ICAO

Doc 9613

Performance-based Navigation (PBN) Manual

Fifth Edition, 2023

Approved by and published under the authority of the Secretary General

INTERNATIONAL CIVIL AVIATION ORGANIZATION

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Vol II – *Implementing RNAV and RNP Operations*
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AMENDMENTS

Amendments are announced in the supplements to the *Products and Services Catalogue;* the Catalogue and its supplements are available on the ICAO website at www.icao.int. The space below is provided to keep a record of such amendments.

RECORD OF AMENDMENTS AND CORRIGENDA

AMENDMENTS		
No.	Date	Entered by

CORRIGENDA			
No.	Date	Language	Entered by

EXECUTIVE SUMMARY

The performance-based navigation (PBN) concept specifies that aircraft RNAV and RNP system performance requirements be defined in terms of accuracy, integrity, continuity and functionality, which are needed for the proposed operations in the context of a particular airspace concept. Performance requirements are identified in navigation specifications, which also identify the choice of navigation sensors and equipment that may be used to meet the performance requirements. These navigation specifications are defined in a sufficient level of detail to facilitate global harmonization by providing specific implementation guidance for States and operators. This manual contains a very broad range of information, guidance and other considerations for stakeholders who are choosing to implement PBN applications. This includes an explanation of the PBN concept, implementation guidance for a PBN application, considerations for States and service providers and guidance/requirements for aircraft and operators.

Under PBN, generic navigation requirements are defined based on operational requirements. Operators then evaluate options in respect to available technology and navigation services, which could allow the requirements to be met. Technology can evolve over time without requiring the operation itself to be reviewed, as long as the expected performance is provided by the RNAV or RNP system.

Within an airspace concept, PBN requirements will be affected by the communications, air traffic services (ATS) surveillance and air traffic management (ATM) services, the navigation aid (NAVAID) infrastructure, and the functional and operational capabilities needed to meet the ATM application. PBN requirements also depend on what reversionary, conventional navigation techniques are available and what degree of redundancy is required to ensure adequate continuity of functions.

Development of the PBN concept

Since the original PBN concept publication in 2008, a number of changes have been introduced. New navigation specifications intended to meet the needs of future navigation applications, notably RNP 2 and Advanced RNP, were included in the 4th edition of the PBN Manual (2013), along with advanced functionality such as radius to fix (RF path terminator).

The RF path terminator functionality was initially included as a capability within the RNP AR APCH navigation specification requiring specific authorization. As more aircraft acquired this capability and airspace designers began to see the advantages of its use, the RF path terminator was included as an optional capability. The use of RF path terminator for anything other than RNP AR APCH has been clarified within the 5th Edition and Doc 8168 (PANS-OPS, Volume II).

Advanced RNP was initially intended as a future navigation specification, which would incorporate requirements and options for the potential development of multiple application concepts, including scalability of the RNP value. In the 5th edition of this manual, this navigation specification is refined to reflect the updated requirements of DO-236()/ED-75(), except the requirement for scalable RNP value has been removed, as described in Volume II, Part C, Chapter 4.

While no attempt has been made in this manual to remove, or mark as obsolete, any navigation specification, it should be considered that, for some applications, a move from RNAV to RNP is now recommended (for example, RNAV 10 is considered archaic, while RNP 4 provides improved operations). As the progression in aircraft and system technologies continues, the designation of navigation specifications as ‘not intended for future applications’ may be considered.

The 4th edition also introduced RNP 0.3 as a navigation specification intended primarily for helicopter use, while in the 5th edition, this is clarified as being solely for the use of helicopters. Similarly, the increasing focus on remotely piloted aircraft systems (RPAS) has generated questions regarding the suitability of the existing navigation specifications for RPAS operations and the need to develop RPAS-specific navigation specifications. No mention is made in this manual of RPAS or the use of PBN by autonomous/semi-autonomous aircraft. It is expected that these systems, where they will be integrated into existing airspace, will comply with the requirements of such airspace and therefore will need to be approved for PBN operations consistent with the guidance and criteria contained in Volume II. Future development, including specific navigation specifications for unmanned aircraft systems (UAS)-type operations, may need to be considered if an operational requirement can be clearly described.

The 5th edition also includes changes affecting RNP implementation including updated technical standards from the Radio Technical Commission for Aeronautics (RTCA) and the European Organisation for Civil Aviation Equipment (EUROCAE), expansion of RNP applications where authorization is required, lessons learned from RNP procedures publication and updated PBN regulatory guidance material.

FOREWORD

History of this manual

The Special Committee on Future Air Navigation Systems (FANS) identified that the method most commonly used over the years to indicate required navigation capability was to prescribe mandatory carriage of certain equipment. This constrained the optimum application of modern on-board equipment. To overcome this problem, the committee developed the concept of required navigation performance capability (RNPC). FANS defined RNPC as a parameter describing lateral deviations from assigned or selected track as well as along track position, fixing accuracy on the basis of an appropriate containment level.

The RNPC concept was approved by the ICAO Council and was assigned to the Review of the General Concept of Separation Panel (RGCSP) for further elaboration. In 1990, the RGCSP, noting that capability and performance were distinctly different, and that airspace planning is dependent on measured performance, rather than designed-in capability, changed RNPC to required navigation performance (RNP).

The RGCSP then developed the concept of RNP further by expanding it to be a statement of the navigation performance necessary for operation within a defined airspace. It was proposed that a specified type of RNP should define the navigation performance of all users within the airspace to be commensurate with the navigation capability available within the airspace. RNP types were to be identified by a single RNP value as envisaged by FANS. While this was found to be appropriate for application in remote and oceanic areas, the associated guidance for route separation was not sufficient for continental RNAV applications; this was due to a number of factors, including the setting of performance and functional standards for aircraft navigation systems, working within the constraints of available airspace, and using a more robust communications, ATS surveillance and ATM environment.

Due to the gradual development of area navigation capability, together with the need to derive early benefits from the installed equipment, different specifications of navigation capability were developed with common navigation accuracy. A divergence of implementation resulted in a lack of harmonization between RNP applications, which needed to be addressed with a globally harmonized concept.

On 3 June 2003, the ICAO Air Navigation Commission, when taking action on recommendations of the fourth meeting of the Global Navigation Satellite System Panel (GNSSP), designated the Required Navigation Performance and Special Operational Requirements Study Group (RNPSORSG) to act as the focal point for addressing several issues related to required navigation performance (RNP).

The RNPSORSG reviewed the ICAO RNP concept, taking into account the experiences of early application as well as current industry trends, stakeholder requirements and existing regional implementations. It agreed on the relationship between RNP and RNAV system functionality and applications and developed the PBN concept, which allows global harmonization of existing implementations and creates a basis for harmonizing future operations.

The PBN concept described in Volume I should be viewed as more than just a remodelling or an extension of the RNP concept (see Chapter 1, 1.1.1). This volume should not be read in isolation as it is both an integral part of, and complementary to, Volume II – *Implementing RNAV and RNP operations*.

A regular review of the material would be necessary to accommodate future changes. The 5th edition has been updated to reflect new requirements, such as the use of RF legs and the introduction of RNP AR departures, as well as to provide additional or revised guidance on a range of subjects. Specific changes include:

a) clarification of the distinction between RNAV and RNP and related functionality; systematic use of the term RNP value, although it is understood that some industry standards continue using RNP with this specific meaning;

b) clarification and guidance on PBN versatility through its ability to enable multiple navigation applications for different airspace concepts from a navigation specification;

c) changes to the advanced RNP navigation (A-RNP) specification, including:

  1) final approach segment no longer considered a part of A-RNP; and

  2) scalability requirements replaced by use of RNP value of 0.3 NM outside of the final approach segment;

d) additional guidance on the implementation of A-RNP;

e) the RNP AR APCH specification is complemented by the RNP AR departure procedures (DP) with consequential changes relating to criteria for the development of AR DP procedures (*Required Navigation Performance Authorization Required (RNP AR) Procedure Design Manual* (Doc 9905)), charting requirements for RNP AR departures (*Aeronautical Chart Manual* (Doc 8697)), the process for authorization of new AR DP specifications (*Performance-based Navigation (PBN) Operational Authorization Manual* (Doc 9997[1])), and route spacing standards for AR Departures (*Procedures for Air Navigation Services – Air Traffic Management* (PANS-ATM, Doc 4444));

f) updates and additions to aircraft systems and equipment performance, functionality and capability (including speed transitions, MagVar, parallel offsets, etc) reflecting RTCA or EUROCAE documents are included in the navigation specification descriptions and attachments as appropriate;

g) refinement regarding use of the radius to fix leg, with consequential changes to Doc 9997, the *Procedures for Air Navigation Services – Aircraft Operations* (PANS-OPS, Doc 8168) with revised criteria for procedure design using RF legs, and PANS-ATM with route spacing standards for aircraft using RF leg;

  1) this includes catering to the needs of General Aviation aircraft operations on PBN routes and procedures, resulting in amendments to certain navigation specifications and augmented text in various other parts of the manual;

h) additional positioning sources such as GBAS and dual frequency multiple constellation technologies are accounted for in RNP navigation specifications, which require use of a core global navigation satellite system (GNSS) constellation, supplemented by an augmentation system, as appropriate;

i) consideration and awareness on the development of GNSS reversion capability;

j) removal of references to the minimum navigation performance Standards (MNPS), which are no longer used;

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1. Formerly the *Performance-based Navigation Operational Approval Manual*, renamed in its third (forthcoming) edition.

k) review of applicable path terminators for navigation specifications and guidance on combinations of such path terminators in procedure design;

l) additional guidance on temperature correction;

m) RNP 0.3 navigation specification, now explicitly defined as helicopter-only;

o) replacement of guidance and functional specifications for barometric VNAV across multiple flight phases with guidance and information for vertical navigation on the final approach segment;

p) guidance on ATC status monitoring for GNSS; and

q) clarification on the definition and the use of holding capabilities.

Structure of the Manual

This manual consists of two volumes:

Volume I – *Concept and implementation guidance*

Volume II – *Implementing RNAV and RNP operations*

Organization and contents of Volume I:

Chapter 1 – *Description of performance-based navigation (PBN),* explains the PBN concept and specifically emphasizes the designation of navigation specifications as well as the distinction between RNAV and RNP navigation specifications. This chapter provides the foundation for the manual.

Chapter 2 – *Airspace concepts,* provides context to PBN operations within a designated airspace, and also clarifies that PBN is one of the communications, navigation, and surveillance (CNS)/ATM enablers in an airspace concept.

Chapter 3 – *Stakeholder uses of performance-based navigation (PBN),* explains how airspace planners, procedure designers, airworthiness authorities, controllers and pilots use the PBN concept. Written by specialists of these various disciplines, this chapter is intended for non-specialists in the various disciplines.

Chapter 4 – *Introduction to PBN implementation,* provides a brief, general overview of how PBN implementation should be accomplished, as well as of the main underlying process.

Attachments to Volume I

Attachment A – *RNAV and RNP Systems*, provides an explanation of RNAV and RNP systems, how they operate and what the benefits are. This Attachment is particularly directed at air traffic controllers and airspace planners.

Attachment B – *Data Processes*, is directed at anyone involved in the data chain, from surveying to packing of the navigation database. This attachment provides a simple and straightforward explanation of a complex subject.

Organization and contents of Volume II

Part A: *General* provides general information on the PBN concept, including on-board performance monitoring and alerting, safety assessment considerations and navigation service monitoring.

Part B: *Implementing RNAV operations* includes information on implementing RNAV navigation specifications.

Part C: *Implementing RNP operations* contains information on implementing RNP navigation specifications.

Attachments to Volume II provide specific information on the topics associated with navigation specifications.

PBN terminology

Two fundamental aspects of any PBN operation are the requirements set out in the appropriate navigation specification and the NAVAID infrastructure (both ground- and space-based) allowing the system to operate.

A navigation specification contains a set of requirements for aircraft, navigation systems and aircrew needed to support a navigation application within a defined airspace concept. The navigation specification defines the performance required by the RNAV or RNP system as well as any functional requirements such as the ability to conduct curved path procedures or to fly parallel offset routes.

RNAV and RNP systems are fundamentally similar. The key difference between them is the requirement for on-board performance monitoring and alerting. A navigation specification that includes a requirement for on-board navigation performance monitoring and alerting is referred to as an RNP navigation specification. One not having such requirement is referred to as an RNAV navigation specification. An area navigation system capable of achieving the performance requirement of an RNP navigation specification is referred to as an RNP system.

In elaborating the PBN concept and developing associated terminology, it became evident to the Required Navigation Performance and Special Operational Requirements Study Group (RNPSORSG) that the use of RNAV and RNP-related expressions could create some complexities. States and international organizations should take particular note of the Explanation of Terms and to Chapter 1 of Volume I of this manual.

Because specific performance requirements are defined for each navigation specification, an aircraft approved for a particular navigation specification is not automatically approved for any other navigation specification. Similarly, an aircraft approved for an RNP or RNAV navigation specification having stringent accuracy requirements (for example, RNP 1 specification) is not automatically approved for a navigation specification having a less stringent accuracy requirement (for example, RNP 4).

Note.— Documents listed in Volume II, Attachment E provide information on the applicable airworthiness requirements to be met for aircraft to be approved for a particular navigation specification.

For additional clarity, and to allow for differentiation between the navigation specification and the RNP value (lateral navigation accuracy), the following conventions have been applied throughout this manual:

RNP 1 refers to the navigation specification (Volume II, Part C, Chapter 3).

RNP 0.3 refers to the navigation specification (Volume II, Part C, Chapter 7).

RNP 1.0 is an RNP value (lateral navigation accuracy) expressed in NM.

RNP 0.30 is an RNP value (lateral navigation accuracy) expressed in NM.

Authorizations for PBN operations

An authorization entitles an operator, owner or pilot-in-command to undertake the authorized operations. Authorizations can take the form of approvals, specific approvals or acceptances.

PBN operations require different levels of authorization depending on the navigation specification in use: RNP AR APCH or RNP AR DP require a *specific approval*, whereas most other PBN operations require an *approval*. The widely used term ‘operational approval’ is most commonly used when referring to the issuance of a specific approval. In this manual, reference to the process of granting an operator permission to conduct PBN operations will therefore be referred to as an ‘operational authorization’.

Future developments

Comments on this manual would be appreciated from all parties involved in the development and implementation of PBN. These comments should be addressed to:

The Secretary General
International Civil Aviation Organization
999 Robert-Bourassa Boulevard
Montréal, Québec, Canada H3C 5H7

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REFERENCES

Note.— Documents referenced in this manual are affected by PBN.

ICAO documents

Annex 4 – *Aeronautical Charts*

Annex 6 – *Operation of Aircraft:*

- Part I – *International Commercial Air Transport – Aeroplanes*
- Part II – *International General Aviation – Aeroplanes*

Annex 8 – *Airworthiness of Aircraft*

Annex 10 – *Aeronautical Telecommunications,* Volume I – *Radio Navigation Aids*

Annex 11 – *Air Traffic Services*

Annex 15 – *Aeronautical Information Services*

Procedures for Air Navigation Services – Air Traffic Management (PANS-ATM) (Doc 4444)

Procedures for Air Navigation Services – Aircraft Operations, (PANS-OPS), Volumes I – *Flight Procedures* and II – *Construction of Visual and Instrument Flight Procedures*, (Doc 8168)

Regional Supplementary Procedures (Doc 7030)

Global Navigation Satellite System (GNSS) Manual (Doc 9849)

Manual on Airspace Planning Methodology for the Determination of Separation Minima (Doc 9689)

Manual on the Use of Performance-Based Navigation (PBN) in Airspace Design (Doc 9992)

Manual on Testing of Radio Navigation Aids (Doc 8071)

Safety Management Manual (SMM) (Doc 9859)

Required Navigation Performance Authorization Required (RNP AR) Procedure Design Manual (Doc 9905)

Performance-based Navigation (PBN) Operational Authorization Manual (Doc 9997)[1]

European Organisation for Civil Aviation Equipment (EUROCAE) documents

MASPS Required Navigation Performance for Area Navigation (RNAV) (ED-75())

1. Formerly the *Performance-based Navigation Operational Approval Manual*, renamed in its third (forthcoming) edition.

Standards for Processing Aeronautical Data (ED-76())

Standards for Aeronautical Information (ED-77())

RTCA, Inc. documents

Standards for Processing Aeronautical Data (DO-200())

Standards for Aeronautical Information (DO-201())

Minimum Operational Performance Standards for Airborne Supplemental Navigation Equipment Using GPS (DO-208())

Minimum Aviation System Performance Standards: Required Navigation Performance for Area Navigation (DO-236())

Minimum Operational Performance Standards for Global Positioning System/Wide Area Augmentation System Airborne Equipment, (DO-229())

Aeronautical Radio, Inc. (ARINC) 424 documents

ARINC 424 Navigation System Database Specification

Advisory material

Advisory material references have only been included in the Reference section of each Navigation Specification in Volume II.

