REPORT ON AVIATION USER NEEDS AND REQUIREMENTS

OUTCOME OF THE EUROPEAN GNSS' USER CONSULTATION PLATFORM

GALILEO EGNOS
NAVIGATION SOLUTIONS
POWERED BY EUROPE

European
Global Navigation
Satellite Systems
Agency

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	3.2	Update of User Requirements Specification, section 6	K. Strelcova	11/07/2018

TABLE OF CONTENTS

FIGURES

01 INTRODUCTION

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

GNSS PROVIDES SIGNIFICANT BENEFITS TO AVIATION AND SERVES AS A CATALYST FOR IMPROVING FLIGHT SAFETY AND EFFICIENCY.

The User Consultation Platform (UCP) is a periodic forum organised by the European Commission and the GSA, involving end users, user associations and representatives of the value chain, such as receiver and chipset manufacturers, application developers and the organisations and institutions dealing, directly and indirectly, with Galileo and EGNOS. The event is a part of the process developed at the GSA to collect user needs and requirements and take them as inputs for provision of user driven Galileo and EGNOS services. In this context, the objective of this document is to provide a reference for the European GNSS Programmes and for the aviation community reporting periodically the most up-to-date GNSS user needs and requirements in the aviation market segment. This report is considered a "living document" in the sense that it will serve as a key input to the next UCP event where it will be reviewed and subsequently updated. The UCP will be held periodically (e.g. once per year) and this report will be also periodically updated, to reflect the evolution in the user needs, market and technology captured during the UCP.

The report aims to provide the GSA with a clear and up-to-date view of the current and potential future user needs and requirements in order to serve as an input to the continuous improvement of the services provided by the European GNSS systems and their evolutions.

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

It must be noted that the listed user needs and requirements cannot usually be addressed by a single technological solution but rather by combination of several signals and sensors. Therefore, the report does not represent any commitment of the European GNSS Programmes to address or satisfy the listed user needs and requirements in the current or future versions of the EGNSS services.

1.1 METHODOLOGY

The following figure details the methodology adopted for the analysis of the Aviation user requirements.

The analysis is split into two main steps including a "desk research", to gather main insights, and a "stakeholders' consultation", to validate main outcomes.

More in details, "desk research" was based on a secondary research and aimed at providing a preliminary structured analysis:

- leveraging on the Aviation applications' segmentation as included in the GSA GNSS market report, additional relevant applications have been identified and included; and
- for each application identified, the function and level of performance required has been determined.

As a result of this activity, a first draft of the Aviation User Requirements document has been produced.

In the second step, the "stakeholder consultation" one, main outcomes included in the document have been validated and updated. In this regards, preliminary validation interviews with selected stakeholders have produced the current document to be used as an input for the UCP review and finalisation.

Figure 1: High-level methodology for the analysis of Aviation User Requirements

OVERALL METHODOLOGY

1 Desk Research

Identification of all existing Aviation applications along with the function that they perform

- All Aviation applications covered in MR5
- Aviation applications found in other sources

User level dimension and characterisation

- Identification of the key GNSS user-level dimensions to describe Aviation user requirements
- Identification and definition of GNSS performance criteria relevant to Aviation

Segmentation of Aviation Applications

- Definition and classification of applications
- Focused on GNSS usage (not device-based)

Definition of the functions and level of performance required for each application

- Aviation user requirements analysis based on open Secondary research information
- GNSS limitations, market/techno trends and drivers
- Table matching the main applications with the performance criteria

User requirement analysis – *draft 1*

SECONDARY RESEARCH INFORMATION

GNSS magazines - Coordinates, GPS World, Inside GNSS; ESA website; Articles on Google Scholar; Thesis and dissertations on specific database; European regulation or standard; Google

2 Stakeholders Consultation

Validation interviews

- Interview guide
- Selection of the consulted stakeholders
- Primary research: Interviews and reporting

User requirement analysis – *final version*

User Consultation Platform

- User requirements submitted to the first UCP forum for review and finalisation

1.2 SCOPE

This document is part of the User Requirements documents issued by the European GNSS Agency for the Market Segments where Position Navigation and Time (PNT) play a key role. Its scope is to cover user requirements for PNT solutions from the strict user perspective and the market conditions that drive them. Therefore, the document includes an analysis of the market trends in this particular segment, then performs a detailed analysis, including the prospective uses of GNSS in this market, finalising with a specification of user requirements.

Users' requirements are largely translated into regulatory requirements. Aviation operates in a global market and efficiency largely depends on airspace organisation and navigation services as well as aircraft technical capacities. Therefore, this document addresses user requirements for what concerns the carriage and use of GNSS equipment from the following angles:

- Technical requirements applicable to GNSS Signal in Space (SiS) performance for the different applications,
- Technical requirements applicable to equipment on board, including airworthiness requirements,
- Operational requirements applicable to air operators and ANSPs/network managers, which define the global conditions for using the radio navigation service. These conditions depend on the type of operation.

The aim of the document is to evaluate the user needs and requirements for the current GNSS applications used in aviation and to describe and analyse the user needs and requirements of the future GNSS applications to address the evolving needs of the aviation industry.

AS AVIATION OPERATES IN A GLOBAL MARKET, EFFICIENCY LARGELY DEPENDS ON AIRSPACE ORGANISATION, NAVIGATION SERVICES AND THE TECHNICAL CAPACITIES OF THE AIRCRAFT.

02 EXECUTIVE SUMMARY

OVERVIEW

This report is looking into analysing the user requirements of the current and future GNSS applications used in the aviation market. It starts with an introduction into the topic by presenting the aim and the scope of the document in section 1, which is followed by this executive summary which offers a high-level understanding of the subject matters laid down in the report in the subsequent sections. Section 3 is only a mention regarding the referenced documents across the entire document.

Section 4 starts by providing an insight into the aviation market and an overview of GNSS use trends in aviation as well as presenting the main players of the GNSS applications in the industry. This section ends by presenting the three main R&D programmes (SESAR, NextGen and H2020) and their projects towards the development of GNSS applications for the Civil Aviation.

The core section of the report, section 5, provides an in-depth analysis of the user needs and requirements for both current developments and future technologies and operations that can arise from the new GNSS applications.

The report ends with the section which is a collection of requirements split into the following different categories: Precision Navigation and Timing Systems, Runway, GNSS timing and ADS-B system (including Flight Tracking), and UAV. They put together all the GNSS related requirements coming out from standards, directives and regulations around the world.

Since the beginning, GNSS has provided significant benefits to aviation. It has also been a catalyst and enabler for several applications that have contributed to the improvements in safety and operational efficiency that passengers and all airspace users have enjoyed. The following, is a snapshot of the level of benefit that has been enabled through GNSS and specifically the European introductions of EGNOS and Galileo.

To enable these and future benefits, it is crucial to ensure that user needs and requirements are captured at the right level and that of specifications and standards that will enable the approval for use in aircraft of these new applications.

EGNOS

Since the beginning, EGNOS has provided a number of benefits to aviation, including:

- improved safety of the operations
- the possibility of providing LPV (3D precision app) to all runway ends without infrastructure requirements

The level of performance is such that additional benefits are now being recognised through ADS-B and Performance Based Navigation with better availability, accuracy, and alert levels.

The following are enabled with EGNOS:

EGNOS IMPROVES FLIGHT SAFETY AND ENABLES THE PROVISION OF LPV TO ALL RUNWAY ENDS WITHOUT INFRASTRUCTURE REQUIREMENTS.

NAVIGATION

- **LPV** (Localizer Performance with Vertical guidance): LPV approaches are the most essential function provided by SBAS technology. LPV are 3D look alike ILS approaches, and are considered as precision approaches. Two type of LPV benefits are realized:
  - on non-precision runways (mostly small & local airports) the main benefit is to allow approaches with minima down to 250 ft and even down to 200 ft for aircraft equipped with SVS (Synthetic Vision System). Herein the objective is to allow approaches in low ceiling conditions.
  - on precision runways (Regional & larges airports), the main benefit is to allow approaches in LVC (Low Visibility Conditions). On such runway LPV200 will be implemented, meaning DA of 200 ft and RVR of 1800 ft. Complemented with EVS (Enhanced Vision System) it will be possible to operate with RVR of 1000 ft and even lower in the future.
- **LPV on VFR airports (under assessment):** deployment at non-instrument runways and VFR airports improves

safety of general aviation users already equipped with IFR and SBAS avionics.

- **Steep approaches:** LPV with different GS (Glide Slope) angles, angles up to 4,5° for normal approaches and above in the case of steep approaches can be implemented. Most turboprops and many Business Jets are able to operate with GS angles up to 7°. For the obstacle clearance purposes and improved accessibility to aerodromes, such LPVs in combination with curved approaches (RF leg) could be developed whilst also reducing fuel consumption.
- **LNAV/VNAV:** Such GNSS approaches are sensitive to QNH setting errors. Now it is possible to perform them leveraging EGNOS vertical guidance.
- **RNP AR:** These "approval required" operations are mostly developed when due to obstacles, straight forward approaches (LPV) cannot be developed. EGNOS provides benefits on such approaches such as:
    - providing better navigation accuracy, better availability and continuity (as a minimum, 4 satellites are needed to be seen at all times).
    - increased capacity of the aerodromes with the parallel runways (when new Amendment on the current standards is in place).
- **Landing monitoring:** To prevent runway excursion, manufacturers are developing systems to detect long landing and to alert pilots to proceed to a Go Around. Due to its accuracy and availability, use of EGNOS in such systems is essential. In addition, EGNOS will also be useful for the development of braking systems for the purpose to reduce "Time on Runway" (Brake to Vacate applications).

SURVEILLANCE:

- **ADS-B:** EGNOS can improve availability and work is ongoing to assess contribution to potential infrastructure rationalisation as part of an integrated CNS strategy.
- **Hybrid Surveillance:** Use of geometric altitudes can enable monitoring of baro-altitudes and eliminate this common failure mode. As part of Hybrid Surveillance (ACAS –X) based on ADS-B data, it is possible to compare the difference between geometric and baro-altitudes provided by the intruders to the one of the aircraft.
- **Ground Warning System (EGPWS, TAWS)** Use of geometric SBAS Altitude can support development of better ground warning systems.

GALILEO

Galileo provides great potential and an enabler for additional benefits that build on the applications already proven or developing with EGNOS. It is expected that when Galileo is complete, that deployment will be through the use of dual frequency multi constellation receivers. Galileo augmentations via SBAS (e.g. EGNOS V3), ABAS (e.g. ARAIM) and GBAS (e.g. GAST-F) will support navigation and surveillance applications with stringent requirements.

Galileo positioning and the Search and Rescue service also supports Aircraft Distress Tracking. Research is ongoing on beacon remote activation and related operational concept, delivering additional benefits to the aviation community.

> GALILEO WILL ENABLE ADDITIONAL BENEFITS THAT BUILD ON THE APPLICATIONS ALREADY PROVEN WITH EGNOS.

Drones market is booming and expecting to increase the number of all other aviation users. Galileo based multiconstellation solutions can support robust navigation by increasing availability and accuracy, which is key especially in urban environments.

The Annexes of the paper present the following topics:

- Annex 1 is a list of acronyms used across the entire document.
- Annex 2 describes the ICAO foundations protocols for operational approval, airworthiness certification and provision of air navigation services.
- Annex 3 presents the EASA certification specifications for the different types of aircraft
- Annex 4 provides an overview of the regulatory environment at both European level and international level.
- Annex 5 outlines the GNSS systems used in the aviation market segment for surveillance and tracking (ADS-B), 4D trajectory, search and rescue (SAR, ELT), terrain awareness (TAWS) and drones.

03 REFERENCE DOCUMENTS

Id.	Reference	Title	Date
[RD1]	5th edition of the GSA's GNSS Market Report	GNSS Market Report	Issue 5 – 2017
[RD2]	ED Decision 2003/012/RM AMC20 (13 separated amendments since initial issue in 2003)	General Acceptable Means of Compliance for Airworthiness of Products, Parts and Appliances	Initial Issue on 5 November 2003
[RD3]	Commission Implementing Regulation (EU) No 1207/2011	Laying down requirements for the performance and the interoperability of surveillance for the single European sky	22 November 2011
[RD4]	Commission Implementing Regulation (EU) No 1028/2014	Amending Implementing Regulation (EU) No 1207/2011 laying down requirements for the performance and the interoperability of surveillance for the single European sky	26 September 2014
[RD5]	EASA AMC 20-24 ED Decision 2008/004/R	Certification Considerations for the Enhanced ATS in Non-Radar Areas using ADS-B Surveillance (ADS-B-NRA) Application via 1090 MHZ Extended Squitter	25 April 2008
[RD6]	EASA CS-ACNS Annex I to ED Decision 2013/031/R	Certification Specifications and Acceptable Means of Compliance for Airborne Communications, Navigation and Surveillance CS-ACNS	17 December 2013
[RD7]	FAA Advisory Circular 20-165B	Airworthiness Approval of Automatic Dependent Surveillance – Broadcast OUT Systems	15 July 2015
[RD8]	FAA Advisory Circular 90-114A	Automatic Dependent Surveillance-Broadcast Operations	28 October 2014
[RD9]	FAA TSO-C195b (no longer applicable after March 2016)	Avionics Supporting Automatic Dependent Surveillance – Broadcast (ADS-B) Aircraft Surveillance Applications (ASA)	29 September 2014
[RD10]	FAA AC 20-172B	Airworthiness Approval for ADS-B In Systems and Applications	20 May 2015
[RD11]	RTCA/DO-260B	Minimum Operational Performance Standards for 1090 MHz Extended Squitter Automatic Dependent Surveillance – Broadcast (ADS-B) and Traffic Information Services – Broadcast, with corrigendum 1.	13 December 2011
[RD12]	RTCA/DO-317b	Minimum Operational Performance Standards (MOPS) for Aircraft Surveillance Applications (ASA) System	17 June 2014
[RD13]	Commission Regulation (EU) 2015/2338	Amending Regulation (EU) No 965/2012 as regards requirements for flight recorders, underwater locating devices and aircraft tracking systems	11 December 2015

Id.	Reference	Title	Date
[RD14]	EASA – Air OPS Part ORO	Acceptable Means of Compliance (AMC) and Guidance Material (GM) to Annex III Organisation Requirements for Air Operations	Consolidated version including Issue 2, Amendment 7 May 2016
[RD15]	EASA – Air Ops Part NCO	Acceptable Means of Compliance (AMC) and Guidance Material (GM) to Annex VII – Part NCO	Consolidated version including Issue 2, Amendment 2 20/02/2015
[RD16]	COSPAS-SARSAT C/S T.001 Issue 4 and T.007 Issue 5	Specification for COSPAS-SARSAT 406 MHz distress beacons and type approval	May 2017
[RD17]	COSPAS-SARSAT C/S T.018 Issue 1	Specification for Second-Generation Cospas-Sarsat 406-MHz	May 2017
[RD18]	EASA Concept of Operations for Drones	Concept of Operations for Drones – A risk-based approach to regulation of unmanned aircraft	May 2015
[RD19]	EASA Advance Notice of Proposed Amendment 2015-10	Introduction of a regulatory framework for the operation of drones	31 July 2015
[RD20]	EASA Technical Opinion RMT.0230	Introduction of a regulatory framework for the operation of unmanned aircraft	18 December 2015
[RD21]	1SESAR JU U-space Blueprint [1]	U-space Blueprint	2017
[RD22]	EASA Advance Notice of Proposed Amendment 2017-05 (A)	Introduction of a regulatory framework for the operation of drones	4 May 2017
[RD23]	EASA Notice of Proposed Amendment 2017-05 (B)	Introduction of a regulatory framework for the operation of drones	12 May 2017
[RD24]	ICAO GADSS 6.0	Global Aeronautical Distress & Safety System (GADSS)	7 June 2017
[RD25]	ICAO Doc 10054	ICAO Manual Location of Aircraft in Distress and Flight Recorder Data Recovery	Under development
[RD26]	EUROCAE WG-98 MASPS ED-237	Criteria to Detect In-flight Aircraft Distress Events to Trigger Transmission of Flight Information	
[RD27]	http://helios-gsa-project.eu/	HELIOS – Second Generation Beacon for GALILEO/EGNOS EGNSS Search And Rescue applications – website	N/A
[RD28]	http://www.gricas-gsa-project.eu/	GRICAS Consortium website	N/A
[RD29]	Convention on International Civil Aviation	ICAO Doc 7300/9	Ninth Edition – 2006 with corrigendum Nov 2007 and Dec 2010
[RD30]	Annex 6 to the Convention on International Civil Aviation	Operation of Aircraft	Tenth Edition, July 2016

Id.	Reference	Title	Date
[RD31]	Annex 8 to the Convention on International Civil Aviation	Airworthiness of Aircraft	11th Edition – July 2010 Amendment 103 and 104 up to 2014 published separately
[RD32]	Annex 10 to the Convention on International Civil Aviation	Aeronautical Telecommunications	6th edition, incorporating Amendments 1–81-July 2010 Amendments 82 to 91 (up to Nov 2014) published separately
[RD33]	Performance-based Navigation (PBN) Manual	ICAO Doc 9613	Fourth Edition –2013
[RD34]	Global Navigation Satellite System (GNSS) Manual	ICAO Doc 9849	Second Edition – June 2013 Note: there is an Advance Third Edition – 2017 (unedited)
[RD35]	Aircraft Operations – Volume 1 Flight Procedures	ICAO Doc 8168	5th Edition 2006 with Amendment 7 – Nov 2016
[RD36]	Aircraft Operations – Volume 2 Construction of Visual and Instrument Flight Procedures	ICAO Doc 8168	6th Edition 2014 with amendment 7 – Nov 2016
[RD37]	Procedures for Air Navigation services – ATM	ICAO Doc 4444	15th edition, 2007 with Amendment 6 – Nov 2014
[RD38]	Regulation (EC) No 216/2008	On common rules in the field of civil aviation and establishing a European Aviation Safety Agency, and repealing Council Directive 91/670/EEC, Regulation (EC) No 1592/2002 and Directive 2004/36/EC	20 February 2008
[RD39]	Regulation (EC) No 690/2009	Amending Regulation (EC) No 216/2008 of the European Parliament and the Council on common rules in the field of civil aviation and establishing a European Aviation Safety Agency, and repealing Council Directive 91/670/EEC, Regulation (EC) No 1592/2002 and Directive 2004/36/EC	30 July 2009
[RD40]	Regulation (EC) No 1108/2009	Amending Regulation (EC) No 216/2008 in the field of aerodromes, air traffic management and air navigation services and repealing Directive 2006/23/EC	21 October 2009
[RD41]	Regulation (EU) No 748/2012	Laying down implementing rules for the airworthiness and environmental certification of aircraft and related products, parts and appliances, as well as for the certification of design and production organisations	3 August 2012
[RD42]	Regulation (EU) No 965/2012	Laying down technical requirements and administrative procedures related to air operations pursuant to Regulation (EC) No 216/2008 of the European Parliament and of the Council	5 October 2012

Id.	Reference	Title	Date
[RD43]	Regulation (EU) No 6/2013	Amending Regulation (EC) No 216/2008 of the European Parliament and of the Council on common rules in the field of civil aviation and establishing a European Aviation Safety Agency, and repealing Council Directive 91/670/EEC, Regulation (EC) No 1592/2002 and Directive 2004/36/EC	8 January 2013
[RD44]	Regulation (EU) No 139/2014	Aerodromes	12 February 2014
[RD45]	Regulation (EC) No 549/2004	Laying down the framework for the creation of the Single European Sky	10 March 2004
[RD46]	Regulation (EC) No 550/2004	On the provision of air navigation services in the Single European Sky	10 March 2004
[RD47]	Regulation (EC) No 551/2004	On the organisation and use of the airspace in the Single European Sky	10 March 2004
[RD48]	Regulation (EC) No 552/2004	On the interoperability of the European Air Traffic Management network	10 March 2004
[RD49]	Regulation (EU) No 691/2010	Laying down a performance scheme for air navigation services and network functions and amending Regulation (EC) No 2096/2005 laying down common requirements for the provision of air navigation services	29 July 2010
[RD50]	Commission Implementing Regulation (EU) No 716/2014	on the establishment of the Pilot Common Project supporting the implementation of the European Air Traffic Management Master Plan	27 June 2014
[RD51]	Annex to ED Decision 2009/009/R	CS-22 / Amendment 2	5 March 2009
[RD52]	Annex to ED Decision 2015/018/R	CS-23 / Amendment 4	15 July 2015
[RD53]	Annex to ED Decision 2015/019/R	CS-25 / Amendment 17	15 July 2015
[RD54]	Annex to ED Decision 2012/021/R	CS-29 / Amendment 3	11 December 2012
[RD55]	Annex to ED Decision 2013/015/R	CS-LSA / Amendment 1	29 July 2013
[RD56]	Annex to ED Decision 2003/10/RM	CS-ETSO (Initial issue)	24 October 2003
[RD57]	Annex to ED Decision 203/006/R	CS-AWO / Initial Issue	17 October 2003
[RD58]	Annex I to ED Decision 2013/031/R	CS-ACNS / Initial Issue	17 December 2013
[RD59]	ETSO C115c	Airborne area navigation equipment flight management system (FMS) using multi-sensor inputs	12 July 2013
[RD60]	ETSO C144a	Passive airborne GNSS antenna	21 December 2010
[RD61]	ETSO C145c	Airborne Navigation Sensors Using the Global Positioning System Augmented by the Satellite Based Augmentation System	21 December 2010

Id.	Reference	Title	Date
[RD62]	ETSO C146c	Stand-Alone Airborne navigation Equipment Using the Global Positioning System Augmented by the Satellite-Based Augmentation System	21 December 2010
[RD63]	ETSO C161a	Ground-Based Augmentation System Very High Frequency Data Broadcast Equipment	5 July 2012
[RD64]	ETSO-C190	Active Airborne Global navigation Satellite System (GNSS) Antenna	21 December 2010
[RD65]	ETSO-C196a	Airborne Supplemental Navigation Sensors for Global Positioning System Equipment Using Aircraft-Based Augmentation	5 May 2012
[RD66]	Annex to Decision 2016/020/R	AMC and GM to Part-SPA – Amendment 3	29 July 2016
[RD67]	RTCA-DO 316	Minimum Operational Performance Standards for Global Positioning System / Aircraft-Based augmentation System Airborne Equipment	April 2009
[RD68]	RTCA DO-229E	Minimum Performance Standards for Global Positioning system/Wide area augmentation system airborne equipment – Rev E	December 2016
[RD69]	RTCA DO-208	Minimum Operational Performance Standards for Airborne Supplemental Navigation Equipment Using Global Positioning System (GPS)	December 1991
[RD70]	EUROCAE ED-72A	MOPS for Airborne GPS Receiving Equipment used for Supplemental Means of Navigation.	April 1997
[RD71]	EUROCAE ED-88	MOPS for Multi-Mode Airborne Receiver (MMR) including ILS, MLS and GPS used for Supplemental Means of Navigation	August 1997
[RD72]	EUROCAE ED-75C	Minimum Aviation System Performance Standards: Required Navigation Performance for Area Navigation	November 2013
[RD73]	RTCA DO-236C	Minimum Aviation System Performance Standards: Required Navigation Performance for Area Navigation	June 2013
[RD74]	RTCA DO-228	Minimum Operational Performance Standards for Global Navigation Satellite Systems (GNSS) Airborne Antenna Equipment	October 1995
[RD75]	RTCA-DO-235	Assessment of Radio Frequency Interference Relevant to the GNSS L1 Frequency Band	March 2008
[RD76]	RTCA-DO-292	Assessment of Radio Frequency Interference Relevant to the GNSS L5/E5A Frequency Band	July 2004
[RD77]	RTCA DO-301	Minimum Operational Performance Standards for Global Navigation Satellite System (GNSS) Airborne Active Antenna Equipment for the L1 Frequency Band	December 2006
[RD78]	KT-229 MOPS-229	Airborne equipment of satellite navigation (AESN) – 4th Edition	March 2011
[RD79]	RTCA DO-245A	Minimum Aviation System Performance Standards for Local Area Augmentation System (LAAS)	September 2004
[RD80]	RTCA DO-246D	GNSS-Based Precision Approach Local Area Augmentation System (LAAS) – Signal-in-Space Interface Control Document (ICD)	December 2008

Id.	Reference	Title	Date
[RD81]	RTCA DO-253C	Minimum Operational Performance Standards for GPS Local Area Augmentation System Airborne Equipment	December 2008
[RD82]	EUROCAE ED-114A	MOPS for a Ground Based Augmentation System (GBAS) ground facility to support CAT I approach and landing	March 2013
[RD83]	RTCA DO-178C	Software considerations in Airborne Systems and Equipment certification	December 2011
[RD84]	RTCA DO-278A	Software Integrity Assurance Considerations for Communication, Navigation, Surveillance and Air Traffic Management (CNS/ATM) Systems	December 2011
[RD85]	EUROCAE ED-12C	Software considerations in Airborne Systems and Equipment certification	December 2012
[RD86]	RTCA DO-248C	Supporting Information for DO-178 C and DO-287 A	December 2011
[RD87]	EUROCAE ED-109A	Software Integrity Assurance Considerations for Communication, Navigation, Surveillance and Air Traffic Management (CNS/ATM) Systems	January 2012
[RD88]	RTCA DO-254	Design Assurance Guidance for Airborne Electronic Hardware	April 2000
[RD89]	EUROCAE ED-79A	Guidelines for Development of Civil Aircraft and Systems	December 2010
[RD90]	EUROCAE ED-80	Design Assurance Guidance for Airborne Electronic Hardware	April 2000
[RD91]	ARP 4761	Guidelines and Methods for Conducting the Safety Assessment Process on Civil Airborne Systems and Equipment	December 1996
[RD92]	RTCA DO-160G	Environmental Conditions and Test Procedures for Airborne Equipment	August 2010
[RD93]	EUROCAE ED-14G with Change1	Environmental conditions and test procedures for airborne equipment	January 2015
[RD94]	Commission IR (EU) 2017/xxx_	PBN Implementing Regulation	2017
[RD95]	EASA Opinion No 10/2016	Performance-based navigation implementation in the European air traffic management network	28 July 2016
[RD96]	RMT.0379 – Issue 1	Terms of Reference for rulemaking task – All Weather Operations	9 December 2015
[RD97]	NSP October 2017 [several papers]	Next Generation GNSS CONOPS: Service provision framework and approval of GNSS elements by States	1 October 2017
[RD98]	EU-US Cooperation on Satellite Navigation Working Group C – ARAIM Technical Subgroup	Milestone 3 Report – Final Version	25 February 2016
[RD99]	GSA/GRANT/01/2017	Call for Proposals for Development of an Advanced RAIM Multi-constellation Receiver (ARAIM)	8 June 2017
[RD100]	Notice of Proposed Amendment 2017-05	Introduction of a regulatory framework for the operation of drones	4 May 2017

04 MARKET OVERVIEW AND TRENDS

Reference	Title	Date
5th edition of the GSA's GNSS Market Report	GNSS Market Report	Issue 5 – 2017

4.1 MARKET EVOLUTION AND KEY TRENDS

Aircraft sales are the main market driver for aviation. GNSS equipment is now nearly fitted on all new aircraft whatever its category is (General aviation, regional and business aviation, commercial aviation). Commercialized drones are already using GNSS for positioning and GNSS is a powerful enabler for specific functions that will be required in the future (sense and avoid etc.) even if performance requirements could be more stringent than for manned aircraft.

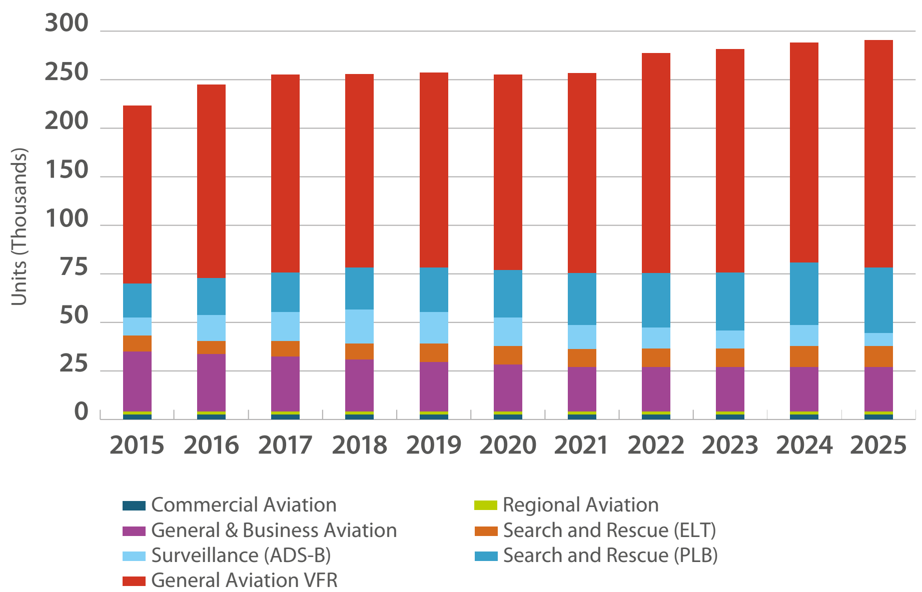
Today, GNSS systems operationally used are GPS, operational SBAS systems (WAAS, EGNOS, MSAS, GAGAN) and GBAS CAT I. In the foreseeable future, additional core constellations will be operationally available (Galileo, BeiDou) as well as improvements natively brought by these navigation constellations (e.g.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

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

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

- The GSA GNSS Market Report identifies the following key market trends:
- Usage of GNSS navigation is rising, particularly for Performance-Based Navigation (PBN),
- SBAS-based procedures are increasingly available at many European aerodromes and operators are equipping aircraft with SBAS enabled avionics,
- GNSS-enabled ELTs are also gaining importance in Aviation,
- GNSS is more utilised in surveillance through technologies like ADS-B and as a component of the data connection services.

Figure 2: Shipments of GNSS devices by application 2015-2025



4.2 MAIN MARKET PLAYERS

Along the aviation value chain, the GNSS Market Report identifies the following main players:

Figure 3: Main market players (source: MR5)

DEVICE MANUFACTURERS

- AVIDYNE CORP
- COBHAM
- ESTERLINE TECH CORP
- GARMIN
- HONEYWELL
- KANNAD
- MCMURDO
- ROCKWELL COLLINS
- THALES AVIONICS*
- UNIVERSAL

AIRCRAFT MANUFACTURERS

- AIRBUS*
- ATR*
- AUGUSTA WESTLAND*
- BOEING
- BOMBARDIER
- CESSNA
- CIRRUS
- DIAMOND AIRCRAFT*
- EMBRAER
- PILATUS*
- PIPER

AIRLINES / AIRCRAFT OWNERS

MAIN AIRLINES ALLIANCES

- ONEWORLD
- SKYTEAM
- STAR ALLIANCE

USER GROUP ASSOCIATIONS

- Aircraft Owners and Pilots Association (AOPA)
- European Business Aviation Association (EBAA)
- European Helicopter Association (EHA)
- European Regions Airline Association (ERA)

AIR NAVIGATION SERVICE PROVIDERS

MAIN ORGANISATIONS

- Civil Air Navigation Services Organisation (CANSO)
- International Civil Aviation Organisation (ICAO)

AERODROMES

- International Airports
- Private Airports
- Regional Airports

The Value chain considers the key global and European companies involved in the GNSS downstream activities.
* European based companies. The world region referes to the headquarter of the company, the actual area of activity might be wider.

4.3 MAIN GNSS AVIATION USERS

Aviation users of GNSS can be characterised as:

- Airspace users: Consist of the aircraft and those using them for commercial, State, business and pleasure. They have to comply with Operational and Airworthiness approvals regulations specified through European and National Safety Agencies. The airspace users themselves can be classified as one of:
  - Commercial aviation
  - Regional aviation
  - Business aviation
  - General aviation
  - Helicopters
  - Drones/RPAS operators
- Aerodrome Operators: In some cases, they are the owners and responsible for implementing flight procedures to/from the airport (approaches, departures) providing the ground infrastructure for these procedures and complying with the applicable regulation (ICAO Annex 14, etc.),
- Airspace Network Managers/ANSPs: depending on the level of service provided (ATC, CNS, etc.) they can be responsible for signal in space performance in the airspace where the flight procedures are going to be flown, complying with ICAO Annex 10 requirements and others.

The equipment's manufacturers (receivers or avionics' manufacturers) are another relevant stakeholder affected by the requirements, but the final responsibility for using the equipment and getting the approval for that remains on the airspace user side.

4.4 R&D FOR CIVIL AVIATION

4.4.1 SESAR

SESAR is an effort initiated by the European Commission to redesign the current Air Traffic Management system. It is composed of three phases (definition, development and deployment) and currently it is in the last phase which implements the technologies emerged from the previous phase. Among other aims of the project, SESAR has been looking at new aircraft separation modes, allowing increased safety, capacity and efficiency, and at trajectory management trying to reduce the constraints of airspace organisation to a minimum. These key features using GNSS technology are under development process through a set of projects and research calls such as:

- Enhanced positioning using multi-constellation GNSS dual frequency
- Aircraft-Based Augmentation System (ABAS)
- Ground-Based Augmentation System (GBAS)
- GBAS CAT II/III based on Dual-Frequency Multi-Constellation (DFMC)GNSS (GPS + Galileo/ L1 + L5)
- A-PNT (Alternative Positioning Navigation and Timing)
- Exploratory Research RPAS Call
- Very Large Demonstration (VLD) geo-fencing call

In addition, SESAR is responsible for the development and maintenance of the European ATM Masterplan. This document establishes the future areas of Research and Development (R&D) and the deployment of new solutions that advance the goals of the Single European Sky. The scope of the ATM Masterplan also addresses requirements for future Communication, Navigation and Surveillance technologies – including GNSS – which would be fundamental to supporting the performance goals of the masterplan. The ATM Masterplan therefore also addresses the roadmaps for deployment of PBN-related technologies. The ATM Master plan is being reviewed in 2018.

Further information can be found at the SESAR JU website: http://www.sesarju.eu/

4.4.2 NEXTGEN

NextGen is a US programme with the aim of creating a new air transportation system that relies on the satellite-based technologies and assets. The main aim is to enable the airspace users to operate on shorter routes, save time and fuel, reduce the current traffic delays as much as possible and to increase the capacity all through the use of GPS technology. The core initiatives in this sense are listed below.

- Ground-Based Augmentation System Approaches
- Alternative Positioning Navigation and Timing (APNT) (CIP#:G06N.01-06)
- Time-Based Flow Management (TBFM), Work Package 3 (IES)

So far, NextGen managed to implement the following technologies across the US territory and airspace:

- Wide Area Augmentation System is used for a better positioning accuracy
- Automatic Dependent Surveillance Broadcast (ADS-B)
- Approach procedures have LPV, CAT I, RNP capabilities
- Arrival procedure enable RNAV STARs with Optimized Profile Descents (OPD)
- Departures: RNAV SIDs
- Q- and T-Routes
  - Q-Routes can be flown using positioning from either satellite signals or Distance Measuring Equipment (DME) in case of a GPS outage
  - T-Routes can be flown only with GNSS and are replacing many Victor routes in airspace from 1,200 feet above the surface to 18,000 feet

HORIZON 2020 PROVIDES FUNDING TO SUPPORT THE DEVELOPMENT OF GNSS-BASED APPLICATIONS FOR THE AVIATION SECTOR.

4.4.3 HORIZON 2020

Horizon 2020 is one of the European framework programmes that provides funding for research, technological development, and innovation with the scope of ensuring Europe produces world-class science, removes barriers to innovation and makes it easier for the public and private sectors to work together in delivering innovation. One of the areas tackled by H2020 is the air transport area where multiple calls have been awarded for the research of new ways for navigation and therefore enabling fuel savings and increasing airspace capacity. Specific research related to the development of applications of GNSS is implemented in the specific calls delegated by the European Commission to GSA:

- Applications in Satellite Navigation – Galileo 2014-2015
- Applications in Satellite Navigation – Galileo 2017

The list below provides a summary of the H2020-application projects related to the use of GNSS technology in aviation:

- Next-Generation Distress Beacons for MEOSAR and Galileo Satellite-Based Search & Rescue systems http://helios-gsa-project.eu/
- GRICAS H2020 http://www.gricas-gsa-project.eu/
- SKYOPENER – Establishing new foundations for the use of Remotely-Piloted Aircraft Systems for civilian applications – https://skyopener.eu/
- SKYOPENER will develop a system and operational processes that will reduce all categories of risks associated with RPAS and allow an ANSP (Air Navigation Service Provider) to manage Very Low Level (VLL) RPAS operations.
- e-airport – Increase airport capacity, safety and security using European GNSS: www.eairport.eu
- The main goal is the development of an integrated airport operations monitor application based on European GNSS to increase the efficiency, safety and security of the cargo and aircraft service processes and its demonstrations in two European airports using EGNOS and Galileo Early services.
- 5LIVES - Search, Challenge, Fight, Care, Rescue for Lives: The objective is to provide innovative solutions in order to overcome actual operational weaknesses, but especially trying to deploy the use of EGNSS for all rotorcraft market segments and operations.
- GMCA - GNSS Monitoring for Critical Applications: The project gathers EGNSS signal data for analysis and comparison, thereby providing the aviation community with the confidence they need for including EGNSS within their planning for navigation. It will monitor new signals alongside the GPS signals and provide operationally relevant information to existing and new users of the GPMS. In addition, the system will be updated to include the capability for the monitoring of interference and spoofing.

The H2020 calls devoted to GNSS applications are managed by GSA. The following 2 calls have been implemented so far in the GNSS service area: GALILEO 2014-2015[1] and GALILEO 2017[2].

4.5 VISION OF KEY ACTORS IN CIVIL AVIATION

4.5.1 ICAO

ICAO lays out its vision for the future exploitation of technologies to address the operational needs of the world's aviation community as agreed at State and industry level within its Global Air Navigation Plan (GANP) (Doc 9670). The document has developed and grouped a set of complementary technologies that can be deployed at a regional level to

1 Applications in satellite navigation – Galileo 2014-2015
2 Applications in satellite navigation – Galileo – 2017

address local needs. The roadmaps covered within the GANP are described as covering:

- Communication
- Navigation
- Surveillance
- Information Management
- Avionics

Within the navigation domain, two capabilities are considered: PBN and Precision Approach (CAT I/II/III).

The GANP recognises the role that GNSS has had as the core capability which has unlocked the benefits of PBN. It is also recognised that it is the basis for future improvements in navigation services, which includes both the core constellations, augmentations and the needs for additional PNT solutions to address situations of GNSS outage or the lack of performance due to geographical constraints.

The navigation and surveillance roadmaps presented by ICAO in the GANP demonstrate the dependency on GNSS supporting both PBN and ADS-B as being core technologies. These are shown below.

