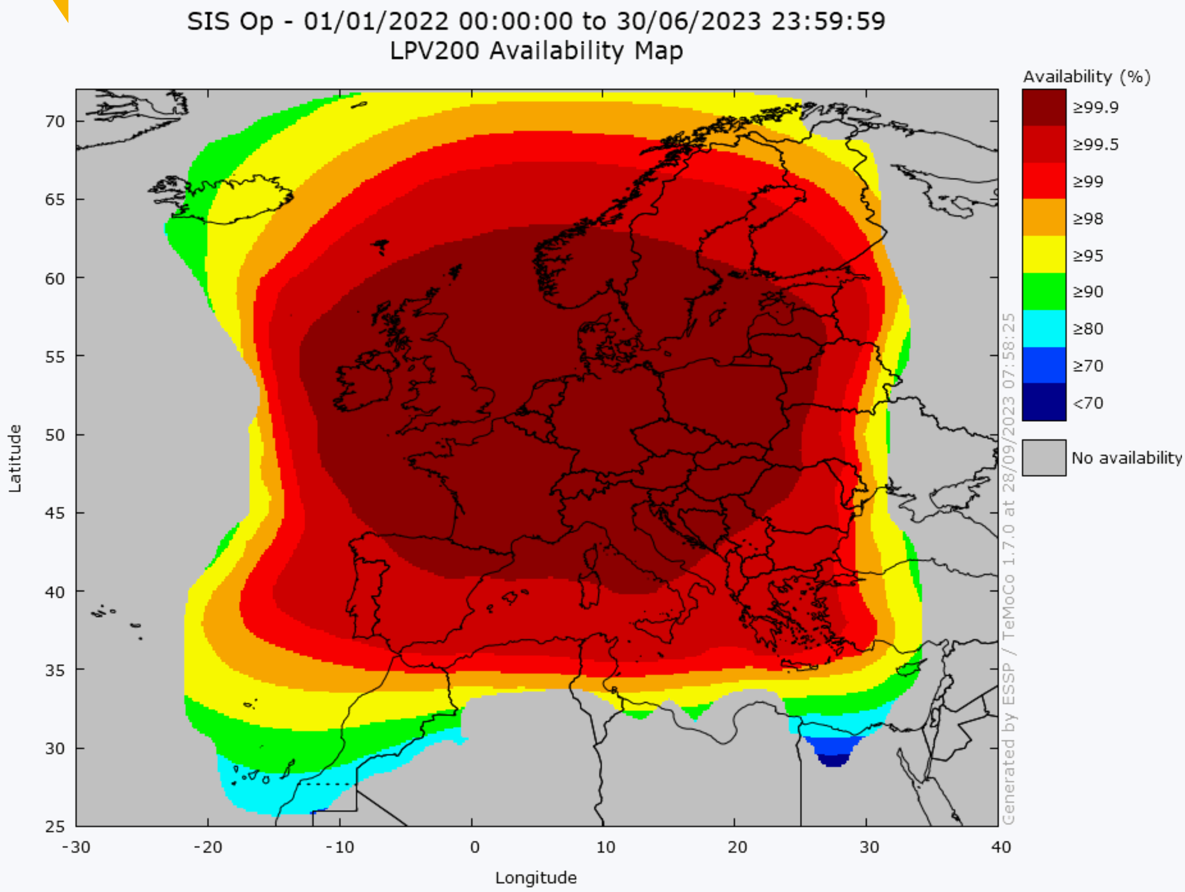


Figure E-3 LPV-200 Availability from 01/01/22 to 30/06/23



The achieved performances have been good although significant underperformance have been observed over the north and the south of the Service Area.

The information on the EGNOS SoL Service 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-user-support.essp-sas.eu/), and recurrently reported through the EGNOS Monthly Performance reports.