Document number changes

The bundling of advisory circulars (ACs) (Federal Aviation Administration (FAA)) or AMCs (European Union Aviation Safety Agency (EASA)) may result in document number changes (for example AC 20-138B supersedes AC 20-129/AC 20-130A/AC 20-138A/AC 25-4). Similarly, some technical standard orders (TSOs) have been superseded by newer publications, for example FAA TSO-C129() is superseded by TSO-C196. Volume II, Attachment E lists the current version for the airworthiness approval guidance material, system/equipment standards, equipment installation approval guidance material, etc. whose applicability and specific requirements are as identified in the navigation specifications. In this manual, these documents are mentioned without the current version number replaced by the symbol (). Only historical document references have been kept with a passed reference when deemed appropriate for the understanding of the reader.

GLOSSARY

Aircraft-based augmentation system (ABAS). An augmentation system that augments and/or integrates the information obtained from the other GNSS elements with information available on board the aircraft.

Note.— The most common form of ABAS is receiver autonomous integrity monitoring (RAIM).

Airspace concept. An airspace concept describes the intended operations within an airspace. Airspace concepts are developed to satisfy explicit strategic objectives such as improved safety, increased air traffic capacity and mitigation of environmental impact. Airspace concepts can include details of the practical organization of the airspace and its users based on particular CNS/ATM assumptions, for example. ATS route structure, separation minima, route spacing and obstacle clearance.

Area navigation. A method of navigation which permits aircraft operation on any desired flight path within the coverage of ground or space-based navigation aids or within the limits of the capability of self-contained aids, or a combination of these.

Area navigation route. An ATS route established for the use of aircraft capable of employing area navigation.

Area navigation system. A navigation system which is either an RNP system or an RNAV system depending on its performance capabilities.

ATS surveillance service. A term used to indicate a service provided directly by means of an ATS surveillance system.

ATS surveillance system. A generic term meaning various surveillance systems such as ADS-B, primary surveillance radar, secondary surveillance radar (SSR) or any comparable ground-based system that enables the identification of aircraft.

Note.— A comparable ground-based system is one that has been demonstrated, by comparative assessment or other methodology, to have a level of safety and performance equal to or better than monopulse SSR.

Current flight plan (CPL). The flight plan, including changes, if any, brought about that reflects changes to the filed flight plan by subsequent ATC clearances.

Cyclic redundancy check (CRC). A mathematical algorithm applied to the digital expression of data that provides a level of assurance against loss or alteration of data.

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

Note 1.— Decision altitude (DA) is referenced to mean sea level and decision height (DH) is referenced to the threshold elevation.

Note 2.— The required visual reference means that section of the visual aids or of the approach area which should have been in view for sufficient time for the pilot to have made an assessment of the aircraft position and rate of change of position, in relation to the desired flight path. In Category III operations with a decision height the required visual reference is that specified for the particular procedure and operation.

Note 3.— For convenience where both expressions are used, they may be written in the form "decision altitude/height" and abbreviated "DA/H".

Filed flight plan (FPL or eFPL). The latest flight plan as filed with an ATS unit submitted and updated by the pilot, an operator or a designated representative, without any subsequent changes for use by ATS units.

Note.— The FPL denotes a filed flight plan exchanged using aeronautical fixed services while eFPL denotes a filed flight plan exchanged using FF-ICE services. The eFPL allows for the exchange of additional information not contained within the FPL.

Flight plan. Specified information provided to air traffic services units, relative to an intended flight or portion of a flight of an aircraft.

Note 1.— The term flight plan may be prefixed by the words "preliminary", "filed", "current" or "operational" to indicate the context and different stages of a flight.

Note 2.— When the word "message" is used as a suffix to this term, it denotes the content and format of the flight plan data as transmitted.

Inertial navigation system. Navigation system using accelerometers and gyroscopes to continuously calculate and track the aircraft's position without the need for external references. The aircraft may integrate an approved inertial navigation system to support eligibility for RNAV and RNP operations.

Note.— This manual uses the generic term "inertial navigation system". However, manufacturers use different, often proprietary terms and acronyms when describing their approved inertial navigation system. For example, some use "IRS" for "inertial reference system", while others use "IRU" for "inertial reference unit". Regardless of the nomenclature, the inertial navigation system needs an airworthiness approval for application during RNAV or RNP operations.

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

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

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

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

a) a ground-based radio navigation aid; or

b) compute*r-generated navigation data from ground-based, space-based, self-contained navigation aids or a combination of these.*

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

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

Note.— Non-precision approach procedures may be flown using a CDFA technique. CDFAs with advisory VNAV guidance calculated by on-board equipment are considered 3D instrument approach operations. CDFAs with manual calculation of the required rate of descent are considered 2D instrument approach operations. For more information on CDFAs, refer to PANS-OPS (Doc 8168), Volume I, Part II, Section 5.

Approach procedure with vertical guidance (APV). A performance-based navigation (PBN) instrument approach procedure designed for 3D instrument approach operations Type A.

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

Navigation aid (NAVAID) infrastructure. NAVAID infrastructure refers to space-based and/or ground-based NAVAIDs available to meet the requirements in the navigation specification.

Navigation application. The application of a navigation specification and the supporting NAVAID infrastructure, to routes and procedures, within a defined airspace volume, in accordance with the intended airspace concept.

Note.— The navigation application is one element, along with communications, ATS surveillance and ATM procedures which meet the strategic objectives in a defined airspace concept.

Navigation function. The detailed capability of the navigation system (such as the execution of leg transitions, parallel offset capabilities, holding patterns, navigation databases) required to meet the airspace concept.

Note.— Navigational functional requirements are one of the drivers for the selection of a particular navigation specification. Navigation functionalities (functional requirements) for each navigation specification can be found in Volume II, Parts B and C.

Navigation specification. A set of aircraft and aircrew requirements needed to support Performance-based Navigation operations within a defined airspace. There are two kinds of navigation specification:

RNAV specification. A navigation specification based on area navigation that does not include the requirement for on-board performance monitoring and alerting, designated by the prefix RNAV, for example RNAV 5, RNAV 1.

RNP specification. A navigation specification based on area navigation that includes the requirement for on-board performance monitoring and alerting, designated by the prefix RNP, for example RNP 4, RNP APCH.

Note.— Volume II of this manual contains detailed guidance on navigation specifications.

Operator. The person, organization or enterprise engaged in or offering to engage in an aircraft operation.

Performance-based navigation. Area navigation based on performance requirements for aircraft operating along an ATS route, on an instrument approach procedure or in a designated airspace.

Note.— Performance requirements are expressed in navigation specifications (RNAV navigation specification, RNP navigation specification) in terms of accuracy, integrity, continuity and functionality needed for the proposed operation in the context of a particular airspace concept. Availability of GNSS signal-in-space (SIS) or some other NAVAID infrastructure is considered within the airspace concept in order to enable the navigation application.

Procedural control. Term used to indicate that information derived from an ATS surveillance system is not required for the provision of air traffic control service.

Receiver autonomous integrity monitoring (RAIM). A form of ABAS whereby a GNSS receiver processor determines the integrity of the GNSS navigation signals using only GPS signals or GPS signals augmented with altitude (baro-aiding). This determination is achieved by a consistency check among redundant pseudo-range measurements. At least one additional satellite needs to be available with the correct geometry over and above that needed for the position estimation, for the receiver to perform the RAIM function.

RNAV operations. Aircraft operations using area navigation for RNAV applications.

RNAV system. A navigation system which permits aircraft operation on any desired flight path within the coverage of station-referenced navigation aids or within the limits of the capability of self-contained aids, or a combination of these. An RNAV system may be included as part of an FMS.

RNP operations. Aircraft operations using an RNP system for RNP navigation applications.

RNP AR operations (RNP AR OPS). Aircraft operations using an RNP system for RNP AR navigation applications.

RNP route. An ATS route established for the use of aircraft adhering to a prescribed RNP navigation specification.

RNP system. A navigation system which permits aircraft operation on any desired flight path within the coverage of station-referenced navigation aids or within the limits of the capability of self-contained aids, or a combination of these. An RNP system requires on-board performance monitoring and alerting. An RNP system may be included as part of an FMS.

Satellite-based augmentation system (SBAS). A wide coverage augmentation system in which the user receives augmentation information from a satellite-based transmitter.

Standard instrument arrival (STAR). A designated instrument flight rule (IFR) arrival route linking a significant point, normally on an ATS route, with a point from which a published instrument approach procedure can be commenced.

Standard instrument departure (SID). A designated instrument flight rule (IFR) departure route linking the aerodrome or a specified runway of the aerodrome with a specified significant point, normally on a designated ATS route, at which the en-route phase of a flight commences.

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ABBREVIATIONS AND ACRONYMS

AAIM	Aircraft autonomous integrity monitoring
ABAS	Aircraft-based augmentation system
ADS-B	Automatic dependent surveillance – broadcast
ADS-C	Automated dependent surveillance – contract
AFM	Aircraft flight manual
AGL	Above ground level
AIP	Aeronautical information publication
AIRAC	Aeronautical information regulation and control
ALSR	Acceptable level of safety risk
ANSP	Air navigation services provider
APCH	Approach
APV	Approach procedure with vertical guidance
A-RNP	Advanced RNP
ARP	Aerodrome reference point
ASE	Altimetry system error
ATC	Air traffic control
ATM	Air traffic management
ATS	Air traffic service
Baro-VNAV	Barometric VNAV
B-RNAV	Basic RNAV
CA	Course to altitude
CDFA	Continuous descent final approach
CDI	Course deviation indicator
CDU	Control and display unit
CF	Course to fix
CNS	Communications, navigation and surveillance
CRC	Cyclic redundancy check
CRM	Crew resource management
DA	Decision altitude
DB	Data block
DER	Departure end of the runway
DF	Direct to fix
DME	Distance measuring equipment
DFMC	Dual-frequency, multi-constellation
EASA	European Union Aviation Safety Agency
ECAC	European Civil Aviation Conference
EHSI	Electronic horizontal situation indicator
EPE	Estimated position error
EPU	Estimated position uncertainty
EUROCAE	European Organisation for Civil Aviation Equipment
EUROCONTROL	European Organisation for the Safety of Air Navigation
FA	Fix to altitude
FAA	Federal Aviation Administration
FAF	Final approach fix (or point)
FANS	Special Committee on Future Air Navigation Systems
FAS	Final approach segment

FDE	Fault detection and exclusion
FGS	Flight guidance system
FM	Fix to manual termination
FMS	Flight management system
FOM	Figure of merit
FOSA	Flight operational safety assessment
FPA	Flight path angle
FRT	Fixed radius transition
FSTD	Flight simulation training devices
FTE	Flight technical error
FTP	Fictitious threshold point
GBAS	Ground-based augmentation system
GLS	GBAS landing system
GNSS	Global navigation satellite system
GPS	Global Positioning System
GS	Ground speed
HIL	Horizontal integrity limit
HSI	Horizontal situation indicator
IAF	Initial approach fix
IAP	Instrument approach procedure
IF	Intermediate fix
IFP	Instrument flight procedure
ILS	Instrument landing system
ISA	International Standard Atmosphere
JAA	Joint Aviation Authorities
LPV	Localiser performance with vertical guidance
LNAV/VNAV	Lateral navigation or vertical navigation
LOA	Letter of authorization
LOFT	Line-oriented flight training
LRNS	Long range navigation systems
MagVar	Magnetic variation
MCDU	Multifunction control and display unit
MEL	Minimum equipment list
MDA	Minimum descent altitude
MLS	Microwave landing system
NDB	Non-directional radio beacon
NAVAID	Navigation aid
NSE	Navigation system error
OAT	Outside air temperature
OBPMA	On-board performance monitoring and alerting
OEI	One engine inoperative
OEM	Original equipment manufacturer
OM	Operations manual
PBN	Performance-based navigation
PDE	Path definition error
PFD	Primary flight display
PIC	Pilot-in-command
RAIM	Receiver autonomous integrity monitoring
RF	Radius to fix
RPAS	Remotely piloted aircraft systems
R/T	Radiotelephony
SB	Service bulletin

SBAS	Satellite-based augmentation system
SID	Standard instrument departure
SIS	Signal-in-space
SOP	Standard operating procedures
SSR	Secondary surveillance radar
STAR	Standard instrument arrival
STC	Supplemental Type Certificate
TAWS	Terrain awareness and warning system
TC	Type Certificate
TF	Track to fix
TOAC	Time of arrival control
TOGA	Take-off/go-around
TSE	Total system error
TSO	Technical standard order
VA	Heading to an altitude
VDI	Vertical deviation indicator
VEB	Vertical error budget
VHF	Very high frequency
VI	Heading to an intercept
VM	Heading to a manual termination
VMC	Visual meteorological conditions
VNAV	Vertical navigation
VPA	Vertical path angle
VOR	VHF omnidirectional radio range
VTF	Vector to final

VOLUME I

CONCEPT AND IMPLEMENTATION GUIDANCE

Chapter 1

DESCRIPTION OF PERFORMANCE-BASED NAVIGATION

1.1 INTRODUCTION

1.1.1 General

1.1.1.1 The performance-based navigation (PBN) concept specifies that aircraft RNAV or RNP system performance requirements be defined in terms of accuracy, integrity, continuity and functionality required for the proposed operations in the context of a particular airspace concept, when supported by the appropriate navigation aid (NAVAID) infrastructure. Compliance with world geodetic systems and data quality prescribed in Annex 15 – *Aeronautical Information* Services is integral to PBN.

1.1.1.2 The PBN concept represents a shift from sensor-based navigation and requires the use of an RNAV or RNP system. Operational requirements drive the performance requirements, which are then identified in navigation specifications and determine the specified choices of navigation sensors and equipment that may be used to meet the performance requirements. These navigation specifications provide specific implementation guidance for States and operators in order to facilitate global harmonization. The operational needs, for example navigation accuracy, integrity, continuity and flight path definition capability form the basis for the content of navigation specifications.

1.1.1.2.1 The publication of RNAV or RNP flight procedures outside of the PBN framework or other approved ICAO procedures is not envisaged.

1.1.1.3 Under PBN, generic navigation requirements are first defined based on the operational requirements. Operators then evaluate options in respect of available technology and navigation services. A chosen solution would be the most cost-effective for the operator, as opposed to a solution being established as part of the operational requirements. Technology can evolve over time without requiring the operation itself to be revisited as long as the requisite performance is provided by the RNAV or RNP system.

1.1.2 Benefits

PBN offers a number of advantages over the sensor-specific method of developing airspace and obstacle clearance criteria. For instance, PBN:

a) reduces the need to maintain sensor-specific routes and procedures, and their associated costs. For example, moving a single very high frequency (VHF) omnidirectional radio range (VOR) ground facility can impact dozens of procedures, as VOR can be used on routes, VOR approaches, missed approaches, etc. Adding new sensor-specific procedures will compound this cost, and the rapid growth in available navigation systems would soon make sensor-specific routes and procedures unaffordable;

b) avoids the need to develop sensor-specific operations with each evolution of navigation systems, which would be cost-prohibitive. The expansion of satellite navigation services is expected to contribute to the continued diversity of RNAV and RNP systems in different aircraft. Some augmentations support PBN operations, and the introduction of new core-constellations and signals will further improve global navigation satellite system (GNSS) performance. The use of GNSS/inertial integration is also expanding;

c) allows for more efficient use of airspace (route placement including the use of free routing, fuel efficiency, noise abatement, etc.);

d) clarifies how RNAV and RNP systems are used; and

e) facilitates and harmonizes the operational authorization process for operators by providing a limited set of navigation specifications intended for global use.

1.1.3 Context of performance-based navigation

1.1.3.1 PBN is one of several enablers of an airspace concept. Communications, air traffic services (ATS) surveillance and air traffic management (ATM) are also essential elements of an airspace concept. This is demonstrated in Figure I-1-1. PBN relies on the use of area navigation and comprises three components:

a) the NAVAID infrastructure;

b) the navigation specification; and

c) the navigation application.

Note.— Application of a) and b) in the context of the airspace concept to ATS routes and instrument procedures results in c).

1.1.3.2 The following paragraphs describe each of these airspace components with section 1.5 explaining their relationship.

1.1.4 Scope of performance-based navigation

1.1.4.1 Lateral performance

For oceanic/remote, en-route and terminal phases of flight, PBN is limited to operations with linear lateral performance requirements due to legacy reasons associated with the previous RNP concept. In the approach phases of flight, PBN accommodates both linear and angular laterally guided operations (see Figure I-1-2). The guidance to fly the instrument landing system (ILS)/microwave landing system (MLS)/ground-based augmentation system (GBAS) landing system (GLS) procedure is not provided by the RNP system, consequently, ILS/MLS/GLS precision approach and landing operations are not included in this manual.

1.1.4.2 Vertical performance

Some navigation specifications include requirements for vertical guidance using augmented GNSS or Barometric vertical navigation (VNAV) (baro-VNAV) in the final approach segment. See Volume II, Part C, Chapter 5, and Attachments A and B to Volume II. However, these requirements do not constitute vertical RNP, which is neither defined nor included in the PBN Concept.