Figure 4: ICAO Navigation Roadmap

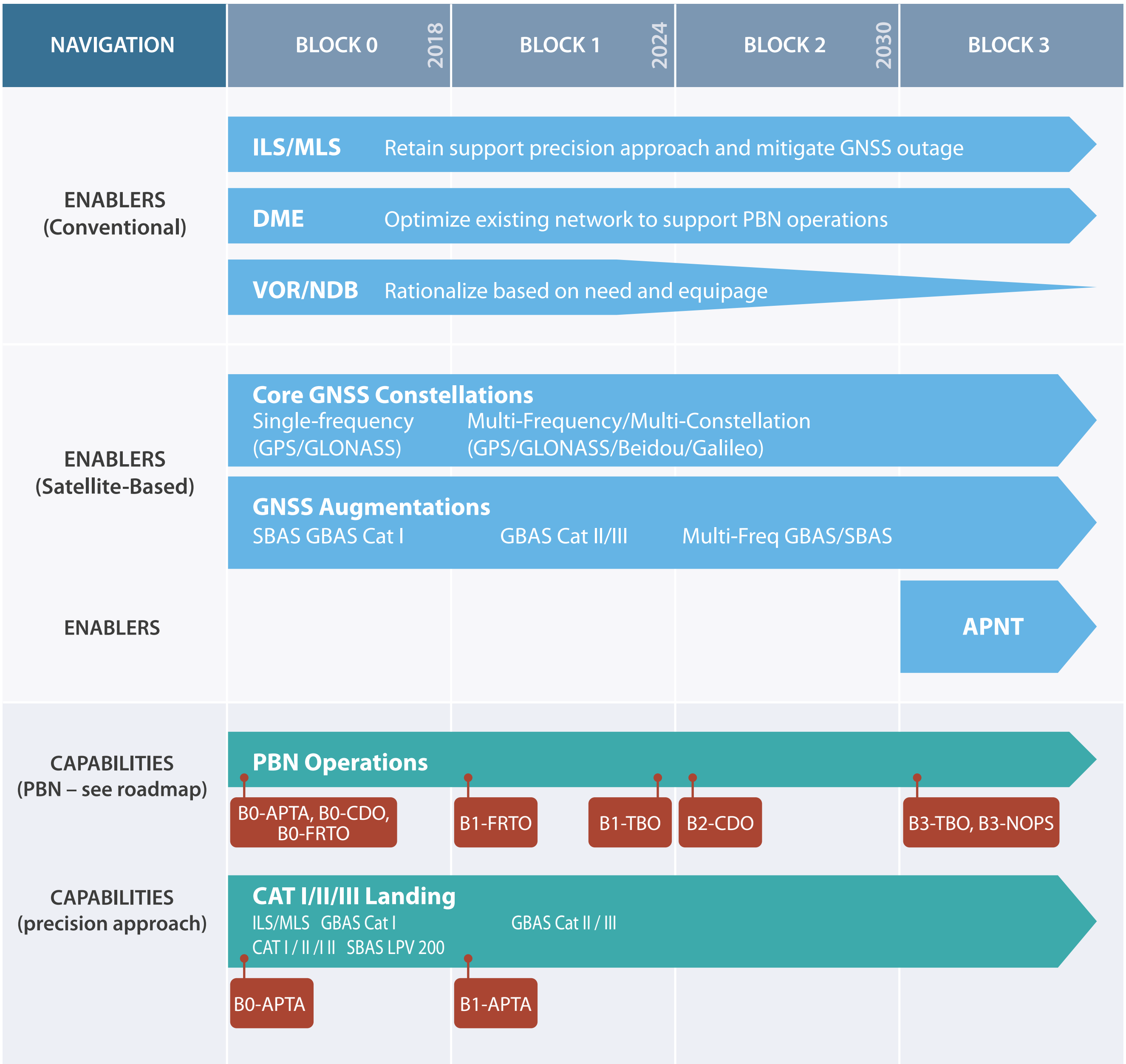
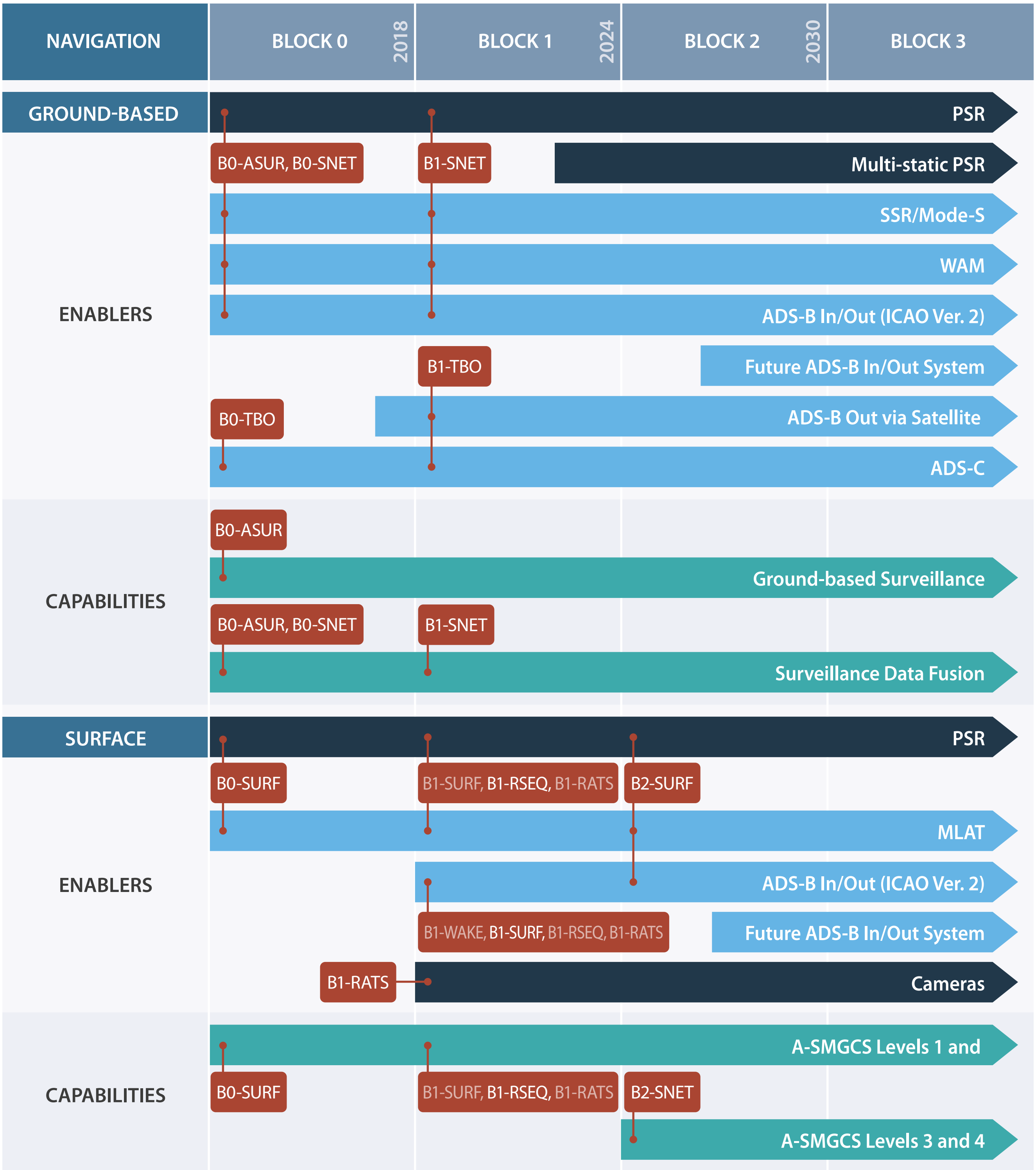


Figure 5: ICAO Surveillance Roadmap



4.5.2 ANSPS – REPRESENTED BY CANSO

As the world's largest representative of ANSPs, CANSO has presented its views on Performance Based Navigation (PBN) in its document "Performance-Based Navigation for ANSPs: Concept 2030." In this document, CANSO has provided a high-level overview of the organisation and presented its view on the benefits of PBN as well as the dependencies on GNSS that the move requires.

CANSO is fully committed to implementing the ICAO Resolution A37-11. CANSO acknowledges that the move to GNSS may require augmentation to support operations in certain airspace where there is a determined need for high accuracy and integrity. This may also be required on the surface to support advanced movement capabilities. The PBN infrastructure of the future is noted as being dependent on the core GNSS constellations and its augmentation services, with a future move to dual frequency providing additional resilience.

Further information at https://www.canso.org/

4.5.3 AIRLINES – REPRESENTED BY IATA

The world's largest representative of the airline community, IATA, publishes its views on CNS technologies in its publication "User Requirements for Air Traffic Services (URATS) – Communications, Navigation, and Surveillance (CNS) Technologies," Edition 3.0 – July 2017. This presents the views of IATA on the needs of the international airlines perspective and the need to have harmonised and interoperable solutions supporting operations crossing multiple State's boundaries.

- IATA acknowledges the need for PBN and calls for the implementation of PBN globally in all phases of flight. Whilst traditional navigation aids are still used globally, IATA notes the importance of GNSS supporting a rapid implementation of GNSS as primary means of navigation and the main enabler of PBN. Support is also provided for specific GNSS technologies as follows:
- ABAS: IATA supports using ABAS as the preferred augmentation system for en-route and terminal-area navigation using GNSS. In line with ICAO Assembly Resolution A37-11, for approach operations, ABAS should be used in combination with Baro-VNAV to provide horizontal and vertical guidance, respectively.
- GBAS: IATA supports GBAS with geometric vertical guidance as a viable candidate to supplement ILS for Precision Approach Operations. GBAS infrastructure and GLS procedures should be implemented as appropriate based on a positive business case and consultation with airlines. Airlines with GLS avionics should approach their regulators to obtain operational approval as necessary.
- SBAS: IATA notes the need for positive business cases based on operational requirements and has posed three essential requirements for SBAS implementations:
    - no mandatory requirements by regulatory authorities to fit SBAS equipment to aircraft;
    - no unjustified restrictions to operations due to a lack of SBAS equipment; and
    - no costs related to SBAS being imposed directly or indirectly to airspace users who do not use such technology.
- DFMC GNSS: IATA notes that further technical and operational researches to substantiate the benefits of DFMC GNSS are encouraged. IATA discourages any attempt to discriminate against the use of any GNSS constellations that meet ICAO requirements. Additionally, States should refrain from issuing any unilateral, prescriptive mandate to airlines.

Further information at http://www.iata.org/

4.5.4 HELICOPTER OPERATORS – REPRESENTED IN EUROPE BY EHA

The European Helicopter Association (EHA) considers SBAS as an enabler of new operations that lead to economic and safety benefits increasing. In particular, many heliports don't offer instrument approaches due to lack of ground-based equipment and related high costs. EGNOS offers a cheap alternative to implement instrument procedures at these heliports, and enable helicopter emergency to operate even in bad weather conditions and at night.

ACCORDING TO THE EUROPEAN HELICOPTER ASSOCIATION, SBAS ENABLES NEW OPERATIONS, ALONG WITH ECONOMIC AND SAFETY BENEFITS.

Rotorcraft operators are increasingly flying IFR using navigation applications based on RNAV 1, RNP1, RNP 0.3 and RNP APCH specifications. Considering that the conventional navaids performances at the altitudes (3000-5000 ft) suitable for rotorcraft are not able to grant RNP1\RNP 0.3 requirements, GNSS and SBAS should be considered the primary means of navigation. Unlike the conventional navaids, the GNSS\SBAS allows the procedures design to be optimized for the rotorcraft performances.

All IFR rotorcraft in production since 2010 have on-board SBAS capabilities as part of the standard IFR configuration. However, rotorcraft are not a candidate for GBAS CATII/III operations, due to the usually limited infrastructure available at their most typical destinations.

Further information at http://www.eha-heli.eu/

4.5.5 PRIVATE AIRCRAFT PILOTS - IAOPA

IAOPA considers that GNSS and SBAS in particular can fully deliver for General Aviation (GA) the PBN capabilities to support the seamless integration of GA within the European airspace, increasing the safety and operational efficiency of GA operations. IAOPA considers the deployment of SBAS as essential to enabling the effective integration of GA operations within European TMA, regional and local aerodromes.

IAOPA does not believe that GA are a candidate for GBAS use, given the additional requirements associated with CAT II/III operations, which are beyond the current configuration or capability of most GA aircraft. SBAS procedures can deliver the performance necessary for GA without a requirement for GBAS.

Further information at https://www.aopa.org/

THE EBAA SAYS IMPLEMENTING EGNOS-BASED OPERATIONS AT REGIONAL AIRPORTS WILL IMPROVE AIRSPACE CAPACITY AND AIRPORT EFFICIENCY.

4.5.6 EUROPEAN BUSINESS AVIATION ASSOCIATION – EBAA

The business aviation (BA) segment has been trying to get back on a growth trend since 2008[3] and, according to EBAA, one of the biggest issues is that the European bodies do not support the implementation of the newly developed technologies into regional airports even if these airports are in the same TMA as major hubs. This only makes navigation harder for the BA operators, due to the high complexity of the airspace.

Therefore, EBAA strongly believes it would be in the interest of all the parties involved, ANSPs as well as all the airspace users, to offer access to the new air infrastructure, which includes satellite-based procedures and applications.

In their position paper about EGNOS, "EBAA contribution to the Commission's Aviation Strategy: Towards a full EGNOS capacity deployment in aviation,"[4] EBAA considers that regional airports which are served only by BA traffic should be put under the scope of the SES regulation and the EGNOS-based operations should be implemented in these airports while the equipment costs are still low. This will allow the regional airports to be part of the network supporting satellite-based technology and will increase the airspace capacity and the airports' efficiency. Additionally, the introduction of PinS for the rotorcraft will reduces the operational interferences between the aircraft and the rotorcraft.

"EBAA urges the Commission to publish a specific Communication to foster the deployment of the GNSS applications to aviation and in particular to include it in the Member States' local investment plans in Air Traffic Management. The Commission is also invited to update its Action plan for airport capacity in Europe to reflect the necessary measures to deploy GNSS in aviation, in particular EGNOS LPV approaches at regional airports. This item should be on the priority list of the Airport Capacity Observatory. And finally, it is emphasised that without explicit support for LPV approaches in its Aviation Strategy, the Commission risks delaying their introduction and use, which would constitute a major flaw of an otherwise bold and trend-setting document[4]."

Further information at http://www.ebaa.org/

4.5.7 EUROPEAN REGIONAL AIRLINES ASSOCIATION – ERA

The European Regions Airline Association (ERA) is a trade association representing the European regional aviation industry.

ERA acknowledges the operational advantages enabled by GNSS for their flight operations.

Further information at https://www.eraa.org/

4.5.8 DRONES

There are several relevant organisations representing the wide area of drones:

- Association for Unmanned Vehicle Systems International (http://www.auvsi.org/)
- UVS International. Federating & Promoting International Coordination, Cooperation, Harmonised Regulations + Information Dissemination Relative to Remotely Piloted Aircraft Systems (RPAS) (https://uvs-international.org/)
- GUTMA (https://gutma.org/) UAS Traffic Management Association is a non-profit consortium of UTM stakeholders. Its mission is to support and accelerate the transparent implementation of globally interoperable UTM systems

In addition, due to the low cost of leisure RPAS and of entrance-level professional RPAS, there is a large number of drone communities. Probably, the largest one is the DIY Drones community that has created the world's first "universal autopilots" (ArduPilot Mega (APM) and its big

3 http://www.ebaa.org/documents/document/20150604173712-the_case_for_business_aviation_in_europe.pdf
4 http://www.ebaa.org/documents/document/20170718095620-egnos.pdf

brother Pixhawk). Amateur and semi-professional drone communities can range from the female-only community of drone pilots like Amelia Droneharts to the Facebook community AerialDrones, to the image and video sharing Skypixel and Dronestagram communities.

That civil aviation authorities get in contact and partner with drone communities is necessary to understand how unmanned aircraft are best and most commonly used. Thus, for example, the US FAA "has announced a program that will partner with communities across the country to figure out the best way to utilize unmanned aircraft technology." (Gray DC, accessed 2017-11-20) The initiative is recent and the interested communities can send notices of intent by the 28th of November.

Last, we mention the interesting example of the UAVSA – a US-based, fast-growing commercial RPAS association – whose official event is the International Drone Expo, the first and largest consumer drone expo open to the general public. UAVSA is a wholly owned subsidiary of the Tesla Foundation Group, whose members range from RPAS and RPAS-related vendors, to academia, research, entertainment and RPAS service providers.

4.5.9 OTHER AIRSPACE USERS

It is noted that the requirements from State aircraft (customs, police and military) are out of the scope of this document.

05 USER REQUIREMENTS ANALYSIS

5.1 CURRENT GNSS USER REQUIREMENTS FOR CIVIL AVIATION APPLICATIONS

5.1.1 NAVIGATION

Reference	Title	Date
ED Decision 2003/012/RM AMC20 (13 separated amendments since initial issue in 2003)	General Acceptable Means of Compliance for Airworthiness of Products, Parts and Appliances	Initial Issue on 5 November 2003

5.1.1.1 INTERNATIONAL REGULATION

The international regulations governing the use of GNSS are defined within ICAO. Currently, requirements for GNSS and its applications are published in the following documents.

5.1.1.1.1 ICAO Annex 6 – Operation of Aircraft
The instrument approach classification defined in ICAO Annex 6 shows the requirements applicable for each type of instrument approach.

Figure 6: Approach operations, approach runways and navigation aids supporting the operation

Domain	Document	Relationship					
Approach Operations	Annex 6	Classification (based minima)	Type A		Type B		
			(250° or higher)		CAT I (less than 250° & 200° or higher)	CAT II (less than 200° & 100° or higher)	CAT III (less than 100°)
		Method	2D	3D			
		Minima	MDA/H	DA/H*			
Approach Runways	Annex 14	M(DA/H) >= VMC	Non-Instrument RWY				
		M(DA/H) >= 250° Visibility >= 1000m	Non-Precision Approach RWY				
		DA/H >= 200° RVR >= 550m	Precision Approach RWY, Category I				
		DA/H >= 100° RVR >= 300m	Precision Approach RWY, Category II				
		DA/H >= 0° RVR >= 0m	Precision Approach RWY, Category III (A, B & C)				
System Performance Procedures	Annex 10 PANS-OPS Vol. II	NPA	NDB, Lctr, LOC, VOR, Azimuth, GNSS				
		APV		GNSS/ Baro/ SBAS			
		PA		ILS, MLS, SBAS CAT I, GBAS			

* NPA procedures require a derived DA/H

5.1.1.1.2 ICAO Annex 10 - Aeronautical Telecommunications

Describes the international standards and recommended practises for Aeronautical Telecommunications, in particular Volume I the GNSS signal in space performance requirements for typical operations.

Figure 7: GNSS signal in space performance requirements – ICAO Annex 10 Vol. I

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

NOTES:

1. The 95th percentile values for GNSS position errors are those required for the intended operation at the lowest height above threshold (HAT), if applicable. Detailed requirements are specified in Appendix B and guidance material is given in Attachment D,3.2.
2. The definition of the integrity requirement includes an alert limit against which the requirement can be assessed. For Category I precision approach, a vertical alert limit (VAL) greater than 10 m for a specific system design may only be used if a system-specific safety analysis has been completed. Further guidance on the alert limits is provided in Attachment D, 3.3.6 to 3.3.10. These alert limitsare:

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

3. The accuracy and time-to-alert requirements include the nominal performance of a fault-free receiver.
4. Ranges of values are given for the continuity requirement for en-route, terminal, initial approach, NPA and departure operations, as this requirement is dependent upon several factors including the intended operation, traffic density, complexity of airspace and availability of alternative navigation aids. The lower value given is the minimum requirement for areas with low traffic density and airspace complexity. The higher value given is appropriate for areas with high traffic density and airspace complexity (see Attachment D, 3.4.2). Continuity requirements for APV and Category I operations apply to the average risk (over time) of loss of service, normalized to a 15-second exposure time (see Attachment D, 3.4.3).

5.1.1.1.3 ICAO Annex 14 – Aerodromes

The airport should take into account ICAO Annex 14 requirements before implementing a determined type of approach. For instance, a LPV 200 approach, based on SBAS guidance will require a runway complying with Annex 14 requirements for Precision Approach, Category I, which means, visual aids, lighting systems, Obstacle Surface Areas, runway dimensions, etc. LPV-200 operations with DH ≥ 250 ft (Type A instrument approach operation) can be promulgated at both category I precision approach runway-ends and non-precision approach runways.

RNP approach down to LPV minima DH≥250ft (Type A approach) can also be implemented to non-instrument runways, non-precision approach runway without any need to upgrade runway infrastructure.

BOTH GLOBAL AND THE EUROPEAN AIR NAVIGATION STRATEGIES ARE MOVING TOWARDS GNSS-BASED SOLUTIONS.

LPV-200 operations with DH < 250 ft (Type B approach) are generally only possible at category I precision approach runways (Ref. ICAO Annex 14), although exceptions can be made on the national level.

5.1.1.1.4 ICAO Doc 9674: WGS-84 Manual

For air navigation the GNSS signal in space performance requirements and Horizontal/Vertical alert limits are those set in Chapter 3.7 of ICAO Annex 10 Volume 1.

5.1.1.1.5 ICAO Doc 9613: PBN Manual

ICAO's PBN manual (ICAO DOC 9613, which superseded the RNP Manual in 2008) provides practical guidance to States and their regulatory authorities, air navigation service providers (ANSPs), manufacturers and OEMs, as well as airspace users, in a series of navigation specifications.

The navigation specifications for PBN operations are described in the next chapter, together with the European requirements for operational approvals.

5.1.1.2 EUROPEAN REGULATION

The Global and European Air Navigation Strategy are moving towards GNSS-based solutions. In Europe, PBN deployment is facilitated by the following EC regulatory initiatives:

- **Pilot Common Projects (PCP) Implementing Rule (IR):** Commission Implementing Regulation (EU) No 716/2014, dated 27 June 2014, on the establishment of the Pilot Common Project supporting the implementation of the European Air Traffic Management Master Plan. This IR is targeting the implementation of PBN RNP APCH vertically guided (LNAV/VNAV and LPV) at all 24+1 airports and PBN SIDs/STARs/Transitions (with RF leg) by 01/01/2024.
- **PBN Implementing Rule**, the Notice of Proposed Amendment (NPA) 2015-01 "Performance-Based Navigation (PBN) implementation in the European Air Traffic Management Network (EATMN) ", RMT.0639 – 19.1.2015, issued by EASA, addresses the safety, interoperability, proportionality and coordination issues related to the implementation of Performance-Based Navigation (PBN) within European airspace. This NPA extends the PBN implementation requirements beyond the 24 EU aerodromes as required by the PCP, mitigates the risks associated with a non-harmonised implementation, thus ensuring a smooth transition to PBN operations, fully supporting the implementation of the European Air Traffic Management Master Plan. This regulation is under discussion and the latest discussion includes the following provisions:
    - By 2024: The PBN IR will bring EGNOS approaches (LPV and CAT I) to all instrument runways.
    - Till 2030 there will be a coexistence of PBN/RNP APCH and operational procedures based on the use of traditional navigation aids.
    - After 2030: Approaches will be mainly RNP APCH (LNAV/VNAV and LPV) with ILS. It is essential to ensure that ILS is included in the rationalisation strategy and only a minimum network is maintained.
- SESAR JU was mandated by the Commission to prepare a proposal on the content of a "Common Project 2 – CP2" by 31/10/2017, based on the solutions resulting from the first SESAR programme.

The European Aviation Safety Agency is addressing implementation and operational use of PBN within a number of rulemaking tasks and experts groups, namely:

- RMT.0256 'Revision of operational approval criteria for PBN' – which impacted Part FCL of the Aircrew regulation and Part SPA of the OPS IR;
- RMT.0445 'Technical requirements and operation procedures for airspace design including procedure design' – which created a new Part as proposed in NPA 2013-08 of 10th May 2013 to contain the PBN requirements for airspace design (ASD) including procedure design;
- RMT.0477 'Technical requirements and operation procedures for AIS/AIM' – which addressed some of the requirements on data originating from increased use in PBN operations;

- RMT.0519 'Provision of requirements in support of global PBN operations' – which addressed primarily populating the Navigation part of the CS ACNS with the airworthiness criteria corresponding to the different PBN specifications;
- RMT.0593 'Technical requirements and operational procedures for the provision of data (DAT) for airspace users for the purpose of air navigation';
- RMT.0639 Performance-Based Navigation (PBN) implementation in the European Air Traffic Management Network (EATMN) - which considered the implementation of a mandate to ensure consistency on the application of PBN specifications within the European airspace. This is expected to lead to the publication of a Community Specification or Implementing Rule under which Air Navigation Service Providers and aerodrome operators responsible for the provision of instrument approach procedures and ATS routes, as well as the Network Manager, shall comply with the specific requirements for the implementation of performance-based navigation set out in Subpart PBN of the Annex.
- The combined EASA General Aviation TeB & GA Committee is the industry's and GA Community's consultative body for General Aviation thematic issues in the Rulemaking process. It addresses priority activities to enhance the safety of General Aviation operations with one of the focus set on the introduction of IFR operations. These regulatory initiatives are driven to have more proportionate requirements tailored to GA needs and covering all EASA domains, from licensing to ATS or AD infrastructure. EASA efforts have produced major progress on airworthiness and pilot licensing in General Aviation, with a proposal for a light Part-M, CS-STAN in airworthiness, Single Engine Turbines for IMC in OPS and Basic Instrument Rating and Declared Training Organisations in Pilot licensing.

The Rule Making Tasks (RMT) which have a major impact on the ability of aircraft and aircrew to operate in a PBN environment are RMT.0256 and RMT.0639.

The changes to the Part FCL have been added to address the needs of flight crew flying PBN procedures in an instrument environment. In particular, this governed the training requirements for flight crew and the need for qualifications and endorsements of flight crew licenses with a PBN rating from 25 August 2018.

The changes to Part ORA have stipulated the use of aircraft and training devices to be equipped with PBN.

- The changes introduced to Parts CAT/NCC/NCO/SPO have resulted in new operating rules requiring that:
- The aircraft meets the airworthiness certification requirements for the applied PBN specification
- The aircraft is operated in conformance with relevant PBN specification and AFM limitations
- The flight crew/pilot has been trained and checked for the intended operation

- Operating procedures are available
- The navigational database is suitable and current
- Sufficient means are available to navigate and land at the destination aerodrome or at any destination alternate aerodrome in the case of loss of capability for the intended approach and landing operation

The changes to Part ORO have resulted in proficiency checks being required for PBN as for IR ratings.

The changes for Part SPA have resulted in specific approval only being required for RNP AR APCH and RNP 0.3 for helicopters with all other PBN specifications not needing specific operational approval. This is highlighted in Table 1. However, RNP AR APCH approval can be provided in the form of a generic approval or procedure-specific approval (e.g. if a certain instrument approach procedure does not comply with ICAO procedure design criteria).

Table 1: Overview of PBN specifications and approval requirements

Navigation specification	Flight Phase							
	En-Route		Arrival	Approach				Departure
	Oceanic	Continental		Initial	Intermediate	Final	Missed	
RNAV 10	10							
RNAV 5		5	5					
RNAV 2		2	2					2
RNAV 1		1	1	1	1		1	1
RNP 4	4							
RNP 2	2	2						
RNP 1			1	1	1		1	1
A-RNP	2	2 or 1	1-0.3	1-0.3	1-0.3	0.3	1-0.3	1-0.3
RNP APCH (LNAV)				1	1	0.3	1	
RNP APCH (LNAV/ VNAV)				1	1	0.3	1	
RNP APCH (LP)				1	1		1	
RNP APCH (LPV)				1	1		1	
RNP AR APCH				1-0.1	1-0.1	0.3-0.1	1-0.1	
RNP 0.3 (H)		0.3	0.3	0.3	0.3		0.3	0.3

Numbers specify the accuracy level | No specify approval required (light shading) | Specify approval required (dark shading)

The user requirements for each PBN specification used in Air Navigation based on GNSS imply the compliance to certain airworthiness and operational approval processes. In Europe, those approval processes have been regulated by specific regulations usually expressed in the EASA AMC 20 "General Acceptable Means of Compliance for Airworthiness of Products, Parts and Appliances" that contains acceptable means of compliance applicable to more than one airworthiness code, across various disciplines. AMC 20 is a catalogue gathering all the AMC20-XX in force.

For what concerns GNSS in PBN operation, the relevant AMCs 20 are listed in the following table:

Table 2: AMC 20.XX of interest for GNSS

Reference and Issue date	Topic	Application to PBN navigation specification
AMC 20-4A 12 Sep 2013	Airworthiness Approval and Operational Criteria for the use of navigation systems in European airspace designated for Basic RNAV operations	RNAV 5 (where a GPS stand-alone equipment is used as the means for Basic RNAV operations)
AMC 20-5 05 Nov 2003	Airworthiness Approval and Operational Criteria for the use of the NAVSTAR Global Positioning system (GPS)	All PBN navigation specifications (GNSS sensors as GPS are eligible sensors for all PBN navigation specifications)
AMC 20-12 22 Dec 2006	Recognition of FAA Order 8400.12a for RNP 10 Operations	RNP 10 in oceanic and remote airspace
JAA TGL 10 (AMC 20-16)	Airworthiness and Operational Approval for Precision RNAV operations in designated European airspace	RNAV 1
AMC 20-27A 12 Sep 2013	Airworthiness Approval and Operational Criteria for RNP APPROACH (RNP APCH) Operations Including APV Baro-VNAV Operations	RNP APCH up to LNAV and LNAV/VNAV minima
AMC 20-26 16 Dec 2009	Airworthiness Approval and Operational Criteria for RNP Authorisation Required (RNP AR) Operations	RNP AR APCH
AMC 20-28 17 Sep 2012	Airworthiness Approval and Operational Criteria related to Area Navigation for Global Navigation Satellite System approach operation to Localiser Performance with Vertical guidance minima using Satellite-Based Augmentation System	RNP APCH down to LPV minima line
AMC 20-115C 12 Sep 2013	Software Considerations for Certification of Airborne Systems and Equipment	Applicable to all equipment providing PBN capability

Important Notices:

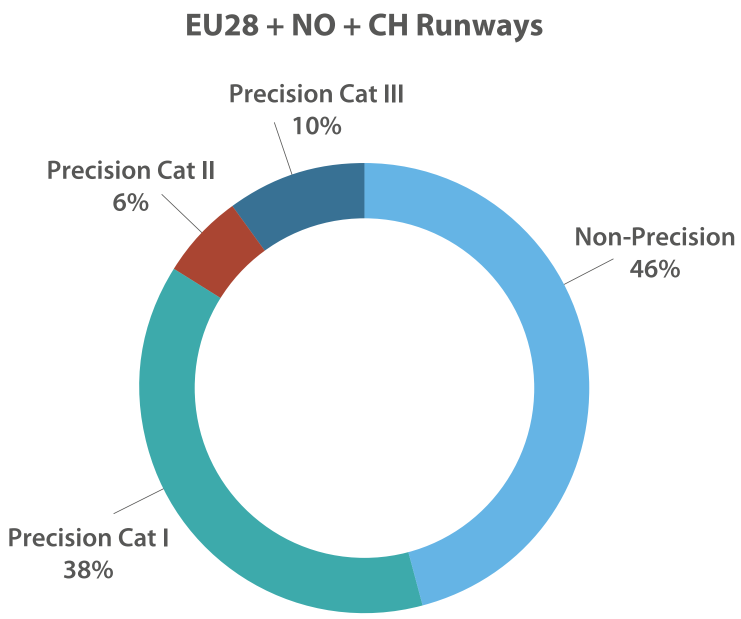
1. AMC 20.XX currently published do not yet cover all PBN navigation specifications.
2. AMC 20.XX requirements are not necessarily equivalent to requirements expressed in the ICAO PBN Manual; some EASA requirements in AMC 20.XX are more stringent. This is justified by the nature of the PBN Manual, which is only of technical and guidance nature, while EASA AMCs 20.XX are of regulatory nature.
3. AMC 20.XX does not only address technical and safety requirements but also operational requirements applicable to air operators' approval. They also put assumptions on the structure and procedures for airspace implementing the related PBN navigation application which are of interest for ANPS and Airspace Managers.
4. Some AMCs 20 XX related to PBN are part of the heritage of the JAA Technical Guidance Leaflets (TGL), on which a number of aircraft still in operation have been certified and air operators approved. Their references and text might be no longer adapted to newer publications (ICAO PBN and GNSS Manual, TSOs, ETSOs, other CS and AMC etc.) but they cannot be cancelled due to aircraft certified on this basis that are still in operation.
5. Following Amendment 3 to Part SPA of the Air Ops Manual and the cancellation of the requirement for an operational approval for all PBN navigation specification except RNP AR APCH and RNP 0.3 for helicopters, the corresponding AMCs listed in the previous table need to be revisited. To this end, AMCs 20-XX related to PBN would be cancelled, the airworthiness part being transferred to the CS-ACNS Navigation Part. The operation parts of these AMCs will be transferred in the Air Ops manual Part OP, including for what concerns Instruments Data and Equipment (IDE). For what concerns operational approval, many other regulatory documents have been amended (e.g. FCL, Air OPS) to reflect training requirements and operational management of PBN applications.
6. As EASA has not yet published the CS-ACNS chapter on navigation, avionics are certified in agreement with the FAA AC as AC 20-138D.
7. Introduction of new PBN specifications are expected: RNP 2, Advanced-RNP and RNP 0.3 as stated in ICAO PBN Manual Edition 4.

Further details on airworthiness criteria and applicable standards for navigation applications are provided in the Annexes.

5.1.1.3 APPLICATIONS

This chapter describes the most relevant approach operations implemented in Europe. The majority of European airports provide non-precision and precision CAT I runway (84%), leading to large-scale implementation of LNAV/VNAV, LPV and CAT I operations, based on GNSS.

Figure 8: Type of Instrument approach procedure runways in EU28, Norway and Switzerland



5.1.1.3.1 RNP APCH down to LPV

SBAS enables RNP APCH down to a minimum as low as 200 ft without the need of any ground infrastructure installation.

In Europe, EGNOS Safety of Life APV-I service level was certified for civil aviation in 2011 and the LPV 200 Service level, was declared operational in 2015. In order to provide the SoL Service, the EGNOS system has been designed so that the EGNOS SiS is compliant to the ICAO SARPs Annex 10 to be used in all phases of flight from en-route, terminal and approach operations (RNP APCH procedures down to LPV as low as 200 ft). The Service Levels defined within the EGNOS SoL Service Definition Document are as follows: ·

- NPA (Non-Precision Approach operations): supporting PBN navigation specifications other than RNP APCH, not only for approaches but also for other phases of flight.·
- APV-I (Approach operations with Vertical Guidance): supporting PBN navigation specification **RNP APCH down to LPV minima (DH) as low as 250 ft in compliance with APV-I** Performance Requirements of ICAO Annex 10.
- LPV-200: supporting **PBN navigation specification RNP APCH down to LPV minima (DH) as low as 200 ft., in compliance with Category I precision approach** Performance Requirements of ICAO Annex 10.

LPV approaches enabled by EGNOS SoL service, provide the following general benefits compared to approaches based on conventional navigation aids (NPA or ILS CAT I):

- Reducing decision height minima as low as 200 ft. based on the Safety of Life LPV 200 service level capability and local geography, which can allow successful approaches in conditions that would otherwise disrupt operations compared to conventional NPAs and therefore increase accessibility.
- Supports ILS CAT I look-alike operations without the need for a ground-based conventional navaids or in case of ILS CAT I approach unavailability. Even small and medium-sized airports and heliports remain accessible in poor weather conditions thanks to EGNOS.
- Increases safety by providing vertical guidance to the aircrew during the approach. This makes the approach easier to fly and reduces the risk of controlled flight into terrain (CFIT).
- Improves flexible use of airspace and allows approach procedures to be developed from any direction, and at steeper approach angles than classic fixed-wing procedures, creating the possibility to avoid densely populated areas.
- Offers the potential to remove circling approaches.
- Brings the major benefits for runway-ends where there is no ILS already available and potentially enabling VOR, NDB, ILS removal, reducing the associated installation / maintenance costs.

As of October 2017, there are 461 EGNOS based procedures (378 LPV) at 261 airports, in 21 countries.

5.1.1.3.2 Precision Approach based on GBAS CAT I

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

In Europe, 4 GBAS CAT I stations are operational in Zurich, Frankfurt, Bremen and Malaga.

The use of SBAS to enhance GBAS performance is now proposed in order to augment the operational capability of existing GBAS avionics. This solution provides significant operational improvement for GBAS equipped users, leveraging SBAS global observation of ionospheric perturbations.

AS OF OCTOBER 2017, THERE WERE 461 EGNOS-BASED PROCEDURES AT 261 AIRPORTS LOCATED IN 21 DIFFERENT COUNTRIES.

5.1.1.3.3 GNSS plus Enhanced Vision Systems

Accessibility to aerodromes and heliports can be significantly increased by combining GNSS with Enhanced Vision System (EVS), ref. EASA AIR-OPS:

- Approach utilising EVS plus any CAT I system (e.g. ILS or SBAS CAT I): visual reference based on natural vision (without reliance on the EVS) must be established (at the latest) at 100 ft. above runway threshold.
- Approach utilising EVS plus APV or NPA flown with the CDFA technique: visual reference based on natural vision (without reliance on the EVS) must be established (at the latest) at 200 ft. above runway threshold.

However, it is noted that the FAA has published a new rule “EVS to land,” which allows the user to decide and land only based on EVS with an RVR down to 1000 ft. There are discussions with EASA to adopt similar rules in Europe.

5.1.2 SURVEILLANCE

Reference	Title	Date
Commission Implementing Regulation (EU) No 1207/2011	laying down requirements for the performance and the interoperability of surveillance for the single European sky	22 November 2011
Commission Implementing Regulation (EU) No 1028/2014	amending Implementing Regulation (EU) No 1207/2011 laying down requirements for the performance and the interoperability of surveillance for the single European sky	26 September 2014
EASA AMC 20-24 ED Decision 2008/004/R	Certification Considerations for the Enhanced ATS in Non-Radar Areas using ADS-B Surveillance (ADS-B-NRA) Application via 1090 MHZ Extended Squitter	25 April 2008
EASA CS-ACNS Annex I to ED Decision 2013/031/R	Certification Specifications and Acceptable Means of Compliance for Airborne Communications, Navigation and Surveillance CS-ACNS	17 December 2013

5.1.2.1 INTERNATIONAL REGULATION

5.1.2.1.1 ICAO

At the international level, requirements on surveillance are published by ICAO in Annex 10, which standardises the performance of surveillance infrastructure supported by industry specifications. The ADS-B Surveillance service should comply with the requirements for the ground segment of the system included in Annex 10, as for the ADS-B message exchange function:

ADS-B DETERMINES AN AIRCRAFT'S POSITION VIA SATELLITE NAVIGATION.