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]. Former AMC [RD-1] and 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]. Former AMC [RD-1] and 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)

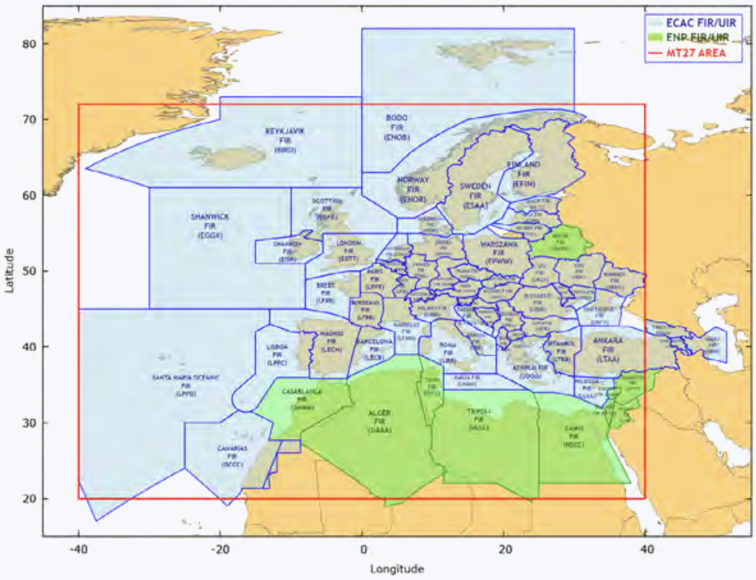
ECAC: Consists of the envelope of all FIRs of ECAC96 member States (including Canary Islands FIR) and the oceanic control areas of Reykjavik, Shanwick and Santa Maria. The ECAC landmass comprises the landmass region of ECAC member states, including ECAC islands (e.g. Canary Islands), and is indicated in Figure F-1.

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 Area: as part of the EGNOS Service Area, the concept of EGNOS SoL Service Area[34] can be defined for each SoL service level (i.e. NPA, APV-I and LPV-200) by the corresponding commitment maps. There-

34. 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."*

Figure F-1 ECAC 96 FIRs and EGNOS service Area (in red)



fore, any reference to EGNOS SoL Service Area should be associated to a specific SoL service level. The EGNOS SoL Service 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)

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) a two-dimensional (2D) instrument approach operation, using lateral navigation guidance only; and

b) 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 D[35] 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 F-1:

35. These navigation modes also correspond to MOPS E.

Table F-1 RTCA MOPS C&D terminology differences for navigation mode

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

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.

Service Level (namely NPA, APV-I, LPV-200): The capability of the EGNOS Safety of life service 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.

- **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.