Note.— There is currently no RTCA/EUROCAE definition or standard for vertical RNP.

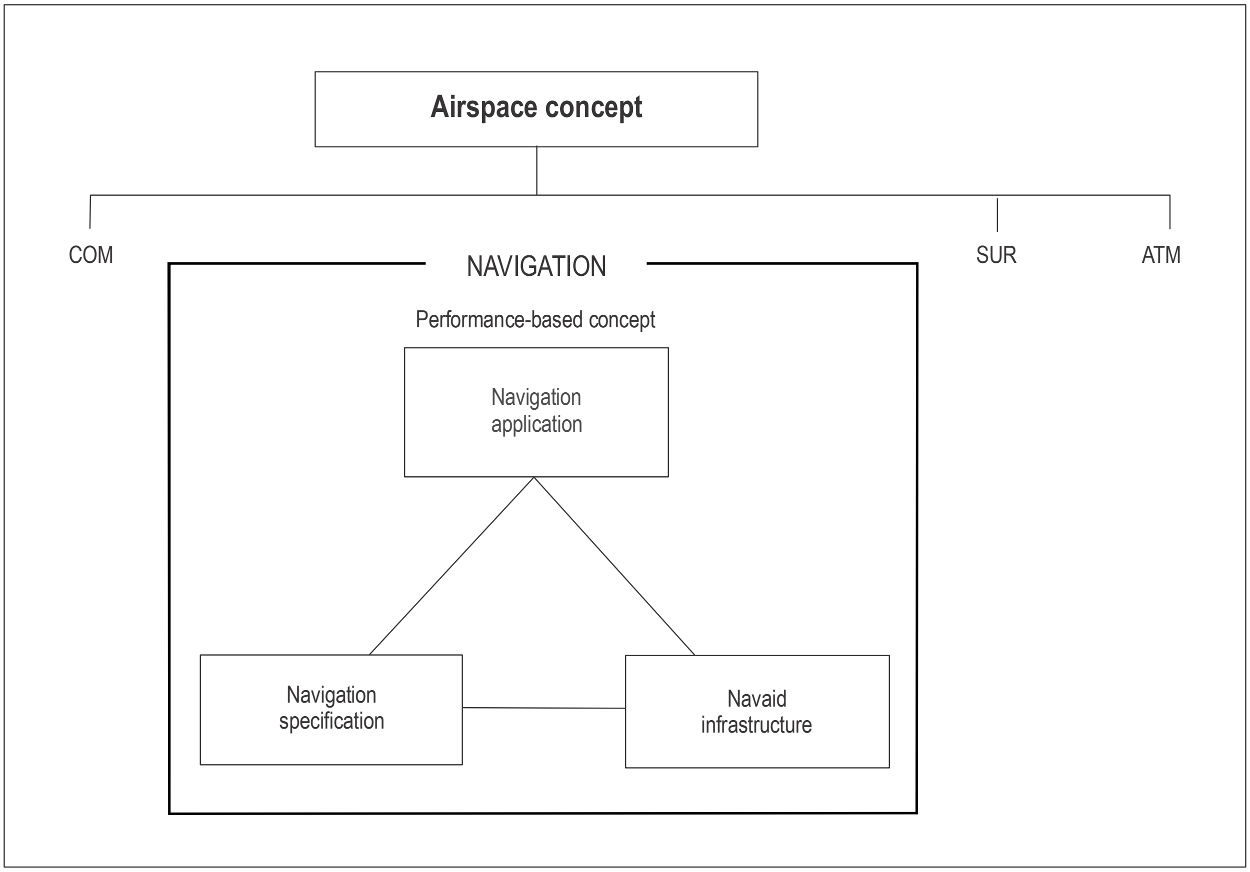

Figure I-1-1. PBN concept

1.2 NAVIGATION SPECIFICATION

1.2.1 Overview

1.2.1.1 The navigation specification is used by a State as a basis for the development of their material for airworthiness eligibility and operational authorization for PBN operations. A navigation specification details the performance required of the RNAV or RNP system in terms of accuracy, integrity, and continuity; which navigation functionalities the RNAV or RNP system must have; which navigation sensors must be integrated into the RNAV or RNP system; and which requirements are placed on the flight crew. ICAO navigation specifications are contained in Volume II of this manual.

1.2.1.2 A navigation specification is either an RNP navigation specification or an RNAV navigation specification. An RNP navigation specification includes a requirement for on-board performance monitoring and alerting, while an RNAV navigation specification does not.

Note.— Different navigation specifications may be used in different flight phases. Information on how these may be connected into a total system operation is found in Chapter 4 and Volume II, Part A, Chapter 1.

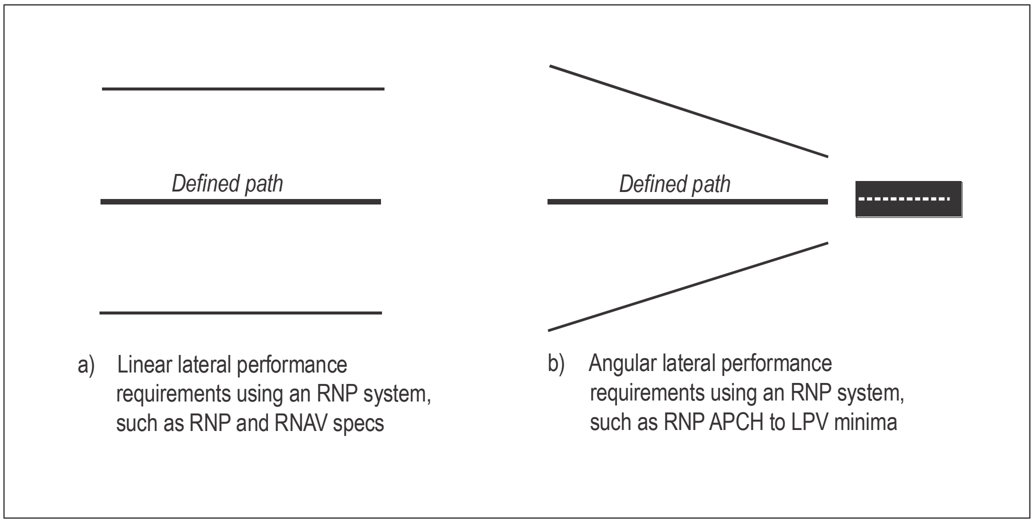

Figure I-1-2. Lateral performance requirements for PBN

1.2.1.3 In Volume II, each navigation specification is contained in a chapter entitled "Implementing RNAV [X]" for Part B and "Implementing RNP [X]" for Part C. The intended applications and operating environment explain the context of the navigation specification together with the requirements of the specification itself. Core material relating to the navigation specification includes performance requirements for accuracy, integrity and continuity of the navigation system, the functionalities necessary to meet the requirements of the navigation application, the authorization process, aircraft eligibility and the operational authorization, as applicable.

1.2.1.4 More contextual material within the navigation specification relates primarily to air navigation services providers (ANSPs) considerations and includes requirements concerning the communications, navigation and surveillance (CNS) infrastructures, air traffic controller training, air traffic control (ATC) support tools, ATS system monitoring and aeronautical publication etc.

1.2.1.5 At this time, ICAO does not envisage creating new RNAV navigation specifications.

1.2.2 On-board performance monitoring and alerting

1.2.2.1 On-board performance monitoring and alerting (OBPMA) is the main element determining:

a) whether the navigation system supports the safety level associated to an RNP application;

b) whether it relates to both lateral and longitudinal navigation performance; and

c) whether it allows the aircrew to detect that the navigation system is not achieving, or cannot guarantee with sufficient integrity, the navigation performance required for the operation.

A detailed description of OBPMA and navigation errors is provided in Volume II, Part A, Chapter 2.

1.2.2.2 RNP systems improve the integrity of operations, thereby permitting closer route spacing and providing sufficient integrity to allow only RNP systems to be used for navigation in a specific airspace. RNP systems may therefore offer significant safety, operational and efficiency benefits over RNAV systems.

Note.— RNP navigation specifications usually have higher performance requirements than RNAV and optional advanced functionalities such as radius to fix (RF) and fixed radius transitions (FRTs) , which can only be associated with RNP navigation specifications.

1.2.3 Navigation functional requirements

1.2.3.1 Both RNAV and RNP navigation specifications include requirements for certain navigation functionalities. At the basic level, these functional requirements may include:

a) continuous indication of aircraft position relative to track to be displayed to the pilot flying on a navigation display situated in his primary field of view;

b) display of distance and bearing to the active (To) waypoint;

c) display of ground speed or time to the active (To) waypoint;

d) navigation data storage function; and

e) appropriate failure indication of the RNAV or RNP system, including the sensors.

1.2.3.2 Most navigation specifications include the requirement for a navigation database (see Attachment B) and the capability to retrieve and execute procedures from this database.

1.2.3.3 The navigation specifications contain other functional requirements than those described here. These additional functionalities, along with navigation system and flight crew requirements, reflect the necessity for the intended navigation applications, as determined by regulators and the aviation community. Examples of such requirements include RF and VNAV Function. They are discussed in more detail in Attachment A and Volume II, Part A, Chapter 1.

1.2.3.4 Certain additional navigation functions associated with a navigation specification can be required when considered mandatory for planned navigation applications. Some, on the other hand, are desired but have insufficient levels of installed capability in the aircraft fleet. These functions are optional only for the considered navigation specification. Functional descriptions are included in the manual for these additional navigation functions to ensure consistency with regulatory authorizations and in-flight operations. Navigation functions are described in more detail in Volume II, Part C (appendices) and attachments. Volume II, Part A, Chapter 1, Table II-A-1-3 summarizes these functions and their level of requirement (required or optional) for each navigation specification.

1.2.4 Lateral navigation accuracy

1.2.4.1 Fixed lateral navigation accuracy

1.2.4.1.1 For oceanic, remote, en-route and terminal operations, an RNP navigation specification is designated as RNP X, for example RNP 4. An RNAV navigation specification is designated as RNAV X, for example RNAV 1.

1.2.4.1.2 For both RNP and RNAV designations, the expression "X" (where stated) refers to the lateral navigation accuracy (total system error (TSE)) in nautical miles, which 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 (see Figure I-1-3). This is referred to throughout the manual as the RNAV value (for RNAV navigation specifications) or the RNP value (for RNP navigation specifications). In some cases, reference is also made to lateral navigation accuracy where additional clarification is considered useful.

Note.— A detailed discussion of navigation error components and alerting can be found in Volume II, Part A, 2.2.

1.2.4.2 Variable lateral navigation accuracy

Where a navigation specification covers various phases of flight or permits different lateral navigation accuracy (RNAV or RNP value) in nautical miles and in various flight phases, two designation schemes exist. A prefix may be used, for example advanced RNP (A-RNP), or a suffix is added, for example RNP approach (APCH), RNP AR APCH or RNP AR DP.

1.2.4.3 Understanding RNAV and RNP designations

1.2.4.3.1 In cases where navigation accuracy is used as part of the designation of a navigation specification, it should be noted that navigation accuracy is only *one* of the functional and performance requirements included in a navigation specification – see Example 1.

1.2.4.3.2 Because functional and performance requirements are defined for each navigation specification, an aircraft approved for an RNP navigation specification is not automatically approved for all RNAV navigation specifications. Similarly, an aircraft approved for an RNP or RNAV navigation specification having a stringent accuracy requirement (for example RNP 1 specification) is not automatically approved for a navigation specification having a *less* stringent accuracy requirement (for example RNP 4).

1.2.4.3.3 It may seem logical, for example, that an aircraft approved for RNP 2 be automatically approved for RNP 4; however, this is not the case. Aircraft approved to the more stringent accuracy requirements may not necessarily meet some of the functional requirements of the navigation specification having a less stringent accuracy requirement.

Example 1

An RNAV 1 designation refers to an RNAV navigation specification that includes a requirement for 1 NM navigation accuracy among many other requirements. Although the designation RNAV 1 may suggest that 1 NM (lateral) navigation accuracy is the only performance criterion required, this is not the case. Like all navigation specifications, the RNAV 1 specification contained in Volume II of this manual includes *all* flight crew and airborne navigation system requirements.

Note.— The designations for navigation specifications are a short-hand title for all the performance and functionality requirements.

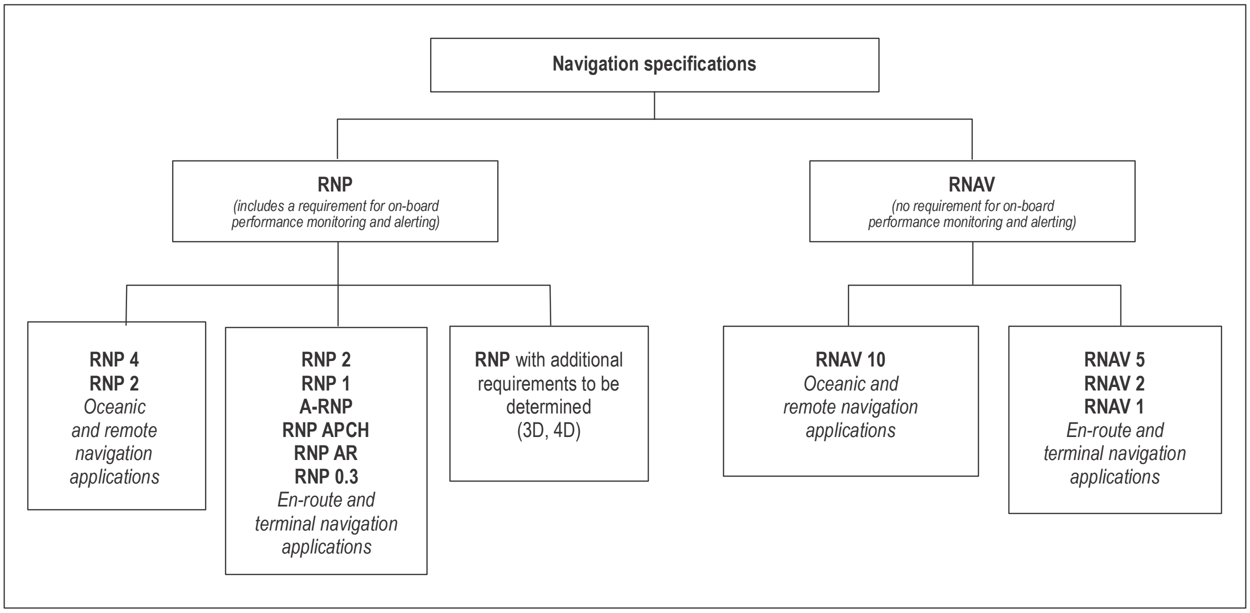

Figure I-1-3. Navigation specification designations

1.2.4.4 Flight planning of RNAV and RNP designations

Manual or automated notification of an aircraft's qualification to operate along an ATS route, on a procedure or in an airspace, is provided to the ATS unit via the filed flight plan.

Note.— Flight plan procedures are addressed in the Procedures for Air Navigation Services – Air Traffic Management (*PANS-ATM, Doc 4444).*

1.2.4.5 Accommodating inconsistent RNP designations

The existing RNP 10 designation is inconsistent with PBN RNP and RNAV navigation specifications. RNP 10 does not include requirements for on-board performance monitoring and alerting. For purposes of consistency with the PBN concept, RNP 10 is referred to as RNAV 10 in this manual. Renaming current RNP 10 routes, operational authorizations, etc., to an RNAV 10 designation would be an extensive and expensive task, which is not cost-effective. Consequently, any existing or new operational authorizations will continue to be designated RNP 10, and any charting annotations will be depicted as RNP 10 (see Figure I-1-3).

1.3 NAVAID INFRASTRUCTURE

The NAVAID infrastructure refers to ground- or space-based NAVAIDs. Conventional ground-based NAVAIDs include distance measuring equipment (DME) and VOR. The PBN concept requires that NAVAID infrastructure provides position information to the aircraft through an on-board area navigation system. Space-based NAVAIDs include GNSS elements. Further guidance on implementing GNSS is given in the *Global Navigation Satellite System (GNSS) Manual* (Doc 9849).

All NAVAID requirements are defined in Annex 10 – *Aeronautical Telecommunications.* The *Manual on Testing of Radio Navigation Aids* (Doc 8071) also contains information concerning the testing of navigation aids supporting PBN.

1.4 NAVIGATION APPLICATIONS

1.4.1 A navigation application is the use of a navigation specification and associated NAVAID infrastructure for ATS routes, instrument approach, departure or arrival procedures and/or to enable user defined routeing in a specified airspace volume in accordance with the airspace concept. An RNP application is supported by an RNP navigation specification; an RNAV application is supported by an RNAV navigation specification.

1.4.2 The navigation application is the PBN component providing the direct connection with the airspace concept, which is comprised of routes and procedures, amongst other things. The navigation application is the only PBN component that is neither fixed nor 'static.' A variety of different navigation applications can be created using a single navigation specification, for example the RNAV 1 specification can be used to design ATS routes, departures or arrivals.