The positioning information provided by systems such as GPS or EGNOS do not require, so far, a certified ANSP responsible of that positioning signal, the responsibility would remain in the ANSP providing the surveillance service, as the one that should check the positioning sources valid to provide the ATC/Surveillance service. With that regard, the requirements for the ADS-B positioning source should be met by the aircraft using ADS-B equipment and checked by the ANSP responsible of the airspace where the ADS-B service is used.

5.1.2.1.2 FAA

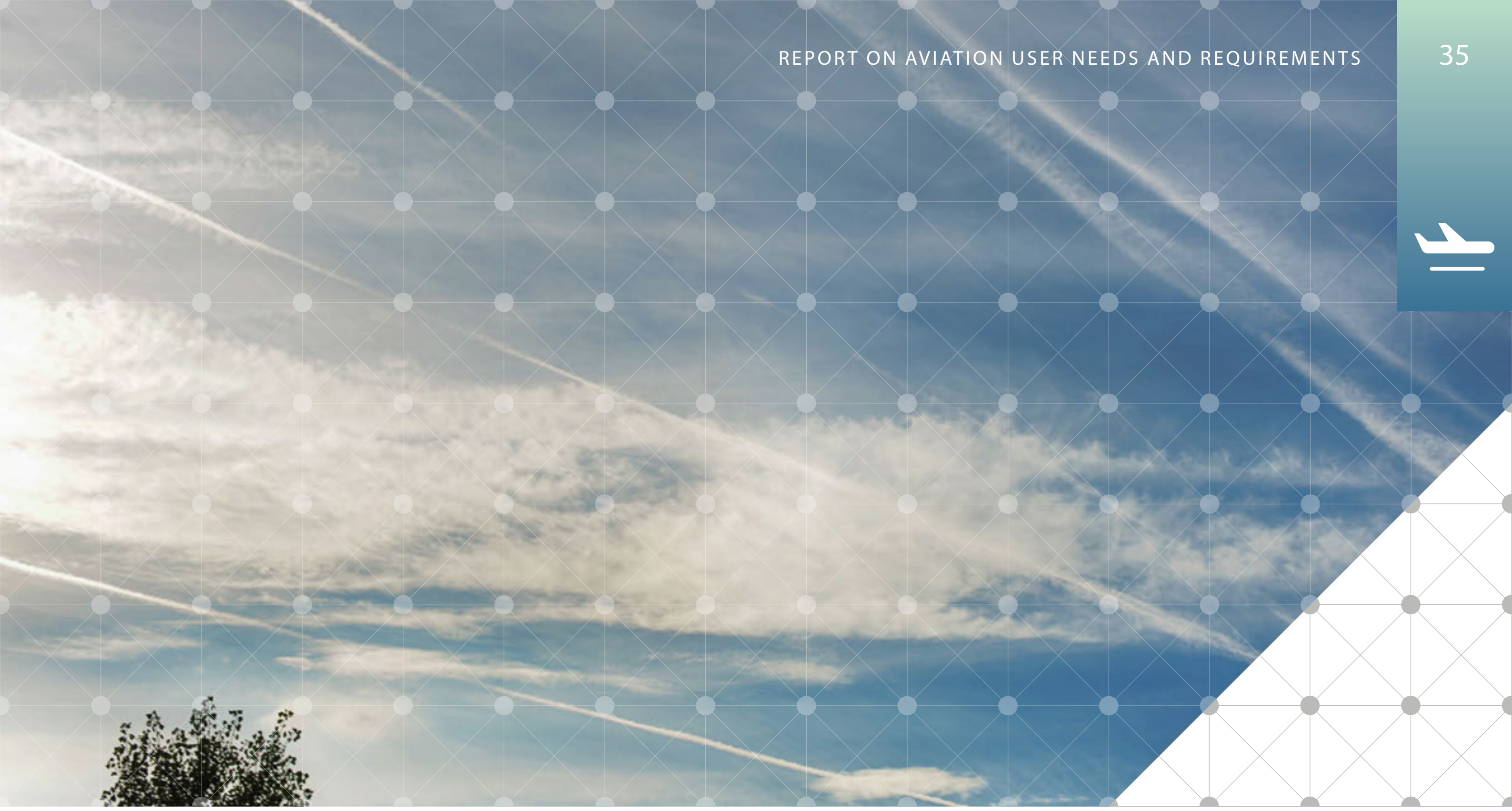
The Federal Aviation Administration (FAA) published Federal Regulation 14 CFR § 91.225 and 14 CFR § 91.227 in May 2010. The final rule dictates that from January 1, 2020, aircraft operating in airspace defined in 91.225 are required to have an Automatic Dependent Surveillance – Broadcast (ADS-B) system that includes a certified position source capable of meeting requirements defined in 91.227. These regulations set a minimum performance standard for both ADS-B Transmitter and the position sources integrated with the ADS-B equipment your aircraft.

The key performance figures stipulated under 14 CFR § 91.227 to meet the ADS-B mandate requirements are:

- For aircraft broadcasting ADS-B Out:
  - NACP must be less than 0.05 nautical miles (NACp ≥ 8);
  - NACV must be less than 10 meters per second (NACv ≥ 1);
  - NIC must be less than 0.2 nautical miles (NIC ≥ 7);
  - SDA must be 2; and
  - SIL must be 3.
- Changes in NACP, NACV, SDA, and SIL must be broadcast within 10 seconds.
- Changes in NIC must be broadcast within 12 seconds.

The rule also describes ADS-B performance requirements, with actual performance depending on the GPS receiver used as the ADS-B position source. The rule does not dictate a particular receiver type and operators, therefore, use different equipment to satisfy the ADS-B Out performance requirements. The operator is responsible for determining that a given sensor and ADS-B pairing is adequate to meet the rule.

The requirements placed on the certified position source lead to FAA recommendation to use a WAAS GPS receiver that is compliant with TSO-C145 or TSO-C146.



5.1.2.2 EUROPEAN REGULATION

The European Commission has published Commission Implementing Regulation (EU) No 1207/2011 and (EU) No 1028/2014 laying down requirements for the performance and the interoperability of surveillance for the Single European Sky. These regulations stipulate mandatory milestones comprising the implementation of ADS-B airborne capability on newly-built aircraft and the upgrading and retrofitting of such equipment in previous-built examples as shown in the following figure. However, there currently exists no mandate for the deployment of ADS-B on the ground, with primary means surveillance predicated on Mode C and Mode S Secondary Surveillance Radar.

Figure 9: ADS-B mandate applicability in Europe (source: EASA)

All flights operating as **general air traffic** in accordance with **instrument flight rules** within the airspace provided for in Article 1(3) of Regulation (EC) No 551/2004.	**ATS providers** which provide ATC services based on surveillance data, and to CNS service providers which operate surveillance systems.
Airborne Mode S Elementary Surveillance	• Forward and Retrofit 7 June 2020
Airborne ADS-B Out & Mode S Enhanced Surveillance[5]	• Forward and Retrofit 7 June 2020
Ground Systems	• Transfer Surveillance data • Surveillance chain must be capable of identifying individual a/c from downlinked a/c ID • System must be efficient

5 MTOW 5700 Kg or max cruising > 250 Kts

The EASA RMT.0679 is currently reviewing the requirements and proposing amendments to the existing regulations that permits non-compliant aircraft deliveries, enables the continued operation of aircraft already equipped with transponders and addresses the issue of state aircraft conspicuity. No NPA will be issued, but a report proposing the amendments.

The minimum horizontal position and velocity data quality requirements are shown in the table below:

Table 3: ADS-B positioning data requirements in Europe

Quality Parameter	Requirement
Position Accuracy (NACp)	NACp<=185.2 m (0.1NM) (i.e. NACp>=7) for both 3 NM and 5 NM separation
Position Integrity Containment Radius (NIC)	3 NM Sep: NIC<=1 111.2 m (0.6 NM) (i.e. NIC>=6) 5 NM Sep: NIC<=1 852 m (1 NM) (i.e. NIC>=5)
Source Integrity Level (SIL)	SIL=3: 10^{-7}/flight-hour
Velocity Accuracy (NACv)	NACv<=10 m/s (i.e. NACv>=1)
System Design Assurance (SDA)	SDA=$2x10^{-5}$/flight-hour - allowable probability level REMOTE (MAJOR failure condition, LEVEL C software and design assurance level)

EVEN IF THE EUROPEAN AND US ADS-B OUT MANDATES SHARE SIMILAR DEADLINES AND STANDARDS, THERE ARE MAJOR DIFFERENCES IN TERMS OF APPLICABILITY.

Note that EASA regulations cover minimum requirements for ADS-B, for ADS-B Out NRA 5NM separation and ADS-B Out RAD. For other application, in particular based on ADS-B In, manufacturers and operators should look at the FAA regulatory guidance materials.

5.1.2.2.1 ADS-B requirements in standards and airworthiness materials

There are many variations between ADS-B aeronautical standards and ADS-B airworthiness materials. This is due to evolutions in airworthiness materials which refer to different ADS-B standards that were updated a long time ago. However, airworthiness materials shall consider previous aircraft certification based on older aeronautical standards.

There are two types of requirements supporting ADS-B mandates worldwide, which are defined in the reference documents below:

- DO-260/ED102 and DO-260A: these documents target non-radar airspace with the objective to provide radar-like separation services (e.g. Australia, Canada, Singapore, Fiji, Vietnam, etc.) The certification considerations for all these mandates are provided by EASA AMC20-24.
- DO-260B/ED-102A: these documents support two types of ADS-B mandates: US and Europe. The objective is to use ADS-B in addition to radar and not as the only surveillance source. These mandates include different performance requirements and are assessed separately.

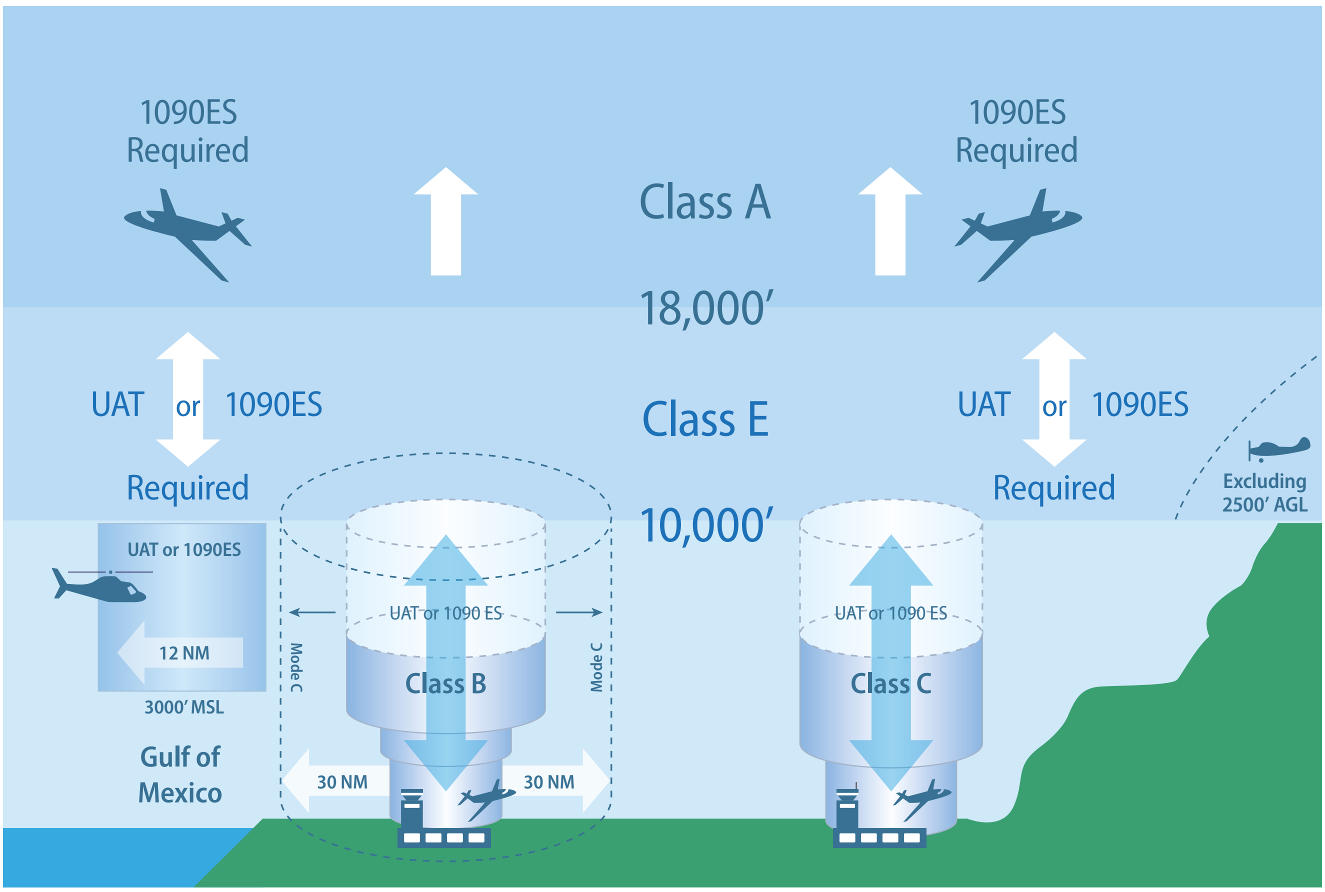
EASA published the CS-ACNS in December 2013. Regarding ADS-B, it is to a large extent in line with the corresponding FAA AC 20-165B material but there are some differences. The requirements of CS ACNS.D.ADSB fully cover and exceed the requirements of AMC 20-24. Therefore, aircraft that comply with CS ACNS.D.ADSB also comply with AMC 20-24 but not vice versa.

5.1.2.3 DIFFERENCES IN REGULATION

Reference	Title	Date
FAA Advisory Circular 20-165B	Airworthiness Approval of Automatic Dependent Surveillance – Broadcast OUT Systems	15 July 2015
FAA Advisory Circular 90-114A	Automatic Dependent Surveillance-Broadcast Operations	28 October 2014
FAA TSO-C195b (no more applicable after March 2016)	Avionics Supporting Automatic Dependent Surveillance – Broadcast (ADS-B) Aircraft Surveillance Applications (ASA)	29 September 2014
FAA AC 20-172B	Airworthiness Approval for ADS-B In Systems and Applications	20 May 2015
RTCA/DO-260B	Minimum Operational Performance Standards for 1090 MHz Extended Squitter Automatic Dependent Surveillance – Broadcast (ADS-B) and Traffic Information Services – Broadcast, with corrigendum 1.	13 December 2011
RTCA/DO-317b	Minimum Operational Performance Standards (MOPS) for Aircraft Surveillance Applications (ASA) System	17 June 2014

Even if the European and the US mandates have several similarities in the deadline and the applicable standards, there is a major difference in the applicability of the mandate. In the European mandate, the use of ADS-B Out is not conditioned by the airspace class in which aircraft operate but by the aircraft type through weight and speed thresholds, while in USA all aircraft flying in determined airspace classes are required to be equipped as depicted in the following figure:

Figure 10: US ADS-B Airspace rule (14 CFR Part 91 § 91.225)



US and Europe mandates target different operations, leading to non-homogeneous request on the position source. In particular, US requirement (NIC>=7) supports 2NM dependent parallel approach operations, while Europe requires 3NM and 5NM (NIC>=5 and NIC>=6)

In US rules, any position source that meets the performance standards of rule 14 CFR 91.227 can be submitted for certification, although GNSS is the most common one. FAA Advisory Circular 20-165 provides guidance for installations compliant with the requirements of rule 14 CFR 91.225 and 91.227, and specific guidelines for qualifying position sources.

The FAA explains that not all GNSS position sources will provide the same availability, and WAAS maximises it. While FAA does not pose a specific availability requirement, operators not equipped with WAAS may face limitations in access to the airspace after January 1, 2020.

Table 4: ADS-B estimated availability in FAA docs

Positioning Service (receiver standard)	Predicted Availability (ADS-B Compliance)
GPS (TSO-C129) (SA On)	≥ 89.0%
GPS (TSO-C196) (SA Off)	≥ 99.0%
GPS/SBAS (TSO-C145/TSO-C146)	≥ 99.9%

Then, in the positioning source/equipment eligibility, the note below is found:

Note: *Not all GNSS position sources will provide the same availability. See appendix 2 for more information on GNSS availability. The FAA recommends TSO-C145 or TSO-C146 position sources that meet the appendix 2 requirements to maximize availability and ensure access to the airspace identified in 14 CFR 91.227 after January 1, 2020.*

TO BENEFIT FROM NEXT GENERATION SERVICE, OPERATORS FLYING FROM EUROPE TO THE US NEED THE LATEST EQUIPMENT STANDARD.

In practice, availability recognition and the recommendation that follows mean the requirements for the use of SBAS as a positioning source on board. This is a major difference with the European mandate where nothing similar regarding availability is found.

The European requirements for GPS systems supporting ADS-B Out under 1207/2011, are detailed in the EASA CS-ACNS. In principle, however, for approval, the horizontal position and velocity data source should hold an EASA equipment authorization in accordance with ETSO-C129a, ETSO-C196 or ETSO-C145/ETSO-C146, with additional qualification requirements specified in EASA CS-ACNS.

Operators will need to install enhanced avionics for full-system compatibility, as defined under the Surveillance Performance and Interoperability EU Regulation No. 1207/2011, which is currently under amendment. Nonetheless, the reduced separation demanded by European regulations renders all generations of GPS avionics suitable for ADS-B Out. However, operators flying from Europe to the US will have no option but to upgrade to the latest equipment standard [SBAS capable] to fully benefit from the next generation service available on both sides of the Atlantic. Regardless of Exemption 12555, first- and second-generation GPS receivers [GPS SA On / Off] will be permitted for operation in the US beyond 2025, but with increased dispatch risk, especially for first-generation receivers, and assessment burden on operators.

5.1.3 TIMING

5.1.3.1 INTERNATIONAL REGULATION

The most relevant regulations regarding time in ICAO standards are described below.

- ICAO Annex 10 Vol I specifies in chapter 3.7 the requirements for the GNSS, compiling GPS, GLONASS and SBAS time-related information about the accuracy of the time offsets of each GNSS system related to UTC and its reference source.
    - GPS Time:
        - Referenced to UTC (US, maintained by U.S. Naval Observatory)

- Time transfer accuracy: 40 nanoseconds (95% time)
- GLONASS Time:
  - Referenced to UTC (SU, maintained by the National Time Service of Russia)
  - Time transfer accuracy: 700 nanoseconds (95% time)
- SBAS Network Time (SNT): the difference between SNT and GPS time shall not exceed 50 nanoseconds

In the future, Galileo standards will have to be included in Annex 10, in a similar way it is currently done for GPS and GLONASS (EGNOS is already included in the ICAO Annex 10 SARPS).

- ICAO Annex 11 includes the following requirements related to timing provision to Air Traffic Services:
  - Section 2.25.1 requires air traffic services (ATS) units shall use Coordinated Universal Time (UTC).
  - According to section 2.25.4, the time shall be obtained from a standard time station (or, if not possible, from another unit which has obtained the correct time from such station).
  - As far as time accuracy is concerned, section 2.25.3 states wherever data link communications are utilized by an air traffic services unit, clocks and other time-recording devices shall be checked as necessary to ensure correct time to within 1 second of UTC.

5.1.3.2 EUROPEAN REGULATION

No regulation identified at this stage.

5.1.4 SEARCH AND RESCUE

Reference	Title	Date
COMMISSION REGULATION (EU) 2015/2338	amending Regulation (EU) No 965/2012 as regards requirements for flight recorders, underwater locating devices and aircraft tracking systems	11 December 2015
EASA – Air OPS Part ORO	Acceptable Means of Compliance (AMC) and Guidance Material (GM) to Annex III Organisation Requirements for Air Operations	Consolidated version including Issue 2, Amendment 7 May 2016
EASA – Air Ops Part NCO	Acceptable Means of Compliance (AMC) and Guidance Material (GM) to Annex VII - Part NCO	Consolidated version including Issue 2, Amendment 2 20 February 2015
COSPAS-SARSAT C/S T.001 Issue 4 and T.007 Issue 5	Specification for COSPAS-SARSAT 406 MHz distress beacons and type approval	May 2017
COSPAS-SARSAT C/S T.018 Issue 1	Specification for Second-Generation Cospas-Sarsat 406-MHz	May 2017

The international bodies regulating the use of ELTs are:

- COSPAS-SARSAT: SAR service provider
- ICAO: International Civil Aviation Organisation
- RTCA: Radio Technical Commission for Aeronautics
- IEC: International Electrotechnical Commission
- ETSI: European Telecommunications Standards Institute

The relevant documents regarding SAR requirements are as follows:

- COSPASC/S T.001 "Specification for COSPAS-SARSAT 406 MHz Distress Beacons
- RTCA MOPS for ELTs RTCA/DO-204 A MOPS for 406 MHz Emergency Locators Transmitters: September 2007
- EUROCAE MOPS for ELTs ED-62A: MOPS for 406 MHz Emergency Locators Transmitters: February 2009
- ICAO Annex 6 and Annex 10
- ICAO Manual Doc 10054 (not published yet):
  - **location of aircraft in distress** will include examples

of technologies like triggered in-flight ED-62B ELT by ED-237 triggers

- **timely flight recorder data recovery** will include examples of technologies like triggered transmission of flight recorder data by ED-237 triggers or installation of ED-112A deployable recorder

5.1.4.1 INTERNATIONAL REGULATION

ICAO Annex 6 – Operation of Aircraft describes requirements for Emergency Locator Transmitter (ELT) in section 6.17 and on location of an aeroplane in distress in section 6.18., for ELT in particular:

"All aeroplanes authorized to carry more than 19 passengers for which the individual certificate of airworthiness is first issued after 1 July 2008 shall be equipped with either:
a) at least two ELTs, one of which shall be automatic; or
b) at least one ELT and a capability that meets the requirements of 'location of an aeroplane in distress."

ELTs are transmitters that can be tracked in order to aid in the detection and localization of aircraft in distress. They are Aeronautical radio beacons that interface worldwide with the international COSPAS-SARSAT satellite system for Search and Rescue (SAR). When activated and under satellite coverage, such beacons send out a distress signal, which, if detected by satellites, can be located by trilateration in combination with triangulation or a more accurate and timely location if the ELT can provide a GNSS-derived position.

There are no specific accuracy requirements for determining the position of an aircraft in distress but a very accurate distress location may be provided by a GNSS-capable 406 MHz ELT, which will normally provide a location to within 120 metre accuracy (http://beacons.org.nz/FAQs.aspx).

Notice that for what concerns Personal Locator Beacon (PLB) EASA only recommends a built-in GNSS receiver with a COSPAS-SARSAT satellite-aided tracking system. This recommendation does not apply to devices with a COSPAS-SARSAT number belonging to series 700 (EASA Air Ops – Part IDE – AMC3 NCO.IDE.B.130b).

Location of an aeroplane in distress

"All aeroplanes of a maximum certificated take-off mass of over 27 000 kg for which the individual certificate of airworthiness is first issued on or after 1 January 2021, shall autonomously transmit information from which a position can be determined by the operator at least once every minute, when in distress."

5.1.4.2 EUROPEAN REGULATION

The Search and Rescue beacons used for commercial aviation are ELTs, while PLBs are used in General Aviation as personal device as a help in case of distress. Both ELTs and PLBs have been mandated by the EC to be installed according to Commission Regulation (EU) No 965/2012, which lays down the requirements for aircraft operators wishing to engage in commercial air transport (CAT) operations.

The regulation does not impose specific requirements for the GNSS receivers in ELT or PLB. The trend of major receiver manufacturers to deliver multiconstellation receivers is being taken up by beacon manufacturers, in order to increase the performances of the independent position provided by the device.

5.1.5 DRONES

Reference	Title	Date
EASA Concept of Operations for Drones	Concept of Operations for Drones – A risk based approach to regulation of unmanned aircraft	May 2015
EASA Advance Notice of Proposed Amendment 2015-10	Introduction of a regulatory framework for the operation of drones	31 July 2015
EASA Technical Opinion RMT.0230	Introduction of a regulatory framework for the operation of unmanned aircraft	18 December 2015
SESAR JU U-space Blueprint[6]	U-space Blueprint	2017
EASA Advance Notice of Proposed Amendment 2017-05 (A)	Introduction of a regulatory framework for the operation of drones	4 May 2017
EASA Notice of Proposed Amendment 2017-05 (B)	Introduction of a regulatory framework for the operation of drones	12 May 2017

5.1.5.1 INTERNATIONAL REGULATION

ICAO has set up a Remotely Piloted Aircraft Systems Panel (RPASP), which shall produce draft standards and recommended practices (SARPs) for unmanned aircraft by 2018, focusing its work on international operations. The panel recommends RPAS to be equipped and have the required operational approvals in terms of required navigation performance, required communication performance and required surveillance performance as required by the airspace within which they plan to operate. RPAS shall also be able to operate in accordance with Instrument Flight Rules and be separated from other air traffic in accordance with the rules applicable to the class of airspace within which they are operating. Therefore, trends towards PBN and surveillance ADS-B Out implementation enabled by GNSS and SBAS are applicable to RPAS.

JARUS (Joint Authorities for Rulemaking on Unmanned Systems) is a cooperation of 40 CAAs worldwide and its aim is to develop harmonized rules for unmanned aircraft. JARUS has been recognized by the European Commission and the European Parliament as the 'working engine' to develop the necessary rules for unmanned aircraft. This will ensure harmonization worldwide and JARUS is expected to contribute to the ICAO work. EASA is, therefore, fully engaged in JARUS and provides significant resources.

5.1.5.2 EUROPEAN REGULATION

In EASA terminology, the term "drones" includes all kinds of remote-pilot and unmanned aircraft. It shall be noticed that for what concerns drones, technical and operational requirements are still to be defined, while the regulatory approach for drones is under preparation.

EASA released in 2015 a concept of operations for drones where different categories of drones are defined:

- 'Open' category (low risk): safety is ensured through operational limitations, compliance with industry standards, requirements on certain functionalities, and a minimum set of operational rules. Enforcement shall be ensured by the police.
- 'Specific operation' category (medium risk): authorisation by National Aviation Authorities (NAAs), possibly assisted by a Qualified Entity (QE) following a risk assessment performed by the operator. A manual of operations shall list the risk mitigation measures.
- 'Certified' category (higher risk): requirements comparable to manned aviation requirements. Oversight by NAAs (issue of licences and approval of maintenance, operations, training, Air Traffic Management (ATM)/ Air Navigation Services (ANS) and aerodrome organisations) and by EASA (design and approval of foreign organisations).

Further to this CONOPS, EASA released an Advance Notice of Proposed Amendment (A-NPA) that led to the issuance of an EASA Technical Opinion in December 2015.

In this Technical Opinion, further steps are defined:

- Elaboration of a CS for unmanned aeroplanes/rotorcraft by Q2/2017),
- Implementing Rules for the 'open' category (no date foreseen),
- Implementing Rules for the 'specific' category based on the JARUS risk assessment process (Q1/2017),

Adaptation of IRS for manned aviation to introduce licenses for remote pilots, the ROC, and unmanned aircraft-specific elements like 'ground control station' for the 'certified' category (as soon as deliverables from JARUS are available).

6 http://www.sesarju.eu/sites/default/files/documents/reports/U-space%20Blueprint%20brochure%20final.PDF

5.2 FUTURE GNSS USER REQUIREMENTS FOR CIVIL AVIATION APPLICATIONS

5.2.1 NAVIGATION

5.2.1.1 INTERNATIONAL DEVELOPMENTS AND APPLICATIONS EVOLUTION

5.2.1.1.1 ICAO Future GNSS CONOPS

Key benefits include constellation independence and redundancy, as well as improved availability, continuity, and robustness for GNSS-based Navigation and Surveillance applications. En-route/TMA benefits include a reduced need to rely on non-GNSS positioning sources. This appeals above all to medium and long-haul operators. Meanwhile, ANSPs and States can expect to benefit from a possible rationalisation of legacy navaids, which have been considered as a backup PNT source alternative to GNSS (APNT), but which can now see their deployment reduced, a sign of the true cost savings that civil GNSS was first conceived for.

All the possibilities of using multi constellation for Air Navigation have not been explored yet, but a new concept of operations for Multi-Constellation Multi-Frequency receivers is being developed at ICAO level.

Consultation to the users about the benefits of future GNSS CONOPS is ongoing and users are welcome to further contribute.

ICAO IS DEVELOPING A NEW CONCEPT FOR OPERATIONS USING MULTI-CONSTELLATION/ MULTI-FREQUENCY RECEIVERS.

5.2.1.1.2 SBAS L1/L5

The future requirements pertaining to the introduction of SBAS L5 DFMC in ICAO SARPs and in DFMC receivers MOPS will bring the following main changes to current GPS L1/SBAS receivers:

- New message types defined for L5,
- Extended list of SBAS PRN usable on both L1 and L5 (120-158 instead of 120-138 as currently defined). This was published as part of the revision E of RTCA DO 229 dated December 15th , 2016).
- Introduction of provision for identification of new SBAS systems (GAGAN, SDCM, Beidou SBAS, KSASS, ASECNA SBAS).

5.2.1.1.3 Multiconstellation, DFMC receivers and ARAIM

The status of MOPS development for multiconstellation receivers is summarised below:

- GPS/GLONASS L1 receiver: a RTCA MOPS is currently under finalization.,
- GPS/Galileo/SBAS MOPS under preparation in EUROCAE and will be further developed jointly with RTCA, that includes DFMC SBAS L1/L5 and H-RAIM.

For the GPS/Galileo/SBAS MOPS, in addition to the processing of Galileo and SBAS L1/L5 signals, new kinds of requirements are still under study:

H-ARAIM

Algorithms for H-ARAIM are well defined, the issue being still the way to define and implement in the receiver the core constellations parameters, notably the probabilities of failure for satellites and constellation which are very important inputs for the global integrity performance of H-ARAIM. For the time being, only GPS constellation parameters can be defined and it is too early for the Galileo constellation to provide consolidated figures on which the EC, as Galileo owner, could commit in ICAO.

V-ARAIM

A global vertical service, V-ARAIM, is still to be developed and can be implemented subsequently once sufficient data is collected and experience gained to demonstrate safe operations. Similarly, analysis and experience with observed data will determine whether additional monitoring capabilities may need to be implemented for V-ARAIM. Alternatively, stakeholders may examine additional criteria and safety cases to extend vertical services to cover other, more stringent operations beyond LPV-200.

GNSS satellite selection/de-selection

The need for user equipment to accommodate suspension of use of certain GNSS elements is the subject of significant discussion. The expectation is that if manual de-selection of a GNSS element is required, this should not add to additional workload or be a distraction to the flight crew. The need for de-selection of GNSS elements requires further consideration.

5.2.1.1.4 Performance-Based Navigation

DFMC GNSS will support all current PBN applications with greater robustness against vulnerabilities enabling significant operational benefits.

Where the improved performances allow the development of innovative applications, assuming adequate COM and

SUR capabilities, it is expected that new Navigation Specifications will be developed by the ICAO PBN SG and detailed in the PBN Manual.

The robustness offered by DFMC GNSS, will not fully eliminate all known vulnerabilities of current GNSS. As a result, in certain areas (e.g. airspace with high complexity and high traffic density) ANSPs may need to maintain a certain number of ground-based navigation aids to ensure reversionary capabilities are retained. In the future, an Alternate Position Navigation and Time (APNT) capability may be developed to provide a contingent navigation and timing capability to GNSS supporting en-route through to non-precision approach operations.

Source: ICAO DFMC CONOPS, October 2017

5.2.1.1.5 A-RNP

Aircraft requirements for A-RNP applications are already developed in the ICAO PBN Manual. In addition to the requirements pertaining to GNSS, specific requirements for aircraft AP/DV guidance (RNAV holding patterns, handling of altitude constraints, fixed radius transition, radius to Fix) might be required. Such requirements are already defined in ARINC 424 standard. An important aspect of A-RNP is the scalability of PBN performance supported by the on-board equipment that may range from RNP 2 down to RNP 0.3, thus potentially covering a large variety of PBN implementation in different airspaces, either for en-route/ Terminal and approach.

From an aircraft certification standpoint, A-RNP airworthiness requirement are only defined by AC 20-138D; there is no European equivalent yet.

The next step for implementation is the development/ update of regulatory documents (e.g. EASA Air Ops) with implementation details and the need or not for a specific operational approval.

5.2.1.1.6 Precision approach operations

SBAS and GBAS currently support CAT I type of operations. In the near future, GBAS will also support CAT II /III autoland operations in mid latitudes and it is expected that DFMC GBAS will enable to support robust CAT II/III operations in all latitudes.

SBAS DFMC R&D activities are being conducted in some States to identify if SBAS DFMC can also support CAT I autoland and operations with Decision Heights below 200 feet.

The extension of ARAIM capabilities to the vertical domain will enable GNSS DFMC services to achieve RNP APCH equivalents to CAT I on a global basis in the medium to long term.

SBAS service providers offering L1 and DFMC services may declare different services areas for the same service performance level (e.g. APV I). There is a need to find an optimal implementation solution to maximize operational benefits that DFMC SBAS can bring while maintaining safety for SBAS L1 users.

There are different GBAS precision approach services:

GAST-C: approach service to enable CAT I precision approach operations (certified and in operation)

GAST-D: approach service to enable CAT II/III precision approach operations (standards finalized, not approved yet) based on GPS L1

GAST-F: approach service to enable CAT II/III based on DFMC.

5.2.1.1.7 GNSS hybridisation with other sensors

5.2.1.1.7.1 EVS / SVS

The focus of the FAA in the near term (by 2020) in the approach phase of flight, will be on increasing safety and improving throughput during low-visibility conditions.

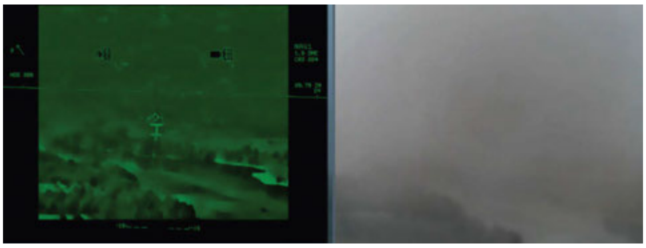
In particular, commitments include:

- Providing operational credit on qualifying approaches with Synthetic Vision Guidance Systems (SVGS). The FAA will issue an updated policy to enable head-down SVGS to be used in lieu of a Head Up Display (HUD) for reduced-visibility operations to qualifying approaches;
- Expanding operational credit using Enhanced Flight Vision Systems (EFVS) on PBN approaches during low-ceiling and low-visibility conditions. Currently, EFVS can be used only for continued operation between the Decision Altitude/Minimum Descent Altitude (DA/MDA) and 100 feet height above touchdown (HAT) zone elevation (see Figure below). The FAA will issue updated regulations and guidance material to enable EFVS operations through the entire visual segment, from 100 feet HAT to touchdown.

  The new regulations leverage vision technology and pilot training to enable dispatch, arrival and approach operations in low-ceiling and low-visibility conditions.

Ref. US DoT FAA PBN NAS NAVIGATION STRATEGY 2016.

Figure 11: EFVS can increase situational awareness at night and during low-visibility weather conditions.



5.2.1.1.7.1 Inertial navigation systems

Inertial systems can sustain some PBN navigation specifications for a certain period of time.

A significant percentage of civil aircraft in the commercial aircraft and business aviation domains are equipped with inertial platforms, commonly integrated with GNSS, which offers the opportunity for assessing this on-board capability as a suitable means of navigation/gap filler for aircraft operations in order to meet PBN/RNAV performance requirements.

A study developed by EUROCONTROL shows that, depending on the type and duration of the aircraft flight operation, inertial systems might fit into PBN navigation specifications.

5.2.1.2 EUROPEAN REGULATION

5.2.1.2.1 Extension of RNP 0.3 applicability and "Final Approach Solutions"

RNP 0.3 navigation specification is already defined in the PBN Manual. For the time being, a distinction is made on the RNP 0.3 applicability:

- For fixed wing aircraft, RNP 0.3 is only applicable to final approach segment approach,
- For rotorcraft RNP 0.3 can be applied to all phases of flight. This results from a request of the IFR helicopter community who identified additional PBN benefits (e.g. implementation of low-level routes). EASA has expressed the need for a specific operational approval for this navigation specification.

RNP 0.3 would enable a significant part of the IFR helicopter fleet to benefit from PBN, in particular enabling the following operations, as described in the PBN Manual:

- Reduced protected areas, potentially enabling separation from fixed-wing traffic to allow simultaneous non-interfering operations in dense terminal airspace;
- Low-level routes in obstacle-rich environments reducing exposure to icing environments;
- Seamless transition from en-route to terminal route;
- More efficient terminal routing in an obstacle-rich or noise-sensitive terminal environment, specifically in consideration of helicopter emergency service IFR operations between hospitals;
- Transitions to helicopter point-in-space approaches and for helicopter departures; and
- Helicopter en-route operations are limited by range and speed and can often equate to the dimensions of terminal fixed-wing operations.

Implementation of low-level routes based on RNP 0.3 is ongoing in France, Italy, Swizerland, Norway, France, and demand from rotorcraft operators, especially HEMS, is increasing. GSA is supporting most of the ongoing operational implementations in the EU. Eurocontrol, under agreement with the GSA, is developing generic guidance material to facilitate implementation of such routes.

For what concerns fixed-wing aircraft, there is also a request to extend the RNP 0.3 applicability to other than the Final Approach Segment, in particular to SID/STAR, initial and intermediate approach segments. This would open the gate to new "Final Approach Solutions", able:

- To solve the transition problem between the different approach segments that are problematic for procedure design,
- To open the way to an end-to-end continuous descent with reduced thrust, from cruising to touch down, in eliminating the current levelling segment before intercepting the Final Approach Segment. This could be achieved by incorporating a 3D profile all along the approach. The SESAR project 6.8.8 lead by Lufthansa dealt with this new concept (Augmented Approached to Land – AAL) through several live demonstrations on different aircraft types (B740-800, A380, A320), demonstrating significant benefits in fuel savings with shorter approach paths, thus reducing environmental impact (noise and emission).
- This concept could also be declined in variants of the approach procedures implementing different vertical path angle and touch down points for the same runway end in order to reduce aircraft longitudinal spacing in final approach mandated by wake turbulence separation rules, thus augmenting the runway throughput.