Appendix G – List of acronyms

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

ACRONYM	DEFINITION
ABAS	Airborne Based Augmentation System
AC	Advisory Circular
AFM	Aircraft Flight Manual
AFTN	Aeronautical Fix Telecommunication Network
AIP	Aeronautical Information Publication
AIS	Aeronautical Information Service
AMC	Accepted Means of Compliance
ANSP	Air Navigation Service Provider
APCH	APproaCH
APV	APproach with Vertical guidance
AR	Authorization Required
A-RNP	Advanced RNP
ASQF	Application Specific Qualification Facility
ATS	Air Traffic Services
C/A	Coarse/Acquisition
CAT I/II/III	Category I/II/III
CCF	Central Control Facility
CDFA	Continuous Descent Final Approach
CDM	Collaborative Decision Making
CNES	Centre National d'Études Spatiales
CPF	Central Processing Facility
CS-ACNS	Certification Specification – Airborne Communications, Navigation and Surveillance
DAB	Digital Audio Broadcast
DA/H	Decision Altitude/ Height
DOP	Dilution Of Precision
EASA	European Aviation Safety Agency
EC	European Commission
ECAC	European Civil Aviation Conference
EDAS	EGNOS Data Access Service
EEA	European Economic Area
EFTA	European Free Trade Association
EGNOS	European Geostationary Navigation Overlay Service
EMEA	Europe, Middle East and Africa
ENT	EGNOS Network Time
ESA	European Space Agency
ESR	EGNOS System Release
ESSP	European Satellite Services Provider
ESP	EGNOS Service Provider
ETRF	EGNOS Terrestrial Reference Frame
ETSO	European Technical Standard Orders
EU	European Union
EUSPA	European Union Agency for the Space Programme
EWA	EGNOS Working Agreement
EWAN	EGNOS Wide Area Network
FAA	Federal Aviation Administration
FAQ	Frequently Asked Questions
FDE	Fault Detection and Exclusion
FIR	Flight Information Region
FTP	File Transfer Protocol
GAGAN	GPS 1Aided GEO Augmented Navigation
GBAS	Ground Based Augmentation System
GEO	Geostationary Satellite
GIVE	Grid Ionospheric Vertical Error
GLS	GNSS Landing System
GNSS	Global Navigation Satellite System
GPS	Global Positioning System
GPST	GPS Time
HAL	Horizontal Alert Limit
HMI	Hazardously Misleading Information
HPE	Horizontal Position Error
HPL	Horizontal Protection Level
IAP	Instrument Approach Procedure
ICAO	International Civil Aviation Organization
ICD	Interface Control Document
IERS	International Earth Rotation and Reference Systems Service
IGP	Ionospheric Grid Point
IGS	International GNSS Service
ILS	Instrument Landing System
IS	Interface Specification
ITRF	International Terrestrial Reference Frame
ITRS	International Terrestrial Reference System

ITU	International Telecommunications Union
KASS	Korea Augmentation Satellite System
LNAV	Lateral NAVigation
LP	Localiser Performance
LPV	Localizer Performance with Vertical guidance
MCC	Mission Control Centre
MDA/H	Minimum Descent Altitude / Height
MI	Misleading Information
MLS	Microwave Landing System
MOPS	Minimum Operational Performance Standards
MSAS	MTSAT Satellite-based Augmentation System
MT	Message Type
MTSAT	Multi-functional Transport Satellite
NLES	Navigation Land Earth Station
NM	Nautical Mile
NOAA	National Oceanic and Atmospheric Administration
NOF	NOTAM Office
NOTAM	Notice To Airmen
NPA	Non-Precision Approach
NSE	Navigation System Error
OCS	Operational Control System
OS	Open Service
PA	Precision Approach
PACF	Performance and Check-out Facility
PANS-OPS	Procedures for Air Navigation Services – Aircraft OPerationS
PBN	Performance Based Navigation
PPS	Precise Positioning Service
PRN	Pseudo-Random Number
PS	Performance Standard
RAIM	Receiver Autonomous Integrity Monitoring
RD	Reference Document
RDS	Radio Data System
RF	Radio Frequency
RHCP	Right Hand Circularly Polarised
RIMS	Range and Integrity Monitoring Station
RNAV	Area Navigation
RNP	Required Navigation Performance
RTCA	Radio Technical Commission for Aeronautics
SARPs	Standards and Recommended Practices
SAS	Société par Actions Simplifiée
SBAS	Satellite-Based Augmentation System
SDCM	System of Differential Correction and Monitoring
SDD	Service Definition Document
SES	Single European Sky
SI	International System of Units
SIS	Signal-In-Space
SL	Service Level
SoL	Safety of Life
SPS	Standard Positioning Service
SSN	SunSpot Number
SWPC	Space Weather Prediction Centre
TEC	Total Electron Content
TTA	Time-To-Alert
UDRE	User Differential Range Error
UERE	User Equivalent Range Error
US	United States
USAF	United States Air Force
USG	United States Government
UTC	Coordinated Universal Time
VAL	Vertical Alert Limit
VNAV	Vertical NAVigation
VNSE	Vertical Navigation System Error
VPE	Vertical Position Error
VPL	Vertical Protection Level
WAAS	Wide Area Augmentation System
WGS84	World Geodetic System 84 (GPS Terrestrial Reference Frame)
YSR	Yearly System Release

Notes

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