1.4.2.1 Where a navigation application is realised as a fixed ATS route, the navigation performance requirement (in the navigation specification) will apply for operation on the published ATS route. This enables strategic de-confliction of proximate flight procedures, that is, two RNP 1 STARs can be strategically de-conflicted or spaced at a determined distance, allowing aircraft to self-navigate thus requiring minimum ATC intervention.

1.4.2.2 Where a navigation application is realised in en-route continental/remote or oceanic airspace as either a user-defined route or a fixed ATS route associated with strategic or tactical de-confliction, a navigation specification required to operate along the flight path within this airspace is a condition for entry into the designated airspace.

Note 1.— Strategic de-confliction refers to the placement of proximate routes to ensure safe separation. Tactical de-confliction requires surveillance monitoring by ATS for purposes of conflict resolution.

Note 2.— It is possible for the same navigation specification to be required for the navigation application referred to in 1.4.2.1 and 1.4.2.2.

1.5 RELATIONSHIP BETWEEN NAVIGATION SPECIFICATION, NAVAID INFRASTRUCTURE AND NAVIGATION APPLICATIONS

1.5.1 PBN consists of three components and there is a direct relationship between them.

1.5.2 Each navigation application must be based upon a particular navigation specification and associated NAVAID infrastructure, which can be different in a different airspace concept – see Example 2.

Example 2

A navigation application (for example arrival/departure) is designed using the navigation specification (for example RNAV 1) based upon a specific NAVAID infrastructure (for example GNSS). which may differ in another State.

The RNAV 1 specification in Volume II shows that any of the following navigation sensors can meet its performance requirements: GNSS or DME/DME/inertial or DME/DME.

Sensors needed to satisfy the performance requirements for an RNAV 1 specification in a particular State are not only dependent on the aircraft on-board capability. A limited DME infrastructure or GNSS policy considerations may lead the authorities to impose specific navigation sensor requirements for an RNAV 1 specification in that State.

As such, the aeronautical information publication (AIP) of State A could stipulate GNSS as a requirement for its RNAV 1 application because State A only has GNSS available in its NAVAID infrastructure. The AIP of State B could require the capability of DME/DME/inertial for its RNAV 1 application.

Each of these navigation specifications would be implemented as an RNAV 1 application. However:

a) aircraft equipped only with GNSS and approved for the RNAV 1 specification in State A would not be approved to operate the RNAV 1 application of State B; and

b) aircraft only fitted with DME/DME/inertial and certified to RNAV 1 will comply with the requirement of State B, but would not be approved to operate the RNAV 1 application of State A.

Aircraft certified to RNAV 1 with both sensors will be able to operate RNAV 1 application in both States with no limitations.

1.5.3 A navigation specification, its associated NAVAID infrastructure and its navigation application can support a number of airspace concepts. One example is the RNAV 5 application, which is used for different continental ATS routes and can support the performance requirement for user-defined routeing.

1.6 FUTURE DEVELOPMENTS

1.6.1 Overview

1.6.1.1 PBN aims to harmonize longitudinal and lateral performance requirements (that is, 2D) for both RNAV and RNP navigation specifications. Vertical path performance requirements (that is, 3D) are included in some RNP navigation specifications. In the future, PBN is expected to include 4D trajectory-based operations (TBO).

1.6.1.2 Although PBN implementations will continue to be based on both RNAV and RNP navigation specifications, future developments will focus on new RNP navigation specifications.

1.6.1.3 As more reliance is placed on GNSS, airspace concepts will increasingly need to ensure the coherent integration of communications, navigation and ATS surveillance enablers. Safety cases should consider the impact of losing GNSS in terms of CNS (see Chapter 2, 2.2.2.5).

1.6.2 GNSS dual-frequency multi-constellation

1.6.2.1 Annex 10 – *Aeronautical Telecommunications*, Volume I – *Radio Navigation Aids* contains Standards and Recommended Practices (SARPs) and guidance material for one signal of Global Positioning System (GPS) and GLONASS and similar work is under progress for BEIDOU and GALILEO. All four core constellations are intended to provide a second signal, and the standardized augmentations (that is, aircraft-based augmentation system (ABAS), GBAS and satellite-based augmentation system (SBAS)) are currently evolving to support these dual frequency signals. This significant evolution in GNSS is described under the Concept of Operations for dual-frequency multi-constellation (DFMC)[1]. Annex 10 introduces the notion of the GNSS element to describe the existing and new individual core-constellation signals and augmentations. To support PBN operations, the different GNSS elements would be used through specific compatible DFMC avionics. The concept of operations describes all such GNSS elements as potentially useable in support of PBN.

1.6.2.2 The transition from a single-frequency single-constellation (that is, GPS/L1) to a DFMC PBN context is significant. Conditions to be met by new GNSS elements other than GPS/L1, to support PBN operations within a given State airspace include:

a) the new GNSS element has to be standardized within Annex 10;

b) the new GNSS element performances might require acceptance by the safety authority in charge of the intended airspace of use; and

c) the State, or group of States responsible for the airspace where the new GNSS element is intended to be used, has to document its acceptance to airspace users within the AIP; and

Note 1.— Some States may not formally declare accepting GPS/L1 in their AIP, despite Recommendation 2.2/2 from the Thirteenth Air Navigation Conference (AN-Conf/13). Further guidance on how to publish GNSS elements in the AIP is under development.

Note 2.— Failure to provide airspace users with information on the GNSS elements permitted within the airspace could lead operators to use unmonitored satellite navigation signals or those not providing the required level of integrity.

d) the operator's fleet should include compatible aircraft avionics.

1.6.2.3 When the above conditions are met, the PBN operations described within this manual can be supported by the new GNSS elements, provided that they meet the specific performance and operational requirements of the intended operation.

1. https://www.icao.int/Meetings/anconf13/Documents/WP/Navigation_Systems_Panel_CONOPS_for_DFMC_GNSS.pdf

Chapter 2

AIRSPACE CONCEPTS

2.1 INTRODUCTION

This chapter explains the airspace concept and its relationship to navigation applications. This builds on the performance-based navigation (PBN) concept described in the previous chapter.

2.2 THE AIRSPACE CONCEPT

2.2.1 Overview

2.2.1.1 An airspace concept describes the intended operations within an airspace. Airspace concepts are developed to satisfy explicit and implicit strategic objectives such as to improve or maintain safety, to increase air traffic capacity, to improve efficiency, to provide more accurate flight paths and to mitigate the environmental impact. Airspace concepts can include details of the practical organization of the airspace and its users based on particular CNS/ ATM assumptions, for example, ATS route structure, separation minima, route spacing and obstacle clearance. It can be seen that the airspace concept has the airspace design at its core. If a portion of the airspace envisages user-defined or free routeing operations, this is also described in the airspace concept.

2.2.1.2 Strategic objectives drive the general vision of the airspace concept (see Figure I-2-1). These objectives are usually identified by airspace users, ATM, airports as well as environmental and government policy. It is the function of the airspace concept and the concept of operations to respond to these requirements. The strategic objectives that most commonly drive airspace concepts are safety, capacity, efficiency, access and the environment. As the example below suggests, strategic objectives can result in changes being introduced to the airspace concept.

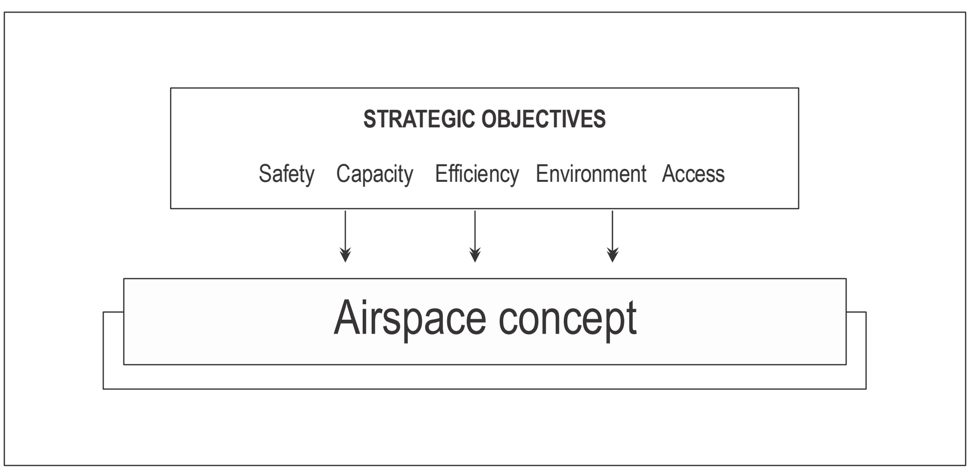

Figure I-2-1. Strategic objectives to airspace concept

Example

Safety: The design of RNP instrument approach procedures (IAPs); in particular with a vertically guided final segment, could be a way of increasing safety (by reducing controlled flight into terrain (CFIT)).

Capacity: Planning the addition of an extra runway at an airport to increase capacity will trigger a change to the airspace concept (new approaches and/or arrival and departure procedures required).

Efficiency: A user requirement to optimize flight profiles on departure and arrival could make flights more efficient in terms of fuel burn.

Environment: Requirements for reduced emissions, noise preferential routes or continuous descent operations (CDO)/continuous climb operations (CCO) are environmental motivators for change.

Access: A requirement to provide an approach with lower minima than supported by conventional procedures, to ensure continued access to the airport during bad weather, may result in providing an RNP approach to that runway.

2.2.2 Airspace concepts and navigation applications

2.2.2.1 The cascade effect from strategic objectives to the airspace concept places requirements on the various "enablers", such as communications, navigation, ATS surveillance, ATM and flight operations. *Navigation functional requirements* – now within a PBN context – need to be identified, *see* the *Manual on the Use of Performance-Based Navigation (PBN) in Airspace Design* (Doc 9992). These navigation functionalities are formalized in a navigation specification that, together with a NAVAID infrastructure, supports a particular navigation application. As part of an airspace concept, navigation applications also have a relationship to communications, ATS surveillance, ATM, ATC tools and flight operations. The airspace concept brings all these elements together in a cohesive whole (see Figure I-2-2).

2.2.2.2 The above approach is top-down: it starts at the generic level (*What* are the strategic objectives? *What* airspace concept is required?) with a view to identifying specific requirements, that is, how CNS/ATM will satisfy this concept and its concept of operations.

2.2.2.3 The role to be played by each enabler in the overall concept is identified. No "enabler" can be developed in isolation, that is, communications, ATS surveillance and navigation enablers should form a cohesive whole. This can be illustrated as shown in Figure I-2-2.

2.2.2.4 The interdependence between CNS enablers is particularly relevant when determining a route structure for an airspace concept. The configuration and spacing of PBN ATS routes in an independent surveillance environment enables an optimum route configuration and reduces route spacing when compared to a procedural environment (where reliance is placed exclusively on communication and navigation performance).

2.2.2.5 However, GNSS can be a common point of failure to CNS. This is important when considering airborne and ATM contingency operations as well as infrastructure optimization. Although GNSS is associated primarily with navigation, GNSS is also required for automatic dependent surveillance – broadcast (ADS-B) applications. Loss of time synchronization impacting time slot management for data links (such as CPDLC and automated dependent surveillance – contract (ADS-C)) may also occur. As such, GNSS positioning and track-keeping functions are no longer only navigation enablers to an airspace concept. GNSS, in this case, is also an ATS surveillance and communication systems enabler.

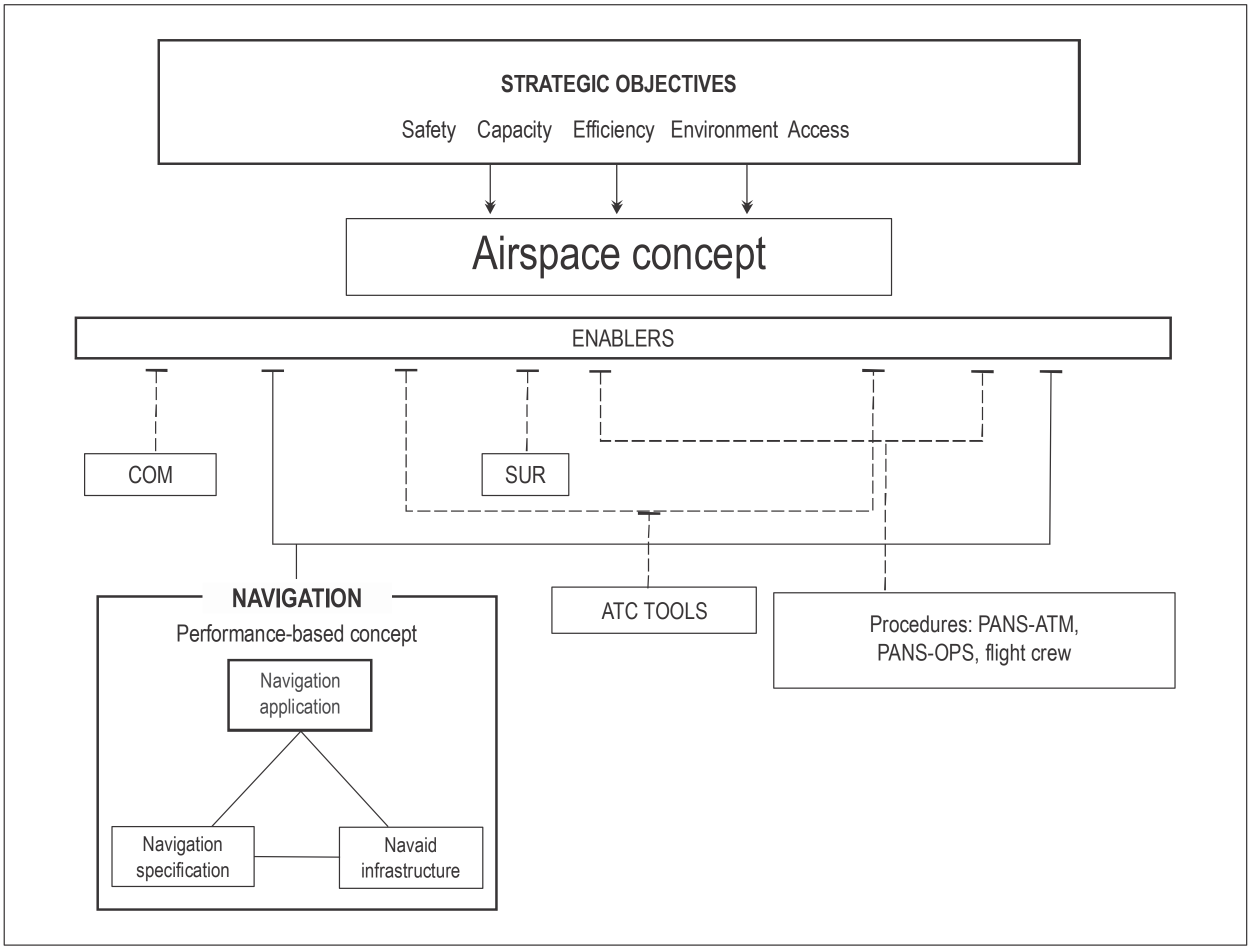

Figure I-2-2. Relationship: PBN and airspace concept

2.3 AIRSPACE CONCEPTS BY AREA OF OPERATION

2.3.1 Oceanic and remote continental

Oceanic and remote continental airspace concepts are currently supported by three navigation applications: RNAV 10, RNP 4 and RNP 2. All these navigation specifications and their applications rely primarily on GNSS to support the navigation element of the airspace concept and may require ATS surveillance for some airspace concepts. In many of these airspace concepts, the flight path is created and determined by the flight crew and is not based on a fixed ATS route network.

Note.— RNAV 10 retains the RNP 10 designation. See Chapter 1, 1.2.4.5.

2.3.2 Continental en-route

Continental en-route airspace concepts are currently supported by RNAV and RNP applications in both fixed ATS route environments and those where the defined flight path is created and determined by the flight crew and/or ATC. RNAV 5 is used in all ICAO Regions where it is the performance required for fixed ATS routes and those predicated on use of direct tracks (DCTs). In the United States, an RNAV 2 application supports an en-route continental airspace concept using fixed ATS routes. RNP 2 application is also used in Australia and Canada to support en-route continental routes. At present, although many continental RNAV applications support airspace concepts that include ATS surveillance and direct VHF controller/pilot voice communications, ATS surveillance is not a pre-requisite. Therefore, RNAV applications can support airspace concepts in a procedural environment, subject to a safety assessment.

2.3.3 Terminal airspace: arrival and departure

Existing terminal airspace concepts, which include arrival and departure, are supported by RNAV and RNP applications. RNP 1 was originally developed to facilitate operations in procedural, low-density terminal airspace. In contrast, RNAV 1, without OBPMA, evolved for use in terminal operations where radar surveillance was available to monitor aircraft performance. Since these developments, additional forms of ATS surveillance are becoming available and both of these specifications are being used with different forms of ATS Surveillance. See Volume II, Part A, Chapter 1, 1.2.1.