In addition, this would represent an intermediate step between RNP APCH and RNP AR APCH, the latter being very onerous in terms of implementation (procedure design, aircraft certification and operational approval), air operators and airport authorities willing to use this navigation specification on a specific airport.

MANY COMMERCIAL AND BUSINESS AIRCRAFT ARE EQUIPPED WITH INERTIAL PLATFORMS INTEGRATED WITH GNSS.

5.2.1.2.2 Precision approach operations

As specified in the EGNOS v3 Implementing Act (COMMISSION IMPLEMENTING DECISION (EU) 2015/1183 of 17th July 2015 setting out the necessary technical and operational specifications for implementing version 3 of the EGNOS system.)http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32015D1183&qid=1498123341066&from=EN, EGNOS v3 DFMC SoL service will provide a Vertical Alert Limit of 10m, which will contribute to enable CAT I autoland approach operations.

With regard to MFMC GBAS CAT II/III, several steps are still to be achieved:

- Finalisation and approval of DFMC GBAS CAT II/III SARPs,
- Publication of MOPS for DFMC GBAS ground station and MOPS for DFMC GBAS airborne equipment. These standards will contain precise users' requirements and the work is on-going.
- Publication by EASA of corresponding airworthiness certification specifications and implementing rules. This work is under consideration.

5.2.1.2.3 Other Advanced approach concepts

Beyond results achieved by SESAR, notably on "Augmented Approaches to Land", these topics should be further addressed in SESAR 2020 in order to set exact future user's requirements at all levels (procedure design, charting, avionics, certification, crew training etc.). The standardization of such operations still needs to be undertaken in order to amend current ICAO documents and standards as well as EASA implementing rules.

These applications are using GNSS "as it is" and will include future capabilities of SBAS DFMC (EGNOS V3) and GBAS DFMC. It is not expected that they will require changes to GNSS SiS performance requirements. Where required, the benefits of a local GBAS station or SBAS can be used by the aircraft in order to follow accurately a complex approach flight path. The impact will more reside in procedure definition/approval for ANSPs/Airspace Managers and on-board navigation computing and monitoring of the reference path to fly for airspace users rather than on GNSS SiS performance requirements.

GNSS can enable advanced approaches procedures (beyond a mere replication of the typical ILS-like single 3º glide slope).

The SESAR project 05.06.03, D06 has researched a number of different navigation concepts, each using APV SBAS down to LPV in the FAS:

- Transition from P-RNAV / RNP / RNP AR to LPV
- Transition from continuous descent approach (CDA) to LPV
- Steep approach (>4.5°) based on GNSS
- Double slope steep approach based on GNSS
- Advanced missed approach enabled by GNSS
- Wake vortex free approaches on HUB runway
- Single slope curved approach based on GNSS
- 'Selected' Advanced LPV Procedure (combining features of several of the previous concepts)

The actual implementation of these advanced approach concepts requires the previous development of the corresponding standards (avionics, ATM, design procedures criteria, etc.).

In the frame of ongoing SESAR 2020, the Multi Annual Programmes is addressing the following advanced concepts:

- PJ.02-01: Wake turbulence separation optimization
- PJ.02-02: Enhanced arrival procedures
- PJ.02-03: Minimum-Pair separations based on RSP
- PJ.02-05: Independent Rotorcraft IFR operations at the Airport
- PJ.02-06: Improved access into secondary airports in low-visibility conditions
- PJ.02-08: Traffic optimisation on single and multiple runway airports
- PJ.02-11: Enhanced Terminal Area for efficient curved operations

5.2.1.2.4 IAP at non-instrument runways

Recent developments at EU and ICAO level open the door to enhance safety of small VFR aerodromes with a low-cost implementation process for instrumental flight operations. General aviation, along with business operators, conducts millions of operations with a fleet equipped with GNSS/SBAS-receivers demanding to benefit from the new aviation technologies. They usually fly to airports with limited infrastructure and demand implementation of IFR operations.

In fact, there are around 5 300 non-instrumental runway ends at EU28 scope (2 673 airports), most of them serving private traffic. The new ICAO Annex 14 classification opens the possibility to implement instrument approaches to these runways, significantly increasing safety and operational advantages to GA and BA users.

RNP APCH down to LPV minima to non-instrument runways do not impose new requirements on the EGNOS SiS performances, as APV-I is deemed adequate. However, the increase of SBAS capable traffic may have impact in a wider context.

GSA is working together with EASA in developing guidelines to facilitate such operations, by gathering current implementation solutions in different EU countries, identifying gaps on the implementation process that would need to be defined or modified in order to set a proportionate scenario for instrument approaches implementation for these communities.

5.2.2 SURVEILLANCE

As discussed in section 4.1, the European and US ADS-B Out requirements differ on the requirements on the horizontal position source. While the European ADS-B Out requirements target 3NM separation as the most demanding ATC Surveillance use case, the US is targeting at 2 NM diagonal separation for dependent parallel approaches. This leads to a European NIC requirement of 0.6 NM (CS-ACNS / ED-161) compared to the US NIC requirement of 0.2 NM (14 CFR 91.227). The European NIC requirement is currently further assessed in the context of the on-going EUROCAE WG-102 work on Generic Surveillance Safety and Performance Requirements, GEN-SUR SPR and may possibly be relaxed.

In order to achieve radar rationalisation using ADS-B, it would be necessary to reach a 100% aircraft equipage with ADS-B. According to Eurocontrol, additional benefits from full ADS-B Out implementation would be[7]:

- Removing the need for costly Mode A/C SSR operations (duplicated costs for ANSPs in addition to operating Mode S, also due to Mode A/C performance constraints);
- Simplifying WAM deployments (through the use of "passive surveillance", noting that WAM active surveillance operations are significantly constrained by ICAO regulation);
- Unlocking the full benefits of "ADS-B In" implementations, including future higher-end applications such as "Interval Management" ("Spacing");
- Facilitating TCAS / ACAS Enhanced Hybrid surveillance (through the use of "passive surveillance"), with a significant effect on reducing 1090 MHz frequency usage;
- Reducing the costs of the implementation and operation of MLAT systems at large airports and also enabling basic A-SMGCS services at medium-sized airports without the need for an MLAT system;

The need to support more stringent requirements in the European Airspace and potential for radar rationalisation is on-going under the CNS Evolution analysis, by EASA and SJU, with the aim of maximizing safety, cost-effectiveness benefits and interoperability.

7 Source: Eurocontrol

The current ADS-B Out aircraft installation requirements, as specified in EASA CS-ACNS, might be found to be too stringent and costly for the GA fleet (in particular regarding the costs that are associated with a fully certified horizontal position source / GNSS receiver). In this context, the FAA TSO-C199 ("TABS") is an important candidate to address this GA need. Therefore, work is ongoing at SESAR and Eurocae WG 102 in order to define appropriate sensors for the GA.

A NEW ICAO CLASSIFICATION COULD SEE INSTRUMENT APPROACHES IMPLEMENTED AT EUROPE'S 5,300 NON-INSTRUMENTAL RUNWAYS.

The deployment of MCMF GNSS receivers will also lead to increased ADS-B availability for different operations. Such progress may enable radar rationalisation and decommissioning of certain redundant navaids, resulting into cost reductions.

The 4D trajectory concept has been extensively explored by SESAR, with successful results in demonstrations carried out by Airbus. It should be understood that the main aspects of the 4D trajectory implementation concept are mostly pertaining to flight management, either on-board and ATM computers rather than positioning with GNSS. The newest airborne systems are already capable, or nearly capable, to support 4D trajectory, even if some improvements are needed.

The main drivers for the 4D trajectory function are thus not the GNSS positioning/navigation contribution to the function, but mostly pertains to:

- The handling of permanent exchanges between on-board system and ATM ground systems through an air-to-ground datalink and the SWIM ATM network, in order to harmonize the results of on-board and on-ground computing so that ATC clearances are in line with flight predictions displayed by the FMS to the crew.
- The deployment of the 4D trajectory function that needs time synchronisation between airborne and ground systems in order to reduce errors due to possible difference of time references used on board or on ground.

Regarding time reference and synchronisation we could, however, expect that current ICAO requirements will be revisited to satisfy operational requirements for:

- ATM networks (e.g. SWIM in SESAR), thus impacting ANSPs/Network Managers,
- 4D trajectory management, thus impacting both ANSPs/Network Managers and airspace users. It is, however, admitted that for what concerns the airborne segment, the current FMS internal clocks are already capable of time handling with an acceptable time accuracy and drift. This does not, however, prevent future avionics integration to rely on the GNSS time to monitor the GNSS and synchronise the on-board time with GNSS time if needed.

Potential limitations of current ICAO timing requirements for future ATM systems have already been raised in ICAO NSP. This should not affect GNSS time accuracy as broadcast by SiS but rather the time synchronisation requirements applicable to ground and airborne systems.

On the other hand, internal GSA analysis identified a number of GNSS/EGNOS applications in the timing domain. These applications can be considered in the frame of a GNSS DFMC (plus augmentations) scenario.

TIM_SUR_1	Use of the GNSS Time Service in SUR – PSR/SSR
TIM_SUR_2	Use of the GNSS Service in SUR – Multi-Radar-Tracking (MRT)
TIM_SUR_3	Use of the GNSS Time Service in SUR - WAM
TIM_SUR_4	Use of the GNSS Time Service in SUR – ADS-B at the ground station
TIM_COM_1	Use of the GNSS Time Service in COM – Air Ground Data Link – CPDLC
TIM_COM_2	Use of the GNSS Time Service in COM – Synchronisation for COM networks
TIM_NAV_1	Use of the GNSS Time Service in NAV – 4D (TOAC)

5.2.3 AVIONICS – AIRBORNE SAFETY NETS

Internal GSA analysis identify two GNSS applications for safety nets as follows:

SAF_1	Use of GNSS PVT as positioning information for Terrain Awareness and Warning System (TAWS)
SAF_2	Use of GNSS PVT for future Airborne Collision Avoidance System (ACAS)

5.2.4 SEARCH AND RESCUE: LOCATION OF AIRCRAFT IN DISTRESS AND FLIGHT TRACKING

Reference	Title	Date
ICAO GADSS 6.0	Global Aeronautical Distress & Safety System (GADSS)	07 June 2017
ICAO Doc 10054	ICAO Manual Location of Aircraft in Distress and Flight Recorder Data Recovery	Under development
EUROCAE WG-98 MASPS ED-237	Criteria to Detect In-flight Aircraft Distress Events to Trigger Transmission of Flight Information	
COSPAS-SARSAT C/S T.001 Issue 4 and T.007 Issue 5	Specification for COSPAS-SARSAT 406 MHz distress beacons and type approval	May 2017
COSPAS-SARSAT C/S T.018 Issue 1	Specification for Second-Generation COSPAS-SARSAT 406-MHz	May 2017
http://helios-gsa-project.eu/	HELIOS - Second Generation Beacon for GALILEO/ EGNOS EGNSS Search And Rescue applications - website	N/A
http://www.gricas-gsa-project.eu/	GRICAS Consortium website	N/A

The effectiveness of the current alerting of search and rescue services should be enhanced by addressing a number of key improvement areas and by developing and implementing the Global Aeronautical Distress and Safety System (GADSS), which addresses all phases of flight under all circumstances including distress. This GADSS will maintain an up-to-date record of the aircraft progress and, in case of a crash, forced landing or ditching, the location of survivors, the aircraft and recoverable flight data.

The main functions of the GADSS are:

- Aircraft Tracking
- Autonomous Distress Tracking
- Post Flight Localization and Recovery
- GADSS Information Management and Procedures

5.2.4.1 AIRCRAFT TRACKING

Aircraft Tracking is defined as follows: A process, established by the operator, that maintains and updates, at standardised intervals, a ground-based record of the four-dimensional position of individual aircraft in flight. (ICAO Annex 6)

5.2.4.1.1 International Regulation

The applicable international regulations and reference materials are described in ICAO Annex 6 and in the ICAO GADSS CONOPS.

The core of the GADSS recommendations and requirements stipulates that aircraft report their position to their airline operations centre no less than once every 15 minutes. Should an aircraft become in distress, however, position reports then must be provided every minute.

5.2.4.1.2 European Regulation

The applicable regulation is the Commission Regulation (EU) 2015/2338 of 11 December 2015 amending Regulation (EU) No 965/2012 as regards requirements for flight recorders, underwater locating devices and aircraft tracking systems. In particular: CAT.GEN.MPA.205 Aircraft tracking system.

The requirements will be incorporated in the new amendments of EASA AIR OPS Part ORO. The requirement for precision seem not to be very demanding but it can be for remote oceanic navigation and it will require GNSS on board:

When not using position data from ATS surveillance systems, the tracking of an individual flight should rely on equipment that transmits time-stamped position data, with latitude and longitude accuracies of 1 nautical mile or higher and altitude accuracy of 700ft, or higher

5.2.4.2 AUTONOMOUS DISTRESS TRACKING

Autonomous Distress Tracking (ADT) is defined as follows: The capability using transmission of information from which a position of an aircraft in distress can be determined at least once every minute and which is resilient to failures of the aircraft's electrical power, navigation and communication systems.

The regulations are not technology-specific and will allow for various solutions. The ADT function can be performed using emergency beacons, called ELT(DT) (for Distress Tracking) and a number of beacon manufacturers (e.g. ELTA, Orolia) are currently developing such ELT(DT) beacons complying with Global Aeronautical Distress Safety System (GADSS) recommendations. Other manufacturers and communication service providers (e.g. FlightAware associated to Aireon) are preparing other solutions.

THE RETURN LINK SERVICE PROVIDES ACKNOWLEDGEMENT MESSAGES TO DISTRESS BEACONS EQUIPPED WITH A GALILEO RECEIVER.

5.2.4.2.1 International Regulation

The ICAO GADSS ConOps (v6.0, 07/06/2017) requires that: "The Autonomous Distress Tracking (ADT) function will be used to identify the location of an aircraft in distress with the aim of establishing, to a reasonable extent, the location of an accident site within a 6 NM radius." (section 3.2.1, page 14).

Post flight localization and recovery function' (section 3.3.1, page 16) states: "When an accident occurs …. Accurate aircraft position information (1 NM or better) is provided through the Post Flight Localization function by means of ELT and/or homing signals to guide SAR services on site."

5.2.4.2.1 European Regulation

The applicable regulation is the Commission Regulation (EU) 2015/2338. In particular: CAT.GEN.MPA.210 Location of an aircraft in distress.

It is expected that in a future release of EASA AIR OPS Part ORO the requirements for location of an aircraft in distress will require greater accuracy.

5.2.4.3 RETURN LINK SERVICE

COSPAS-SARSAT is deploying a new MEOSAR system based on the use of search and rescue transponders on board new Galileo, GLONASS and GPS satellites, along with a new ground segment. This new MEOSAR system will significantly improve the timeliness and accuracy of alerts provided by ELTs and allow for new services to be provided.

The SAR/Galileo Service, with its Forward Link Service (FLS) is an integral part of the future MEOSAR system and ensures the detection and localization of the ELT beacon distress signals through the relay of these signals by the Search and Rescue repeaters on board the Galileo satellites, their reception by the ground stations called MEOLUTs and alerts transmission to the Mission Control Centers.

In addition, the SAR/Galileo Service will also introduce a new Search and Rescue function, called the Return Link Service (RLS), which provides **acknowledgment messages** to distress beacons equipped with a Galileo receiver, through the Galileo L1 signal. The RLS may also offer the possibility to **remotely activate the ELT beacon.**

Therefore, the RLS will offer the possibility:

- to improve the search and rescue phase by informing the person in distress that the distress message has been received, or
- to remotely activate the ELT (under research). This link will enable the ELT to be triggered from the ground, by a third party having access to the Return Link Service Provider, and send the aircraft position upon request from the relevant aviation authorities facing a non-cooperative aircraft with loss of radar position and/or VHF communications.

5.2.4.3.1 International Regulation

The international standards on RLS are being developed by COSPAS/SARSAT:

https://www.cospas-sarsat.int/en/documents-pro/system-documents

The specification for 406 MHz beacons already includes a Return Link Service Location protocol. COSPAS-SARSAT adds the following note to this protocol:

"By decision of the Cospas-Sarsat Council at its Fifty-fourth Session, these protocols will be effective as of 1 January 2017, as a target, subject to further review and consideration."

Position data may be provided by an external or internal navigation device and encoded with different resolutions (up to 4 seconds Lat, Long).

5.2.4.3.1 European regulation

The EUROCAE WG-98 "Aircraft Emergency Locator Transmitters" is in charge of developing the MASPS for ELT Return Link Service.

WG-98 has developed the MASPS ED-237 for Criteria to Detect In-flight Aircraft Distress Events to Trigger Transmission of Flight Information.

5.2.5 DRONES

5.2.5.1 REGULATORY REQUIREMENTS

EASA has proposed 3 categories for drones: Open, Specific and Certified. The big RPAS – most likely under Certified category - are expected to integrate non-segregated airspace as manned aircraft flying under instrument flight rules. They will be considered as such, and will require the type of performances, equipment and capabilities. The RPAS in Open and Specific category on the other hand are expected to be mass produced, and might not be able to comply with manned aviation standards and certifications. EASA has proposed a basic regulatory framework for the operation of drones in those categories (NPA2017-05). It will require geo-fencing functionalities, electronic identification and CE marking as mandatory for most RPAS. AMC are still to be developed, and a significant role for GNSS is expected, particularly for the geo-fencing applications. Simultaneously the term U-space is commonly being used. It consist of the ATM framework, focussed on RPAS, knowing that they will fly mostly low-level operations. On the security aspect, it is expected that Galileo OS NMA could bring many benefits, however, specific applications and services still need to be defined.

5.2.5.1.1 National and International Regulation

This section provides an overview of key regulations related to UAS for countries in the EU. A few countries outside the EU, with developed UAS markets, have also been included for comparison (Switzerland, Australia, Canada, South Africa and USA).

The table above shows that the regulations related to UAS applications do vary from country to country and there is a lot of scope to make regulations more consistent throughout Europe.

An area that differs significantly between countries is the requirements for BVLOS. In Europe, the policies chosen by countries can be simplified into 4 different categories:

- It is possible to fly BVLOS when required
- Permission is required to fly BVLOS
- Segregated Airspace is required for BVLOS (Segregated airspace means that only one operator can fly in it. It usually means that it is reserved for military use but it can also be reserved by UAS pilots)
- BVLOS operations are not permitted

Although most UAS users would encourage regulators to relax BVLOS laws, allowing UAS pilots to fly BVLOS will

Table 5: Comparison of global regulations

Compatibility with UAS Applications	Country	Weight Limit	BVLOS
Application Friendly	France	150 kg	Yes
	Italy	150 kg	Yes
	Spain	150 kg	If <2kg
Permission based	Belgium	150 kg	Need permission
	Austria	150 kg	Need permission
	Croatia	150 kg	Need permission
	Lithuania	25 kg	Need permission
Segregated Airspace	Czech Republic	150 kg	Segregated Airspace
	Finland	150 kg	Segregated Airspace
	Sweden	150 kg	Segregated Airspace
	UK	150 kg	Segregated Airspace
	Romania	150 kg	Segregated Airspace
	Germany	25 kg	Segregated Airspace
	Poland	150 kg	Segregated Airspace
Most Constrained	Ireland	150 kg	No [2]
	Netherlands	150 kg	No
	Malta	150 kg	Unclear
	Latvia	20 kg	Unclear
	Denmark	150 kg	Unclear
	Slovenia	150 kg	Unclear
No RPAS regulations	Greece	Unclear	Unclear
	Hungary	150 kg	Unclear
			Bulgaria, Cyprus, Estonia,
Rest of the World	Switzerland	150 kg	Need permission
	Australia	No limit	Need permission
	Canada	No limit	Need permission
	South Africa	20 kg	Unclear
	USA [3]	25 kg	No

[1] Authorisation other than pilot or aircraft certificate
[2] Not until Detect and Avoid (also known as Sense and Avoid) is more developed
[3] It is possible to apply for exemptions to FAA drone regulations under section 333

Sources: European Aviation Safety Agency (EASA), EUROCONTROL, Joint Authorities for Rulemaking on Unmanned Systems (JARUS), Ministries of Transport, National Aviation Authorities (NAA)

Height Limit	Lateral Distance	VLOS	License [1]
150m	1000m	Yes	If > 25kg
150m	VLOS up to 500m	Yes	If >25 kg
120m if <25kg	500m	Yes	No
120m	VLOS	Yes	Yes
150m	500m	Yes	Yes
No Limit	VLOS up to 500m	Yes	Prior Learning
61m	1000m	Yes	Yes
100-300m	VLOS up to 500m	Yes	Yes
No Limit	VLOS	Yes	No
120m	VLOS	Yes	If >7kg
120m	VLOS up to 500m	Yes	Yes
130m	VLOS up to 500m	Yes	No
100m	VLOS	Yes	If > 5kg
Unclear	Unclear	Yes	Prior Learning
120m if <20kg	500m if <20kg	Yes	No
120m	500m	Yes	Yes
122m	150m	Yes	Medical Decleration
120m	500m	Yes	Unclear
100m	VLOS	Unclear	If >7kg
Unclear	Unclear	Yes	Yes
Unclear	Unclear	Need permission	Unclear
Unclear	Unclear	Need permission	Unclear
Luxemborg, Portugal and Slovakia have no RPAS regulations			
No Limit	VLOS	Yes	Prior Learning
122m	VLOS	Yes	Yes
No Limit	No Limit	Yes	If > 2kg
122m	VLOS up to 500m	Yes	No
122m	VLOS	Yes	Yes

increase the potential risks. For example, if the UAS loses connection whilst it is flying BVLOS, there is a high chance that it may crash-land, causing damage to a by-stander or property. Regulations on flying BVLOS is an area that will have to be carefully regulated to allow uptake for agriculture and surveying applications and also ensure that the relaxed regulations do not increase the potential risks from UASs.

The regulations for height and lateral limits do also vary in the countries around Europe. France and Lithuania are the most liberal countries for lateral limits, allowing UASs to fly up to 1 000 m laterally from the user. Most other countries in Europe's policy on lateral distance is limited to VLOS up to 500 m (or equivalent). This compares to Canada, which has no limit on the lateral distance UASs can fly from the pilot. The regulations for how high the UASs can fly also vary significantly throughout Europe. In Switzerland, Croatia and Finland there is no limit to how high the UASs can be flown. Most other countries in Europe have vertical limits between 100-150 m, with some as low as 61 m in Lithuania.

EGNOS AND GALILEO ARE FUNDAMENTAL FOR ROBUST NAVIGATION AND, AS SUCH, CAN SUPPORT SAFE DRONE OPERATIONS.

The regulations for the maximum take-off weight and VLOS are fairly consistent throughout Europe. All countries listed have a maximum take-off limit of 150 kg, except Germany and Lithuania, which are limited to 25 kg and Latvia which is limited to 20 kg.

In summary, UAS regulations do vary throughout Europe. In particular, an important area that policies differ from each other in is whether UASs should be able to fly BVLOS. Regulations for other limits, such as; lateral, vertical and weight, are more consistent. But there is still plenty of opportunity to harmonise the regulations across all member states.

5.2.5.1.2 European Regulation

The recently published SESAR drone Outlook Study demonstrated clearly the growth that is anticipated from the inclusion of drones within the airspace – especially in the low-level operations. The increase of drones and the number of annual movements will increase not only the density of the airspace, but also the exposure to persons on the ground and persons in the air as passengers of CAT.

In parallel with the advances being made by NASA with the UAS Traffic Management (UTM) solution, SESAR has been mandated by the European Commission to look at the U-SPACE – a solution that will be able to handle drones within the Very Low Level (VLL) airspace.

However, the introduction of drones that integrate with manned aviation, and the high numbers of drones that are anticipated to be operating on a regular basis in the next few years pose a number of questions on the dependency of PVT information which is derived or shared between many different users. Questions to be addressed include:

- Will the increase in operations increase the dependency on GNSS?
- Will increased dependency on GNSS increase the exposure from a safety perspective that will require changes to the performance requirements and/ or the introduction of alternatives that are yet to be deployed?
- Will this increase create the need for automation of ATM and increased dependency with an associated change on the CONOPS and use of GNSS within ATM?
- Will the diversification of constellations improve the situation?
- Will the availability of authentication, such as that provided by Galileo, provide an additional performance requirement and/or enable the increased use of automation of services within a U-SPACE/UTM/ATM environment?

5.2.5.1.3 Standardisation

In EUROCAE, a specific working has been created to gather all the stakeholders of UAS standardisation. The EUROCAE WG105 -Unmanned Aircraft is composed of several subgroups (focus teams) dealing with the following subjects (Focus Areas):

- UAS Traffic Management (UAS)
- Command, Control, Communication (C3)
- Detect and Avoid (DAA)
- Design and Airworthiness Standards
- Specific Operations Risk Assessment (SORA)
- Enhanced RPAS Automation (ERA)

In conjunction with the ICAO, EASA and Eurocontrol activities, the EUROCAE WG105 will produce the necessary guidance and standards for the UAS operations.

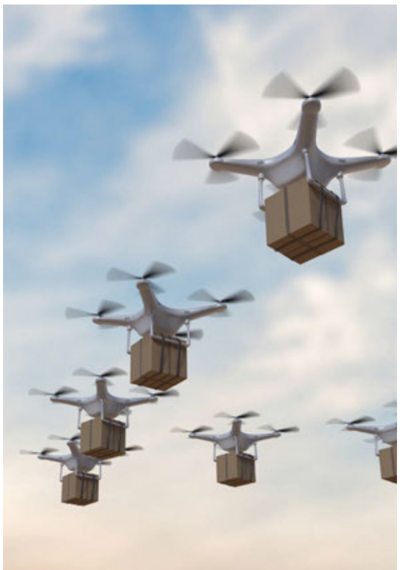
5.2.5.2 NAVIGATION

The advent of new drone applications that enable operations beyond line of sight will depend on ownship navigation capabilities that will be a function of both mission requirements and the airspace in which the drone will operate. Navigation requirements for drones currently presuppose the existence of GNSS and carriage of receivers, either as standalone or integrated with IRS/INS systems, is currently available. However, not all the applications for which drones may be deployed are yet determined as the platform opens up new possibilities for constant exploitation. Therefore whether the performance that is afforded to drones through GNSS is sufficient to support future applications is not yet confirmed. As a minimum, it is expected that performance requirements for drone applications will be in line with aviation navigation requirements.

5.2.5.3 SURVEILLANCE

Integration of surveillance capabilities will be needed for drones as the number of simultaneous operations increase and begin mixing with manned aviation. A move to ADS-B as a means of surveillance would enable interoperability with manned aviation but will be limited by frequency congestion as traffic numbers of both manned and drone traffic increase.

In addition, surveillance applications (such as ADS-B) will be needed to support the self-deconfliction and separation of drones operating in autonomous or automatic modes especially in Beyond Visual Line of Sight (BVLOS) situations.



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

5.2.5.4 GEOFENCING

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

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

The implemented geofence could be a simple cube or a more complex geometric shape which fits more with the airspace in which the drone is operating and could extend for tens of kilometres as a containment area – for example to support power line inspections.

There is currently no standard on the performance expected from geofencing or whether this should vary depending on the airspace or traffic environment in which the drone is operating. However, the requirement for geofencing is already recognised in NPA2017-05. It is expected as part of meeting the expected performances from the NPA that robust integration of navigation and other technology might be needed. This would expect to include EGNOS and Galileo where user authentication may provide added value.

5.2.5.5 DRONE TRAFFIC MANAGEMENT

The concept of managing drones to enable integration with all existing airspace users is the principle of both examples of drone traffic management:

- Unmanned Traffic Management (UTM) proposed by NASA
- U-space proposed by the European Commission.

Of particular relevance in this assessment is U-space. According to the U-Space Blueprint, "U-space is a set of new services and specific procedures designed to support safe, efficient and secure access to airspace for large numbers of drones. These services rely on a high level of digitalisation and automation of functions, whether they are on board the drone itself, or are part of the ground-based environment. U-space provides an enabling framework to support routine drone operations, as well as a clear and effective interface to manned aviation, ATM/ANS service providers and authorities."

The implementation of U-space will result in a number of services that depend on GNSS as a source of PVT and surveillance. The dependence on GNSS as part of this surveillance strategy that enables the seamless integration with other airspace users and protection of third parties on the ground will need to be taken into account. However, it is noted that the full concept for U-space is not yet fully developed and work is still being undertaken by the SESAR Joint Undertaking to define operational concepts and roadmaps to work towards the deployment of U-Space.

5.3 INCREASED ROBUSTNESS AGAINST EXTERNAL INTENTIONAL OR UNINTENTIONAL THREATS/ATTACKS TO THE GNSS NAVIGATION SERVICE

5.3.1 OPERATIONAL BENEFITS OF DFMC GNSS

Source: ICAO NSP 4 / IP6, October 2017

This section presents a qualitative assessment of the mitigations to known GNSS vulnerabilities and the Operational benefits stemming from the additional performance and robustness provided by DFMC GNSS receivers that integrate augmentations (e.g. ARAIM, DFMC GBAS and DFMC SBAS), with respect to current GNSS receivers based on GPS and GLONASS L1.

5.3.1.1 MITIGATIONS TO VULNERABILITIES

Vulnerability	Benefits	Method of Mitigation
Mitigates vulnerability to ionospheric delay and delay variation caused by Space Weather.	Removal of large unpredictable ionosphere delay at expense of additional receiver noise and small residual ionosphere error.	Requires avionics to process two frequencies from GNSS satellites.
Mitigates vulnerability to scintillation caused by Space Weather. (e.g. ionospheric irregularities)	Through increased numbers of GNSS satellites in view.	Requires avionics to process and use ranging signals from dual frequencies and various GNSS constellations.
Mitigates vulnerability to RF Interference in individual frequency bands.	Through avionics processing GNSS signals independently on different frequencies.	Requires avionics to independently process GNSS signals on different frequencies.
Mitigates vulnerability to core constellation fault.	Through increased numbers of GNSS constellations.	Requires avionics to process and use ranging signals from multiple GNSS constellations.
Mitigates dilution of precision due to poor geometry or terrain/obstacle screening.	Through increased numbers of navigation satellites in view.	Requires avionics to process and combine ranging signals from multiple GNSS constellations.

In addition to the mitigations that are derived from the availability of additional constellations and signals, it is also anticipated that the DFMC GNSS receivers and antennas could need to include superior technologies and algorithms that will improve the performance of the new receivers compared to the current generation, particularly with regards to radio frequency interference (RFI).

5.2.5.2 OPERATIONAL BENEFITS

The vulnerability mitigations described in the table above and the capability to offer improved performances enable the operational benefits summarised in the table below.

This is a generic assessment of operational benefits that will be provided by DFMC to meet ATM demands with a 20-year time horizon and will need to be customised by RTCA, EUROCAE and avionics vendors for different user requirements e.g. different types of avionics and airspace users (general aviation, commercial air transport etc.).

- Improved Business Continuity
  DFMC GNSS will improve availability and continuity of Positioning and Time distribution to increase the robustness of CNS and time systems and applications currently based on GPS L1. This will result in a risk reduction benefit in ATM systems and to every flight that improves the business continuity to airspace users.

- Improved 3D Approaches
  Vertical guidance worldwide for all users to allow stabilized geometric approaches providing a reduction in CFIT accidents.
- Innovation
  Facilitate new concepts and applications that in some cases cannot be imagined today. e.g. to support applications being researched within Next Gen, SESAR and CARATS.
- Airborne Equipment
  Rationalisation of airborne equipment.
- Flight Planning
  No need for RAIM prediction under certain conditions.

5.3.2 ROBUST DFMC GNSS SERVICE REQUIREMENTS

It is common knowledge that GNSS signals, nowadays widely used for timing, positioning and navigation applications on critical and non-critical infrastructure, are received on ground with a very low power level. This makes them vulnerable to natural and artificial electromagnetic phenomena that can degrade or disrupt the GNSS service.

The GNSS community is devoting substantial efforts to strengthening GNSS services from unintentional as well as intentional interference. As part of these efforts, Europe is studying and evaluating the addition of authentication features for EGNOS and Galileo.

> WITH EGNOS FULLY OPERATIONAL AND GALILEO IN ITS INITIAL SERVICES, IT IS NECESSARY TO CONTINUOUSLY MAKE IMPROVEMENTS AND PLAN FUTURE EVOLUTIONS.

5.4 CONCLUSIONS

With EGNOS fully operational and Galileo in its Initial services, it is necessary to continuously improve the services and plan future evolutions accordingly. A key driver for improvements and evolutions are user needs. For this purposes, this report has been developed to provide an overview of GNSS market trends in the four main aviation applications using GNSS: navigation, surveillance, aircraft tracking and drones; to outline the current and future GNSS user needs for Civil aviation applications.

EGNOS is a key technology to respond to the users' needs for navigation, benefiting not only to commercial, regional and business users, but also general aviation and VFR users, helicopter operations. With the increasing implementation of RNP approaches and EGNOS-capable fleet, the need for increased coverage area for all EU and continuity is demanded. New opportunities are coming into the picture, such as RNP APCH down to LPV to non-instrument runways, which is an opportunity for safer approaches to an additional 2000 airports in Europe. GBAS down to CATII/III will be possible with Galileo. The trend to combine GNSS with other technologies such as Enhanced Vision Systems and Synthetic Vision Systems is increasing. While EU mandates for ADS-B do not require SBAS, airspace users report increased interest in combining upgrades for navigation and surveillance applications leveraging SBAS and look forward to the possibilitites opened by multiconstellation and multifrequency.

Regarding Search & Rescue and autonomous aircraft distress tracking, Galileo provides a numerous benefits to aviation through its service Search and Rescue Service, in particular with its Return Link Service capability contributing to COSPAS-SARSAT. The development of beacons integrating Galileo RLS is progressing and led by major EU manufacturers, who are also exploring advanced uses, such as automatic triggering of ELT and remote activation from the ground, opening new opportunitites for search and rescue operations.

Finally, there is a growing demand for drone operations. EGNOS and Galileo are fundamental for robust navigation, can contribute to the geoawareness, robust navigation and support safe drone operations. Galileo is expected to have superior performance in challenging environments, facilitating operations in for example urban canyons. Considering the existing system and operational environment and given the early stage of regulations and RPAS standards, work is ongoing to define a common set of requirements on positioning, navigation and surveillance for drones at the moment. Follow-up discussions on user needs and requirements for drone operations related to GNSS are fundamental.

06 USER REQUIREMENTS SPECIFICATION

6.1 PBN SYSTEM REQUIREMENTS SPECIFICATION

6.1.1 REQUIREMENTS FOR RNAV 10 AND RNP 4 APPLICABLE TO EN-ROUTE OPERATIONS

Table 6: GNSS navigation requirements for RNAV 10 and RNP 4

Id	Description	Type	Source
GSA-MKD-USR-REQ-AVI-0010	The PBN solution shall enable a minimum horizontal accuracy (95%) of 2 NM. (NSE 2σ)	Performance (Horizontal Accuracy)	ICAO Annex 10 ICAO PBN Manual RTCA and EUROCAE GNSS receiver MOPS
GSA-MKD-USR-REQ-AVI-0020	The PBN solution shall provide an alert within 5mn if the Horizontal Protection Level computed by the system exceeds the Horizontal Alarm Limit of 4 NM in Oceanic Airspace and of 2 NM in Continental Airspace.	Performance (Horizontal Alarm Limit and Time to Alert)	
GSA-MKD-USR-REQ-AVI-0030	The PBN solution shall ensure an Integrity performance of $1\text{-}1 \times 10^{-7}$ per hour or better.	Performance (Integrity)	
GSA-MKD-USR-REQ-AVI-0040	The PBN solution shall provide an availability of 0.99 (99%) to 0.99999 (99.999%) of the time.	Performance (availability)	
GSA-MKD-USR-REQ-AVI-0050	The PBN solution shall provide a continuity performance of $1\text{-}1 \times 10^{-4}$ to $1\text{-}1 \times 10^{-8}$ per hour or better.	Performance (continuity)	

6.1.2 REQUIREMENTS FOR RNAV 5 APPLICABLE TO EN-ROUTE AND TERMINAL OPERATIONS

Table 7: GNSS navigation requirements for RNAV 5

Id	Description	Type	Source
GSA-MKD-USR-REQ-AVI-0060	The PBN solution shall enable a minimum horizontal accuracy (95%) of 0.4 NM	Performance (Horizontal Accuracy)	ICAO Annex 10 ICAO PBN Manual RTCA and EUROCAE GNSS receiver MOPS
GSA-MKD-USR-REQ-AVI-0070	The PBN solution shall provide an alert within 15 sec if the Horizontal Protection Level computed by the system exceeds the Horizontal Alarm Limit of 1 NM.	Performance (Horizontal Alarm Limit and Time to Alert)	
GSA-MKD-USR-REQ-AVI-0080	The PBN solution shall ensure an integrity performance of $1\text{-}1 \times 10^{-7}$ per hour or better.	Performance (Integrity)	
GSA-MKD-USR-REQ-AVI-0090	The PBN solution shall provide an availability of 0.99 to 0.99999 of the time.	Performance (availability)	
GSA-MKD-USR-REQ-AVI-0100	The PBN solution shall provide a continuity performance of $1\text{-}1 \times 10^{-4}$ to $1\text{-}1 \times 10^{-8}$/h or better.	Performance (continuity	

6.1.3 REQUIREMENTS FOR RNP 1 AND 2, RNAV 1 AND 2 APPLICABLE TO EN-ROUTE, TERMINAL AND DEPARTURE OPERATIONS

Table 8: GNSS navigation requirements for RNAV 1, RNAV 2 and RNP1, RNP 2

Id	Description	Type	Source
GSA-MKD-USR-REQ-AVI-0110	The PBN solution shall enable a minimum horizontal accuracy (95%) of 0.4 NM in Enroute and arrival route (STAR) and 220 m in departure (SID).	Performance (Horizontal Accuracy)	ICAO Annex 10 ICAO PBN Manual RTCA and EUROCAE GNSS receiver MOPS
GSA-MKD-USR-REQ-AVI-0120	The PBN solution shall provide an alert within 10 sec if the Horizontal Protection Level computed by the system exceeds the Horizontal Alarm Limit of 1 NM in en-route and STAR, and of 0.3 NM in SID.	Performance (Horizontal Alarm Limit and Time to Alert)	
GSA-MKD-USR-REQ-AVI-0130	The PBN solution shall ensure an integrity performance of 1-1x10^{-7} per hour or better.	Performance (Integrity)	
GSA-MKD-USR-REQ-AVI-0140	The PBN solution shall provide an availability of 0.99 to 0.99999 of the time.	Performance (availability)	
GSA-MKD-USR-REQ-AVI-0150	The PBN solution shall provide a continuity performance of 1-1x10^{-4} to 1-1x10^{-8}/h or better.	Performance (continuity)	

6.1.4 REQUIREMENTS FOR RNP APCH (LNAV) APPLICABLE TO NPA OPERATIONS

Table 9: GNSS navigation requirements for RNP APCH (LNAV)

Id	Description	Type	Source
GSA-MKD-USR-REQ-AVI-0160	The PBN solution shall enable a minimum horizontal accuracy (95%) of 220 m.	Performance (Horizontal Accuracy)	ICAO Annex 10 ICAO PBN Manual RTCA and EUROCAE GNSS receiver MOPS
GSA-MKD-USR-REQ-AVI-0170	The PBN solution shall provide an alert within 10 sec if the Horizontal Protection Level computed by the system exceeds the Horizontal Alarm Limit of 0.3 NM.	Performance (Horizontal Alarm Limit and Time to Alert)	
GSA-MKD-USR-REQ-AVI-0180	The PBN solution shall ensure an Integrity performance of 1-1x10^{-7} per hour or better.	Performance (Integrity)	
GSA-MKD-USR-REQ-AVI-0190	The PBN solution shall provide an availability of 0.99 to 0.99999 of the time.	Performance (availability)	
GSA-MKD-USR-REQ-AVI-0200	The PBN solution shall provide a continuity performance of 1-1x10^{-4} to 1-1x10^{-8}/h or better.	Performance (continuity)	

6.1.5 REQUIREMENTS FOR RNP APCH (LNAV) APPLICABLE TO NPA OPERATIONS

Table10: GNSS navigation requirements for RNP APCH (BARO-VNAV)

Id	Description	Type	Source
GSA-MKD-USR-REQ-AVI-0210	The PBN solution shall enable a minimum horizontal accuracy (95%) of 220 m.	Performance (Horizontal Accuracy)	ICAO Doc 9849 "GNSS Manual", page 27, Note 3; ICAO Doc 9613 "PBN Manual", II-C-5-1, Chapter 5, Section A - RNP APCH OPERATIONS DOWN TO LNAV AND LNAV/VNAV MINIMA ICAO Annex 10 ICAO PBN Manual RTCA and EUROCAE GNSS receiver MOPS
GSA-MKD-USR-REQ-AVI-0230	The PBN solution shall provide an alert within 10 sec if the Horizontal Protection Level computed by the system exceeds the Horizontal Alarm Limit of 40 m.	Performance (Horizontal Alarm Limit and Time to Alert)	
GSA-MKD-USR-REQ-AVI-0250	The PBN solution shall ensure an Integrity performance of $1-1x10^{-7}$ per hour or better.	Performance (Integrity)	
GSA-MKD-USR-REQ-AVI-0260	The PBN solution shall provide an availability of 0.99 to 0.99999 of the time.	Performance (availability)	
GSA-MKD-USR-REQ-AVI-0270	The PBN solution shall provide a continuity performance of $1-1x10^{-4}$ to $1-1x10^{-8}$/h or better (considering the new PBN regulation that leads to the whole fleet being equipped, an appropriate performance figure should be met to ensure safe operations)	Performance (continuity)	

6.1.6 REQUIREMENTS FOR RNP APCH BARO-VNAV APPLICABLE TO APV OPERATIONS

Table11: GNSS navigation requirements for RNP APCH (LPV)

Id	Description	Type	Source
GSA-MKD-USR-REQ-AVI-0280	The PBN solution shall enable a minimum horizontal accuracy (95%) of 16 m.	Performance (Horizontal Accuracy)	ICAO Annex 10 ICAO PBN Manual RTCA and EUROCAE GNSS receiver MOPS
GSA-MKD-USR-REQ-AVI-0290	The PBN solution shall enable a minimum vertical accuracy (95%) of 20 m.	Performance (Vertical Accuracy)	
GSA-MKD-USR-REQ-AVI-0300	The PBN solution shall provide an alert within 10 sec if the Horizontal Protection Level computed by the system exceeds the Horizontal Alarm Limit of 40 m.	Performance (Horizontal Alarm Limit and Time to Alert)	
GSA-MKD-USR-REQ-AVI-0310	The PBN solution shall provide an alert within 10 sec if the Vertical Protection Level computed by the system exceeds the Vertical Alarm Limit of 50 m.	Performance (Vertical Alarm Limit and Time to Alert)	
GSA-MKD-USR-REQ-AVI-0320	The PBN solution shall ensure an Integrity performance of $1-2x10^{-7}$ in any approach or better.	Performance (Integrity)	
GSA-MKD-USR-REQ-AVI-0330	The PBN solution shall provide an availability of 0.99 to 0.99999 of the time.	Performance (availability)	
GSA-MKD-USR-REQ-AVI-0340	The PBN solution shall provide a continuity performance of $1-8x10^{-6}$ per 15 sec or better.	Performance (continuity)	

6.1.7 REQUIREMENTS FOR RNP AR APCH APPLICABLE TO APV OPERATIONS

Table12: GNSS navigation requirements for RNP APCH (BARO-VNAV)

Id	Description	Type	Source
GSA-MKD-USR-REQ-AVI-0420	The PBN solution shall enable a minimum horizontal accuracy (95%) of 16 m. Note: RNP AR APCH is flown with GPS/ABAS & barometric altimetry down to LNAV/VNAV minima according to EASA AMC 20-26.	Performance (Horizontal Accuracy)	ICAO Annex 10 ICAO PBN Manual RTCA and EUROCAE GNSS receiver MOPS
GSA-MKD-USR-REQ-AVI-0440	The PBN solution shall provide an alert within 10 s if the Horizontal Protection Level (HPL) computed by the system exceeds the Horizontal Alarm Limit (HAL) of 0.3 NM.	Performance (Horizontal Alarm Limit and Time to Alert)	
GSA-MKD-USR-REQ-AVI-0460	The PBN solution shall ensure an Integrity performance of $1\text{-}2\text{x}10^{-7}$ per hour or better.	Performance (Integrity)	
GSA-MKD-USR-REQ-AVI-0470	The PBN solution shall provide an availability of 0.99 (99%) to 0.99999 (99.999%) of the time.	Performance (availability)	
GSA-MKD-USR-REQ-AVI-0480	The PBN solution shall provide a continuity performance of $1\text{-}1\text{x}10^{-4}$ 1 to 1 - $1\text{x}10^{-8}$/h or better (considering the new PBN regulation that leads to the whole fleet being equipped, an appropriate performance figure should be met to ensure safe operations).	Performance (continuity)	

Note: Hybridisation with other sensors (e.g. Inertial navigation systems) might be required to ensure extraction of RNP AR

6.1.8 REQUIREMENTS FOR RNP APCH APPLICABLE TO LPV200 OPERATIONS

Table13: GNSS navigation requirements for RNP APCH applicable to LPV200 operations

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

6.1.9 REQUIREMENTS FOR PA CAT I APPLICABLE TO PRECISION APPROACH

Table14: GNSS navigation requirements for Precision Approach Cat I

Id	Description	Type	Source
GSA-MKD-USR-REQ-AVI-0490	The nav. solution shall enable a minimum horizontal accuracy (HNSE, 95%) of 16 m.	Performance (Horizontal Accuracy)	ICAO Annex 10 ICAO Annex 10, Table 3.7.2.4-1 ICAO PBN Manual RTCA and EUROCAE GNSS receiver MOPS
GSA-MKD-USR-REQ-AVI-0500	The nav. solution shall enable a minimum vertical accuracy (VNSE, 95%) of 4 m.	Performance (Vertical Accuracy)	
GSA-MKD-USR-REQ-AVI-0510	The nav. solution shall provide an alert within 6 s if the HPL computed by the system exceeds the HAL of 40 m.	Performance (Horizontal Alarm Limit and Time to Alert)	
GSA-MKD-USR-REQ-AVI-0520	The nav. solution shall provide an alert within 6 s if the VPL computed by the system exceeds the VAL of 10 m. (CAT I Autoland enabled)	Performance (Vertical Alarm Limit and Time to Alert)	
GSA-MKD-USR-REQ-AVI-0530	The nav. solution shall ensure an Integrity performance of 1 - $2x10^{-7}$ in any approach (150 s) or better.	Performance (Integrity)	
GSA-MKD-USR-REQ-AVI-0540	The nav. solution shall provide an availability of 0.99 to 0.99999 of the time.	Performance (availability)	
GSA-MKD-USR-REQ-AVI-0550	The nav. solution shall provide a continuity performance of 1 - $8x10^{-6}$ per 15 s or better.	Performance (continuity)	

In addition, users requested improved EGNOS service coverage for EU-28 with LPV and LPV200 service and that EGNOS continuity requirement (for NPA service level, APV-I service level and LPV-200 service level) is compliant with ICAO Annex 10.

6.2 ADS-B SYSTEM REQUIREMENTS

Note 1: Source Integrity Level (SIL) is introduced in DO-260B/ ED 12A as the probability of the reported horizontal position exceeding the integrity containment radius (RC) without alerting, assuming no avionics fault. It was previously defined as "Surveillance Integrity Level" in DO-260A.

Note 2: the System Design Assurance (SDA) is the probability of avionics fault causing the reported horizontal position to exceed the Integrity Containment Radius (RC) without alerting.

6.2.1 ADS-B NON RADAR AIRSPACE (NRA 5 NM SEPARATION)

Table15: ADS-B requirements in Non-Radar Airspace (NRA 5 NM separation)

Id	Description	Type	Source
GSA-MKD-USR-REQ-AVI-0620	The system shall provide a minimum horizontal accuracy of 0.5 NM.	Performance (Horizontal accuracy)	EASA AMC 20-24 EASA CS-ACNS FAA AC 20-165A EUROCAE ED 126 RTCA DO 303
GSA-MKD-USR-REQ-AVI-0630	The system shall provide an alert within 10 sec when the computed HPL exceeds the Horizontal Alarm Limit of 2 NM.	Performance (Integrity)	
GSA-MKD-USR-REQ-AVI-0640	The system shall provide an integrity risk (SDA) of $1x10^{-5}$/ hour or lower.	Performance (Integrity)	
GSA-MKD-USR-REQ-AVI-0650	The system shall provide a continuity of 1 - $2x10^{-4}$ per hour or better.	Performance (Continuity)	

6.2.2 ADS-B NON RADAR AIRSPACE (NRA 3 NM SEPARATION)

Table16: ADS-B requirements in Non-Radar Airspace (NRA 3 NM separation)

Id	Description	Type	Source
GSA-MKD-USR-REQ-AVI-0660	The system shall provide a minimum horizontal accuracy of 0.3 NM.	Performance (Horizontal accuracy)	FAA AC 20-165A EUROCAE ED 126 and ED 102A RTCA DO 303 and DO 260B
GSA-MKD-USR-REQ-AVI-0670	The system shall provide an alert within 10 sec when the computed HPL exceeds the Horizontal Alarm Limit of 1 NM.	Performance (Integrity)	
GSA-MKD-USR-REQ-AVI-0680	The system shall provide an integrity risk (SDA) of $1x10^{-5}$/ hour or lower.	Performance (Integrity)	
GSA-MKD-USR-REQ-AVI-0690	The system shall provide a continuity of 1 - $2x10^{-4}$ per hour or better.	Performance (Continuity)	

6.2.3 ADS-B RADAR AIRSPACE (RAD 5 NM SEPARATION)

Table 17: ADS-B requirements in Radar Airspace (RAD 5 NM separation)

Id	Description	Type	Source
GSA-MKD-USR-REQ-AVI-0700	The system shall provide a minimum horizontal accuracy of 0.1 NM (EU) – 0.05 NM (US).	Performance (Horizontal accuracy)	EASA CS ACNS FAA AC 20-165A EUROCAE ED 126 and ED 102A RTCA DO 303 and DO 260B
GSA-MKD-USR-REQ-AVI-0710	The system shall implement a Horizontal Alarm Limit of 1 NM (EU) – 0.2 NM (US).	Performance (Integrity)	
GSA-MKD-USR-REQ-AVI-0720	The system shall provide an integrity risk (SDA) of $1x10^{-5}$/ hour or lower.	Performance (Integrity)	
GSA-MKD-USR-REQ-AVI-0730	The system shall provide a Source Integrity Level (SIL) of $1x10^{-7}$/hour or lower.	Performance (Integrity)	
GSA-MKD-USR-REQ-AVI-0740	The system shall provide a velocity accuracy of 10 m/s	Performance (Velocity accuracy)	

6.2.4 ADS-B RADAR AIRSPACE (RAD 3 NM SEPARATION)

Table 18: ADS-B requirements in Radar Airspace (RAD 3 NM separation)

Id	Description	Type	Source
GSA-MKD-USR-REQ-AVI-0750	The system shall provide a minimum horizontal accuracy of 0.1 NM (EU) – 0.05 NM (US).	Performance (Horizontal accuracy)	EASA CS ACNS FAA AC 20-165A EUROCAE ED 126 and ED 102A RTCA DO 303 and DO 260B
GSA-MKD-USR-REQ-AVI-0760	The system shall implement a Horizontal Alarm Limit of 0.6 NM (EU) – 0.1 NM (US).	Performance (Integrity)	
GSA-MKD-USR-REQ-AVI-0770	The system shall provide an integrity risk (SDA) of $1x10^{-5}$ 1x our or lower.	Performance (Integrity)	
GSA-MKD-USR-REQ-AVI-0780	The system shall provide a Source Integrity Level (SIL) of $1x10^{-7}$/hour or lower.	Performance (Integrity)	
GSA-MKD-USR-REQ-AVI-0790	The system shall provide a velocity accuracy of 10 m/s	Performance (Velocity accuracy)	

6.2.5 ADS-B RADAR AIRSPACE (RAD < 2.5 NM SEPARATION)

Table 19: ADS-B requirements in Radar Airspace (RAD <2.5 NM separation)

Id	Description	Type	Source
GSA-MKD-USR-REQ-AVI-0800	The system shall provide a minimum horizontal accuracy of 171 m.	Performance (Horizontal accuracy)	EUROCAE ED 161 RTCA DO 318
GSA-MKD-USR-REQ-AVI-0810	The system shall implement a Horizontal Alarm Limit of 0.2 NM.	Performance (Integrity)	
GSA-MKD-USR-REQ-AVI-0820	The system shall provide an integrity risk (SDA) of $1x10^{-5}$ 1x our or lower.	Performance (Integrity)	
GSA-MKD-USR-REQ-AVI-0830	The system shall provide a Source Integrity Level (SIL) of $1x10^{-7}$ 1x our or lower.	Performance (Integrity)	

6.2.6 ADS-B RADAR AIRSPACE (INDEPENDENT AND PARALLEL APPROACH)

Table 20: ADS-B requirements in Radar Airspace (Independent and parallel approach)

Id	Description	Type	Source
GSA-MKD-USR-REQ-AVI-0840	The system shall provide a minimum horizontal accuracy of 121 m.	Performance (Horizontal accuracy)	EUROCAE ED 161 RTCA DO 318
GSA-MKD-USR-REQ-AVI-0850	The system shall implement a Horizontal Alarm Limit of 0.2 NM.	Performance (Integrity)	
GSA-MKD-USR-REQ-AVI-0860	The system shall provide an integrity risk (SDA) of $1x10^{-5}$ 1x our or lower.	Performance (Integrity)	

6.2.7 ADS-B AIRPORT (APT)

Table 21: ADS-B Airport requirements (APT)

Id	Description	Type	Source
GSA-MKD-USR-REQ-AVI-0870	The system shall provide a minimum horizontal accuracy of 10 m.	Performance (Horizontal accuracy)	EUROCAE ED 163
GSA-MKD-USR-REQ-AVI-0880	The system shall implement a Horizontal Alarm Limit of 10 m.	Performance (Integrity)	
GSA-MKD-USR-REQ-AVI-0890	The system shall provide an integrity risk (SDA) of $1x10^{-4}$ 1x our or lower.	Performance (Integrity)	
GSA-MKD-USR-REQ-AVI-0900	The system shall provide a velocity accuracy of 1 to 3 m/s.	Performance (Velocity accuracy)	
GSA-MKD-USR-REQ-AVI-0910	The system shall provide a continuity of 1 - $3x10^{-4}$ 1x our or better.	Performance (Continuity)	

6.2.8 ADS-B ATSA – VISUAL SEPARATION IN APPROACH

Table 22: ADS-B ATSA Visual Separation in Approach

Id	Description	Type	Source
GSA-MKD-USR-REQ-AVI-0920	The system shall provide a minimum horizontal accuracy of 0.3 NM.	Performance (Horizontal accuracy)	EUROCAE ED 160 RTCA DO 314
GSA-MKD-USR-REQ-AVI-0930	The system shall implement a Horizontal Alarm Limit of 0.75 NM.	Performance (Integrity)	
GSA-MKD-USR-REQ-AVI-0940	The system shall provide an integrity risk (SDA) of 1x10^{-3} 1x our or lower.	Performance (Integrity)	
GSA-MKD-USR-REQ-AVI-0950	The system shall provide a velocity accuracy of 10 m/s.	Performance (Velocity)	

6.2.9 ADS-B ITP (IN TRAIL PROCEDURE)

Table 23: ADS-B ITP (In Trail Procedure)

Id	Description	Type	Source
GSA-MKD-USR-REQ-AVI-0960	The system shall provide a minimum horizontal accuracy of 0.5 NM.	Performance (Horizontal accuracy)	EUROCAE ED 159 RTCA DO 312
GSA-MKD-USR-REQ-AVI-0970	The system shall implement a Horizontal Alarm Limit of 1 NM.	Performance (Integrity)	
GSA-MKD-USR-REQ-AVI-0980	The system shall provide an integrity risk (SDA) of 1x10^{-5} 1x our or lower.	Performance (Integrity)	
GSA-MKD-USR-REQ-AVI-0990	The system shall provide a velocity accuracy of 10 m/s.	Performance (Velocity accuracy)	

6.2.10 ADS-B ATSA - AIRBORNE SITUATIONAL AWARENESS (AIRB)

Table 24: ADS-B ATSA AIRB– Airborne Situational Awareness

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

6.2.11 ADS-B ATSA SURF – SURFACE TRAFFIC AWARENESS

Table 25: ADS-B ATSA SURF – Surface Traffic Awareness

Id	Description	Type	Source
GSA-MKD-USR-REQ-AVI-1020	The system shall provide a minimum horizontal accuracy of 30 m.	Performance (Horizontal accuracy)	EUROCAE ED 165
GSA-MKD-USR-REQ-AVI-1030	The system shall provide a velocity accuracy of 10 m/s.	Performance (Velocity accuracy)	
GSA-MKD-USR-REQ-AVI-1040	The system shall provide a Source Integrity Level (SIL) of $1x10^{-5}$ 1x our or lower.	Performance (Integrity)	

6.3 AIRCRAFT AUTONOMOUS DISTRESS TRACKING

Table 26: Aircraft tracking and autonomous distress tracking

Id	Description	Type	Source
GSA-MKD-USR-REQ-AVI-1100	C/S First Generation 406Mhz distress beacons ELT (DT) 2D static: accuracy <= 200 m Altitude, static: accuracy <=700 m	Performance (accuracy)	C/S T.001, Issue 4 – Revision 3, June 2018, section 4.5.5.6 ELT(DT) Navigation Device Requirements
	C/S T.007 Annex K Procedure intended to provide guidance on the testing of an ELT(DT) under typical conditions that may be found on an aircraft in order to ensure the correct operation of the GNSS Receiver within the ELT(DT) using a GNSS Simulator.		C/S T.007 – Issue 5 – Rev.2, June 2018 ANNEX K: ELT(DT) ENCODED POSITION DATA UPDATE INTERVAL GNSS SIMULATOR TEST PROCEDURE
GSA-MKD-USR-REQ-AVI-1110	C/S Second Generation 406Mhz distress beacons ELT (DT) • 2D: accuracy <= 30 m, (95%) • Altitude, accuracy <=50 m (95%)	Performance (accuracy)	C/S T.018, Issue 1 – Revision 3, June 2018
GSA-MKD-USR-REQ-AVI-1120	Galileo RLS enabling ELT remote activation from the ground offering the possibility to localize in-flight a non-cooperative aircraft	Functionality	EUROCAE MASPS for Aircraft ELT RLS - work in progress (KOM held in April 2018)
GSA-MKD-USR-REQ-AVI-1130	For ELT(DT)s the value of the repetition period shall be: • 5 seconds + 0.0 / - 0.2 seconds during the first 120 seconds after beacon activation; • 10 seconds + 0.0 / - 0.2 seconds between 120 seconds and 300 seconds after beacon activation; and • after the first 300 seconds after beacon activation until the beacon is deactivated the period shall be randomised around a mean value of 28.5 seconds, so that time intervals between transmissions are randomly distributed on the interval 27.0 to 30.0 seconds.	Performance	C/S T.001, Issue 4 – Revision 2, February 2018

6.4 DRONES

At the moment, it is difficult to define a common set of requirements for drones operations given the multiple operational scenarios and the early stage of regulations and RPAS standards. The RPAS community is working on definition of requriements and standards, also relevant for positioning, navigation and surveillance of drones, and links to the different RPAS categories.

Discussion on user needs and requirements for drones operations related to GNSS was initiated in the first User Consultation Platform and specific information will be added in the next updates of the document.

ANNEX 1 – LIST OF ACRONYMS

ABAS	Airborne-Based Augmentation System
AC	Advisory Circular (FAA)
ACAS	Airborne Collision Avoidance System
ACAC	Arab Civil Aviation Commission
ACARS	Aircraft Communication, Addressing and Reporting System
A-CNS	Airborne Communications, Navigation and Surveillance
ADS-B	Automatic Dependent Surveillance – Broadcast
AEC	Airborne Equipment Class
AFCAC	African Civil Aviation Commission
AIP	Aeronautical Information Publication
AIR OPS	A short cut designation of (EU) No 965/2012
AMC	Acceptable Means of Compliance
AMSS	Aeronautical Mobile Satellite Service
ANSP	Air Navigation Service Provider
AOC	Air Operator Certificate
APV	Approach Procedure with Vertical guidance
ARA	Authority Requirements for Aircrew
ARAIM	Advanced RAIM
ARINC	Aeronautical Radio, Incorporated
A-RNP	Advanced-RNP
ARO	Authority Requirements for Air Operations
ASBU	Aviation System Block Upgrades
ATM	Air Traffic Management
ATSA	Air Traffic Situational Awareness
AWO	All Weather Operations
CofA	Certificate of Airworthiness
CAT	Commercial Air Transport
Cat	Category
CFR	Code of Federal Regulations (US)
CNS	Communication, Navigation and Surveillance
CS	Certification Specifications
CVR	Cockpit Voice Recorder
EASA	European Aviation Safety Agency
ECAC	European Civil Aviation Conference
EFTA	European Free Trade Association
ELT	Emergency Locator Transmitter
EN	European Norm

EUROCAE	European Organisation for Civil Aviation Equipment
ETSO	European Technical Standard Order (EASA)
ESSAR	EUROCONTROL Safety Regulatory Requirements
FAA	Federal Aviation Administration
FAS	Final Approach Segment or "Final Approach Solutions"
FDR	Flight Data Recorder
FIS-B	Flight Information Service – Broadcast
ft	feet
FTE	Flight Technical Error
GA	General Aviation
GADSS	Global Aeronautical Distress Safety System
GAMA	General Aviation Manufacturers Association
GANP	Global Air Navigation Plan (ICAO)
GBAS	Ground-Based Augmentation System
GM	Guidance Material
GMDG	GNSS Monitoring Drafting Group
H-ARAIM	Horizontal ARAIM
HLSC	High-Level Safety Conference
ICAO	International Civil Aviation Organisation
IDE	Instruments Data and Equipment
IEEE	Institute of Electrical and Electronics Engineers
IFR	Instrument Flying Rules
ILS	Instrument Landing System
IR	Implementing Rule
ISA	International Standard Atmosphere
ISM	Integrity Support Message
ITU	International Telecommunication Union
JAA	Joint Aviation Authorities
JARUS	Joint Authorities for Rulemaking on Unmanned Systems
km	Kilometre
LACAC	Latin American Civil Aviation Commission
LPV	Localizer Performance with Vertical guidance
m	meter
DFMC	Multi-Constellation Multi-Frequency
MCTOW	Maximum Certified Take-Off Weight
MSL	Mean Sea Level
NAS	National Airspace (US)
NAC	Navigation Accuracy Category
NACp	Navigation Accuracy Category position
NACv	Navigation Accuracy Category vertical
NBAA	National Aviation Business Association
NCC	Non-commercial operations with complex motor-powered aircraft
NCO	Non-commercial operations with other-than-complex motor-powered aircraft
NIC	Navigation Integrity Category
NM	Nautical Mile

NPA	Non-Precision Approach
NPA	Notice of Proposed Amendment (EASA)
NSP	Navigation System Panel
OCH	Obstacle Clearance Height
OPS	Operations
PANS	Procedure for Air Navigation Services
PBN	Performance-Based Navigation
PDE	Path Definition Error
PLB	Personal Locator Beacon
RAIM	Receiver Autonomous Integrity Monitoring
RC	(Integrity) Containment Radius
RLS	Return Link Service (SAR)
RNAV	aRea NAVigation
RNP	Required Navigation Performance
RPA	Remotely Piloted Aircraft
RNP AR APCH	RNP Authorization Required Approach
RNP-APCH	RNP Approach
RPAS	Remotely Piloted Aircraft System
RTCA	Radio Technical Commission for Aeronautics
SA	Special Authorization
SAR	Search And Rescue
SAE	Society of Automotive Engineers
SARPs	Standards and Recommended Practices
SBAS	Satellite-Based Augmentation System
SDA	System Design Assurance
SERA	Standardised European Rules of the Air
SESAR	Single European Sky ATM Research
SIL	Source Integrity Level (previously Surveillance Integrity Level)
SoL	Safety of Life
SPA	operations requiring specific approvals
SPO	Specialised Operations
SSR	Secondary Surveillance Radar
STC	Supplemental Type Certificate
SWIM	System Wide Information Management
TAWS	Terrain Awareness and Warning System
TC	Type Certificate
TGL	Temporary Guidance Leaflet
TSE	Total System Error
TSO	Technical Standard Order (FAA)
UAT	Universal Access Transceiver
UCP	User Consultation Platform
V-ARAIM	Vertical ARAIM
VFR	Visual Flying Rules

ANNEX 2 – ICAO FOUNDATION PROTOCOLS

ICAO FOUNDATIONS FOR PROVISION OF AIR NAVIGATION SERVICES

The Chicago Convention lays down the obligations of contracting States for what concerns air navigation services (Art 28):

"Each contracting State undertakes, so far as it may find practicable, to:

a) Provide, in its territory, airports, radio services, meteorological services and other air navigation facilities to facilitate international air navigation, in accordance with the standards and practices recommended or established from time to time, pursuant to this Convention;"

Specific to GNSS service provision the ICAO Assembly issued the resolution A32-19 (1998). This resolution also called "Charter on the Rights and Obligations of States relating to GNSS Services" provides precisions on responsibilities and obligations of States with regard to GNSS signals used for air navigation. Indeed Art.28 of the ICAO Convention was initially targeting ground navaids like NDB, VOR, DME and ILS which are usually under State control. Using GNSS for air navigation raised questions to the States willing to use such signals in their airspace without having any control on them.

The ICAO resolution A-32-19 brings the following important precisions:

a) The implementation of GNSS leaves unaffected the responsibility of States under Article 28,...a State using these signals for providing Air Navigation Services remained responsible under Article 28 despite the fact that it did not control such signals.",

b) States shall monitor and record GNSS signals they authorize for use in their airspace.

It should be however noted that the obligation of ANSPs for monitoring and recording of GNSS signals they authorize in their airspace is a decision of their safety oversight Authority (usually the CAA they depend on).

ICAO FOUNDATIONS FOR AIRWORTHINESS CERTIFICATION

Chapter V of the Chicago Convention provides the basis for aircraft certification and personnel licensing. This chapter is supplemented by Annex 8, which details the procedures and the airworthiness codes. For what concerns aircraft certification articles 31 and 33 set the basis for all national (or regional) regulations, including validation of airworthiness certificates issued by another contracting State:

"Article 31: Every aircraft engaged in international navigation shall be provided with a certificate of airworthiness issued or rendered valid by the States in which it is registered."

According to ICAO, an airworthiness certificate is mandatory for international flights. For domestic flights it can be deduced that States apply their own laws, which often repeat the same obligations as those mentioned in the ICAO Convention.

"Article 33: Certificates of airworthiness and certificates of competency and licenses issued or rendered valid by the contracting State in which the aircraft is registered, shall be recognized as valid by the other contracting States, provided that the requirements under which such certificates or licences were issued or rendered valid are equal to or above the minimum standards which may be established from time to time pursuant to this Convention."

The meaning of the term "valid" is important for the international recognition of the aircraft certification. The definition of this term is given in Annex 8 of the Convention which stipulates that rendering an Airworthiness Certificate valid is, for a signatory State of the Convention, the action of considering the Airworthiness Certificate awarded by another signatory State as equivalent to the Airworthiness Certificate it could assign itself.

ICAO FOUNDATIONS FOR OPERATIONAL APPROVAL

In its Articles 5, 6 and 7, the ICAO Convention subjects the commercial transport to the right of States to authorise or not an air operator to perform such activity. In their national laws the contracting States have then subjected the air operators to a regime of transport licence. Thus the technical airworthiness of an aircraft is necessary but not sufficient to perform commercial air transport operations. The aircraft operator shall also fulfil operational requirements that are detailed in the Annex 6 of the ICAO Convention.

ANNEX 3 – EASA CERTIFICATION SPECIFICATIONS

Certification Specifications are referred to and made applicable in articles 18 and 19 of the Basic regulation. EASA developed the following CS of interest:

Table 28: EASA Certification Specifications of interest

CS Ref.	CS Name	Applicability
CS-22	Sailplanes and powered sailplanes	Sailplanes and powered sailplanes
CS-23	Normal, Utility, Aerobatic and Commuter Aeroplanes	Aeroplanes that have a seating configuration, excluding the pilot seat(s), of nine or fewer and a maximum certificated take-off weight of 5 670 kg (12 500 lb) or less. Propeller-driven twin-engine aeroplanes in the commuter category that have a seating configuration, excluding the pilot seat(s), of nineteen or fewer and a maximum certificated take-off weight of 8 618 kg (19 000 lb) or less.
CS-25	Large aeroplanes	Turbine-powered Large Aeroplanes
CS-27	Small Rotorcraft	Rotorcraft with maximum weights of 3 175 kg (7 000 lbs) or less and nine or less passenger seats. Multi-engine rotorcraft may be type certificated as Category A provided the requirements referenced in Appendix C are met.
CS-29	Large Rotorcraft	Large rotorcraft must be certificated in accordance with either the Category A or Category B requirements. A multi-engine rotorcraft may be type-certificated as both Category A and Category B with appropriate and different operating limitations for each category. Rotorcraft with a maximum weight greater than 9 072 kg (20 000 pounds) and 10 or more passenger seats must be type-certificated as Category A rotorcraft. Rotorcraft with a maximum weight greater than 9 072 kg (20 000 pounds) and nine or less passenger seats may be type-certificated as Category B rotorcraft provided the Category A requirements of Subparts C, D, E, and F are met. Rotorcraft with a maximum weight of 9 072 kg (20 000 pounds) or less but with 10 or more passenger seats may be type-certificated as Category B rotorcraft provided the Category A requirements of CS 29.67(a)(2), 29.87, 29.1517, and of Subparts C, D, E, and F are met. Rotorcraft with a maximum weight of 9 072 kg (20 000 pounds) or less and nine or less passenger seats may be type-certificated as Category B rotorcraft.
CS-VLA	Very Light Aeroplanes	Aeroplanes with a single engine (spark or compression-ignition) having not more than two seats, with a Maximum Certificated Take-off Weight of not more than 750 kg and a stalling speed in the landing configuration of not more than 83 km/h (45 knots)(CAS), to be approved for day-VFR only.
CS-VLR	Very Light Rotorcraft	Very light rotorcraft (helicopters) with maximum certified take-off weights not exceeding 600 kg which are of a simple design, are designed to carry not more than two occupants, are not powered by turbine and/or rocket engines and are restricted to VFR day operations.

CS-LSA	Light Sport Aeroplanes	Applicable to Light Sport Aeroplanes to be approved for day-VFR only that meet all of the following criteria: a) A Maximum Take-Off Mass of not more than 600 kg for aeroplanes not intended to be operated on water or 650 kg for aeroplanes intended to be operated on water. b) A maximum stalling speed in the landing configuration (VS0) of no more than 83 km/h (45 knots) CAS at the aircraft's maximum certificated Take-Off Mass and most critical centre of gravity. c) A maximum seating capacity of no more than two persons, including the pilot. d) A single, non-turbine engine fitted with a propeller. e) A non-pressurized cabin.
CS-ETSO	European Technical Standard Orders	Directory of the European Technical Standard Orders applicable to specific equipment, parts or processes used on civil aircraft.
CS-AWO	All Weather Operations	Applicable to aeroplanes, which are capable of automatic landing carried out in association with an Instrument Landing System (ILS), a Microwave Landing System (MLS) or both. In addition, the automatic landing system must meet the requirements of CS 25.132
CS-ACNS	Airborne Communications, Navigation and Surveillance	Applicable to all aircraft for the purpose of compliance with equipage requirements with respect to on-board Communication, Navigation and Surveillance systems.

ANNEX 4 – OVERVIEW OF THE AVIATION GNSS REGULATORY FRAMEWORK

1. INTERNATIONAL ORGANISATIONS

ICAO: International Civil Aviation Organisation is a specialized agency of the United Nations; ICAO's main task is to manage the administration and governance of the Convention on International Civil Aviation (Chicago Convention). The strategic objectives of ICAO are safety, air navigation capacity and efficiency, security and facilitation, economic development of air transport and environmental protection. ICAO has its seat in Montreal and deployed a regional structure over the world:

Table 29: ICAO regions and regional offices

ICAO Region	ICAO Acronym	Regional Office
Africa – Indian Ocean Region	AFI	Dakar (Western and Central Africa) Nairobi (Eastern and Southern Africa)
Asia Region	ASIA	Bangkok
Caribbean Region	CAR	Mexico
European Region	EUR	Paris
Middle East Region	MID	Cairo
North American Region	NAM	Mexico
North Atlantic Region	NAT	Paris
Pacific Region	PAC	Bangkok
South American Region	SAM	Lima

ICAO works with the Convention's 191 participating Member States and industry groups to reach consensus on international civil aviation Standards and Recommended Practices (SARPs) and policies in support of a safe, efficient, secure, economically sustainable and environmentally responsible civil aviation sector. These SARPs and policies are used by ICAO Member States to ensure that their local civil aviation operations and regulations conform to global norms

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

IATA: The International Air Transport Association is the trade association for the world's airlines, representing some 260 airlines or 83% of total world air traffic. IATA supports many areas of aviation activity and helps formulate industry policy on critical aviation issues. IATA also sponsors projects and infrastructure in partnership with ICAO or local bodies to improve flight safety and ATM services in countries or areas with poor institutional/financial means.

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

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

2. EUROPEAN ORGANISATIONS

European Commission: The EC plays a major role in the aviation domain in Europe. It defines the global strategy at economical level, issues regulations related to aviation, notably in the frame of Single European Sky and conducts research in that domain (SESAR). In its regulator role the EC is assisted by EASA and EC Member States. The European Commission's activities in civil aviation fall within the responsibility of the Directorate-General Mobility and Transport.

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

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

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

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

Airlines associations: In Europe the main regional airlines associations are the AEA (Association of European Airlines), the European Regions Airline Association (ERAA) and the European Low Fares Airline Association. All these associations lobby for better traffic conditions and lower air navigation/airport fees. A new association has just been created and is not yet operational, the Airlines for Europe (A4E): this association grouping several major European airlines will also lobby against traffic authorisations given to Middle-East airlines.

3. REGIONAL BODIES

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

- ECAC: European Civil Aviation Conference, created in 1955.
- AFCAC: African Civil Aviation Commission, created in 1969, is a specialised aviation body of the African Union. It comprises 53 Member States.
- ACAC: Arab Civil Aviation Commission, created in 1996, is a specialised aviation body of the Arab League. It comprises 18 Member States.
- LACAC (1973): created in 1973 by 12 Latin America States, this regional aviation body is mostly interested in civil aviation economics rather than technical matters.

4. AVIATION STANDARDISATION ORGANISATIONS

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

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

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

Aviation manufacturers also use engineering standards or guidelines from other standardisation bodies like ARINC and IEEE for equipment or SAE guidelines for development of aircraft systems.

5. ICAO REGULATORY FRAMEWORK

BACKGROUND

Reference	Title	Date
Convention on International Civil Aviation	ICAO Doc 7300/9	Ninth Edition – 2006 with corrigendum Nov 2007 and Dec 2010

Although legally the ICAO can only express "recommendations", the Annexes to the Chicago Convention, also known as SARPs (Standards and Recommended Practices), are in practice considered as technical requirements that ICAO Member States shall implement in their national regulations. In case they do not comply with a specific requirement they shall notify any deviation to the ICAO and reflect this deviation in their Aeronautical Publications (AIP). There are 19 Annexes, not all being of interest for GNSS:

Table 30: ICAO SARPs of interest for GNSS

Annexe No.	Title	Interest for GNSS
1	Personnel Licensing	None - No GNSS specificity
2	Rules of the Air	None - No GNSS specificity
3	Meteorological Services	None - No GNSS specificity
4	Aeronautical Charts	Adoption of WGS-84 as the standard geodetic reference system for international aviation, & Appendix 6 – Aeronautical data quality requirements.
5	Units of Measurement	None – No GNSS specificity
6	Operation of Aircraft	Interest for airlines operating aircraft equipped with GNSS Interest for aircraft SAR equipment
7	Aircraft Nationality and Registration Marks	None - No GNSS specificity
8	Airworthiness of Aircraft	Interest for aircraft equipped with GNSS
9	Facilitation	None - No GNSS specificity
10	Aeronautical Telecommunications	Interest since defining the different GNSS signals in space
11	Air Traffic Services	None - No GNSS specificity but specifies requirements for time provision
12	Search and Rescue	None - No GNSS specificity
13	Aircraft Accident and Incident Investigation	None - No GNSS specificity
14	Aerodromes	Low interest for GNSS (Runway lightings specification for different approach types)
15	Aeronautical Information Services	Appendix 1 describes GNSS elements usable for flight operations.
16	Environmental Protection	None - No GNSS specificity
17	Security	None - No GNSS specificity
18	The Safe Transportation of Dangerous Goods by Air	None - No GNSS specificity
19	Safety management	None - No GNSS specificity

ICAO CONVENTION ANNEX 6 – OPERATION OF AIRCRAFT

Reference	Title	Date
Annex 6 to the Convention on International Civil Aviation	Operation of Aircraft	Tenth Edition, July 2016

Annex 6 to the ICAO Convention "Operation of Aircraft" provides the basis for the approval of international air transport operators. The first volume of this Annex is dedicated to International Commercial Air Transport – Aeroplanes, the second volume being devoted to International General Aviation – Aeroplanes and the third volume to helicopters.