2.3.4 Approach

2.3.4.1 Approach concepts cover all segments of the instrument approach, (initial, intermediate, final and missed approach) requiring a navigation accuracy ranging from 1 NM to 0.3 NM and even to 0.1 NM for some stringent navigation applications. Typically, three operational concepts characterize this phase of flight:

a) new procedures to runways never served by an instrument procedure;

b) procedures either replacing or serving as back-up to existing instrument procedures based on different technologies; and

c) procedures developed to enhance airport access in demanding environments.

2.3.4.2 The relevant RNP navigation specifications covered in Volume II include RNP APCH and RNP AR APCH.

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Chapter 3

STAKEHOLDER USES OF PERFORMANCE-BASED NAVIGATION

3.1 INTRODUCTION

3.1.1 Overview

3.1.1.1 Various stakeholders are involved in the development of the airspace concept and the resulting navigation application(s). These stakeholders are the airspace planners, procedure designers, aircraft manufacturers, pilots and air traffic controllers; each stakeholder has a different role and set of responsibilities. This chapter provides a non-technical (non-specialist) explanation of how these stakeholders use performance-based navigation (PBN) with a view to enhancing a cross-disciplinary appreciation of different stakeholder's interest in PBN. More detailed information directed at specialists is available in other ICAO documents or in attachments to this document, such as information for specialists on operational authorization, which is provided in the *Performance-based Navigation (PBN) Operational Authorization Manual* (Doc 9997)[1].

3.1.1.2 The stakeholders of PBN use the concept at different levels:

a) at a *strategic level*, airspace planners and procedure designers translate "the PBN concept" into the reality of route spacing, aircraft separation minima and procedure design;

b) also at a *strategic level*, airworthiness and regulatory authorities ensure that aircraft and aircrew satisfy the operating requirements of the intended implementation. Similarly, operators/users need to understand the operating requirements and effect any necessary changes for equipage and personnel training; and

c) at a *tactical level*, controllers and pilots use the PBN concept in real-time operations. They rely on the preparatory work completed at the strategic level by other stakeholders.

3.1.1.3 All stakeholders use all the elements of the PBN concept, however, each stakeholder tends to focus on a particular part of the PBN concept. This is depicted in Figure I-3-1.

3.1.1.3.1 Airspace planners, for example, focus more on the navigation system performance required by the navigation specification. While they are interested to know how the required performance of accuracy, integrity and continuity are to be achieved, they use the required performance of the navigation specification to determine route spacing and separation minima.

3.1.1.3.2 Procedure designers design instrument flight procedures (IFPs) in accordance with obstacle clearance criteria associated with a particular navigation specification. Unlike airspace planners, procedure designers focus on the entire navigation specification (performance, functionality and the navigation sensors of the navigation specification), as

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1. Formerly the *Performance-based Navigation Operational Approval Manual*, renamed in its third (forthcoming) edition.

well as flight crew procedures. These specialists are also particularly interested in the NAVAID infrastructure because of the need to ensure that the instrument flight procedure (IFP) design takes into account the available or planned NAVAID infrastructure.

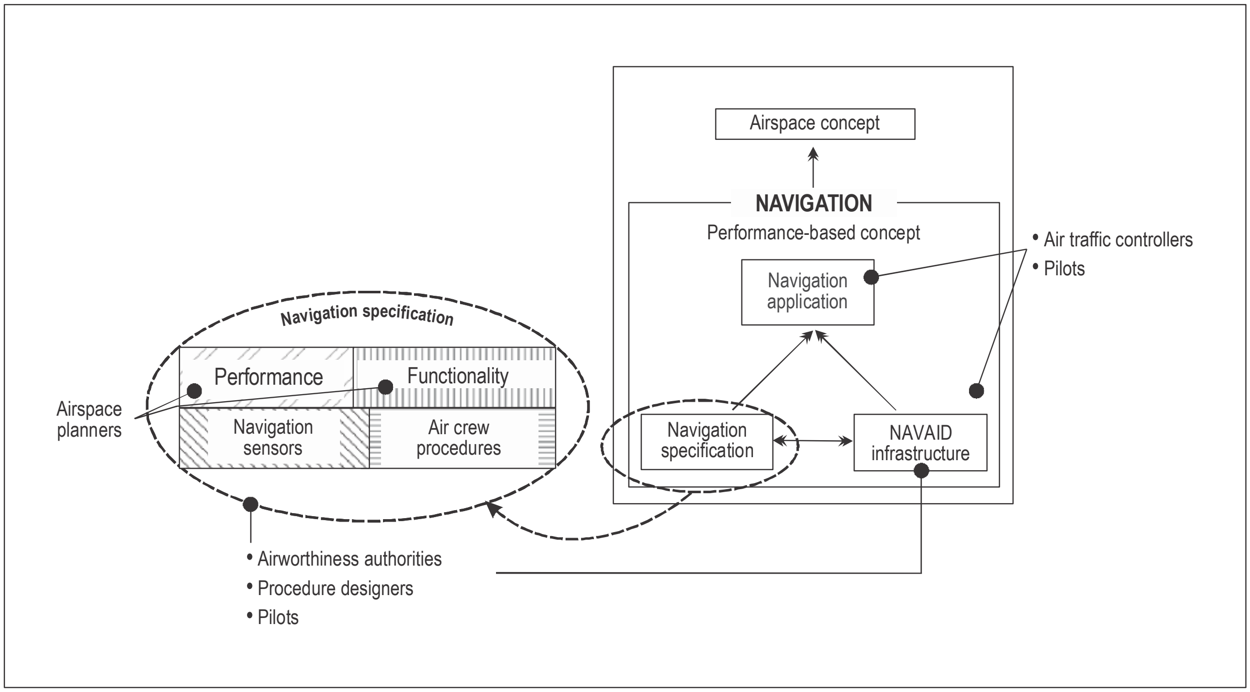


Figure I-3-1. PBN elements and specific points of interest of various stakeholders

3.1.1.3.3 The State of the Operator/Registry must ensure that the aircraft is properly certified and approved to operate in accordance with the navigation specification prescribed for operations in an airspace, along an ATS route or instrument procedure. Consequently, the State of the Operator/Registry must be cognisant of the navigation application because this provides a context to the navigation specification.

3.1.1.3.4 Operators/users need to make determinations regarding their equipage and personnel training in accordance with the associated navigation specification and any other operational requirements.

3.1.1.3.5 The navigation specification can therefore be considered an anchor point for these four PBN stakeholders because of the specific implementation considerations and other information and guidance contained in them. This does not mean that stakeholders consider the navigation specification in isolation, but rather that it is their primary focus.

3.1.1.4 The position is slightly different for pilots and controllers. As end-users of the PBN concept, controllers and pilots are more involved in the navigation application, which includes the navigation specification and the NAVAID infrastructure. For example, particularly in a mixed aircraft equipage environment, controllers may need to know what navigation sensor is required for the use of the trajectory (that is, one RNAV 1 trajectory can be supported by a critical DME, and its outage would have to be reported). Pilots operate along a route designed and placed by the procedure designer and airspace planner while the controller ensures that separation is maintained between aircraft operating on these routes.

3.1.2 Safety in PBN implementation

3.1.2.1 All users of the PBN concept are concerned with safety. Airspace planners and procedure designers, as well as aircraft manufacturers and ANSPs, need to ensure that their part of the airspace concept meets the pertinent safety requirements. States of the Operator specify requirements for on-board equipment, and they need to be satisfied that these requirements are actually being met by the manufacturers. Other authorities specify requirements for safety at the airspace concept level. These requirements are used as a basis for airspace and procedure design and, again, the authorities need to be satisfied that their requirements are being met.

3.1.2.2 Demonstrating that safety requirements are being met is achieved in different ways by different stakeholders, according to applicable national legislation. The means used to demonstrate the safety of an airspace concept is not the same used to demonstrate that safety requirements at the aircraft level are being met. When all safety requirements have been satisfied, air traffic controllers and pilots must adhere to their respective procedures in order to ensure the safety of operations.

3.2 AIRSPACE PLANNING

3.2.1 Overview

3.2.1.1 The determination of separation minima and route spacing for use by aircraft is a major element of airspace planning. The *Manual on Airspace Planning Methodology for the Determination of Separation Minima* (Doc 9689) and the *Manual on the Use of Performance-Based Navigation (PBN) in Airspace Design* (Doc 9992) are key reference documents that planners should consult.

3.2.1.2 Separation minima and route spacing can be described as a function of three factors: navigation performance, aircraft's exposure to risk and the mitigation measures that are available to reduce risk (see Figure I-3-2). Aircraft-to-aircraft separation and ATS route spacing are not exactly the same. As such, the degree of complexity of the equation, depicted graphically in Figures I-3-2 and I-3-3, depends on whether separation between two aircraft or route spacing criteria is being determined.

3.2.1.3 Aircraft to aircraft separation, for example, is applied between two aircraft and, as a consequence, the traffic density part of the risk is usually considered to be a single aircraft pair. For route spacing purposes, this is not the case: the traffic density is determined by the volume of air traffic operating along the spaced ATS routes. This means that if aircraft in an airspace are all capable of the same navigation performance, one could expect the separation minima between a single aircraft pair to be less than the spacing required for parallel ATS routes.

3.2.1.4 The complexity of determining lateral route spacing and horizontal separation minima is affected by the availability of an ATS surveillance and the type of communications used. If ATS surveillance is available, this means that the risk can be mitigated by including requirements for ATC intervention. This is particularly the case when the aircraft lateral position provided by the ATS surveillance system is derived from a positioning source that is independent from the one used by the aircraft for navigation positioning. These interrelationships are reflected in Figure I-3-3 for separation and route spacing.

3.2.2 Impact of performance-based navigation on airspace planning

3.2.2.1 When separation minima and route spacing are determined using a conventional sensor-based approach, the *navigation performance* data used to determine the separation minima or route spacing depend on the accuracy of the raw data from specific NAVAIDs such as VHF omnidirectional radio range (VOR), DME or non-directional radio beacon (NDB). In contrast, PBN requires an RNAV or RNP system that integrates raw navigation data to provide a positioning and navigation solution. In determining separation minima and route spacing in a PBN context, this integrated navigation performance "output" is used.

3.2.2.2 In Chapter 1, it was discussed that the navigation performance required from the RNAV or RNP system is part of the navigation specification. To determine separation minima and route spacing, airspace planners fully exploit that part of the navigation specification that prescribes the performance required from the RNAV or RNP system. Airspace planners also make use of the required performance, namely accuracy, integrity and continuity, to determine route spacing and separation minima.

3.2.2.3 Chapter 1 also explained that there are two types of navigation specifications: RNAV navigation specifications and RNP navigation specifications, and that the distinctive feature of RNP is a requirement for on-board performance monitoring and alerting. As such, procedural separation minima and route spacing derived from an RNP 1 specification on straight and curved segments requiring radius to fix (RF) capability is smaller than those derived for an RNAV 1 specification.

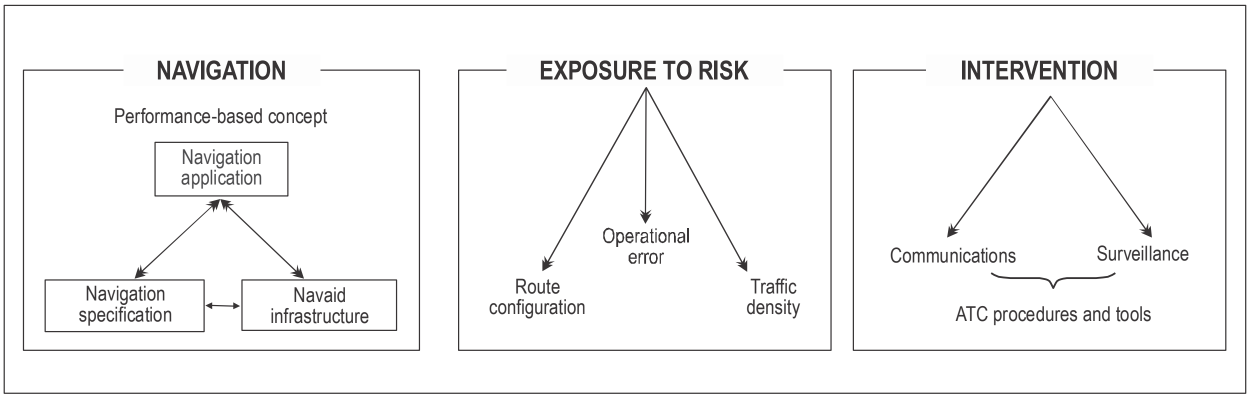
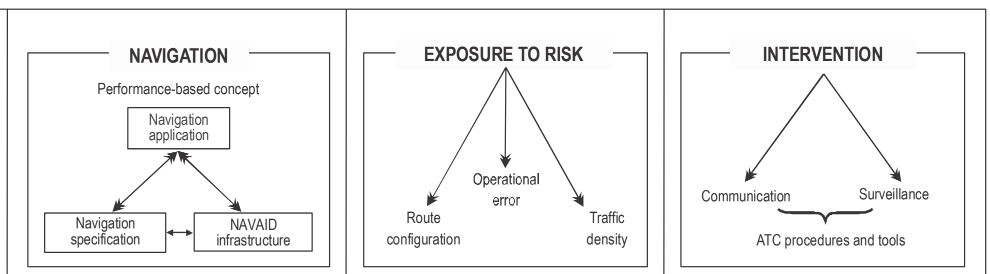


Figure I-3-2. Generic model used to determine separation and ATS route spacing



PBN	NAVIGATION	EXPOSURE TO RISK	INTERVENTION
Determination of **separation minima** *(1)* for tactical use *without* ATC surveillance	✓	✓ (2)	×
Determination of **separation minima** *(1)* for tactical use *with* ATC surveillance	×	× (2) and (3)	✓
Determination of **route spacing** *without* ATC surveillance	✓	✓	×
Determination of **route spacing** *with* ATC surveillance	✓	✓	✓

*✓relevant; × Largely irrelevant; **(1)** In context, separation minima based on NAVAID or navigation sensor or PBN; **(2)** traffic density = single aircraft pair; **(3)** separation minima determined as a function of performance of ATC surveillance system.*

Figure I-3-3. Factors affecting the determination of separation and route spacing

3.2.2.4 In procedurally controlled airspace, separation minima and route spacing based on RNP navigation specifications would be expected to provide a greater benefit than those based on RNAV navigation specifications. This is because RNP navigation specifications usually include more demanding performance and functionality than RNAV navigation specifications. The RNP performance and functionality reduce the incidence of navigation errors and OBPMA provides for detection and management of navigation errors. This reduces exposure and operational risk. In an independent surveillance environment, navigation errors are mitigated by ATC intervention capability (detection and correction of deviations). This may permit a reduction of route spacing in such environments.

3.2.3 Performance-based navigation impact on NAVAID infrastructure planning

3.2.3.1 Infrastructure planning is complex, particularly with the increased integrated reliance on GNSS by CNS, and the increased pressure to decommission unnecessary terrestrial NAVAID infrastructure. Therefore, NAVAID infrastructure planners cannot look at the NAVAID infrastructure in isolation, but need to work closely with ATM system engineers, surveillance and communication infrastructure, operators and regulators when planning the infrastructure for both normal and contingency operations. Infrastructure evolution planning must be part of PBN implementation planning. The removal of conventional navigation aids and associated procedures constitutes an airspace change. In this respect, extensive consultation needs to take place with all impacted stakeholders.

3.2.3.2 PBN implementation will require infrastructure planners to consider:

a) the infrastructure requirements for normal operations (a function of the airspace concept objectives);

b) the infrastructure required for contingency operations (a function of the objective of the contingency operations (such as safety only, required levels of service, compliance with regulatory requirements); and

c) how CNS supports both normal and contingency PBN operations (trade-offs between C-N-S can be made).

3.2.3.3 When setting the objectives of the contingency operation, the duration of the outage period for which the contingency operations are intended to apply should be determined. Infrastructure to maintain normal operations for two hours may have different investment implications than one intended to continue normal operations for a week.

3.2.3.4 Alternative position navigation and timing (A-PNT) relates to an alternative to GNSS positioning for contingency operations derived from the combination of measurements from other existing navigation sensors such as DME, VOR and inertial navigation system. While A-PNT is usually required, available backup networks do not provide timing information. Research is currently being conducted on A-PNT systems that offer positioning and timing services alternative to GNSS.

Note.— The term A-PNT is also used to evaluate possible future alternative systems for aviation use (new systems, hybrid applications).

3.3 INSTRUMENT FLIGHT PROCEDURE DESIGN

3.3.1 Introduction

3.3.1.1 Instrument flight procedure (IFP) design includes the construction of routes, as well as arrivals, departures and approach procedures. These procedures consist of a series of predetermined manoeuvres to be conducted solely by reference to flight instruments with specified protection from obstacles.