In Part 1, the following sections 4.2 mandates the granting of the Air Operator Certificate (AOC) by the State of the operator and provides the headlines for the compliance demonstration the air operator has to perform to its aviation Authority.

Of interest for the navigation equipment is the requirement to include in the AOC *"The operations specifications associated with the air operator certificate".* Therefore, the operator capacity to fly RNAV or RNP specifications shall be mentioned. To this end Annex 6 clearly references the ICAO Performance-Based Navigation Manual.

Amendment 39 to Annex 6 Part I introduces new definitions for the classification of approaches. The introduction of the performance based navigation concept was not fully consistent with the previous classification of approaches. This new classification:

- Makes approach classification a standard and not only a definition,
- Adjusts definitions and provisions accordingly,
- CAT I, II & III specifications remain intact,
- Introduces Approach Classification Types (A & B),
- Disassociates the type of Navigation System from the Approach Category,
- Removes the terms Non-Precision, APV & Precision from the operation (Performance-based approach),
- The approach classification is not sensor specific, instead it is based on the point from which visual references are required,
- Sets baseline for future operational enhancements like Head-Up display, Enhanced Vision or Synthetic vision systems.
- A clear distinction is made between procedure and operations:
- Procedure is the instrument flight procedure allowing an aircraft to navigate on the final approach down to a given OCH, relying on a given type of navigation infrastructure,
- Operation is the manner in which an aircraft is conducted to operate on a procedure.

The new ICAO classification focusses solely on the operation side and is based on minima and flight method:

- Approach operations are classified according to the designed lowest operating minima of an approach procedure:
    - Type A: Instrument approach operation 250' or above,
    - Type B: Instrument approach operation below 250'.
- Flight method for executing an approach operation:
    - 2D lateral guidance only,
    - 3D lateral guidance and vertical guidance.

Type A operations only require the Non-precision RWY infrastructure and related visual aids while all Type B operations will require a Precision RWY infrastructure and related visual aids.

In the SAR domain, Amendment 39 to Annex 6 Part I introduces requirements for aircraft flight tracking applicable after 8 November 2018.

ICAO CONVENTION ANNEX 8 – AIRWORTHINESS OF AIRCRAFT

Reference	Title	Date
Annex 8 to the Convention on International Civil Aviation	Airworthiness of Aircraft	11th Edition – July 2010 Amendment 103 and 104 up to 2014 published separately

Part I of this Annex is devoted to definitions. Part II mentions the possibility for the State of Registry to apply its own airworthiness code or that of a signatory State for the certification of an aircraft provided that the airworthiness code used complies with standards set in Annex 8. Furthermore, when a State registers an aircraft certified by another signatory State, it can validate all or part of the certification. This exempts the need to follow a new certification procedure in the State of Registry or in the case of a partial validation it alleviates these procedures.

Part II of Annex 8 also contains standards for Type Certificates, production, certificates of airworthiness and addresses the rules for continuing airworthiness.

A Type Certificate (TC) is awarded by aviation regulating bodies to manufacturers after it has been established that the particular design of a civil aircraft, engine, or propeller has fulfilled the regulating bodies' current prevailing airworthiness requirements for the safe conduct of flights under all normally conceivable conditions. TCs are usually issued by the Civil Aviation Authorities of the States where products are designed.

Based on this approved design, each series aircraft shall receive from the Civil Aviation Authority of the State of registry an airworthiness certificate: this is the authorization granted by the Civil Aviation Authority to operate an individual aircraft in its airspace, provided the operator has itself the approved Air Operator Certificate. The Airworthiness Certificate is valid and the aircraft may be operated as long as it is maintained in accordance with the rules issued by the CAA. This corresponds to what is called the "continuing airworthiness" as detailed in Annex 8, Part II, Chapter 4.

Annex 8 **Part III** applies to planes over 5 700 kg for the international transportation of passengers, cargo and mail. These aircraft are at least twin-engine. This part constitutes a qualitative approach to an airworthiness code since it addresses the airframe, propulsion and propellers. The reader is referred to the national airworthiness codes for a detailed and quantitative approach. On-board equipment is addressed very summarily and the reader is referred to Annex 6 (Operations) of the Convention for more details on the requirements in terms of carriage of equipment depending on the aviation regulations.

Part IV applies to helicopters for the international carriage of passengers, cargo or postal mail and mentions the same remarks as for aircraft.

Part V applies to small aeroplanes (mass over 750 Kg and less than 5700 kg).

Part VI and VII respectively apply to engines and propellers.

Annex 8 is thus a qualitative envelope for certification but cannot be considered as a complete airworthiness code. It is complemented by the ICAO Doc 9768 – Airworthiness Manual which contains guidance for States on implementation of their airworthiness oversight system.

Important notice on airworthiness and operational approval

It is important to note that:

- Aircraft airworthiness requirements primarily intend to ensure the global safety of the aircraft operations, the minimum equipment needed to fly and the general rules to be observed for integration of equipment.
- The carriage of specific navigation equipment is not part of airworthiness requirements since subject to the navigation requirements applicable to the airspace the aircraft is intended to fly. It is then part of operational requirements. However, the installation of specific equipment shall comply with general airworthiness requirements.

ICAO CONVENTION ANNEX 10 – AERONAUTICAL TELECOMMUNICATIONS – VOLUME 1

Reference	Title	Date
Annex 10 to the Convention on International Civil Aviation	Aeronautical Telecommunications	6th edition, incorporating Amendments 1-81– July 2010 Amendments 82 to 91 (up to Nov 2014) published separately

This volume of ANNEX 10 provides GNSS systems characteristics (GPS-GLONASS-SBAS-ABAS-GBAS). Galileo and Beidou system characteristics are under elaboration. It also provides signal-in-space performance requirements for different typical air operations as described in the following table.

Table 31: ICAO GNSS signal-in-space performance requirements

Typical Operation	Accuracy horizontal 95%	Accuracy vertical 95%	Integrity	Time-to-alert	Continuity	Availability
En-route	3.7 km (2.0 NM)	N/A	$1 - 1\times10^{-7}$/h	5 min	$1 - 1\times10^{-4}$/h to $1 - 1\times10^{-8}$/h	0.99 to 0.99999
En-route, Terminal	0.74 km (0.4 NM)	N/A	$1 - 1\times10^{-7}$/h	15 s	$1 - 1\times10^{-4}$/h to $1 - 1\times10^{-8}$/h	0.99 to 0.99999
Initial approach, Intermediate approach, Non-precision approach (NPA), Departure	220 m (720 ft)	N/A	$1 - 1\times10^{-7}$/h	10 s	$1 - 1\times10^{-4}$/h to $1 - 1\times10^{-8}$/h	0.99 to 0.99999
Approach operations with vertical guidance (APV-I)	16.0 m (52 ft)	20 m (66 ft)	$1 - 2\times10^{-7}$ in any approach	10 s	$1 - 8\times10^{-6}$ per 15 s	0.99 to 0.99999
Approach operations with vertical guidance (APV-II)	16.0 m (52 ft)	8.0 m (26 ft)	$1 - 2\times10^{-7}$ in any approach	6 s	$1 - 8\times10^{-6}$ per 15 s	0.99 to 0.99999
Category I precision approach	16.0 m (52 ft)	6.0 m to 4.0 m (20 ft to 13 ft)	$1 - 2\times10^{-7}$ in any approach	6 s	$1 - 8\times10^{-6}$ per 15 s	0.99 to 0.99999

The above table is complemented with a lot of notes, in particular documenting the implementation of GNSS service taking into account the operational environment (traffic density, airspace complexity etc.).

The definition of the integrity requirement includes an alert limit against which the requirement can be assessed. For Category I precision approach, a vertical alert limit (VAL) greater than 10 m for a specific system design may only be used if a system-specific safety analysis has been completed. This section of Annex 10 provides alert limits figures for the different air operations:

Table 32: HAL and VAL for typical operations

Typical Operation	Horizontal Alarm Limit	Vertical Alarm Limit
En-route (oceanic/continental low density)	7.4 km (4 NM)	N/A
En-route (continental)	3.7 km (2 NM)	N/A
En-route, Terminal	1.85 km (1 NM)	N/A
NPA	556 m (0.3 NM)	N/A
APV-I	40 m (130 ft)	50 m (164 ft)
APV-II	40 m (130 ft)	20 m (66 ft)
Category I precision approach	40 m (130 ft)	35.0 m to 10.0 m (115 ft to 33 ft)

Resulting from the changes to ICAO PANS-OPS ATM and ICAO Annex 6 introducing a new approach classification, the amendment 88 (effective November 2014) to ICAO Annex 10 introduced a mapping with Annex 6 definitions of approaches:

Table 33: Mapping of approach classification – ICAO Annexes 10 and 6

Performance requirements in support of instrument approach operations		
Annex 10 system performance		**Annex 6 Method – Approach operation category**
Non-precision approach (NPA)		2D – Type A (1)
Approach with vertical guidance (APV)		3D – Type A (2)
Precision approach (PA)	Category I, DH equal or greater than 75 m (250 ft)	3D – Type A (3)
	Category I, DH equal to or greater than 60 m (200 ft) and less than 75 m (250 ft)	3D – Type B – CAT I (3)
	Category II	3D – Type B – CAT II
	Category III	3D – Type B – CAT III
Without vertical guidance. With barometric or SBAS vertical guidance. With ILS, MLS, GBAS or SBAS vertical guidance.		

ICAO CONVENTION ANNEX 14 – AERODROMES

Annex 14 contains Standards and Recommended Practices that prescribe the physical characteristics, obstacle limitation surfaces and visual aids to be provided at aerodromes, as well as certain facilities and technical services normally provided at an aerodrome.

The interest of this Annex for what concerns GNSS lies in the prescription for runway markings and lighting systems necessary to implement GNSS-based approach procedures. This is based on Annex 14 definition of runway-types:

a) *"Non-precision approach runway. A runway served by visual aids and non-visual aid(s) intended for landing operations following an instrument approach operation type A and a visibility not less than 1000 m."*

b) *"Precision approach runway, category I. A runway served by visual aids and non-visual aid(s) intended for landing operations following an instrument approach operation type B with a decision height (DH) not lower than 60 m (200 ft) and either a visibility not less than 800 m or a runway visual range not less than 550 m."*

As a consequence, LPV-200 service level-based operations:

- With DH ≥ 250 ft (Type A instrument approach operation) can be promulgated at both category I precision approach runway-ends and non-precision approach runways.
- With DH < 250 ft (Type B instrument approach operation) can only be promulgated at category I precision approach runway-ends.

OTHER ICAO PUBLICATIONS OF INTEREST FOR GNSS USE

Reference	Title	Date
Performance-based Navigation (PBN) Manual	ICAO Doc 9613	Fourth Edition –2013
Global Navigation Satellite System (GNSS) Manual	ICAO Doc 9849	Second Edition – June 2013 Note: there is an Advance Third Edition – 2017 (unedited)
Aircraft Operations – Volume 1 Flight Procedures	ICAO Doc 8168	5th Edition 2006 with Amendment 7 – Nov 2016
Aircraft Operations – Volume 2 Construction of Visual and Instrument Flight Procedures	ICAO Doc 8168	6th Edition 2014 with amendment 7 – Nov 2016
Procedures for Air Navigation services – ATM	ICAO Doc 4444	15th edition, 2007 with Amendment 6 – Nov 2014

ICAO Doc 9613 – Performance-Based Navigation manual

The first draft of this manual was released in 2003. The current version is dated 2013 (4th Edition). This document and the PBN concept were initially developed to harmonize the implementation of area navigation (RNAV) and Required Navigation Performance (RNP) in the different regions of the world. The different strategies used in US and Europe, for instance, resulted in heavy burden and certification costs for airlines.

Although the PBN concept is still using the same acronyms, their definitions have been revisited in depth and the real progresses in this concept are:

a) *The link between the airspace concept which includes CNS infrastructure as well as procedures, and the aircraft navigation equipage (see section 2.2),*

b) *The transition from navigation equipment carriage mandates (e.g. VOR/ILS, DME, NDB, INS etc.) to navigation performance requirements that can be matched with different navigation sensors among a list of eligible sensors for each RNAV or RNP specifications.*

For airspace users the navigation specifications are the central point of interest. The PBN manual defines two main types of navigation specifications. Both are based on the aircraft capability to fly a direct trajectory between two waypoints but differs on the performance monitoring and alerting function that is only required for RNP specifications which mandates the use of a GNSS sensor.

The PBN Manual also focuses on operational approval which cannot be separated from technical requirements applicable to aircraft. From an airline or air operator perspective, having a GNSS-equipped aircraft capable of LPV approach is not sufficient to exploit this capability since the operational approval from the relevant civil aviation authority is necessary. This results in a significant additional burden to airlines which have to prove that they have implemented the necessary actions and related documents in their internal management system.

ICAO Doc 9849 – GNSS manual

The current edition of the ICAO GNSS Manual is dated 2013 but is currently under evolution led by the GNSS Monitoring Drafting Group (GMDG) under ICAO NSP leadership. This informative manual is primarily for the use of States and ANSPs implementing GNSS use of in their airspace. This document addresses in 7 chapters the GNSS technology and components and then addresses in detail the implementation of GNSS services:

- Chapter 1: Introduction to GNSS elements, applications and implementation,
- Chapter 2: Performance requirements (with reference to Annex 10, Volume 1),
- Chapter 3: Existing core constellations (GPS and GLONASS),
- Chapter 4 Augmentation systems (ABAS, SBAS, GBAS),
- Chapter 5: GNSS vulnerability (interference and spoofing, spectrum regulations),
- Chapter 6: GNSS evolution (Multi-constellation / Multi-frequency, evolution of core constellations, ABAS, SBAS and GBAS evolution, new constellations, institutional issues),
- Chapter 7: Implementation of GNSS services (planning, business case, safety assessment, certification and operational approval, testing and procedure validation, GNSS monitoring and recording/GNSS NOTAMs, mitigation of GNSS vulnerabilities).

THE CURRENT EDITION OF THE ICAO GNSS MANUAL IS BEING UPDATED BY THE GNSS MONITORING DRAFTING GROUP (GMDG), UNDER ICAO NSP LEADERSHIP.

ICAO Doc 8168 – Procedures for Air Navigation Services – Aircraft

PANS (OPS and ATM) documents contain, for the most part, details on operating procedures as well as material of a more permanent character which is considered too detailed for incorporation in an Annex, or is susceptible to frequent amendment, for which the processes of the Convention would be too cumbersome.

This important document is composed of two volumes:

- Aircraft operations: Volume I – Flight procedures: this volume describes operational procedures recommended for the guidance of flight operations personnel. It also outlines the various parameters on which the criteria in Volume II are based so as to illustrate the need for operational personnel including flight crew to adhere strictly to the published procedures in order to achieve and maintain an acceptable level of safety in operations.
- Aircraft operations: Volume II – Construction of visual and instrument flight procedures: this volume describes operational procedures recommended for the guidance of flight operations personnel. It also outlines the various parameters on which the criteria in Volume II are based so as to illustrate the need for operational personnel including flight crew to adhere strictly to the published procedures in order to achieve and maintain an acceptable level of safety in operations.

In Part II of Volume I, flight procedures based on GNSS (including SBAS and GBAS augmentations) and area navigation are described for the different flight phases. A procedure based on LPV-200 service may be constructed fully equivalent to ILS Category I since the same Obstacle Assessment Surfaces (OAS) has to be used.

Part III of Volume II addresses the design of area navigation procedures using GNSS or conventional sensors (VOR-DME or DME/DME).

ICAO Doc 4444 – Procedures for Air Navigation Services – ATM

The Procedures for Air Navigation Services – Air Traffic Management are complementary to the SARPS contained in Annex 2 – Rules of the Air and in Annex 11 – Air Traffic Services. The PANS ATM specifies in greater detail than in the SARPS the actual procedures to be applied to provide the various Air Traffic Services to air traffic. They are supplemented when necessary by regional procedures contained in the Regional Supplementary Procedures (ICAO Doc n°7030). Chapter 3 of this document provides some recommendations concerning procedures for the management of Air Traffic Service capacity (within a particular area, approach or aerodrome) and in particular concerning flexible use of airspace in order to increase airspace capacity and to improve the efficiency and flexibility of aircraft operations. It also provides some guidelines for Air Traffic Flow Management.

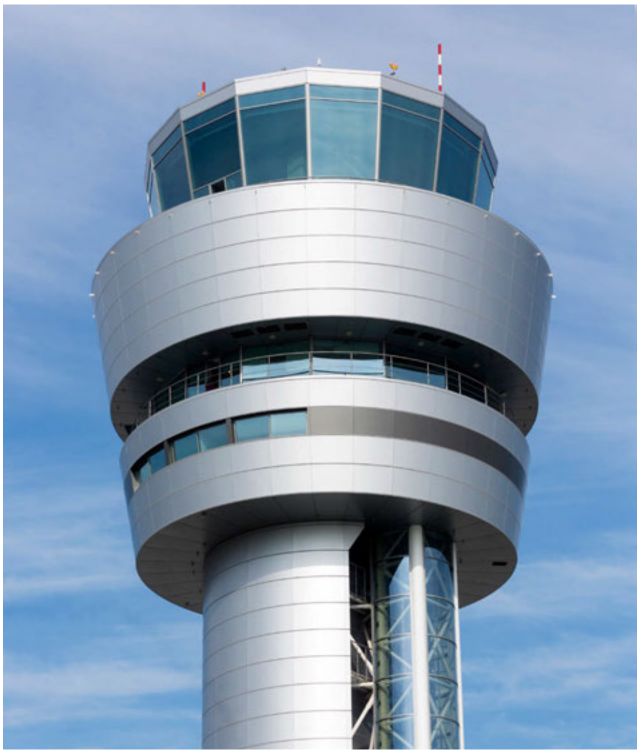
Chapter 5 contains procedures and procedural separation minima for use in the horizontal and vertical separation of aircraft. For horizontal separation procedures, reference is made to the ICAO Performance-Based Navigation Manual for the definition of RNAV operations. Much detail is given concerning the separation to be put in place depending on the required procedures and Navaids available.

6. OVERVIEW OF THE EUROPEAN REGULATORY FRAMEWORK

REGULATORY PROCESS IN THE EU

Rule-making at European Union level involves various European institutions, in particular the European Commission, the Council of the European Union and the European Parliament (EP). There are two types of legislative tools:

- Regulations - are directly applicable in all the EU States once published in the EU Official Journal,
- Directives - have to be transposed into the national legal order by the EU Member States.



Regulations and Directives may be adopted at two levels - by the European Council & Parliament or by the European Commission. In the latter case the Commission adopts "Implementing Rules" (IRs) in those areas where the Council & Parliament have given a mandate to the Commission to develop further the regulations. European Community legislation has primacy over any national rule (in that sense Regulations by the Council/Parliament and IRs are identical in terms of their effect).

The Commission has the 'right of initiative'. In general, it is the Commission that proposes new legislation, but it is the Council and Parliament that pass the laws. To get the technical details right the Commission consults experts, via its various committees and groups. There are also other institutions and bodies which play a role in the legislative process.

The Commission has developed comprehensive policies and mechanisms to provide for a simple and high quality regulatory framework in the EU. This includes the following key actions and mechanisms of particular relevance for the governance of the Commission's work:

- Regulatory Impact assessment: an important part of making high quality laws is having a full picture of their impacts. The Commission systematically examines the economic, social and environment impacts of its proposals.
- Collection and use of expertise: the Commission has established good practices related to the collection and use of external experts at all stages of policy-making. This includes participation of EASA, EUROCONTROL and Member States expertise as well as public consultation.
- Clear rules and efficient safeguards.

The following principles are observed in the rule-making process:

- The EU should only regulate if the proposed action can be better achieved at EU level and should look at all possible alternatives, including co-regulation and self-regulation;
- Any EU action should not go beyond what is necessary to achieve the policy objectives pursued;
- It needs to be cost efficient and take the lightest form of regulation called for;
- Simplification intends to make legislation at both Community and national level less burdensome, easier to apply and therefore more effective.

The Commission has developed a range of community regulations and directives, supported by implementing rules (IRs). Since the launch of the Single European Sky initiative, all major aspects of air traffic management and air navigation Services provided to general air traffic have been covered and for that purpose the European Commission has been assisted by the Single Sky Committee (SSC) composed of two representatives from each EU Member State and chaired by a representative from the European Commission. Through this framework, the safety elements of these rules therefore form now an integral part of the safety regulatory baseline applicable in those States where EC applies. In this field, the Community has transposed many of EUROCONTROL Safety Regulatory Requirements (ESARRs) previously developed into corresponding IRs.

EU REGULATIONS AND EASA COMPETENCIES

Reference	Title	Date
Regulation (EC) No 216/2008	On common rules in the field of civil aviation and establishing a European Aviation Safety Agency, and repealing Council Directive 91/670/EEC, Regulation (EC) No 1592/2002 and Directive 2004/36/EC	20 February 2008
Regulation (EC) No 690/2009	Amending Regulation (EC) No 216/2008 of the European Parliament and the Council on common rules in the field of civil aviation and establishing a European Aviation Safety Agency, and repealing Council Directive 91/670/EEC, Regulation (EC) No 1592/2002 and Directive 2004/36/EC	30 July 2009
Regulation (EC) No 1108/2009	Amending Regulation (EC) No 216/2008 in the field of aerodromes, air traffic management and air navigation services and repealing Directive 2006/23/EC	21 October 2009
Regulation (EU) No 748/2012	Laying down implementing rules for the airworthiness and environmental certification of aircraft and related products, parts and appliances, as well as for the certification of design and production organisations	3 August 2012
Regulation (EU) No 965/2012	Laying down technical requirements and administrative procedures related to air operations pursuant to Regulation (EC) No 216/2008 of the European Parliament and of the Council	5 October 2012
Regulation (EU) No 6/2013	Amending Regulation (EC) No 216/2008 of the European Parliament and of the Council on common rules in the field of civil aviation and establishing a European Aviation Safety Agency, and repealing Council Directive 91/670/EEC, Regulation (EC) No 1592/2002 and Directive 2004/36/EC	8 January 2013
Regulation (EU) No 139/2014	Aerodromes	12 Feb 2014

EASA Basic regulation and competencies

The Maastricht Treaty places the transport policy under the first pillar (common policy) of the European Union (EU). This means that the EU has the competency to regulate this domain through the community process involving the European Commission, the European Parliament and the Council. Then the EC and the Parliament with the Council agreement issue regulations that are directly applicable by the Member States without prior translation in their national law. CAAs put into force these regulations through lower level texts like decree, rules etc.

The European Aviation Safety Agency, EASA, is an agency of the European Union whose mission is to promote the highest common standards of safety and environmental protection in civil aviation. EASA has been given specific regulatory tasks in the field of aviation safety and has been established through the adoption of Regulation (EC) No 1592/2002 by the European Parliament and the Council of the European Union (EU). EASA became operational in 2003.

Originally, EASA was created to overcome the complex implementation process of harmonising the Joint Aviation Authorities (JAA) certification specifications that required a national translation in the regulatory framework of each JAA Member State. Since 2002, EASA competencies were extended to other domains through a number of EC regulations repealing or amending the initial regulation setting-up EASA.

The current "basic" regulation in force is (EC) 216/2008 that extends EASA competency to air operators as well as personnel and organisations involved in the operation of aircraft. Since 2008 this regulation has been amended by:

- Regulation (EC) No 690/2009: amendment to environmental requirements,
- Regulation (EC) No 1108/2009: extension of EASA competency to aerodromes, air traffic management and air navigation services,
- Regulation (EU) No 6/2013 amendment to environmental requirements and transitional measures.

These requirements set the basis for the safe integration of equipment in the aircraft environments and their safe functioning as well as unambiguous human machine interface. The last requirement (1.c.4) constitutes the foundation for the detailed requirements related to that are developed in the airworthiness codes.

It should be noted that these requirements make distinction between equipment which carriage is required for type certification for safety reasons and those required by operating rules. This is fully consistent with ICAO Annex 6 that makes the same distinction.

EASA Implementing Rules

The Implementing Rules (IR) result from the Basic Regulation and subsequent amendments or complementary regulations. Although published as EU regulations they are prepared by EASA as part of the frame of its rule-making role. IR defines in details the implementation of the essential requirements set in Annex 1 of the Basic Regulation as well as the rules to govern their implementation. Implementing Rules are of interest for airworthiness and air operators' approvals are listed below:

- Regulation (EU) No 748/2012: airworthiness and environmental certification of aircraft, products parts and appliances, as well as of design and production organisations,
- Regulation (EU) No 965/2012: technical requirement and administrative procedure related to air operations. It is important to note that the annexes to this regulation constitute the Air OPS manual formerly known as JAR-OPS or EU-OPS.

For what concerns airworthiness only aircraft, engines and propellers are considered as "products" and shall be certified as a whole. To this end they are subject to a "Type Certificate (TC)" that acknowledges the product is safely designed and that it complies with functioning and performance requirements. Major modifications to product can be certified through a Supplemental Type Certificate (STC) that only relates to the modification aspects. The STC can be designed by a third company to the original aircraft manufacturer provided this organisation complies with requirements for design and/or production organisations as well as particular conditions. The STC process is largely used, e.g. to implement a LPV-SBAS capability on aircraft not originally designed with this capability.

Equipment are not certified but approved through a technical and administrative marking process based on one or several specific ETSO (European Technical Standard Order) or FAA TSOs. However, their contribution to specific capabilities of the aircraft (e.g. Performance-based navigation) is verified during the aircraft type certification (or STC) process provided the aircraft manufacturer (or third company in case of an STC) applied for such capabilities in the type certification application. This is necessary to verify the correct integration and performance of equipment working together on the aircraft.

The IR for air operator approval clearly calls for compliance with provisions in Annex V (Specific approvals) of the Regulation 965/2012. In July 2016 EASA published Amendment 3 to the Part SPA of the Air Ops manual. This amendment completely revisited the need of operation approval for what concerns performance-based navigation. All navigation specifications do not need an operational approval, except RNP AR APCH and RNP 0.3 for helicopters. Notice that former requirements for PBN operations approval have not been really cancelled but just moved in other regulations pertaining to general requirements for air operators, flight crew training etc.

EASA'S MISSION IS TO PROMOTE THE HIGHEST COMMON STANDARDS OF SAFETY AND ENVIRONMENTAL PROTECTION IN CIVIL AVIATION.

SES REGULATIONS AND IMPLEMENTING RULES

Reference	Title	Date
Regulation (EC) No 549/2004	Laying down the framework for the creation of the Single European Sky	10 March 2004
Regulation (EC) No 550/2004	On the provision of air navigation services in the Single European Sky	10 March 2004
Regulation (EC) No 551/2004	On the organisation and use of the airspace in the Single European Sky	10 March 2004
Regulation (EC) No 552/2004	On the interoperability of the European Air Traffic Management network	10 March 2004
Regulation (EU) No 691/2010	Laying down a performance scheme for air navigation services and network functions and amending Regulation (EC) No 2096/2005 laying down common requirements for the provision of air navigation services	29 July 2010
Commission Implementing Regulation (EU) No 716/2014	On the establishment of the Pilot Common Project supporting the implementation of the European Air Traffic Management Master Plan	27 June 2014

Initial SES regulations package

Initially the first SES regulation package consisted of a Framework Regulation (No 549/2004) plus three technical regulations on the provision of air navigation services (No 550/2004), the organisation and use of the airspace (No 551/2004), and the interoperability of the European air traffic management network (No 552/2004) as well as a set of common requirements for the provision of air navigation services (Regulation (EC) 2096/2005, amended by regulation (EC) 1315/2007 which added a safety oversight function in air traffic management to the attributions of national supervisory authorities). These Regulations are designed, in particular, to improve and reinforce safety and to restructure the airspace on the basis of traffic instead of national frontiers.

These regulations provide a platform for improved technological progress in ATM systems. The actions defined in the regulations also reinforce the integration of civil and military air traffic control.

The Interoperability Regulation aims at defining common requirements to guarantee interoperability between the various air traffic management systems. Besides it establishes a harmonized system of certification for components and systems. For this purpose, Community Specifications (CS) may be established. Such specifications may be either European standards for systems or constituents (EN), together with the relevant procedures, drawn up by the European standardization bodies (CEN/CENELEC/ETSI) in cooperation with EUROCAE, or specifications drawn up by EUROCONTROL for safety or operational coordination purposes (e.g. EUROCONTROL Safety Regulatory Requirements – ESARRs).

It should be noted that the Interoperability Regulation applies to on-board systems. However, in order to avoid duplication of work, some Implementing Rules clarify that the EASA certification replaces the conformity assessment when the EASA certification covers the safety requirements included in the IR. The Community Specifications (CS) should not be confused with the EASA Certification Specifications (CS), although the legal status is the same.

The Interoperability regulation also introduces the Declaration of Conformity or Suitability for Use: Constituents must be accompanied by an EU declaration of conformity or suitability for use. Before a system is put into service, the relevant air navigation service provider must establish an EC declaration of verification, confirming compliance, and must submit it to the National Supervisory Authority together with a technical file.

Second SES regulation package

The steady increase in demand for air transport is straining the capacity of infrastructure and pushing airports and ATM to their limits. Safety levels need to be improved in parallel with the traffic increase. The fragmentation of ATM hinders optimal capacity use and imposes an unnecessary financial

burden on aviation. The increased environmental awareness is also putting pressure on aviation to demonstrate its environmental performance.

To tackle these issues, the Commission has come up with a second SES legislative package aimed to:

- Create a single safety framework to enable harmonised development of safety regulations and their effective implementation;
- Improve the performance of the ATM system through setting of targets;
- Open the door to new technologies enabling the implementation of new operational concept and increasing safety levels by a factor of ten;
- Improve management of airport capacity.

To these ends some additional regulations were adopted:

- A performance scheme has been set-up with EC Regulation 691/2010,
- The extension of EASA remit to ATM, ANS and airports adopted as EC Regulation 1108/2009.

Currently a SES II+ package is at an advanced stage of preparation by the EU to update previous regulations. This update focuses on seven main areas:

- Independence and resources of National Supervisory Authorities (NSAs),
- Support services,
- Customer (airspace users) focus,
- Performance scheme and the Performance Review Body (PRB),
- Functional Airspace Blocks (FABs) which are the basis for restructuring the European Airspace,
- Network Manager which is the actor connecting the different aviation stakeholders,
- EASA, EUROCONTROL and the institutional landscape ("work sharing" between the EC, EASA and EUROCONTROL).

IMPLEMENTING REGULATION (EU) NO 716/2014 – PCP IMPLEMENTATION

Reference	Title	Date
Commission Implementing Regulation (EU) No 716/2014	On the establishment of the Pilot Common Project supporting the implementation of the European Air Traffic Management Master Plan	27 June 2014

This implementing regulation looks at deploying in Europe a first batch of ATM systems developed by the SESAR programme. GNSS is an important enabler for the functions to be deployed which are mainly focussed on ATMS systems. Among the ATM improvements the following where GNSS is a major enabler should be noted:

Extended Arrival Management (AMAN) and Performance-Based Navigation (PBN) in high-density Terminal Manoeuvring Areas (TMAs): PBN in high-density TMAs covers the development and implementation of fuel efficient and/or environmentally friendly procedures for arrival and departure (Required Navigation Performance 1 Standard Instrument Departures (RNP 1 SIDs), Standard Arrival Routes (STARs)) and approach (Required Navigation Performance Approach (RNP APCH)). Extended AMAN and PBN operations shall be operated on 24 major European airports and Istanbul Ataturk airport by 1st January 2024.

Airport Integration and Throughput: among ATM systems required to satisfy the global requirements are new functions for A-SMGCS system (planning, routing and alerting). A-SMGCS systems use GNSS as a positioning source together with surface radar and multilateration systems. Such implementation shall be operational on 24 major European airports and Istanbul Ataturk airport by 1st January 2024.

Flexible Airspace Management and Free Route: Free Route may be deployed during defined periods both through the use of Direct Routing Airspace and through Free Routing Airspace. Network Manager, air navigation service providers and airspace users shall operate Direct Routing by 1st January 2018 and Free Routing Airspace by 1st January 2022. GNSS is an important enabler for free route airspace in order to comply with the applicable PBN specification.

EASA technical regulations and materials for airworthiness approval

To facilitate the necessary regulatory uniformity, the EASA produces Certification Specifications (CS). These CS are used to demonstrate compliance with the Basic Regulation and its Implementing Rules. These include in particular:

- Airworthiness Codes,
- Acceptable Means of Compliance (AMC).

CERTIFICATION SPECIFICATIONS OR AIRWORTHINESS CODES

Reference	Title	Date
Annex to ED Decision 2009/009/R	CS-22 / Amendment 2	5 March 2009
Annex to ED Decision 2015/018/R	CS-23 / Amendment 4	15 July 2015
Annex to ED Decision 2015/019/R	CS-25 / Amendment 17	15 July 2015
Annex to ED Decision 2012/021/R	CS-29 / Amendment 3	11 December 2012
Annex to ED Decision 2013/015/R	CS-LSA / Amendment 1	29 July 2013
Annex to ED Decision 2003/10/RM	CS-ETSO / Initial Issue	24 October 2003
Annex to ED Decision 203/006/R	CS-AWO / Initial Issue	17 October 2003
Annex I to ED Decision 2013/031/R	CS-ACNS / Initial Issue	17 December 2013

Airworthiness codes are standard technical interpretations of the airworthiness essential requirements contained in Annex 1 of the Basic Regulation in compliance with related ICAO SARPS. They describe in detail the specifications and the expected performance for aircraft, equipment and aerospace products to ensure compliance with the Basic Regulation.

For what concerns aircraft and helicopters, the applicable airworthiness codes are provided in the first part of the aircraft category relevant CS called "Book 1 – Certification Specifications". It should be noticed that CS are frequently amended: the reference given for each CS are those applicable at the time of writing this document.

ACCEPTABLE MEANS OF COMPLIANCE

Reference	Title	Date
ED Decision 2003/012/RM AMC20 (13 separated amendments since initial issue in 2003)	General Acceptable Means of Compliance for Airworthiness of Products, Parts and Appliances	5 November 2003

In addition to certification regulations and airworthiness codes, EASA publishes some documents intended to clarify the application of these texts. These documents are called Acceptable Means of Compliance (AMC).

AMC are non-exclusive (non-binding) means to demonstrate compliance with the airworthiness codes or with the Implementing Rules. They illustrate a means, but not the only means, by which a specification contained in a requirement of an airworthiness code or a requirement of an Implementing Rule can be met. Satisfactory demonstration of compliance using a published AMC shall provide for presumption of compliance with related requirement. In addition, AMCs provide information on the condition of use. AMCs are ways to facilitate the tasks of certification for an applicant and the competent authority.

AMCs are included in the second part of the CS, called "Book 2". A numbering system is used in which the Acceptable Means of Compliance uses the same number as the paragraph in Book 1 to which it is related.

EASA also maintains the AMC 20 "General Acceptable Means of Compliance for Airworthiness of Products, Parts and Appliances" which contains acceptable means of compliance applicable to more than one airworthiness code, across various disciplines. AMC 20 is a catalogue gathering all the AMC20-XX in force. Since the initial issue, 13 amendments (including new AMCs and cancellation of previous AMCs) have been published; unfortunately, EASA did not yet published a consolidated full version of the AMC 20 taking the published amendments into account; this makes AMC 20 exploitation cumbersome.

CSs requirements for aircraft and helicopters equipment

Requirements for equipment in the aircraft and helicopters CSs are found in Subpart F of each CS. They contain a list of minimum flight, engine and navigation instruments that are required for airworthiness certification. They do not specify in details functions and performance for each kind of equipment (e.g. GNSS). The corresponding AMC to each item of the CS are found in the Book 2 of the CS document.

Of fundamental importance in CS 25, and similarly in CS 23, 27 and 29, are CS 25.1309 and AMC 25.1309.

CS 25.1309 and AMC 25.1309

This is one of the most important requirements for equipment in CS 25.1309 – Equipment, systems and installations. This specification is related to the design and installation of equipment. It defines qualitatively and quantitatively the safety requirements that shall be met by on-board equipment based on the likelihood and severity of consequences of a failure condition.

To this end several classes of failure condition are severity for failure conditions are defined:

- No Safety Effect
- Minor
- Major
- Hazardous
- Catastrophic

Probability terms are also defined qualitatively and quantitatively:

- Probable: Average Probability Per Flight Hour greater than of the order of $1x10^{-5}$,

- Remote: Average Probability Per Flight Hour of the order of $1x10^{-5}$ or less, but greater than of the order of $1x10^{-7}$,
- Extremely Remote: Average Probability Per Flight Hour of the order of $1x10^{-7}$ or less, but greater than of the order of $1x10^{-9}$,
- Extremely Improbable: Average Probability Per Flight Hour of the order of $1x10^{-9}$ or less.

The safety objective to be met is the result of the crossing of severity and probability of failure condition. It is summarised in the following figure:

AMC 25.1309 also distinguishes methodologies to show compliance with CS 25.1309 and introduces the notion of "complex equipment". Although not said in the AMC text GNSS equipment shall be considered as complex equipment.

Then AMC 25.1309 suggests applying Development Assurance Methods for this kind of equipment for both hardware and software. The reference to SAE ARP 4754A/EUROCAE ED-79A "Guidelines for development of civil aircraft and systems" is provided. This is important since directly in relation with development and approval costs bear by manufacturers.

EASA CS-ETSO

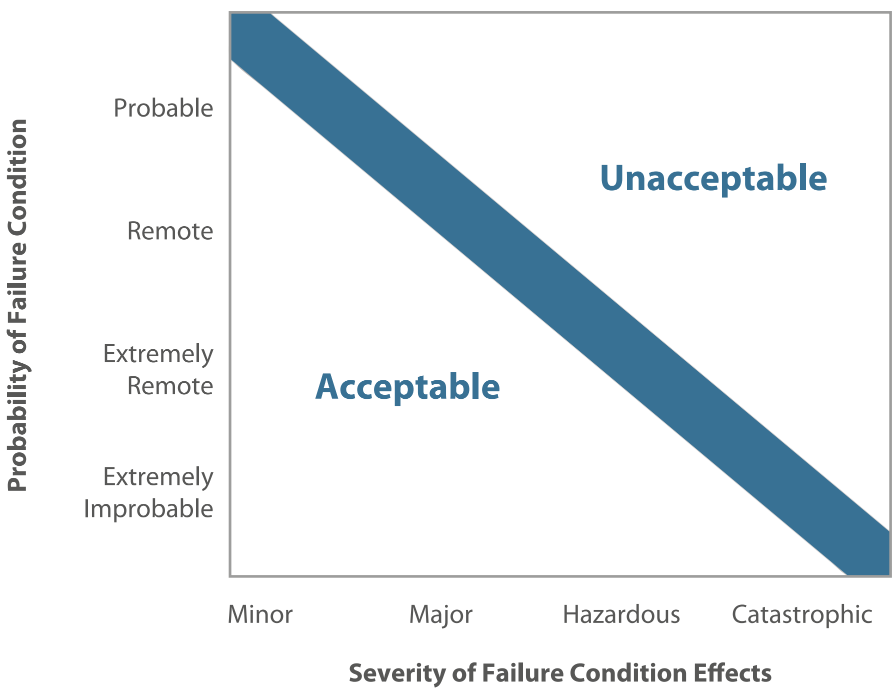
Aircraft equipment are not considered as "products", this term being reserved for airworthiness certification of aircraft, engines and propellers for which specific Certification Specification are issued. The approval of systems and equipment is currently performed through the global airworthiness certification of the aircraft, engine and propellers.