3.3.1.2 Each State is responsible for ensuring that all published IFPs in their airspace can be flown safely by the relevant aircraft. Safety is not only accomplished by application of the technical criteria in the *Procedures for Air Navigation Services – Aircraft Operations* (Doc 8168) and associated ICAO provisions, but also requires measures that control the quality of the process used to apply that criteria, which may include regulation, air traffic monitoring and validation. These measures must ensure the quality and safety of the procedure design product through review, verification, coordination and validation at appropriate points in the process, so that corrections can be made at the earliest opportunity in the process.

3.3.1.3 The following paragraphs regarding IFP design describe conventional procedure design and sensor-dependent area navigation procedure design, their disadvantages and the issues that led up to PBN.

3.3.2 Non-area navigation: conventional procedure design

Conventional procedure design is applicable to non-area navigation applications when aircraft are navigating based on direct signals from ground-based radio NAVAIDs. The disadvantage to this type of navigation is that the routes are dependent on the location of the navigation beacons (see Figure I-3-4). This often results in longer routes since optimal arrival and departure routes are impracticable due to siting and cost constraints on installing ground-based radio NAVAIDs. Additionally, obstacle protection areas are comparatively large, and the navigation system error (NSE) increases as a function of the aircraft's distance from the NAVAID.

3.3.3 Introduction of sensor-specific area navigation procedure design

3.3.3.1 Initially, area navigation was introduced using sensor-specific design criteria. A fundamental breakthrough with area navigation was the creation of fixes defined by name, latitude and longitude. Area navigation fixes allowed the design of routes to be less dependent on the location of NAVAIDs, therefore, the designs could better accommodate airspace planning requirements (see Figure I-3-5). The flexibility in route design varied by the specific radio navigation system involved, such as DME/VOR or GNSS. Additional benefits included the ability to store the routes in a navigation database, reducing pilot workload and resulting in more consistent flying of the nominal track as compared to cases where the non-area navigation procedure design was based on heading, timing or DME arcs. As PBN is accomplished using an aircraft navigation database, a major change for the designer is the increased need for quality assurance in the procedure design process.

3.3.3.2 Despite the advantages, area navigation had a number of issues and characteristics that needed to be considered. Among these were the sometimes-wide variations in flight performance and flight paths of aircraft, as well as the inability to predict the behaviour of navigation computers in all situations. This resulted in large obstacle assessment areas and, as a consequence, not much benefit was achieved in terms of reducing the obstacle protection area.

3.3.3.3 As experience in area navigation operations grew, other important differences and characteristics were discovered. Aircraft area navigation equipment, functionalities and system configurations ranged from the simple to the complex. There was no guidance for the designer as to what criteria to apply for the aircraft fleet for which the IFPs are being designed. Some of the system behaviour was the result of the development of RNAV and RNP systems that would fly database procedures derived from ATC instructions. This attempt to mimic ATC instructions resulted in many ways to describe and define an aircraft flight path, resulting in an observed variety of flight performance. Furthermore, the progress in aircraft and navigation technology caused an array of types of procedures, each of which require different equipment, imposing unnecessary costs on the air operators.

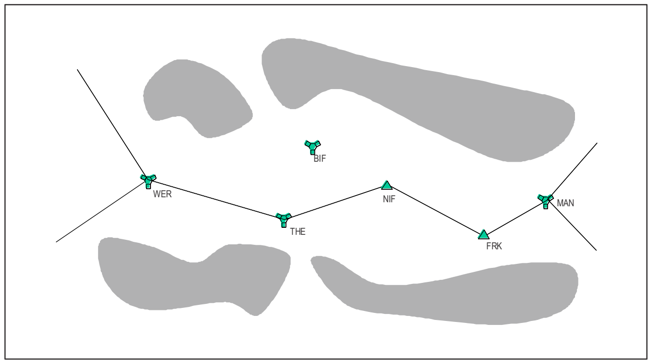


Figure I-3-4. Conventional IFP design

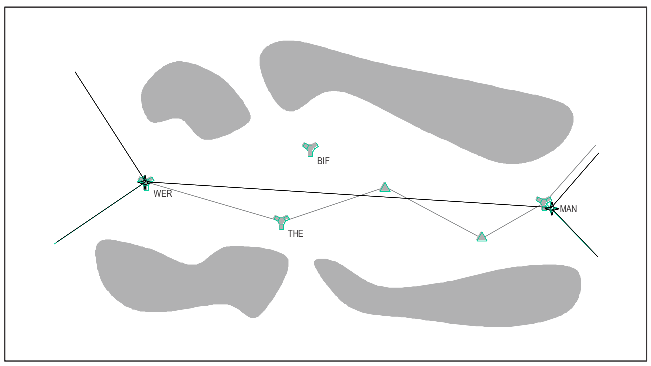


Figure I-3-5. Area navigation procedure design

3.3.4 Performance-based navigation procedure design

3.3.4.1 Area navigation using PBN is a performance-based operation in which the navigation performance characteristics of the aircraft are well specified, and the problems described above for the initial RNAV and RNP criteria can be resolved. The performance-based descriptions address various aircraft characteristics that were causing variations in flight trajectories, leading to more repeatable, reliable and predictable flight tracking, as well as smaller obstacle assessment areas.

3.3.4.2 The main change for the designers consisted of not designing for a specific sensor, but rather according to a navigation specification (such as RNAV 1). The selection of the appropriate navigation specification is based on the airspace requirements, the available NAVAID infrastructure, and the equipage and operational capability of aircraft expected to use the route. For example, where an airspace requirement is for RNAV 1 or RNAV 2, the available NAVAID infrastructure would have to be GNSS or DME/DME, and aircraft would be required to utilize one of these NAVAIDs to conduct operations. The procedure design along with qualified aircraft and operators result in greater reliability, repeatability and predictability of the aircraft flight path. It should be understood that no matter what infrastructure is provided, the designer may still apply the same general design rules in fix and path placement; however, adjustments may be required based upon the associated obstacle clearance or separation criteria.

3.3.4.3 The design criteria take full account of the aircraft capabilities and are fully integrated with the aircraft approval and qualification requirements. The tightly integrated relationship between aircraft and operational and procedure design criteria for RNP AR requires closer examination of aircraft qualification and operator authorization, since special authorization is required. This additional requirement will incur cost to the airlines and will make these types of procedures only cost-beneficial in cases where other procedure design criteria and solutions will not fit.

Note.— Procedure design criteria for the RNP AR APCH navigation specification may be found in the Required Navigation Performance Authorization Required (RNP AR) Procedure Design Manual (Doc 9905).

3.4 AIRWORTHINESS AND OPERATIONAL AUTHORIZATION

3.4.1 General

3.4.1.1 Aircraft must be equipped with an RNAV or RNP system able to support the desired navigation application. The RNAV or RNP system and aircraft operations must be compliant with regulatory material that reflects the navigation specification developed for a particular navigation application (see Chapter 1) and approved by the appropriate regulatory authority for the operation.

3.4.1.2 The navigation specification details the flight crew and aircraft requirements needed to support the navigation application. This specification includes the level of navigation performance, functional capabilities, sensors and operational considerations required for the RNAV or RNP system. RNAV and RNP system installations should be certified in accordance with Annex 8 – *Airworthiness of Aircraft*, and operational procedures should respect the applicable aircraft flight manual (AFM) limitations, if any exist.

3.4.1.3 The system should be operated in accordance with recommended practices described in Annex 6 – *Operation of Aircraft* and PANS-OPS (Doc 8168), Volumes I and III. Flight crew and/or operators should respect the operational limitations required for the navigation application.

3.4.1.4 All assumptions related to the navigation application are listed in the navigation specification. A review of these assumptions is necessary when proceeding to the airworthiness and operational authorization process.

3.4.1.5 Operators and flight crew are responsible for checking that the installed RNAV or RNP system is operated in areas where the airspace concept and the NAVAID infrastructure described in the navigation specification are fulfilled. To ease this process, certification and/or operational documentation should clearly identify compliance with the related navigation specification. In addition, to assist the flight crew the State should clearly identify the permitted NAVAID infrastructure to support the State's declared Navigation Application(s) (see Chapter 1, 1.6.2.2 c)).

3.4.1.6 The navigation specifications found in Volume II, Parts B and C do not in themselves constitute regulatory guidance material against which either the aircraft or the operator will be assessed and approved. Original equipment manufacturers (OEMs) build their products using a basic code of airworthiness for the aircraft type and in accordance with the relevant guidance material. Operators are approved using their national operating rules. The navigation specification provides the technical and operational criteria. Therefore, there is still a need to have the instruments for authorization. This can be achieved either through a dedicated authorization document or through recognition that existing regional RNAV or RNP implementation certification documents (such as the Federal Aviation Administration (FAA) AC or the European Union Aviation Safety Agency (EASA) AMC) can be applied to satisfy the objectives set out in the PBN specification.

3.4.2 Airworthiness approval process

3.4.2.1 The airworthiness approval process assures that each item of the area navigation equipment installed is of a type and design appropriate to its intended function and that the installation functions properly under foreseeable operating conditions. Additionally, the airworthiness approval process identifies any installation limitations that need to be considered for operational authorization. Such limitations and other information relevant to the approval of the RNAV and RNP system installations are documented in the AFM, or AFM Supplement, as applicable. Information may also be repeated and expanded upon in other documents such as flight crew operating manuals. The airworthiness approval process is well established among States of the Operators/Registry, as applicable, and this process refers to the intended function of the navigation specification to be applied.

3.4.2.2 Approval of RNAV systems for RNAV X operations

3.4.2.2.1 The RNAV system installed should be compliant with a set of basic performance requirements as described in the navigation specification, which defines accuracy, integrity and continuity criteria. It should also be compliant with a set of specific functional requirements, have a navigation database and support each specific path terminator as required by the navigation specification.

Note.— For certain navigation applications, a navigation database may be optional and there may not be a requirement for path terminators as the specification is not foreseen for terminal airspace.

3.4.2.2.2 For a multi-sensor RNAV system, an assessment should be conducted to establish which sensors are compliant with the performance requirement described in the navigation specification.

3.4.2.2.3 The navigation specification generally indicates if a single or a dual installation is necessary to fulfil availability and/or continuity requirements. The airspace concept and NAVAID infrastructure are key elements in deciding if a single or a dual installation is necessary.

3.4.2.3 Approval of RNP systems for RNP X operations

3.4.2.3.1 Aircraft must be equipped with an RNP system able to support the desired navigation application, including the OBPMA function. It should also be compliant with a set of specific functional requirements, have a navigation database and support each specific path terminator as required by the navigation specification.

3.4.2.3.2 For a multi-sensor RNP system, an assessment should be conducted to establish sensors which are compliant with the RNP performance requirement described in the RNP navigation specification.

3.4.3 Operational authorization

3.4.3.1 The aircraft must be equipped with an RNAV or RNP system enabling the flight crew to navigate in accordance with operational criteria as defined in the navigation specification.

3.4.3.1.1 The State of the Operator is the authority responsible for approving flight operations. Many aircraft and systems have already received airworthiness approvals and operator authorizations for RNAV and RNP operations. It is not intended that the State will require any requalification of such aircraft and systems when a compliance assessment is all that is necessary.

3.4.3.1.2 The authority must be satisfied that operational programmes are adequate. Training programmes and operations manuals should be evaluated.

Note.— More detailed information is provided in the Performance-based Navigation (PBN) Operational Authorization Manual *(Doc 9997)*[2].

3.4.3.2 General PBN authorization process

3.4.3.2.1 The operational authorization process first assumes that the corresponding installation/airworthiness approval has been granted.

3.4.3.2.1.1 During operation, the crew should respect any limitations set out in the AFM and AFM supplements.

3.4.3.2.1.2 Normal operating procedures are provided in the navigation specification, including detailed necessary crew action to be conducted during pre-flight planning, prior to commencing the procedure and during the procedure.

3.4.3.2.1.3 Abnormal operating procedures are provided in the navigation specification, including detailed crew action to be conducted in case of on-board RNAV or RNP system failure and in case of system inability to maintain the prescribed performance of the on-board monitoring and alerting functions.

3.4.3.2.1.4 The operator should have in place a system for investigating events affecting the safety of operations in order to determine their origin (coded procedure, accuracy problem, etc.).

3.4.3.2.1.5 The minimum equipment list (MEL) should identify the minimum equipment necessary to satisfy the navigation application.

3.4.3.3 Flight crew training

Each pilot must receive appropriate training, briefings and guidance material in order to safely conduct an operation.

3.4.3.4 Navigation database management

3.4.3.4.1 During the airworthiness approval of the equipment, the applicant should define minimum requirements for the quality of data to be loaded into the navigation database, particularly if the database processing should comply with an established data quality assurance process, as specified in DO 200() or EUROCAE ED 76().

3.4.3.4.2 Any specific requirement regarding the navigation database should be provided in the navigation specification, particularly if the navigation database integrity is supposed to demonstrate compliance with an established data quality assurance process, as specified in DO 200()/EUROCAE ED 76().

Note.— This demonstration may be documented with a letter of authorization (LOA) or other equivalent means as accepted by the State.

3.4.3.4.3 FAA AC 20-153B was written to help data providers meet the objectives of an FAA LOA. Data services providers should also comply with Regulation (EU) 2017/373 (Part-DAT) to meet EASA requirements.

2. Formerly the *Performance-based Navigation Operational Approval Manual*, renamed in its third (forthcoming) edition.

3.5 FLIGHT CREW AND AIR TRAFFIC OPERATIONS

3.5.1 Overview

3.5.1.1 Pilots and air traffic controllers are the end-users of PBN, each having their own expectations of how the use and capability of the RNAV or RNP system affects their working methods and everyday operations.

3.5.1.2 What pilots need to know about PBN operations is whether the aircraft and flight crew are qualified to operate in the airspace, on a procedure or along an ATS route. For their part, controllers assume that the flight crew and aircraft are suitably qualified for PBN operations. However, they also require a basic understanding of area navigation concepts, the relationship between RNAV and RNP operations, and how their implementation affects control procedures, separation and phraseology. As importantly, an understanding of how RNAV and RNP systems work as well as their advantages and limitations is necessary for both controllers and pilots.

3.5.1.3 For pilots, one of the main advantages of using an RNAV or RNP system is that the navigation function is performed by highly accurate and sophisticated on-board equipment allowing a reduction in cockpit workload and, in some cases, increased safety. In controller terms, the main advantage of aircraft using an RNAV or RNP system is that ATS routes can be straightened, as it is not necessary for routes to pass over locations marked by conventional NAVAIDs. Another advantage is that area navigation-based arrival and departure routes can complement, and even replace, vectoring, thereby reducing approach and departure controller workload. Consequently, parallel ATS route networks are usually a distinctive characteristic of airspace in which RNAV and/or RNP applications are used. These parallel track systems can be unidirectional or bidirectional and can, occasionally, cater to parallel routes requiring a different navigation specification for operation along each route, such as an RNP 4 route alongside a parallel RNP 10 route (based on RNAV 10 navigation specification). Similarly, RNAV arrivals and departures are featured extensively in some terminal airspaces. The use of RNP applications may allow or increase access to an airport in terrain-rich environments or with airspace limitations where such access was limited or not previously possible.

3.5.1.4 Air traffic controllers sometimes assume that, where all aircraft operating in an airspace may be required to be approved at the same level of performance, these aircraft will systematically provide entirely or exactly repeatable and predictable track-keeping performance. This is not an accurate assumption because the different algorithms used in different flight management system (FMS) and the different ways of coding data used in the navigation database can affect the way an aircraft performs during turns. Exceptions are where fixed ground tracks are designed to manage the turn performance and provide highly predicable and repeatable flight paths (such as the radius to fix (RF) path terminator and/or the FRT). Experience gained in States that have already implemented RNAV and RNP applications shows that such mistaken assumptions can be corrected by adequate training in PBN. ATC training in RNAV and RNP applications is essential before implementation to enhance controllers' understanding and confidence, and to ensure ATC support for the implementation. PBN implementation without adequate emphasis on controller training can have a serious impact on any RNP or RNAV project schedule (see Volume II, Parts B and C, Controller Training paragraphs in each navigation specification).

3.5.2 Flight crew procedures

Flight crew procedures complement the technical contents of the navigation specification. Flight crew procedures are usually embodied in the company operating manual. These procedures could include, for example, that the flight crew notify ATC of contingencies (that is, equipment failures and/or weather conditions) that could affect the aircraft's ability to maintain navigation accuracy. These procedures would also require the flight crew to state their intentions, coordinate a plan of action and obtain a revised ATC clearance in case of contingencies. At a local or regional level, established contingency procedures should be made available so as to permit the flight crew to follow such procedures in the event that it is not possible to notify ATC of their difficulties.

3.5.3 Air traffic services procedures

3.5.3.1 Air traffic services (ATS) procedures are needed for use in airspace utilizing RNAV and RNP applications. Examples include procedures to enable the use of the parallel offset on-board functionality (see Attachment A) or to enable the transition between airspaces having different performance and functionality requirements (that is, different navigation specifications). Detailed planning is required to accommodate such a transition, as follows:

a) determining the specific points where the traffic will be directed as it transits from airspace requiring a navigation specification with less stringent performance and functional requirements to an airspace requiring a navigation specification with more stringent performance and functional requirements; and

b) coordinating efforts with relevant parties in order to obtain a regional agreement detailing the required responsibilities.

3.5.3.2 Air traffic controllers should take appropriate action to provide increased separation and to coordinate with other ATC units, as appropriate, when informed that the flight is unable to maintain the prescribed level of navigation performance.

Chapter 4

INTRODUCTION TO PERFORMANCE-BASED NAVIGATION IMPLEMENTATION

4.1 INTRODUCTION

4.1.1 This chapter provides a brief, general overview of how performance-based navigation (PBN) implementation should be accomplished.

4.1.2 It is generic in nature, providing an overview of implementation and making the necessary links to other documents or parts of this manual. This chapter is useful to those seeking to implement RNAV or RNP applications in a given region, State or group of States as a precursor to using the *Manual on the Use of Performance-Based Navigation (PBN) in Airspace Design* (Doc 9992).

4.1.3 The material in this chapter is provided for States, primarily from the perspective of air navigation service provision as experience shows this is where the knowledge and experience of RNAV and RNP applications is the most limited. In addition, the State and/or its delegated ANSP are often responsible for integrating the many facets of PBN implementation, ranging from airspace organization and management to airspace design, ATM, procedure design, etc. This does not suggest that other PBN partners are excluded from the implementation planning process; on the contrary, they are integral to it (regulator/user considerations are provided in the process diagrams contained in Doc 9992). For completeness, an overview of these processes is provided here.

4.1.4 More detailed implementation guidance for ANSPs is contained in Doc 9992, and operational authorization guidance is contained in the *Performance-based Navigation (PBN) Operational Authorization Manual* (Doc 9997)[1].

4.2 PROCESS OVERVIEW

4.2.1 Doc 9992 provides an implementation process to assist States in the implementation of PBN. The process covers four phases:

a) planning;

b) design;

c) validation; and

d) implementation.

1. Formerly the *Performance-based Navigation Operational Approval Manual*, renamed in its third (forthcoming) edition.

4.2.2 Project planning and airspace design outlines steps for a State or region to determine the strategic and operational requirements for the development of an airspace concept. To this end, fleet equipage and CNS/ATM infrastructure in the State or region will be assessed and navigation functional requirements will be identified, and an appropriate navigation specification selected.

4.2.3 The design concepts of validation and implementation provide steps that allow the operational requirement and corresponding navigation specification to be turned into an implementation reality.

Note.— Airspace design activities within airspace concept development are described in the Manual on the Use of Performance-Based Navigation (PBN) in Airspace Design *(Doc 9992).*

4.2.4 The four classic project organization phases (adapted to PBN implementation) are broken down into various steps:

a) *Planning.* This phase includes: agreement on operational requirement; creation of PBN implementation team; agreement on objectives, scope and time-scales; analysis of reference scenario; safety and performance criteria; and, finally, CNS/ATM assumptions, enablers and constraints.

b) *Design.* This phase includes: design of routes and holds; initial procedure design; design of volumes and sectors; and confirmation of ICAO navigation specification.

c) *Validation.* This phase includes: validation of the airspace concept; finalising the procedure design; flight validation; and flight inspection.

d) *Implementation.* This phase rounds off the processes with the ATC system integration considerations, awareness and training material, implementation and post implementation review.

4.2.5 Key to the correct use of the process is that, despite its apparent linear progression, the steps in the process require several iterations, sometimes even between phases as a later development influences what was done in an earlier phase.

4.3 DEVELOPING A NEW NAVIGATION SPECIFICATION

4.3.1 The process described above is designed to enable the application of harmonized global standards and avoid proliferation of local/regional standards. Developing a new navigation specification would be considered in those very rare cases, where:

a) a State or region has determined it impossible to use an existing ICAO navigation specification to satisfy its intended airspace concept; and

b) it is impossible to change the elements of a proposed airspace concept to use an existing ICAO navigation specification.

4.3.2 Such a development is an extensive and rigorous exercise in airworthiness and flight operations development. It should be expected to be a very complex and lengthy international effort leading to a globally harmonized specification.

4.3.3 For the above reasons, the rare development of a new navigation specification would be coordinated through ICAO to ensure continued interoperability and international standardization.

ATTACHMENTS TO VOLUME I

Attachment A

RNAV AND RNP SYSTEMS

1. PURPOSE

This attachment provides informative material on RNAV and RNP systems, their capabilities and their limitations.

2. BACKGROUND

2.1 Area navigation is defined as a method of navigation that permits aircraft operation on any desired flight path within the coverage of station-referenced NAVAIDs or within the limits of the capability of self-contained aids, or a combination of both. This removes the restriction imposed on conventional routes and procedures where the aircraft must normally overfly referenced NAVAIDs, thereby permitting operational flexibility and efficiency. This is illustrated in Figure I-Att A-1.

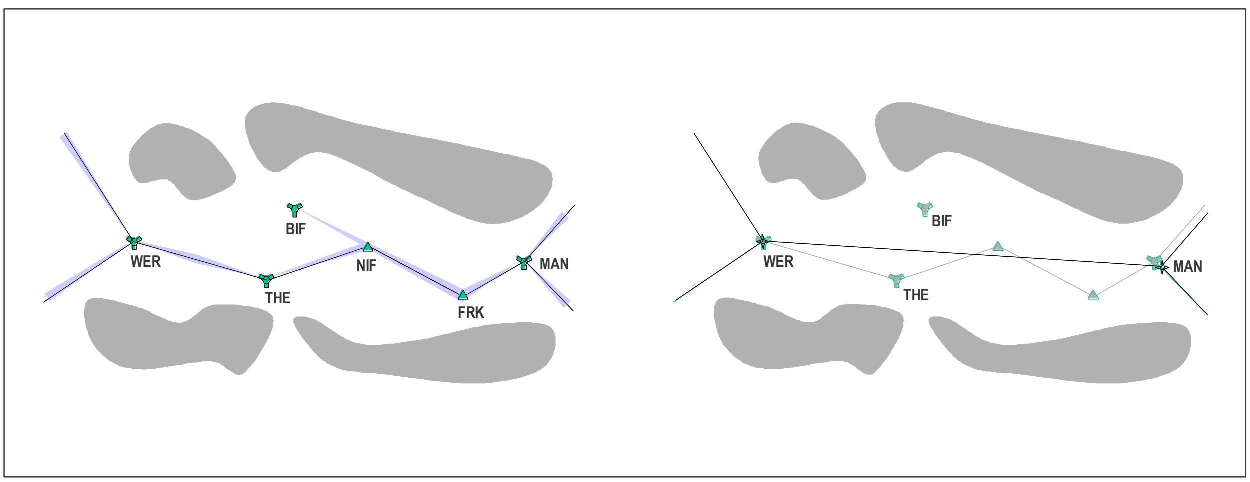


Figure I-Att A-1. Navigation by conventional navigation compared to area navigation

2.2 Differences in the types of aircraft systems and their capabilities, features, and functions have resulted in a degree of uncertainty and confusion regarding how aircraft perform RNAV operations. This attachment provides information to aid in understanding RNAV and RNP systems. This section explains what comprises an RNP system and provides information on how it relates to an RNAV system. Section 3 describes the commonalities of RNAV and RNP systems, while sections 4 and 5 describe what functions and features are required for RNP and how they may relate to an RNAV system.

2.3 RNAV and RNP systems range from single-sensor-based systems to those with multiple types of navigation sensors. The diagrams in Figure I-Att A-2 are only examples of how the complexity and interconnectivity can vary greatly between the different RNAV and RNP system avionics utilized in a wide variety of aircraft including commercial air transport, helicopter, business and general aviation.

2.4 The RNAV or RNP system may also be connected with other systems, such as auto-throttle and autopilot/flight director, allowing more automated flight operation and performance management. Despite the differences in architecture and equipment, the basic types of functions contained in the RNAV and RNP systems are common.

3. RNAV AND RNP SYSTEMS – BASIC FUNCTIONS

3.1 Overview

RNAV and RNP systems are designed to provide a given level of accuracy, with repeatable and predictable path definition, appropriate to the application. RNAV and RNP systems typically integrate information from sensors, such as air data, inertial navigation systems, radio navigation and satellite navigation, together with inputs from internal databases and data entered by the crew to perform the following functions (see Figure I-Att A-3):

a) navigation;

b) flight plan management;

c) guidance and control; and

d) display and system control.

3.2 Navigation

3.2.1 The navigation function computes data that can include aircraft position, velocity, track angle, vertical flight path angle, drift angle, magnetic variation, barometric-corrected altitude, and wind direction and magnitude. It may also perform automatic radio tuning as well as support manual tuning.

3.2.2 While navigation can be based upon a single type of navigation sensor such as GNSS, many systems are multi-sensor RNAV and RNP systems. Such systems use a variety of navigation sensors including GNSS, DME, VHF omnidirectional radio range (VOR) and inertial navigation systems to compute the position and velocity of the aircraft. While the implementation may vary, the system will typically base its calculations on the most accurate positioning sensor available.

3.2.3 RNAV and RNP systems will confirm the validity of the individual sensor data and, in most systems, will also confirm the consistency of the various sets of data before they are used. GNSS data are usually subjected to integrity and accuracy checks prior to being accepted for navigation position and velocity computation. DME and VOR data are typically subjected to a series of "reasonableness" checks prior to being accepted for FMC radio updating. This difference in rigour is due to the capabilities and features designed into the navigation sensor technology and equipment. For multi-sensor RNAV and RNP systems, if GNSS is not available for calculating position/velocity, then the system may automatically select a lower priority update mode such as inertial navigation, DME/DME or VOR/DME. If these radio update modes are not available or have been deselected, then the system may automatically revert to inertial coasting. For single-sensor systems, sensor failure may lead to a dead reckoning mode of operation.

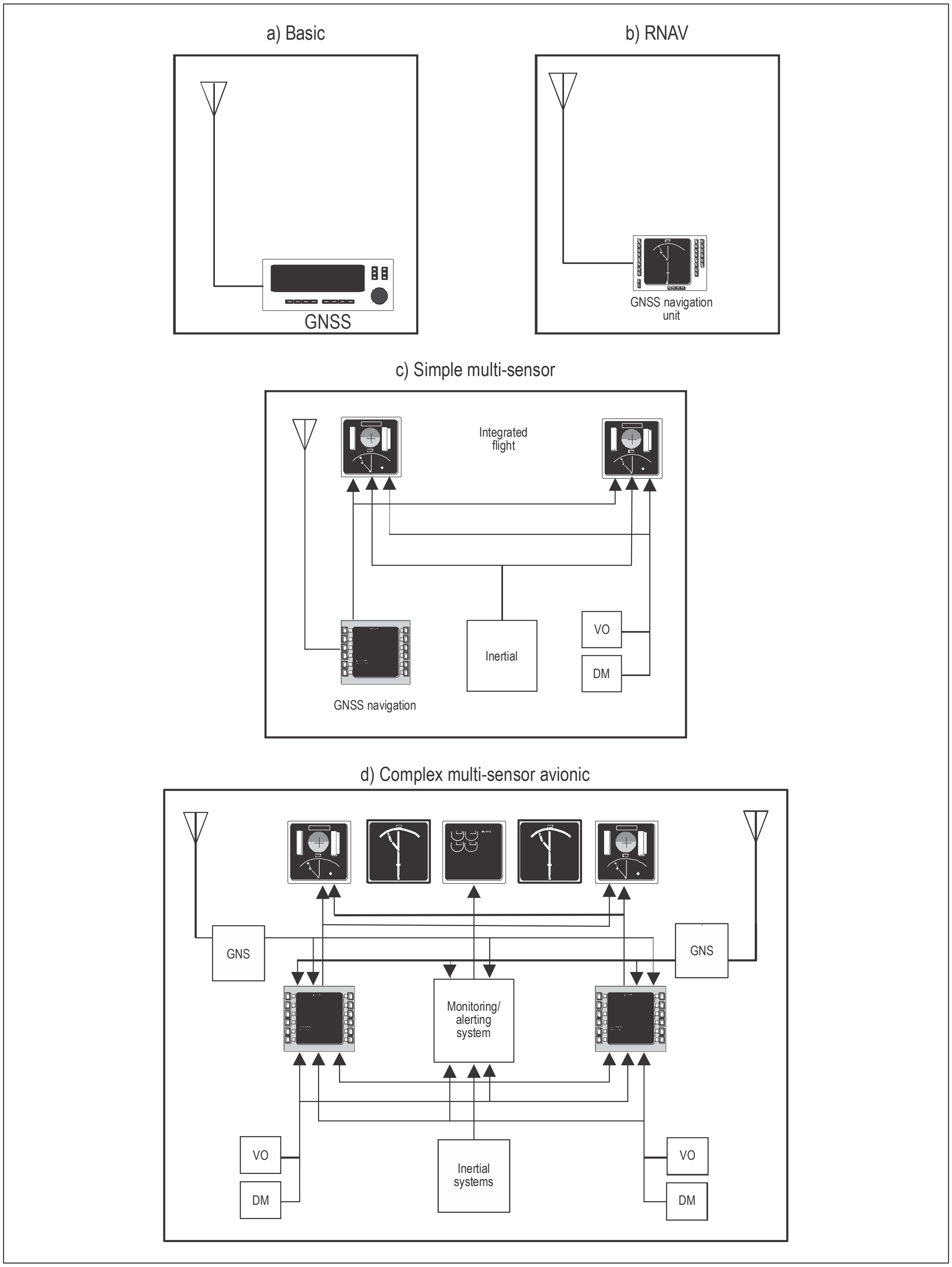


Figure I-Att A-2. RNAV and RNP systems – from basic to complex

Note.— Many RNP systems default to the navigation performance available through inertial coasting when GNSS is lost. In these RNP systems the integration of GNSS with the aircraft's inertial navigation system(s) results in the inertial-only positioning being the best available navigation performance upon loss of GNSS. As the inertial navigation system(s) performance degrades over time due to inertial drifting, the RNP system will typically then begin updating the inertial navigation system(s) through integration of ground-based NAVAIDs, where available. Typically, when DME facilities are available, these RNP systems will automatically select a DME/DME/inertial navigation mode.

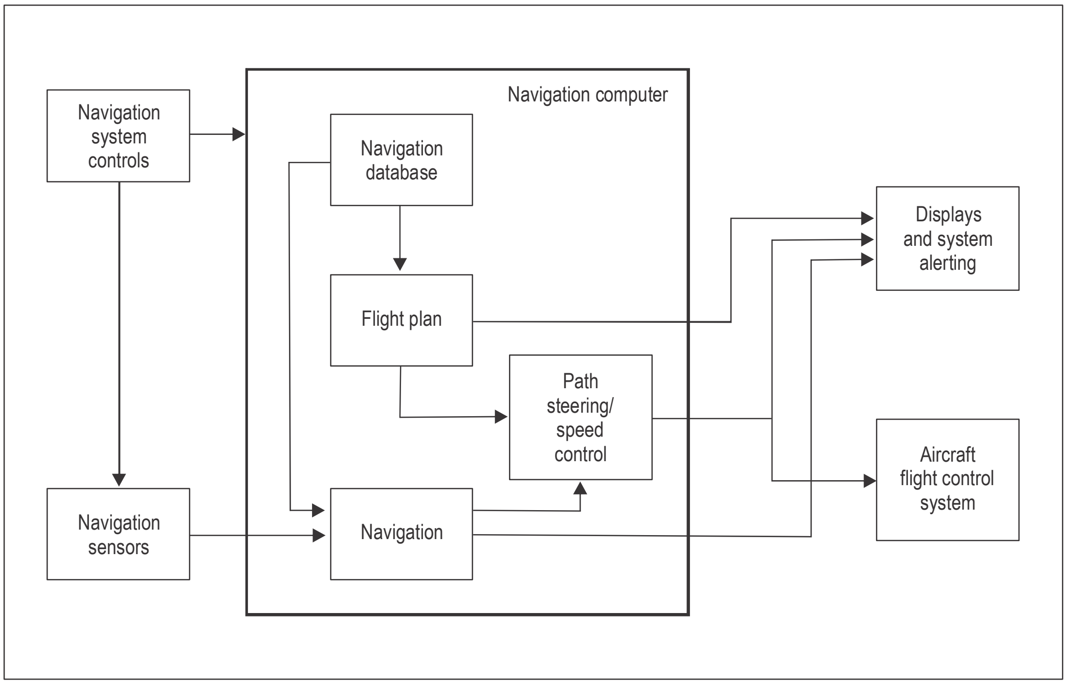


Figure I-Att A-3. Basic RNA and RNP system functions

3.2.4 As the aircraft progresses along its flight path, and if the RNAV or RNP system is using ground NAVAIDs, it uses its current estimate of the aircraft's position and its internal database to automatically tune the ground stations in order to obtain accurate radio position.