Civil aviation authorities however found useful since many years to issue technical specifications for "approval" of aircraft equipment. Although not all kinds of equipment are subjected to such specifications, GNSS equipment and navigation systems have specific technical specifications to comply with before being fully certified with the global aircraft airworthiness certification.

The EASA CS-ETSO (Certification Specifications for European Technical Standard Orders) contains a list of ETSOs, which are minimum performance standards for specified articles (i.e. any part and appliance to be used on civil aircraft). An ETSO is a detailed airworthiness specification issued by EASA to ensure compliance with the essential requirements of the Basic Regulations. An ETSO authorisation is an approval of the technical definition of the associated article.

In practice ETSOs often just provide the RTCA/EUROCAE standards to comply with for functions, performance, environment and software quality assurance. The CS-ETSO is organised in two indexes:

Figure 12: Relationship between probability and severity of failure condition effects



CS-ETSO

Reference	Title	Date
ETSO C115c	Airborne area navigation equipment flight management system (FMS) using multi-sensor inputs	12 July 2013
ETSO C144a	Passive airborne GNSS antenna	21 December 2010
ETSO C145c	Airborne Navigation Sensors Using the Global Positioning System Augmented by the Satellite-Based Augmentation System	21 December 2010
ETSO C146c	Stand-Alone Airborne navigation Equipment Using the Global Positioning System Augmented by the Satellite-Based Augmentation System	21 December 2010
ETSO C161a	Ground-Based Augmentation System Very High Frequency Data Broadcast Equipment	5 July 2012
ETSO-C190	Active Airborne Global Navigation Satellite System (GNSS) Antenna	21 December 2010
ETSO-C196a	Airborne Supplemental Navigation Sensors for Global Positioning System Equipment Using Aircraft-Based Augmentation	5 May 2012

- Index 1 lists all those ETSOs which are technically similar to FAA-TSOs,
- Index 2 lists all those ETSOs which are not technically similar to FAA-TSOs due to deviation to FAA TSOs or non-existing FAA TSO.

For practical aspects, EASA uses the same ETSO numbers as FAA. The following table provides ETSOs relevant for GNSS equipment. All are part of Index 1:

Table 34: ETSOs of interest for GNSS

ETSO Number	ETSO Title
ETSO-C115c	Flight Management Systems (FMS) using Multi-Sensor Inputs
ETSO -C144a	Passive Airborne Global Positioning System (GNSS) Antenna
ETSO-C145c	Airborne Navigation Sensors Using the Global Positioning System Augmented by the Satellite-Based Augmentation System
ETSO-C146c	Stand-Alone Airborne navigation Equipment Using the Global Positioning System Augmented by the Satellite-Based Augmentation System
ETS0-C161a	Ground-Based Augmentation System Positioning and Navigation Equipment
ETSO-C190	Active Airborne Global Navigation Satellite System (GNSS) Antenna
ETSO-C196a	Airborne Supplemental Navigation Sensors for Global Positioning System Equipment Using Aircraft-Based Augmentation

Common requirements to CS-ETSOs

ETSOs applicable to equipment using GNSS shall comply with EUROCAE/RTCA document ED-14D change 3/DO-160D 'Environmental Conditions and Test Procedures for Airborne Equipment'.

When the equipment includes airborne software and unless otherwise stated in paragraph 3.1.3 of the specific ETSO, one acceptable means of compliance for the development of the airborne software is outlined in the latest revision of AMC 20-115 on software considerations in Airborne Systems and Equipment Certification.

Software level also called Item Development Assurance Level (IDAL) may be determined by using the guidance proposed below. The applicant must declare the software level(s) to which the software has been developed and verified.

If the article contains a complex Application-Specific Integrated Circuit (ASIC) or complex programmable logic (e.g. Programmable Array Logic components (PAL), Field-Programmable Gate Array components (FPGA), General Array Logic components (GAL), or Erasable Programmable Logic Devices) summarised as Complex Electronic hardware to accomplish the function, develop the component according to EUROCAE/RTCA document ED-80/DO-254 'Design Assurance Guidance for Airborne Electronic Hardware', dated April 2000.

Design Assurance Level also called Item Development Assurance Level (IDAL) for Airborne Electronic Hardware (AEH) may be determined by using the proposed guidance. The applicant must declare the Design Assurance level (s) to which the AEH has been developed and verified. EUROCAE/SAE document ED-79A/ARP 4754A 'Guidelines for development of civil Aircraft and Systems' dated December 2010 may be used to assign the Development Assurance Level of the equipment, software and AEH. The document may be used as well as guidance to ensure a proper development, validation and verification of the ETSO and the functional equipment requirements.

The equipment shall be developed according to, at least, the development assurance level appropriate to the failure condition classifications.

ETSO-C115C

Such equipment shall comply with standards set forth in the RTCA DO-283A "Minimum Operational Performance Standards for Required Navigation Performance for Area Navigation, dated 28/10/2003".

In addition, the following specific requirements shall be considered:

"When using GNSS, the aircraft navigation system shall provide an alert when the probability of signal-in-space errors causing a lateral position error greater than two times the desired RNP (2 × RNP) exceeds 1×10^{-7} per hour.

Note: This exception supports international harmonisation of requirements for RNAV and RNP. The exception is comparable to the ETSO-C115b exception that invoked ETSO-C129a system performance requirements when integrating GNSS as part of a multi-sensor navigation solution.

Failure condition classification: Design the system to the appropriate failure condition classification(s) as detailed in further guidance material dedicated to the different navigation specification (for instance RNP1, LPV, RNP AR…)".

ETSO-C144A

Performance standard:

"Standards set forth in RTCA document DO-228, "Minimum Operational Performance Standards for Global Navigation Satellite Systems (GNSS) Airborne Antenna Equipment" dated October 20, 1995, Section 2 (excluding Sections 2.2.2 and 2.4.3) and Change 1 to DO-228.

Note 1: For Active Airborne Global Navigation Satellite System (GNSS) Antenna, see ETSO-C190

Note 2: The ETSO standards herein apply to equipment intended to receive and provide signals to a global positioning system (GPS)/satellite-based augmentation system (SBAS) operational Class 1, or GPS, sensor or system that will provide flight path deviation commands to the pilot or autopilot. These standards do not address the use of the signals received through this antenna for other applications. GPS/SBAS operational classes are defined in RTCA document DO-229D "Minimum Operational Performance Standards for Global Positioning System/Wide Area Augmentation System Airborne Equipment", dated December 13, 2006, Section 1.4.2."

The failure of the function identified above has been determined to be a major failure condition.

ETSO-C145C

This ETSO gives the requirements which new models of airborne navigation sensors using GPS augmented by the Satellite-Based Augmentation System (SBAS).

The standards of this ETSO apply to equipment intended to provide position information to a navigation management unit that outputs deviation commands referenced to a desired flight path, Pilots or autopilots will use these deviations to guide the aircraft.

Minimum performance standard:

Standards set forth for functional equipment Class Beta in RTCA document DO-229D, Minimum Operational Performance Standards for Global Positioning System/Wide Area Augmentation System Airborne Equipment dated December 13, 2006, Section 2, except as modified in Appendix 1 of this ETSO.

Class Beta equipment is defined in DO-229D, Section 1.4.

Failure condition classification:

Failure of the function is a:

- Major failure condition for loss of function and malfunction of en-route, terminal, approach lateral navigation (LNAV), and approach LNAV/vertical navigation (VNAV) position data,
- Major failure condition for loss of function of approach localiser performance without vertical guidance (LP), and approach localiser performance with vertical guidance (LPV) position data, and
- Hazardous failure condition for malfunction of approach (LP and LPV) position data.

Appendix 1 to this ETSO brings significant changes to RTCA DO-229D.

ETSO-C146C

This ETSO gives the requirements which new models (designed after the issuance of this ETSO) of stand-alone airborne navigation equipment using the GPS augmented by SBAS must meet.

Minimum performance standard:

Standards set forth for functional equipment Class Gamma or Delta in RTCA document DO-229D, Minimum Operational Performance Standards for Global Positioning System/Wide Area Augmentation System Airborne Equipment, dated December 13 2006, Section 2, except as modified by Appendix 1 of this ETSO.

Classes Gamma and Delta equipment are defined in DO-229D, Section 1.4.

Failure condition classification:

- Major failure condition for loss of function and malfunction of en-route, terminal, approach lateral navigation (LNAV), and approach LNAV/vertical navigation (VNAV) position data,
- Major failure condition for loss of function of approach localiser performance without vertical guidance (LP), and approach localiser performance with vertical guidance (LPV) position data, and
- Hazardous failure condition for malfunction of approach (LP and LPV) position data.

Appendix 1 to this ETSO brings significant changes to RTCA DO-229D.

ETSO-C161A

This ETSO applies for GBAS airborne equipment

Minimum performance standard:

Standards set forth in the Radio Technical Commission for Aeronautics (RTCA) Document DO-253C, Minimum Operational Performance Standards for GPS Local Area Augmentation System Airborne Equipment, dated 16/12/2008, section 2 as modified by appendices 1 and 2 of this ETSO for airborne equipment class (AEC) C to support Category I precision approach. These standards also apply to equipment that implements the optional GBAS positioning service. This ETSO does not apply to AEC D equipment as the additional requirements to support the GBAS Approach Service Type D and Category III precision approaches have not been validated. A new ETSO or a revision to this ETSO for AEC D equipment will be issued once these additional requirements are validated.

This TSO's standards apply to equipment intended to output deviations relative to a precision approach path using GBAS, and to provide position information to an ETSO-C161a navigation management unit that outputs deviation commands referenced to a desired flight path. These standards do not address integration issues with other avionics except for automatic dependent surveillance. The positioning and navigation functions are defined in section 2.3 of RTCA/DO-253C. In accordance with section 2.1 of RTCA/DO-253C, equipment obtaining this ETSO must also comply with the position, velocity and time (PVT) output requirements of either, ETSO-C145c, ETSO-C146c or ETSO-C196a.

Note: ETSO-C196a, which is based on RTCA/DO-316, Minimum Operational Performance Standards for Global Positioning System/Aircraft-Based Augmentation System Airborne Equipment, is not referenced in RTCA DO-253C. RTCA/DO-316 was published after the publication of DO-253C. ETSO-C129a is not applicable to this ETSO.

Failure condition classification:

- Failure of the function has been determined to be a major failure condition for the malfunction of position data and a hazardous failure condition for the malfunction of precision approach navigation data.
- Failure of the function has been determined to be a minor failure condition for the loss of position data and a minor failure condition for the loss of precision approach navigation data.

This ETSO brings significant changes to some requirements of RTCA/DO 253 through 2 appendixes.

ETSO-C190

This ETSO gives the requirements for new models of Active Airborne Global Navigation Satellite System (GNSS) Antenna.

It applies to equipment intended to receive and provide signals to global positioning system (GPS)/satellite-based augmentation system (SBAS) sensors or systems of all operational classes, and GPS/ground-based augmentation system (GBAS) sensors or systems that will provide flight path deviation commands to the pilot or autopilot. These standards do not address the use of the signals received through this antenna for other applications. GPS/SBAS receiver operational classes are defined in RTCA document DO-229D "Minimum Operational Performance Standards for Global Positioning System/Wide Area Augmentation System Airborne Equipment" dated December 13, 2006, Section 1.4.2.

Minimum Performance Standard:

Standards set forth in the RTCA document DO-301 "Minimum Operational Performance Standards for Global Navigation Satellite System (GNSS) Airborne Active Antenna Equipment for the L1 Frequency Band" dated December 13, 2006, Section 2.

Failure Condition Classification:

Failure of the function constitutes a loss of navigation which is a major failure condition.

ETSO-C196A

This ETSO provides the requirements which Airborne Supplemental Navigation Sensors for Global Positioning System Equipment Using Aircraft-Based Augmentation (ABAS).

This ETSO cancels ETSO-C129a Airborne Supplemental Navigation Equipment Using Global Positioning System (GPS).

Minimum performance standard

Standards set forth in the Radio Technical Commission for Aeronautics (RTCA) document DO-316, Minimum Operational Performance Standards (MOPS) for Global Positioning System/Aircraft-Based Augmentation System Airborne Equipment, dated 14/04/2009, Section 2.

Failure condition classification

Failure of the function has been determined to be a major failure condition for malfunction of oceanic/remote, en-route and terminal navigation and lateral navigation (LNAV) approaches.

Failure of the function has been determined to be a minor failure condition for loss of navigation of oceanic/remote,

en-route and terminal navigation and lateral navigation (LNAV) approaches.

Barometric-aided Fault Detection and Exclusions (FDE):

If the equipment uses barometric-aiding to enhance FDE availability, then the equipment must meet the requirements in RTCA/DO-316, Appendix G.

CS-ACNS

Reference	Title	Date
Annex I to ED Decision 2013/031/R	CS-ACNS / Initial Issue	17 December 2013

General

The decision to create a specific CS for airborne communication, navigation and surveillance has been taken end of 2013 in order to promote cost efficiency in the regulatory and certification process and to avoid duplication at national level.

The CS-ACNS translates airworthiness requirements previously set in the different AMC 20-XX into formal Certification Specifications. Like other CS, CS-ACNS is composed of two books:

- Book 1: Certification Specifications
- Book 2: Acceptable Means of Compliance (AMC) and Guidance Material (GM)

Each book addresses the same structure in subparts titled:

- General
- Communication (COM)
- Navigation (NAV)
- Surveillance (SUR)
- Others

As indicated in the General subpart, these certification specifications are applicable to all aircraft for the purpose of compliance with equipage requirements with respect to on-board Communication, Navigation and Surveillance systems. Furthermore, compliance with the appropriate section of these certification specifications ensures compliance with several European regulations.

For the moment only the subparts COM, SUR and Other have been populated with requirements respectively concerning VHF 8.33 kHz, airborne transponders, TAWS and RVSM. The subpart NAV is just marked "reserved".

TAWS and ADS-B use or may use a GNSS positioning source provided this source and its integration into the system comply with specific requirements. The following section details requirement for GNSS applicable to TAWS and ADS-B airborne transmit units.

GNSS as TAWS enabler

The CNS-ACNS Subpart "Other" provides in its section 1 requirements for Terrain Awareness and Warning Systems (TAWS). Two equipment classes (A and B) are defined depending on the implemented functions and crew interfaces. The basic TAWS is the Class B equipment.

Such systems use the positioning information elaborated by the aircraft sensors used for navigation. The CS ACNS.E.TAWS.060 puts requirements on positioning information as part of system performance requirements.

The requirements applicable to GNSS as a positioning source are mainly related to:

- The positioning information (i.e. horizontal and vertical position, velocity, or rate of information) is provided from an approved positioning source.
- The approval required for the GNSS sensor used by the TAWS. It can be internal or external to the TAWS.

GNSS as ADS-B enabler

There are currently two main issues regarding ADS-B:

- From a regulatory point of view, the mandates put on ADS-B carriage by US, Europe and Asia are not harmonized, mainly for technical requirements and performance,
- The level of performance required for some ADS-B parameters, particularly the Navigation Integrity Category (NIC), is difficult to meet in harsh environments (masking of satellites disables the RAIM or RAIM/FDE) when using a simple GNSS source not SBAS capable. The FAA recognised that up to today the use of SBAS is the only solution but without mandating SBAS use for ADS-B purposes.

In the CS-ACNS in Book 1 subpart D (SUR) section 4 is dedicated to 1090 MHz Extended Squitter which is the "complementary" ADS-B Out function for Mode S transponders. In the corresponding AMC, EASA clearly states that the requirements of CS-ACNS are more stringent that those formerly stated in the AMC20-24[8].

In addition to the requirement for approval of the equipment[9] contributing to the ADS-B Out function, the certification specifications requirements are mainly related to:

- The set of ADS-B Out system output parameters,
- The required approval of data sources used by ADS-B, in particular GNSS with specific requirements on positioning and integrity that shall be checked,
- Installation guidance.

IMPORTANT NOTE: EASA has undertaken the review of the Commission Implementing Regulation (EU) No 1207/2011 of 22 November 2011 laying down requirements for the performance and the interoperability of surveillance for the single European sky. This could lead to amended requirements for ADS-B in the CS-ACNS.

8 AMC 20-24 Certification Considerations for the Enhanced ATS in Non-Radar Areas using ADS-B Surveillance (ADS-B-NRA) Application via 1090 MHz Extended Squitter
9 The applicable ETSOs for ADS-B transmit unit are ETSO-C166b and ETSO-C112d

EASA TECHNICAL REGULATIONS FOR AIR OPERATORS, OPERATIONAL APPROVAL

Reference	Title	Date
Regulation (EU) No 965/2012	Laying down technical requirements and administrative procedures related to air operations pursuant to Regulation (EC) No 216/2008 of the European Parliament and of the Council	5 October 2012
Annex to Decision 2016/020/R	AMC and GM to Part-SPA – Amendment 3	29 July 2016

The basis for air operator's approval, resulting in the granting of an Air Operator Certificate (AOC) is the Regulation (EU) No 965/2012. It is often designated as AIR OPS, in line with the former reference documents used along the time (JAR OPS, EU OPS).

Annexes to this regulation constitute the EASA compendium of EASA documents (parts) on air operations:

- Definitions,
- Part ARO: Authority Requirements for air Operations,
- Part ORO: Organisation Requirements for air Operations,
- Part CAT : Commercial Air Transport,
- Part SPA: Application for a Specific Approval,
- Part NCC: Non-Commercial operations with Complex motor-powered aircraft,
- Part NCO: Non-Commercial operations with other-than-complex motor-powered aircraft
- Part SPO: Specialised Operations.

These different Parts provide Acceptable Means of Compliance (AMC) and Guidance Material (GM). The AMC and GM requirements are numbered according to their nature (AMC XXX, GM XXX).

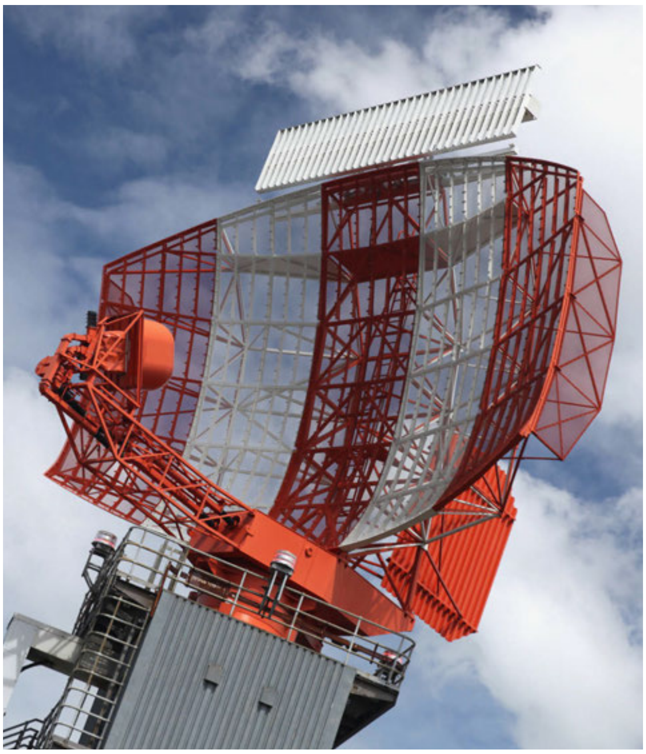
In several parts of the AIR OPS (Parts CAT, NCC, NCO) a specific subpart D is dedicated to aircraft equipment and carriage rules. For navigation equipment these subparts only rule the carriage of conventional navigation means (ADF, VOR, DME, ILS, Marker beacons etc.).

It is interesting to note that ELTs specifications are addressed in these subparts. The integration of GNSS in ELT is not a mandatory requirement as it is expressed. The term "should" shall be interpreted as a recommendation or "a nice to have":

"PLB TECHNICAL SPECIFICATIONS

(a) A personal locator beacon (PLB) should have a built-in GNSS receiver with a cosmicheskaya sistyema poiska avariynich sudov – search and rescue satellite-aided tracking (COSPAS-SARSAT) type approval number. However, devices with a COSPAS-SARSAT number belonging to series 700 are excluded as this series of numbers identifies the special-use beacons not meeting all the technical requirements and all the tests specified by COSPAS-SARSAT".

For what concerns GNSS carriage the requirements are set in Part SPA. Following Amendment 3 to Part SPA of the Air Ops, only RNP AR APCH and RNP 0.3 for helicopters require an operational approval.



AERONAUTICAL STANDARDS FOR GNSS EQUIPMENT

Reference	Title	Date
RTCA-DO 316	Minimum Operational Performance Standards for Global Positioning System / aircraft-Based augmentation System Airborne Equipment	April 2009
RTCA DO-229E	Minimum Performance Standards for Global Positioning system/Wide area augmentation system airborne equipment – Rev E	December 2016
RTCA DO-208	Minimum Operational Performance Standards for Airborne Supplemental Navigation Equipment Using Global Positioning System (GPS)	December 1991
EUROCAE ED-72A	MOPS for Airborne GPS Receiving Equipment used for Supplemental Means of Navigation.	April 1997
EUROCAE ED-88	MOPS for Multi-Mode Airborne Receiver (MMR) including ILS, MLS and GPS used for Supplemental Means of Navigation	August 1997
EUROCAE ED-75C	Minimum Aviation System Performance Standards: Required Navigation Performance for Area Navigation	November 2013
RTCA DO-236C	Minimum Aviation System Performance Standards: Required Navigation Performance for Area Navigation	June 2013
RTCA DO-228	Minimum Operational Performance Standards for Global Navigation Satellite Systems (GNSS) Airborne Antenna Equipment	October 1995
RTCA-DO-235	Assessment of Radio Frequency Interference Relevant to the GNSS L1 Frequency Band	March 2008
RTCA-DO-292	Assessment of Radio Frequency Interference Relevant to the GNSS L5/E5A Frequency Band	July 2004
RTCA DO-301	Minimum Operational Performance Standards for Global Navigation Satellite System (GNSS) Airborne Active Antenna Equipment for the L1 Frequency Band	December 2006

Per se aeronautical standards are not regulatory material. The EASA technical regulations enforce them when requiring compliance to these standards. Standards applicable to GNSS equipment can be either specific to an equipment (e.g. GNSS airborne receiver) or of general nature for a large variety of equipment (e.g. environmental standards or design assurance).

MASPS and MOPS content

Many standards applicable to GPS and GNSS have been published for GNSS in aviation, some of them being already superseded. Published by the two main standardisation bodies for civil aviation, EUROCAE and RTCA:

- Minimum Aviation System Performance Standards (MASPS): they ensure an end-to-end system will perform its intended functions within a defined airspace: they constitute useful information for GNSS-based navigation,
- Minimum Operational Performance Standard (MOPS): they ensure equipment will perform its intended functions. They are the core standards for GNSS receivers' functions, performance and testing.

Notice MASPS are dedicated to systems while MOPS are related to specific equipment. EUROCAE and RTCA also issue other documents supporting standardisation like Operational Services & Environment Definition (OSED), Operational, Safety &Performance Requirements (SPR) or Interoperability Requirement (IRR).

RTCA and EUROCAE are more and more working jointly, particularly in the GNSS field but also on other CNS aspects pertaining to the definition and development of the new standards for ATM/CNS necessary for the NextGen and SESAR projects. The usage is to develop common MOPS and to publish them under a particular reference to each body if necessary.

For what concerns GNSS the working groups are:

- RTSA SC-159 (all receivers and GBAS),
- EUROCAE WG 62 (GPS, SBAS, Galileo and combined receivers),
- EUROCAE WG 28 (GBAS ground stations).

Relevant MASPS and MOPS for GNSS

The current MOPS for GPS airborne receivers are:

- RTCA-DO 316 Minimum Operational Performance Standards for Global Positioning System / aircraft-Based Augmentation System Airborne Equipment: this MOPS is related to GPS L1 equipment implementing ABAS (RAIM, AAIM etc.) for integrity monitoring.
- RTCA DO-229 E Minimum Performance Standards for Global Positioning system/Wide area augmentation system airborne equipment: this MOPS considers GPS+SBAS single frequency (L1) receivers. The revision E was issued in 2017.
- RTCA DO-208 Minimum Operational Performance Standards for Airborne Supplemental Navigation Equipment Using Global Positioning System (GPS): this is an older MOPS for airborne GPS equipment (DO-316 is much more up to date) which has not been cancelled since it supports the FAA TSO C129a approval of numerous equipment types still in operational service.
- EUROCAE ED-72A: MOPS for Airborne GPS Receiving Equipment used for Supplemental Means of Navigation. This MOPS is equivalent to RTCA DO-208 but has not been updated with an equivalent to DO-316.

EUROCAE ED-88: MOPS for Multi-Mode Airborne Receiver (MMR) including ILS, MLS and GPS used for Supplemental Means of Navigation.

Note that EUROCAE published in January 2000 an "Interim Technical Performance Statement for EGNOS / WAAS Airborne Equipment" under ED-97 reference. This document is now out of date and the GPS/SBAS receiver MOPS is the RTCA one (DO-229D).

MASPS in relation with GPS and more globally with GNSS are:

- EUROCAE ED-75C: Required Navigation Performance for Area Navigation.
- RTCA DO-236 C - Minimum Aviation System Performance Standards: Required Navigation Performance for Area Navigation.
- In civil aviation, GNSS antennas are subject to separated standards – Only RTCA has published GPS antenna MOPS:
- RTCA DO-228 - Minimum Operational Performance Standards for Global Navigation Satellite Systems (GNSS) Airborne Antenna Equipment: Defines the antenna performance for antennas that will be used with GNSS receiver equipment. This MOPS contains Minimum Operational Performance Standards (MOPS) for GNSS airborne antenna equipment designed to use GPS or GLONASS augmented by other systems/equipment/techniques as appropriate to meet the performance requirements for primary means of navigation for en-route, terminal, non-precision, and precision approach phases of flight. Incorporated within these standards are equipment characteristics that should be useful to users, designers, manufacturers, and installers of equipment. DO-228 is accompanied by its Change 1 published in Jan 2000.
- RTCA DO-301 - Minimum Operational Performance Standards for Global Navigation Satellite System

(GNSS) Airborne Active Antenna Equipment for the L1 Frequency Band: This document contains Minimum Operational Performance Standards (MOPS) for GNSS airborne active antenna equipment designed to use the GPS or Galileo L1 frequency augmented by other systems/equipment/techniques as appropriate to meet the performance requirements for primary means of navigation for en-route, terminal, non-precision, and precision approach phases of flight. An active antenna is one integrated with a preamplifier.

- ARINC 743A-5 GNSS Sensor GPS/GLONASS receivers: this engineering standard provides among other dimension specifications for GNSS antennas.

GLONASS receiver specifications

Reference	Title	Date
KT-229 MOPS-229	Airborne equipment of satellite navigation (AESN) – 4th Edition	March 2011
KT-229 MOPS-229	GNSS/SBAS Airborne Navigation Equipment	March 2011

The Interstate Aviation Committee of the Russian Federation developed the following specifications for GLONASS receivers:

- KT-34-01 (4th Edition) - Airborne equipment of satellite navigation (AESN): This document prescribes the minimum performance standard that airborne navigation equipment using GLONASS and GPS (AESN) must meet to be applied as primary of supplemental means of navigation
- KT-229 MOPS-229 (KT-229) for GNSS/SBAS Airborne Navigation Equipment: This document contains minimum operational performance standards (MOPS) for airborne navigation equipment (avionics) using navigation signals from GLONASS/GPS satellite constellations augmented by SBAS, such as WAAS, EGNOS, and MSAS.

GBAS standards

Reference	Title	Date
RTCA DO-245A	Minimum Aviation System Performance Standards for Local Area Augmentation System (LAAS)	September 2004
RTCA DO-246D	GNSS-Based Precision Approach Local Area Augmentation System (LAAS) – Signal-in-Space Interface Control Document (ICD)	December 2008
RTCA DO-253C	Minimum Operational Performance Standards for GPS Local Area Augmentation System Airborne Equipment	December 2008
EUROCAE ED-114A	MOPS for a Ground-Based Augmentation System (GBAS) ground facility to support CAT I approach and landing	March 2013

GBAS standards are published by both EUROCAE and RTCA for ground and airborne equipment. Initially standardized for CAT I operations, the standards now take into account CAT II/III operations based on GPS L1. Notice that the US were using the acronym LAAS (Local Area Augmentation System) to designate GBAS.

- RTCA DO-245 A: Minimum Aviation System Performance Standards for Local Area Augmentation System (LAAS)

This document contains the Minimum Aviation System Performance Standards for the Local Area Augmentation System (LAAS), a system developed to support precision approach and landing operations and other navigation and surveillance applications, within a local area including and surrounding an airport.

This revision harmonizes the LAAS requirements for supporting Category I operations and the LAAS differential positioning service with the LAAS MOPS [DO 253A] and the ICAO Annex 10 GBAS SARPs through Amendment 79. The requirements to support LAAS Category II and III precision approach operations are added/updated as well as requirements for the LAAS when supporting complex terminal procedures through the broadcast of Terminal Area Path (TAP) data using the LAAS VHF Data Broadcast (VDB).

This document is under revision by RTCA SC 159 to be in line with the SARPs evolution on GBAS.

- RTCA DO-246D GNSS-Based Precision Approach Local Area Augmentation System (LAAS) – Signal-in-Space Interface Control Document (ICD): DO-246D includes the earlier document revisions and incorporates the standards for LAAS to support CAT II and III precision approach. DO-246C included changes to harmonize the document with DO-245A, LAAS MASPS. The three primary areas of change were:
    - Definition of additional data for supporting CAT II/III precision approach operations (Additional data blocks 3 and 4 for Message Type 2).
    - Definition of LAAS uplinked Terminal Area Paths (TAP) data for supporting additional Terminal Area Procedures (Provisions for TAP data to be included in Message Type 4).
    - All references to pseudolites / Ground-Based Ranging Sources were removed.
- RTCA DO-253C Minimum Operational Performance Standards for GPS Local Area Augmentation System Airborne Equipment:

This document provides the Minimum Operational Performance Standards (MOPS) for Airborne Navigation Equipment Using the Global Positioning System (GPS) Augmented by the Local Area Augmentation System (LAAS). The standards in the document define minimum performance requirements, functions, and features for LAAS airborne equipment to support CAT I, II and III precision approach operations. Compliance with these standards by manufacturers, installers, and users is recommended as a means of assuring that the equipment will satisfactorily perform its intended functions under conditions encountered in routine aeronautical operations. DO-253A superseded DO-253 and included: 1) Recommendations harmonized with the ICAO GNSS Panel Standards and Recommended Practices (SARPs), 2) The use of LAAS differential position to support area navigation, and 3) The easing of the LAAS Ground Subsystem Siting constraints (Ephemeris Error Protection). DO-253B harmonized the LAAS MOPS with the revised WAAS MOPS - DO-229D. DO-253C includes the earlier revisions and provides the requirements / standards for LAAS to support CAT II and III precision approach. In addition, the revision incorporates changes to existing Cat. I and positioning service standards, and includes velocity requirements to further support ADS-B.

- EUROCAE ED-114A MOPS for a Ground-Based Augmentation System (GBAS) ground facility to support CAT I approach and landing:

This MOPS only addresses ground station requirements for GBAS CAT I operations with GPS L1. There are no MOPS established by EUROCAE for GBAS airborne equipment.

IN ORDER TO BE APPROVED, GNSS RECEIVERS MUST COMPLY WITH ALL RELEVANT ENVIRONMENTAL CONDITIONS.

Other standards applicable to GNSS equipment

Reference	Title	Date
RTCA DO-178C	Software considerations in Airborne Systems and Equipment certification	December 2011
RTCA DO-278A	Software Integrity Assurance Considerations for Communication, Navigation, Surveillance and Air Traffic Management (CNS/ATM) Systems	December 2011
EUROCAE ED-12C	Software considerations in Airborne Systems and Equipment certification	December 2012
RTCA DO-248C	Supporting Information for DO-178 C and DO-287 A	December 2011
EUROCAE ED-109A	Software Integrity Assurance Considerations for Communication, Navigation, Surveillance and Air Traffic Management (CNS/ATM) Systems	January 2012
RTCA DO-254	Design Assurance Guidance for Airborne Electronic Hardware	April 2000
EUROCAE ED-79A	Guidelines for Development of Civil Aircraft and Systems	December 2010
EUROCAE ED-80	Design Assurance Guidance for Airborne Electronic Hardware	April 2000
ARP 4761	Guidelines and Methods for Conducting the Safety Assessment Process on Civil Airborne Systems and Equipment	December 1996
RTCA DO-160G	Environmental Conditions and Test Procedures for Airborne Equipment	August 2010
EUROCAE ED-14G with Change1	Environmental Conditions and Test Procedures for Airborne Equipment	January 2015

Software design assurance

Applicable to airborne GNSS receivers, the following standards are published by both RTCA and EUROCAE and are equivalent:

- RTCA DO-178 C Software considerations in Airborne Systems and Equipment certification: This document provides recommendations for the production of software for airborne systems and equipment that performs its intended function with a level of confidence in safety that complies with airworthiness requirements. Compliance with the objectives of DO-178C is the primary means of obtaining approval of software used in civil aviation products.
- RTCA DO-278A Software Integrity Assurance Considerations for Communication, Navigation, Surveillance and Air Traffic Management (CNS/ATM) Systems: This document provides guidelines for the assurance of software contained in non-airborne CNS/ATM systems and provides recommendations for the production of that software commensurate with a level of confidence in safety. DO-278A defines a set of objectives recommended to establish assurance that the developed CNS/ATM software has the integrity needed for use in a safety-related application.
- EUROCAE ED-12C Software considerations in Airborne Systems and Equipment certification: equivalent to RTCA DO-178 C.
- RTCA DO-248C Supporting Information for DO-178 C and DO-287A: This document addresses the questions of both the industry and regulatory authorities. It contains frequently asked questions (FAQs), discussion

papers (DPs) and rationale. Many of the FAQs and DPs are based on the previous version of this document, DO-248B; however, some have been modified to address the changes from DO-178B to DO-178C and to make it applicable to DO-278A. Additionally, some new FAQs and DPs have been added to provide additional clarification on DO-178C and/or DO-278A.

- EUROCAE ED-109A / Guidelines for CNS/ATM Systems Software Integrity Assurance: it is equivalent to RTCA DO-278A. It provides guidelines for the assurance of software contained in non-airborne CNS/ATM systems and provides recommendations for the production of that software commensurate with a level of confidence in safety.

Hardware design assurance

The following standards, published by both RTCA and EUROCAE are equivalent and applicable to the hardware design of GNSS receivers:

- RTCA DO-254 Design Assurance Guidance for Airborne Electronic Hardware: This document is intended to help aircraft manufacturers and the suppliers of aircraft electronic systems assure that electronic airborne equipment safely performs its intended function. The document identifies design life cycle processes for hardware that includes line replaceable units, circuit board assemblies, application-specific integrated circuits (ASICs), programmable logic devices, etc. It also characterizes the objective of the design life cycle processes and offers a means of complying with certification requirements.
- EUROCAE ED-79A – Guidelines for Development of Civil Aircraft and Systems: this document addresses the assignment of Development Assurance Level (DAL) throughout the functional breakdown of aircraft-level functions and the development life cycle of systems that implement them. It is complementary to SAE ARP 4754.
- EUROCAE ED-80 – Design Assurance Guidance for Airborne Electronic Hardware: equivalent to RTCA DO-254. It provides guidance to be used by aircraft manufacturers and suppliers of electronic hardware items used in aircraft systems.
- SAE ARP 4754 Rev. A – Guidelines for Development of Civil Aircraft and Systems: This document discusses the development of aircraft systems taking into account the overall aircraft operating environment and functions. It provides guidelines for the DAL allocation process and includes validation of requirements and verification of the design implementation for certification and product assurance. It provides practices for showing compliance with the regulations and serves to assist a company in developing and meeting its own internal standards by considering the guidelines.
- SAE ARP 4761 Guidelines and Methods for Conducting the Safety Assessment Process on Civil Airborne Systems and Equipment: This document describes guidelines and methods of performing the safety assessment for certification of civil aircraft. It is primarily associated with showing compliance with safety requirements stated in the airworthiness certification specifications (EASA CS 25.1309 and FAR 25.1309).

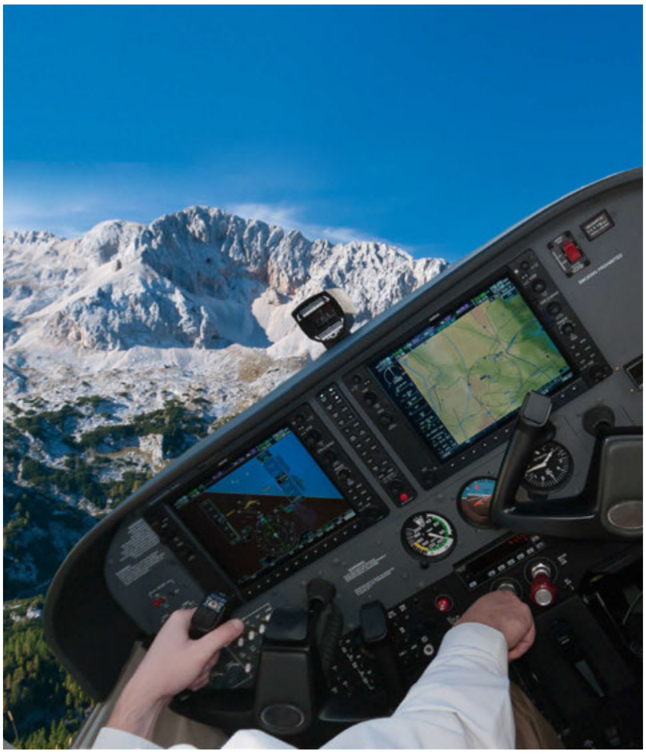
Environmental standards

GNSS receivers shall comply with environmental conditions to be approved. The main standards for such conditions and testing are:

- RTCA-DO 160G Environmental Conditions and Test Procedures for Airborne Equipment: DO-160G provides standard procedures and environmental test criteria for testing airborne equipment for the entire spectrum of aircraft from light, general aviation aircraft and helicopters through the "jumbo jets" and SST categories of aircraft. The document includes 26 sections and three appendices. Examples of tests covered include vibration, power input, radio frequency susceptibility, lightning and electrostatic discharge.

EUROCAE ED-14G: Environmental conditions and test procedures for airborne equipment: equivalent to RTCA DO-160G.

Coordinated with EUROCAE, RTCA/DO-160G and EUROCAE/ED-14G are identically worded. DO-160G is recognized by the International Organisation for Standardization (ISO) as de facto international standard ISO-7137.



ANNEX 5 – OVERVIEW OF THE GNSS-BASED NAVIGATION APPLICATIONS IN CIVIL AVIATION

AIR NAVIGATION

GNSS will be used in Air Navigation under the so called PBN concept, enabling all current PBN navigation specifications. The PBN evolution makes GNSS the main means of navigation while other sources, such as conventional navaids, are kept on some level and where feasible, as back-up systems for safety reasons.

Within PBN, RNAV and RNP applications are commonly characterized by a designator X referring to the lateral navigation accuracy in nautical miles. In case the required lateral accuracy varies along the path a suffix is used (e.g. RNP APCH for approach). The lateral accuracy performance is expected to be achieved at least 95 per cent of the flight time by the population of aircraft operating within the airspace, route or procedure.

The fundamental difference between RNAV and RNP applications is the need for a positioning monitoring and alerting function for RNP applications which mandates the use of GNSS.

- Oceanic and remote continental airspace concepts: they are supported by three navigation applications (RNAV 10, RNP 4 and RNP 2) relying primarily on GNSS for navigation.
- Continental en-route airspace concepts: they are currently supported by RNAV and RNP applications (RNAV 2, RNAV 5, RNP 5).
- Terminal airspace concepts (for arrival and departure): they are supported by RNAV applications and RNP used in the European (EUR) Region, the United States and, increasingly, elsewhere. The European terminal airspace RNAV application is known as P-RNAV (Precision RNAV).

Approach concepts: they cover all segments of the instrument approach, i.e. initial, intermediate, final and missed approach. These include RNP specifications requiring a navigation accuracy of 0.3 NM to 0.1 NM or lower. Typically, three sorts of RNP applications are characteristic of this phase of flight: new procedures to runways never served by an instrument procedure, procedures either replacing or serving as back-up to existing instrument procedures based on different technologies, and procedures developed to enhance airport access in demanding environments.

PBN SPECIFICATION

Reference	Title	Date
Commission IR (EU) 2017/xxx_	PBN Implementing Regulation	[end 2017]
EASA Opinion No 10/2016	Performance-based navigation implementation in the European air traffic management network	28 July 2016

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

The following figure, extracted from the EASA PBN IR Opinion 10/2016, shows the variations of the different options proposed along the public consultation of the aviation community:

Table 35: Future Navigation Specifications applicable in European airspace

	ICAO Resolution A37-11	Pilot Common Project Regulation (24 EU Aerodromes)	EASA NPA	EASA Opinion
Approach	RNP APCH to LNAV/ VNAV, LPV or LNAV minima to all IREs by 2016	RNP APCH to LNAV/ VNAV or LPV minima by 2024	RNP APCH to LNAV/ VNAV or LPV minima at IREs without precision approaches by 26 January 2024 or RNP-AR as required by obstacles.	RNP APCH to LNAV/ VNAV, LPV minima at IREs without precision approaches by 30 January 2020 or RNP-AR as required by obstacles. Plus RNP 0.3 for rotorcraft operations
TMA	RNAV and RNP where required	RNP 1 SIDs, STARs plus radius to fix (RF) by 2024	After 6 December 2018, RNP 1 SIDs, STARs plus • altitude constraints, • radius to fix (RF)	After 6 December, 2018 RNAV 1 SID/ STARs or RNP 1 Plus • altitude constraints, • radius to fix(RF) Plus RNP 0.3 for rotorcraft operations
En route	RNAV and RNP where required	N/A	After 6 December 2018, A-RNP (1 NM accuracy) above FL195 plus • altitude constraints, • fixed radius transition(FRT) • A-RNP (1 NM accuracy) below FL 195 plus, • RNAV Holding	Maintain current RNAV 5 (in addition to free route airspace required by the Pilot Common Project Regulation

It should be noticed that:

- The Pilot Common Project regulation already mandates RNP 1 SIDs/STARs on 24 major European airports and Istanbul.
- The option of A-RNP for en-route with specific exploitation of aircraft guidance modes above and below FL 195 as indicated on the above figure has finally been abandoned by EASA.
- RNP AR APCH and RNP 0.3 for rotorcraft operations have been retained and require a specific operational approval. The other navigation specifications do not require operational approval.

A-RNP

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

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

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

RNP 0.3

RNP 0.3 represents the same Advanced RNP philosophy but only for helicopter's operations. It's intended for all phases of flight: ATS Routes, SID, STAR and transitions to RNP APCH final approach or Point in Space (e.g. hospital helipads in urban environments).

PRECISION APPROACHES

GBAS CAT II/III

GBAS CAT I based on GPS is already in operation in some airports and CAT II/III based on GPS is under final stage of development and standardisation. It is expected to be deployed by 2020 according to the SESAR Navigation Roadmap.

CAT II/III is feasible using just GPS L1 signal augmented by GBAS, but this can be improved once Galileo is in operation (DFMC GBAS CAT II/III). SESAR project 15.3.7 (Multi GNSS CAT II/III GBAS) made significant progress on this topic (concept, identification of issues, definition of implementation options, standardisation and initial draft SARPs etc.). This project will have a follow-up in SESAR 2020 to start in Q4 2016.

SBAS CAT I, SA CAT I AND CAT I AUTOLAND

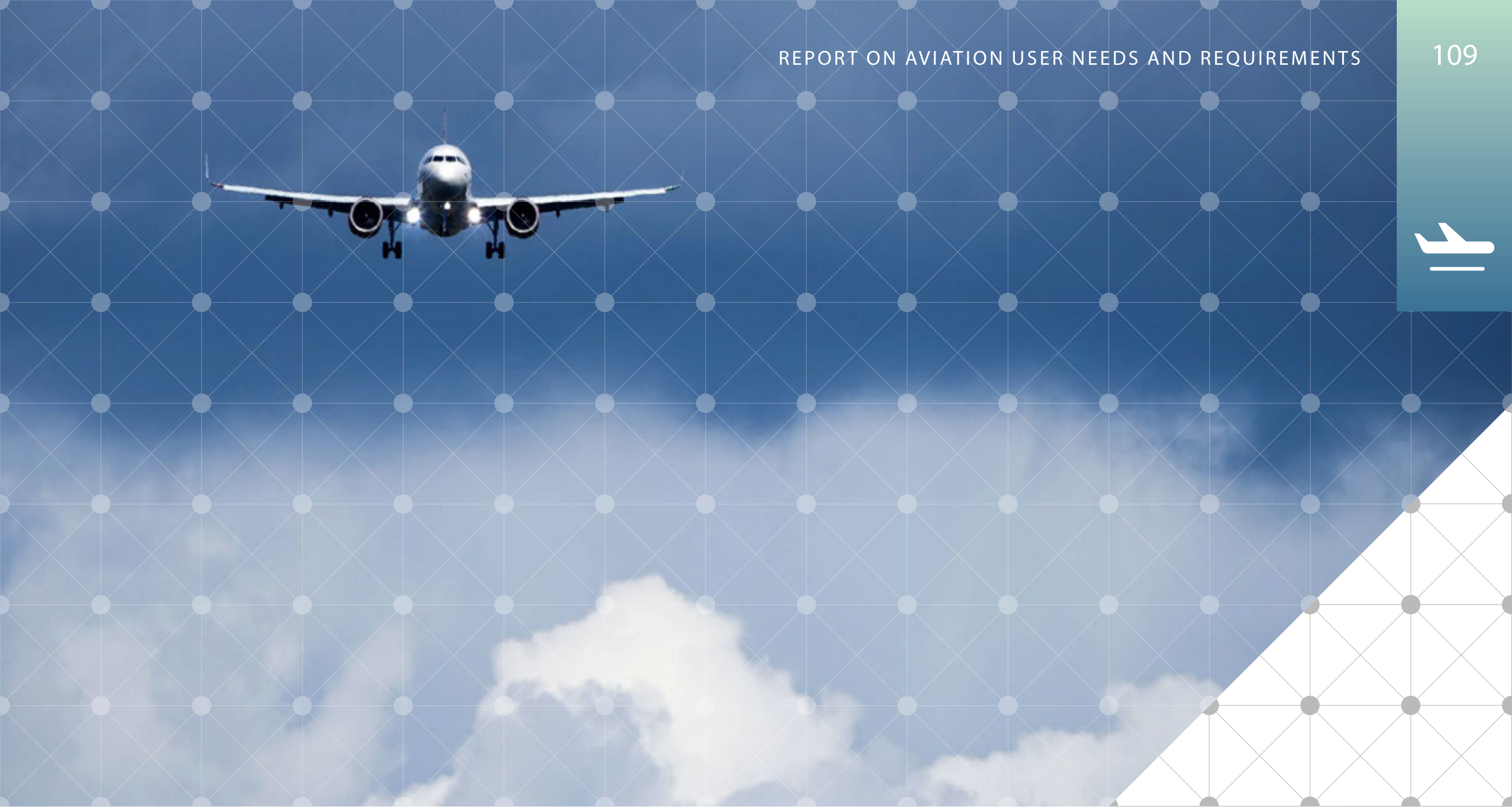
Reference	Title	Date
RMT.0379 – Issue 1	Terms of Reference for rulemaking task – All Weather Operations	9 December 2015

A new rulemaking task has been triggered by EASA in order to re-align the current European AWO rules considering technological advancements (e.g. Enhanced or Synthetic Vision Systems) as well the ICAO Annex 6 amendment introducing the new classification of approach with new CAT II and CAT III minima.

In the concept paper attached to the above reference, among the subjects that need to be addressed is *"other AWO, such as CAT I operations using ILS, approach landing system using ground-based augmented global navigation satellite system information (GLS) or satellite-based augmentation system (SBAS), or approach operations to higher minima using area navigation (RNAV) (global navigation satellite system (GNSS)), non-directional beacons (NDBs) or VHF omnidirectional ranges (VORs)".*

LPV 200 level of service meets the requirements of ICAO CAT I performances so it can be considered as SBAS CAT I operation with an equivalent operational level as ILS CAT I. It allows a minimum Decision Height down to 200 ft. The current concept considered by EASA is in between of the current CAT I and CAT II and is called Special Authorisation CAT I (SA CAT I).

One of the objectives of the AWO project is to introduce SA CAT I approach operations with a minimum DA/H of 150 ft and a minimum RVR of 450m to the European regulatory framework. SA CAT I operations are already successfully applied in a number of States, e.g., the US, Australia, and China. SBAS could be potentially used for this new approach category.



Autoland Category I has been already certified on Airbus aircraft using GBAS and some studies are assessing how EGNOS can be used for this application.

OTHER ADVANCED APPROACH CONCEPTS

Transition from P-RNAV/RNP/RNP AR to LPV: An approach can be based on RNP APCH or RNP AR. RNP APCH has a performance requirement of 1NM and RNP AR down to 0.1NM.

SESAR project 5.6.3 studies the possibility to make a transition between RNP APCH or RNP AR to a final approach with an SBAS 3D guidance. Approaches with RF in the final segment or RF capability for RNP APCH can be studied. Also AMC 20-26 and PBN Manual do not allow a transition from RNP AR to LPV procedures based on SBAS since the vertical guidance in the final approach segment can only be supplied by barometric signal.

Transition from continuous descent approach (CDA) to LPV continuous descent approach allows an aircraft to descend from an optimal point with minimum thrust. This technique has relevant environmental benefits (noise and emission) and fuel savings. The SESAR project studies how to combine CDA with SBAS final approach segments like LPV or APV.

Steep approach (5º) based on GNSS (EGNOS): current approaches have in the final segment an angle of 3º. Approaches with a greater angle (5º) can give some operational benefits and enhance the access to airports sited in mountainous or urban areas (e.g. London city). SBAS approaches are very suitable to environments with difficult relief, so steep approaches can be an additional benefit to improve accessibility to these aerodromes.

PBN Approach procedures in simultaneous operations to instrument parallel runways (SOIR): A new amendment is in progress to PANS-OPS and PANS-ATM (as well as SOIR Manual – ICAO DOC 9643-) in order to incorporate PBN approach procedures in SOIR. RNP APCH and/or RNP AR APCH navigation specification will be required and it is of paramount importance that, once the aircraft is established in the RNP AR APCH, no vertical separation will be required with the aircraft on parallel approach (currently it is necessary to keep at least a vertical separation of 1000 ft between aircraft before the final approach segment). This will have a positive effect on the capacity of the airports with parallel runways and moves the focus beyond only complex obstacle scenarios.

AN APPROACH CAN BE BASED ON RNP APCH OR RNP AR, WITH RNP APCH HAVING A PERFORMANCE REQUIREMENT OF 1NM AND RNP AR DOWN TO 0.1NM.

MULTI-CONSTELLATION – MULTI-FREQUENCY RECEIVERS

Reference	Title	Date
NSP October 2017 [several papers]	Next Generation GNSS CONOPS: Service provision framework and approval of GNSS elements by States	Oct 2017
EU-US Cooperation on Satellite Navigation Working Group C – ARAIM Technical Subgroup	Milestone 3 Report – Final Version	25 February 2016
GSA/GRANT/01/2017	Call for Proposals for Development of an Advanced RAIM Multi-constellation Receiver (ARAIM)	08 June 2017

The main R&D topics for DFMC are related to the development of DFMC SBAS systems (such as EGNOS V3) and DFMC receivers' technology (that will include SBAS and ABAS).

SBAS L1/L5 – Multi-constellation

The development of Dual-Frequency Multi-Constellation SBAS is on-going at ICAO Navigation System Panel for DFMC SBAS SARPs and at EUROCAE Working Group 62 for the DFMC SBAS MOPS.

The draft standard including a complete definition of the DFMC SBAS message is applicable to EGNOS V3, which the GSA is procuring via ESA.

For what concerns maturing draft standards, this work is carried out in parallel with the development of EGNOS V3. It should be noticed that EGNOS V3 includes options for the extension of the service area to Ukraine and Africa. The GSA is currently defining a programmatic study of EGNOS V3 over sub-Saharan Africa, funded by the EU-African Partnership programme.

Advanced RAIM (A-RAIM)

This concept has been developed in the frame of the EU-US Cooperation on Satellite navigation – WG C - ARAIM Technical Subgroup.

The A-RAIM concept aims at overcoming the limitations of the conventional RAIM algorithms mainly applicable to a single constellation and not able to address the vertical plane. To this end, A-RAIM will allow:

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

The A-RAIM concept distinguishes two application steps:

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

Several R&D projects on A-RAIM have been funded in Europe. The SAFE project, funded by EUROCONTROL, demonstrated the feasibility and benefits of introducing H-ARAIM in the first generation of DFMC receivers. In September 2016 a contract was awarded by the EC (H2020) for the development and test of an A-RAIM demonstrator.

Development of DFMC receivers

There are several R&D activities of different nature currently running:

Thales Avionics is developing a DFMC prototype receiver to the level required for flight tests by 2021 within the EDG2E project.

With regards to standardisation, the GESTA project of the GSA will support development and validation of MOPS and SARPs.

SESAR WP 9.27 carried activities for the development of a mock up DFMC received that will continue in SESAR H2020.

DFMC GNSS MOPS under elaboration

RTCA

Considering the RTCA SC-159 updated ToRs in June 2015, the work programme for GNSS standardisation for the next years intends to deliver the following standards:

Table 34: RTCA programme of Work (ToRs-June 2015)

Product	Description	Due Date
DO-253D	Updated GBAS MOPS	March 2016 (Not yet issued)
DO-246E	Updated GBAS ICD	March 2016 (Not yet issued)
GPS/GLONASS L1-only MOPS	New MOPS for GPS/GLONASS (FDMA + antenna) L1-only airborne equipment	March 2016 (Not yet issued)
GNSS-Aided Inertial Systems MOPS	New MOPS for GNSS-aided inertial navigation systems.	July 2017
DO-235C	Updated L1 interference environment report	December 2017
DO-292A	Updated L5 interference environment report	December 2017
GNSS L1/L5 Antenna MOPS	New GNSS dual-frequency (1575/1176 MHz) antenna MOPS for airborne equipment	December 2017
GNSS(SBAS) L1/L5 MOPS	Initial MOPS for Verification and Validation Validated GPS/SBAS MOPS for dual-frequency equipment including, if possible, at least one additional core constellations	2019-2020 2021-2022

In order to address other core constellations (Galileo, BeiDou, GLONASS CDMA) in their future standards the RTCA requires the submission of a number of information on each constellation.

In this programme of work, the following augmentations will be considered:

- Aircraft-based augmentation system – as defined by ICAO, this includes receiver autonomous integrity monitoring (RAIM), which uses GNSS information exclusively, and aircraft autonomous integrity monitoring (AAIM), which uses information from additional on-board sensors (e.g., barometric altimeter, clock and inertial navigation systems). Consideration should be given to advanced RAIM (ARAIM) methods currently under development, including for horizontal-only applications.
- SBAS.
- GBAS.

RTCA also intends to address to the practicable extent, the threats of intentional interference and spoofing as well as the possibility of higher levels of adjacent-band interference.

RTCA work will be coordinated with EUROCAE WG62 (Galileo) and WG 28 (GBAS) as well as with the ICAO NSP.

EUROCAE

EUROCAE WG 62 intends to produce a draft MOPS for Galileo/GPS/SBAS (DFMC) in the coming years based on information contained in the draft Galileo OS/ABAS Receiver MOPS. This latter document will likely never be published as a MOPS since no avionics manufacturer seems interested by a Galileo-only receiver.

The draft MOPS for Galileo/GPS/SBAS will be released to RTCA for finalizing this MOPS with GPS L5 features and to be published as the GNSS(SBAS) L1/L5 MOPS including the Galileo constellation.

For what concerns Dual frequency / Multi-constellation GBAS, no MOPS has been propsed yet for GBAS systems using dual frequency and multi-constellation. The on-going work focuses on the in-field validation of standards for GBAS CAT II/III based on GPS L1 in order to satisfy airlines operational requirements.

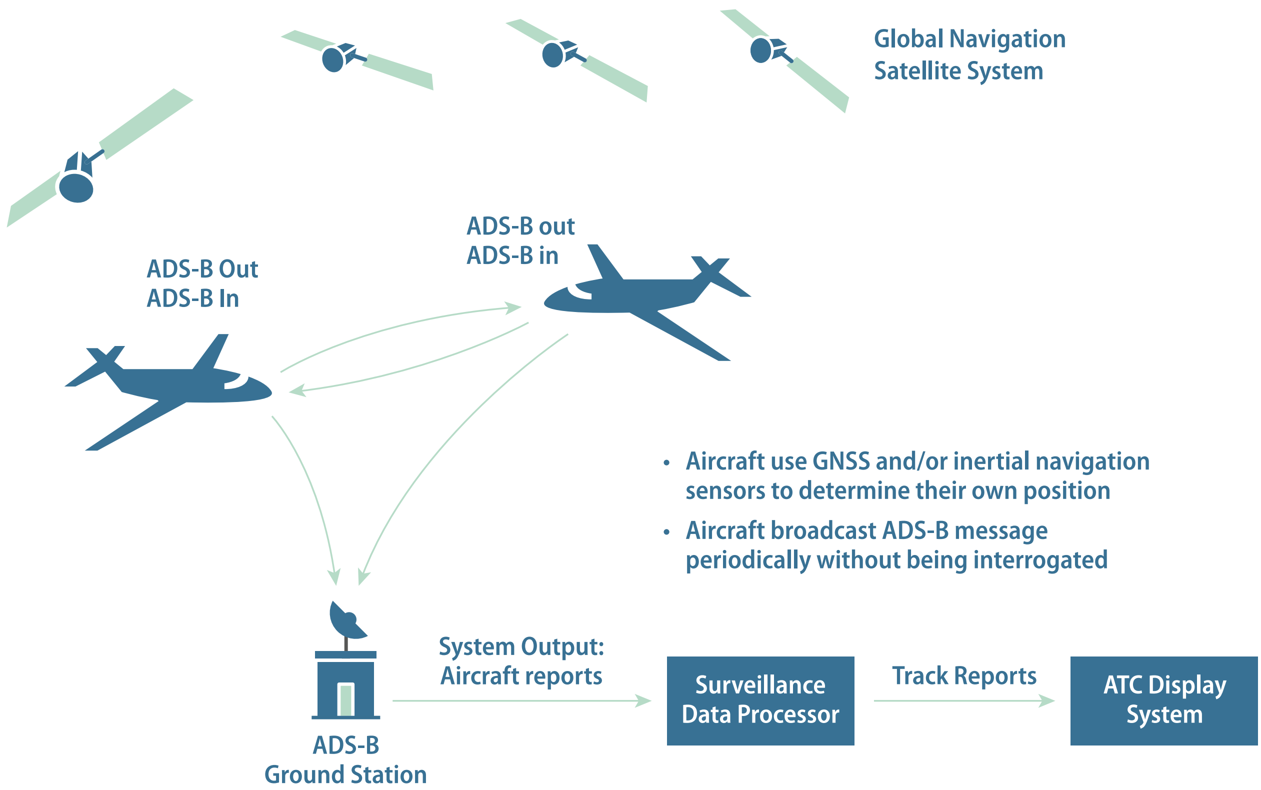
To reach the stringent requirements for such CAT II/III operations the main difficulty remains the ionosphere particularly in the southern hemisphere and in Japan. Transitioning to dual-frequency and dual constellation GBAS would remove part of these difficulties. EUROCAE WG 28 has put in its long term working plan the standardisation of DFMC GBAS based on GPS and Galileo. The research work is conducted in SESAR Work Package 15-3-7 project and continues in SESAR 2020.

SURVEILLANCE ADS-B

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

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

Figure 13: ADS-B functional architecture



The use of SBAS as a positioning source for ADS-B provides the same level of service as SSR (99.9% availability) that can allow in the future the reduction of SSR duplicity with new ADS-B infrastructure: Mode S SSR coverage duplicity is to be eliminated from Europe through the replacement of the required SSRs with ADS-B ground stations.

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

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

There are ADS-B Out carriage mandates already in force or with defined targeted dates:

Table 37: Main ADS-B mandates and timelines

USA				1 January ADS-B Out mandatory
Europe		8 June 2016 ADS-B Out for new aircraft		7 June 2020 ADS-B Out retrofit
Australia	12 Dec 2013 All above FL290	Feb 2016 Western Australia	Feb 2017 All IFR	
Canada	ADS-B Out Hudson Bay			ADS-B Out mandatory (expected)

ADS-B IN

When aircraft systems already implement ADS-B Out, flights are able to take advantage of all the benefits of real-time broadcast of the position of the aircraft around the sky. The ADS-B In system is a receptor that allows the processing and display to the crew of ADS-B Out information emitted by other mobiles.

ADS-B In is designed:

- To increase the situational awareness of the flight crew. The aircraft caught the signal emitted by the ADS-B Out systems through the transponder and the TCAS processed it in order to meet the traffic situation around them,
- To allow the participation of the crew to maintain aircraft separation, thus sharing this responsibility with the ATC controller. This is particularly efficient over Oceanic airspace when no surveillance service is available, thus allowing optimized aircraft separation including for flight level change, or in approach to optimize aircraft separation in terminal and approach phases thus increasing the airport throughput with substantial savings of fuel cost and CO_2 emission.

Some ADS-B In and Out applications are already in service in some airspace (e.g. ADS-B In Trail Procedure –ITP- over the North Atlantic Ocean) and new application deployments are under consideration in SESAR, knowing that RTCA/EUROCAE standards are already published but still need regulatory documents for implementation:

- ADS-B in Radar Airspace with three separation levels: 5 NM, 3 NM and <2.5 NM,
- ADS-B in Radar Airspace for independent or parallel approaches,
- ADS-B ATSA (Air Traffic Situational Awareness),
- ADS-B Airport,
- ADS-B ATSA for Visual Separation in Approach (VSA),
- ADS-B ATSA during Airborne Flight Operations (AIRB),
- ADS-B ATSA on the Airport Surface (SURF),
- ADS-B ATSA for Flight Deck Interval Management (IM). For this latter application no standards are yet published.

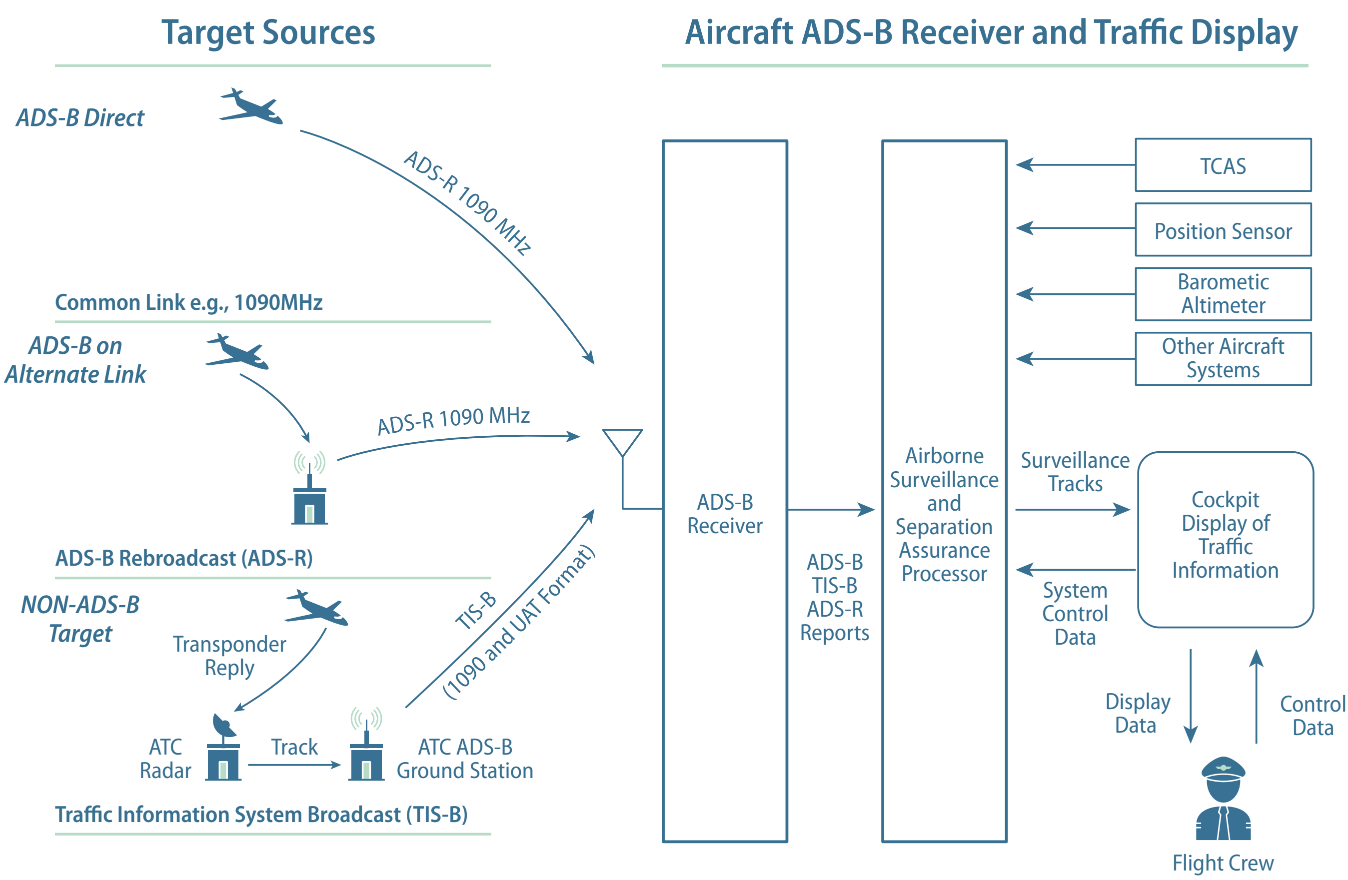
ADS-B In quick adoption in the US is currently driven by General Aviation due to free ADS-B Flight Information Services-Broadcast (FIS-B) distributed through UAT (traffic and weather) in the NAS. There are 10 000 aircraft, mostly GA aircraft, already equipped with ADS-B In. Avionics makers and associations such as the General Aviation Manufacturers Association (GAMA) and the National Aviation Business Association (NBAA) have reported that GA aircraft operators find ADS-B In beneficial, in part, because of the numerous free services available to the aircraft via the Universal Access Transceiver (UAT). Originally developed as the single ADS-B data link for the NAS, UAT is now the preferred data link for all GA aircraft that fly below 18,000 feet.

For commercial aircraft equipment with ADS-B In, the situation is more contrasted, since traffic and weather information service is a US specificity and requires a UAT transceiver. Airlines are seeking for implementation of new ADS-B applications (In and Out) without the need to equip their fleet with a UAT transceiver in addition to the Mode S transponder.

To ensure a full interoperability between aircraft equipped with only one ADS-B system, either Mode S or UAT, the ADS-R (Rebroadcast) allows translating, reformatting, and rebroadcasting the information from each frequency to enable aircraft operating on the alternate frequency to process and use the other's information. This process occurs within the ADS-B ground station. It is mostly used in the US.

The following figure provides a synthesis of the different functions and means for ADS-B In applications:

Figure 14: ADS-B In and Out extended applications



ADS-B In and Out extended applications

ADS-B Out can also be used by Advanced Surface Movement Ground Control Systems for airport operations. It is currently mainly used for airport vehicles. However, in the A-SMGCS community GNSS positioning is still considered as a complementary source of position, the primary sensors being surface radar and MLAT systems.

The current R&D carried out in SESAR, to be pursued in SESAR H2020, is more oriented towards airports safety nets and new a-SMGCS functions (routing and planning, guidance) rather than the evolution of positioning requirements applicable to GNSS as defined in ICAO documents and standards. New operational requirements for airport safety nets may however be subject to evolution of positioning requirements.

OTHERS

Search and Rescue

Reference	Title	Date
ICAO GADSS 6.0	Global Aeronautical Distress & Safety System (GADSS)	07 June 2017

After the problems raised in the location of some of the last major aircraft distresses the issues of aircraft tracking and location of an aircraft in distress have become critical. New regulation is being proposed trying to prevent these problems.

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

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

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

RLS Return Link Service

The Return Link Service (RLS) is a new feature enabled by Galileo which can be incorporated into SAR beacons. The service is revolutionary as it has the ability to introduce a number of new functions including:

- Informing the casualty that the rescuer is on the way, this can provide peace of mind and will reduce panic and stress in the situation.
- Remote operation of beacons to find missing ships, aeroplanes or persons that have been reported missing and their location is unknown.
- Minimisation of false alarms, the return link will facilitate the emission of an alert notifying the users that the beacon has been activated. This can then be deactivated if it is a false alert.
- Broadcast message, used to alert nearby beacons that there has been an incident and request assistance from them if appropriate.

Flight tracking

After the recent aircraft losses in the ocean (flights AF447 and MH370) ICAO recognized in the second High Level Safety Conference (HLSC 2015) the need to increase significantly the effectiveness of the current alerting and Search and Rescue services. At European level that recommendation has been transposed to EASA decisions as a proposal to amend the EASA AIR OPS including new requirements for flight tracking.

There is a proposal to amend the Acceptable Means of Compliance and Guidance material of EASA parts ORO, CAT, NCC and SPO related to flight recorders, underwater locating devices and aircraft tracking systems. The specific objectives of this proposal are to address the issues of aircraft tracking, location of an aircraft in distress, CVR recording protection, data link recording applicability, and performance specifications for the FDR and the FDR parameters trying to prevent the problems found in the location of some of the last major aircraft distresses.

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

After the Amendment 39 to ICAO Annex 6, flight tracking systems will be generalised by November 2018, allowing a position report at least every 15 minutes even in airspaces where an ATS Unit only obtains aeroplane position information at greater than 15 minute intervals.

Time synchronisation

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

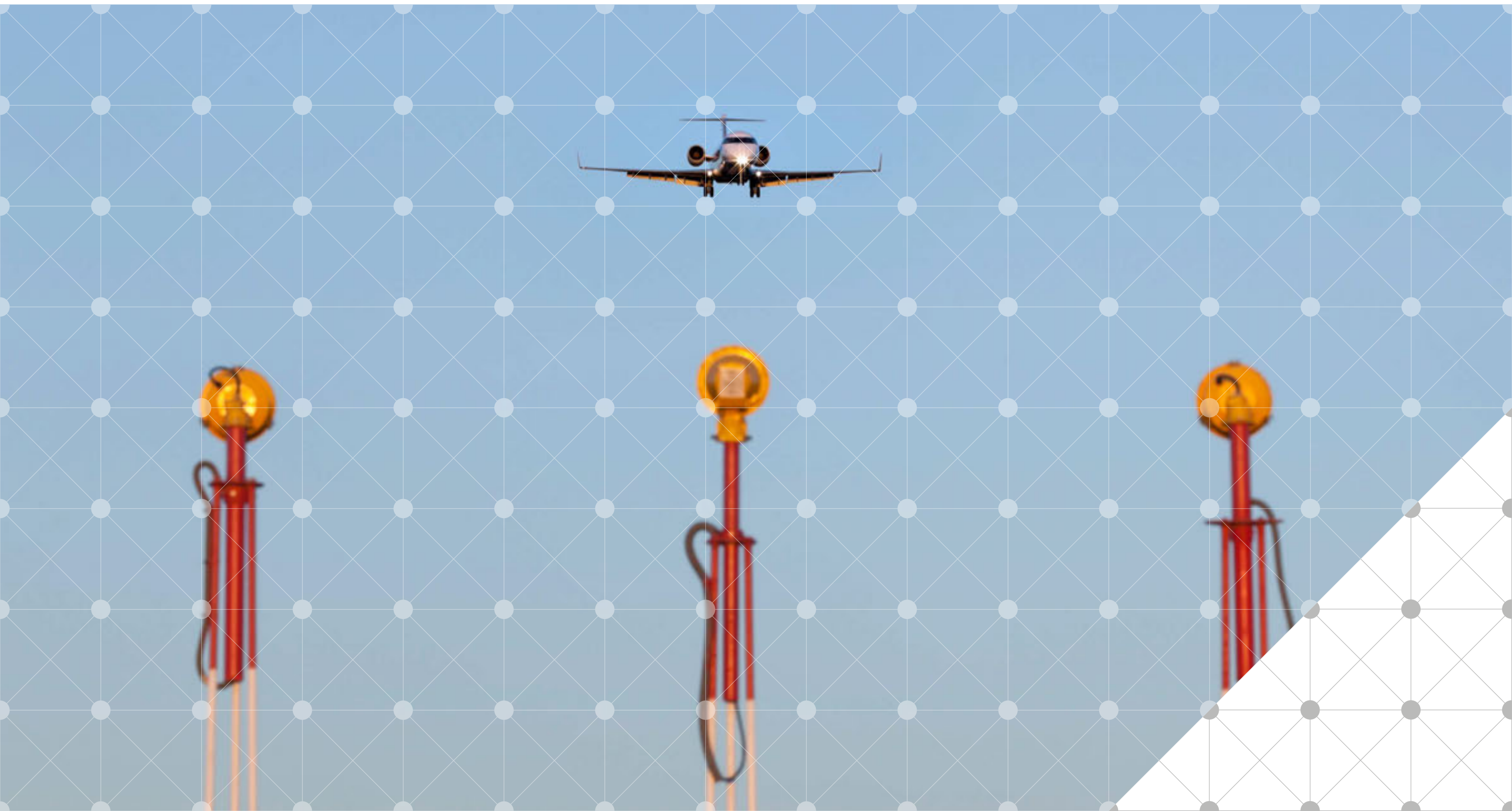
In the aviation domain, surveillance sensor data exchange with ATM systems is the most common application using GNSS timing, as the surveillance data have to be time-stamped, to inform the system of the target position measurement event time.

For this purpose, both surveillance systems and ATM systems at air traffic control (ATC) centres mostly rely on GNSS for time referencing. In general, it provides time signals to more than one master clock in each ATM or Surveillance systems, which act as UTC time servers for the rest of the ATM or surveillance modules.

Terrain awareness

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

- Ground Proximity Warning System (GPWS): this system is a safety net based on the radio altimeter providing alarms to the crew. It appeared in the 70's. This kind of system does not use GNSS.
- Terrain Avoidance and Warning System (TAWS) or Enhanced Ground Proximity Warning System (EGPWS): this kind of system has been introduced by Honeywell in the late 90's and is based on the aircraft position (mostly GNSS) correlated with an almost worldwide terrain/obstacles/airport database regularly updated by the system manufacturer. It provides sophisticated alerts to the crew depending on functions installed in the



equipment. Such systems (two classes A and B defined) are mandatory for aircraft of more than 5700 kg and with more than 9 seats as well as for helicopters of more than 3175 kg and 9 seats for IFR operations.

Drones

Notice of Proposed Amendment 2017-05	Introduction of a regulatory framework for the operation of drones	4 May 2017

EASA's definition of drone is as follows: "Drone shall mean an aircraft without a human pilot on board, whose flight is controlled either autonomously or under the remote control of a pilot on the ground or in another vehicle."

The range of type of drones is huge, from microdrones to big aeroplanes, and the type of operations is also quite diverse with a number of different potential applications. Therefore, it's not possible to talk about one single aviation application when talking about drones. Furthermore, the regulatory framework is still under development and the main challenge is to integrate drones into non- segregated airspace together with other types of aircraft.

Although drones are not primarily intended for passenger transport, they should follow the same safety concerns as any other aircraft and even more because of the added risk of loss of communications needed to fly them. The consequences of a drone accident could also be critical and affect humans or valuable infrastructure.

Besides the safety reasons, there could be aviation applications where more accurate and integrate systems are required. The number of drone's applications requiring a high degree of navigation performance is growing in parallel to their development. Some drone's applications for science, agriculture, goods delivery, surveying or even search and rescue might require higher precision in the future and the need to fly at low altitudes, close to the ground.

The integrity requirements for manned aircraft might not be sufficient for some drones for the reasons above and taking also into account the dimensions of some of them. SBAS and the future multi-constellation multi-frequency receivers with H-ARAIM would also allow a more robust ATM system into the case of drones' integration in controlled airspace.

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