3.2.5 Lateral and vertical guidance is made available to the pilot either on the RNAV or RNP system display itself or supplied to other display instruments. In many cases, the guidance is also supplied to an automatic flight guidance system (FGS). In its most advanced form, this display consists of an electronic map with an aircraft symbol, planned flight path, and ground facilities of interest, such as NAVAIDs and airports.

3.2.6 Aircraft navigate using a blend of true and magnetic references. Excessive differences in the magnetic variation (MagVar) used by aircraft systems, as well as what is associated with ground NAVAIDS, and what is specified for routes and procedures can result in unacceptable aircraft lateral guidance performance, and/or misleading information to the flight crew. Volume II, Attachment D, Magnetic Variation, provides guidance for the determination and use of magnetic variation by RNAV and RNP systems in the conduct of flight operations.

3.3 Navigation database

The RNAV or RNP system is expected to access a navigation database, if available. The navigation database contains pre-stored information on NAVAID locations, waypoints, ATS routes and terminal procedures, and related information. The RNAV and RNP system will use such information for flight planning and may also conduct cross-checks between sensor information and the database.

3.4 Flight planning

Note.— Flight planning in the context of the RNAV and RNP system refers to the creation of the FMS flight plan.

3.4.1 The flight planning function creates and assembles the lateral and vertical flight plan used by the guidance function. A key aspect of the flight plan is the specification of flight plan waypoints using latitude and longitude, without reference to the location of any ground NAVAIDs.

3.4.2 More advanced RNAV and RNP systems include a capability for performance management where aerodynamic and propulsion models are used to compute vertical flight profiles matched to the aircraft and able to satisfy the constraints imposed by air traffic control. A performance management function can be complex, utilizing fuel flow, total fuel, flap position, engine data and limits, altitude, airspeed, Mach, temperature, vertical speed, progress along the flight plan and pilot inputs.

3.4.3 RNAV and RNP systems routinely provide flight progress information for the waypoints en-route, for terminal and approach procedures, and the origin and destination. The information includes estimated time of arrival, and distance-to-go, which are both useful in tactical and planning coordination with ATC.

3.5 Guidance and control

RNAV and RNP systems provide lateral guidance, and in many cases, vertical guidance as well. The lateral guidance function compares the aircraft's position generated by the navigation function with the defined lateral flight path and then generates steering commands used to fly the aircraft along the defined path. Geodesic or great circle paths joining the flight plan waypoints, typically known as "legs", and circular transition arcs between these legs, are calculated by the RNAV or RNP system. The lateral deviation from the reference path is computed by comparing the aircraft's present position and direction with the reference path. Roll steering commands to track the reference path are based upon the lateral deviation from the reference path. The path deviation is shown on flight instruments and steering commands are output to a flight guidance system (FGS), which either controls the aircraft directly or generates commands for the flight director. The vertical guidance function, where included, is used to control the aircraft along the vertical profile within constraints imposed by the flight plan. The outputs of the vertical guidance function are typically pitch commands to a display and/or FGS and thrust or speed commands to displays and/or an auto-thrust function.

3.6 Display and system control

Display and system controls provide the means for system initialization, flight planning, path deviations, progress monitoring, active guidance control and presentation of navigation data for flight crew situational awareness.

4. RNP SYSTEM – BASIC FUNCTIONS

4.1 An RNP system is an RNAV system whose functionalities support on-board performance monitoring and alerting. Current specific requirements include:

a) capability to follow a desired ground track with reliability, repeatability and predictability (including optional curved path); and

b) optional capability to follow vertical profiles using vertical angles, speed restrictions or specified altitude constraints to define a desired vertical path.

4.2 The on-board performance monitoring and alerting (OBPMA) capabilities may be provided in different forms depending on the system installation, architecture and configurations, including:

a) display and indication of both the required and the estimated navigation system performance;

b) monitoring of the system performance and alerting the crew when RNP requirements are not met; and

c) lateral deviation displays scaled to RNP, in conjunction with separate monitoring and alerting for navigation integrity.

4.3 An RNP system utilizes its navigation sensors, system architecture and modes of operation to satisfy the RNP navigation specification requirements. It must perform the integrity and reasonableness checks of the sensors and data and may provide a means to deselect specific types of NAVAIDs to prevent reversion to an inadequate sensor. RNP requirements may limit the modes of operation of the aircraft, such as for RNP < 1.0 NM, where the flight technical error (FTE) is a significant factor, manual flight by the crew may not be allowed. Dual system/sensor installations may also be required depending on the intended operation or need.

5. SPECIFIC RNAV AND RNP SYSTEM FUNCTIONS

Performance-based flight operations are based on the ability to assure reliable, repeatable and predictable flight paths for improved capacity and efficiency in planned operations. The implementation of performance-based flight operations requires not only the functions traditionally provided by the RNAV or RNP system, but also may require specific functions to improve procedures, the efficiency of the airspace and air traffic operations. The system capabilities for established fixed radius paths, holding, lateral offsets and speed restrictions fall into this latter category.

5.1 Fixed radius paths

5.1.1 For RNP systems, the fixed radius paths take two forms: one is the RF leg type (see Figure I-Att A-4). The RF leg is one of the leg types described that should be used when there is a requirement for a specific curved path radius in a terminal or approach procedure. The radius to fix (RF) leg begins at the fix for the preceding path terminator and is defined by a turn direction, a turn centre point and termination fix that the RNP systems uses to calculate the radius and path. RNP systems supporting this leg type provide the same ability to conform to the track-keeping accuracy during the turn as in the straight-line segments.

Note.— Bank angle limits for different aircraft types and winds aloft are taken into account in procedure design.

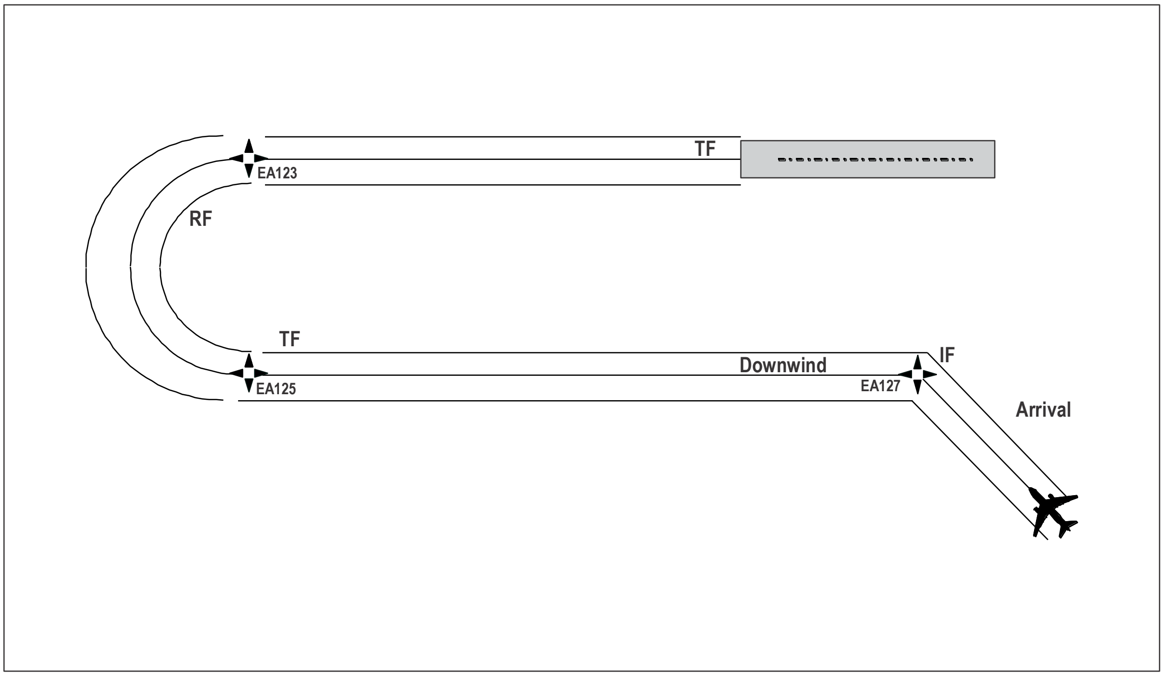


Figure I-Att A-4. RF leg

5.1.2 The other form of the fixed radius path is intended to be used with en-route procedures. Due to the technicalities of how the procedure data are defined, it falls upon the RNP system to create the fixed radius turn (also called a fixed radius transition or FRT) between two route segments (see Figure I-Att A-5).

5.1.3 It is expected that FRTs will typically have two radii, 22.5 NM for high altitude routes (above FL 195) and 15 NM for low altitude routes. Using such path elements in an ATS route enables improvement in airspace usage through closely spaced parallel routes. Any other values will be determined by a State/the ATM service provider as appropriate to operational needs, and as supported by operational safety assessments.

5.2 Fly-by turns

For fly-by turns, RNAV and RNP systems use information on aircraft altitude and speed, bank angle, wind, and track angle change, to calculate a flight path turn that smoothly transitions from one path segment to the next. However, because the parameters affecting the turn radius can vary from one aircraft to another, as well as due to changing conditions in speed and wind, the turn initiation point and turn area can vary (see Figure I-Att A-6). Based upon the industry standard RTCA DO-236()/EUROCAE ED-75(), paragraph 3.2.5.4.1, at altitudes above FL 195 the start of the turn for the aircraft is limited to a maximum of 20 NM from the fix. This establishes a maximum limit for the turn area at all altitudes. A nominal limit can be determined based upon the aircraft and flight conditions using the requirements contained in DO-236()/ED-75(). The RNAV and RNP system transitions from one leg to the next at the bisector of the turn, as illustrated in the Figure I-Att A-6.

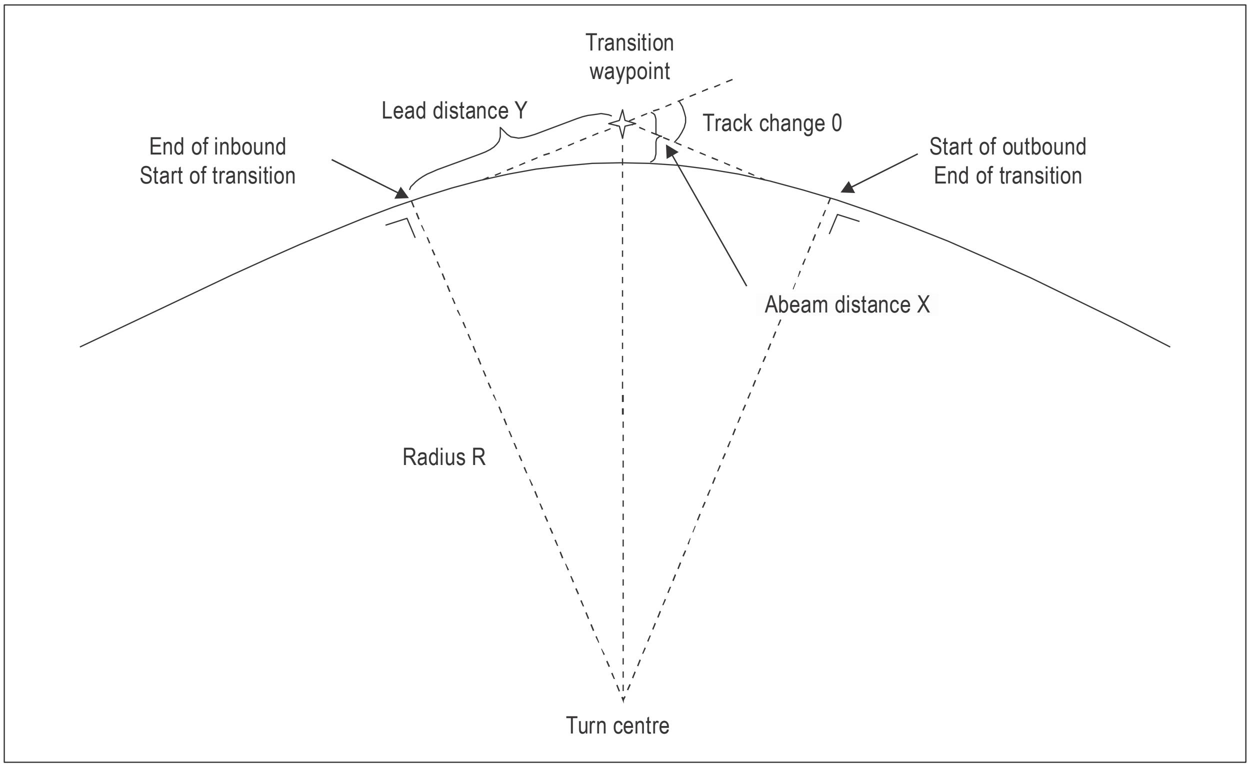


Figure I-Att A-5. Fixed radius transition

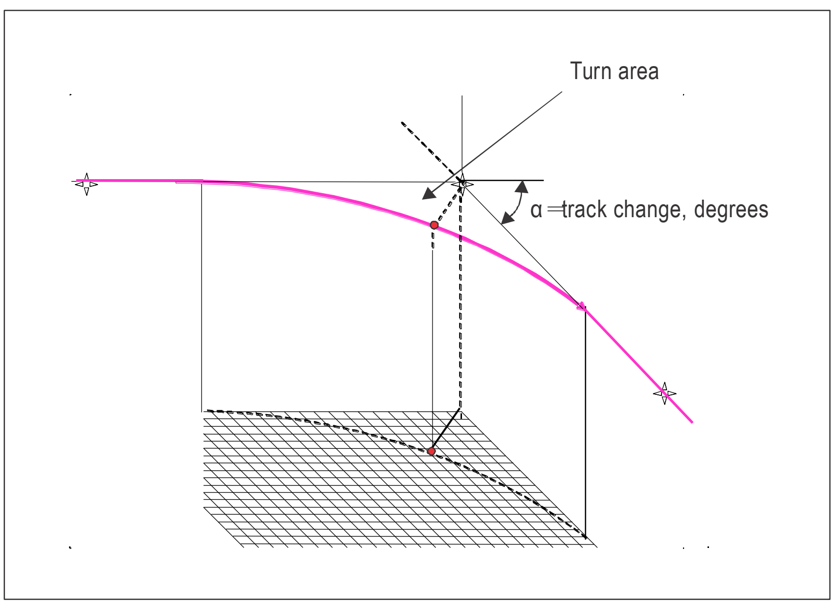


Figure I-Att A-6. Fly-By Turn and Turn Area

5.3 Holding pattern

The RNAV and RNP system facilitates the holding pattern specification by allowing the definition of the inbound course to the holding waypoint, turn direction and leg time or distance on the straight segments, as well as the ability to plan the exit from the hold.

5.4 Offset flight path

5.4.1 RNP systems may provide the capability for the flight crew to specify a lateral offset from a defined route. Generally, lateral offsets can be specified in increments of 1 NM up to 20 NM. When a lateral offset is activated in the RNP system, the aircraft will leave the defined route and typically intercept the offset at a predefined angle. When the offset is cancelled, the aircraft returns to the defined route in a similar manner. Such offsets can be used both strategically, that is, fixed offset for the length of the route, or tactically, that is, temporarily. Most RNP systems automatically cancel offsets in the terminal area or at the beginning of an approach procedure, at a hold, or during course changes of 90 degrees or greater. The amount of variability in these types of operations should be considered as operational implementation proceeds (see Figure I-Att A-7).

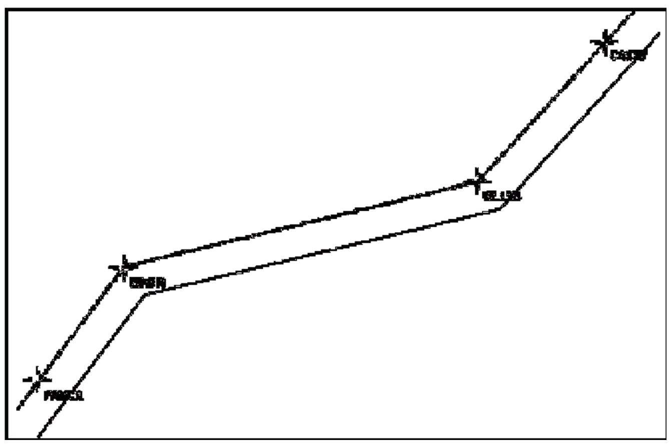


Figure I-Att A-7. Offset flight path

5.4.2 When used, parallel offset applies to ATS routes, excluding arrivals/departures. This is an available in-service capability within some aircraft and systems that perform RNAV and RNP applications. No functional requirements exist except for RNP4, RNP2, and Advanced RNP. Lacking a standard for aircraft and system, general use of the parallel offset capability is at the discretion of the operator and their operating procedures. The parallel offset function identified within A-RNP is specified in accordance with DO-236()/ED-75() and provides a basis for the specification of airspace and ATS routes.

5.5 Speed restrictions

5.5.1 The RNP system should support airspeed restrictions at altitudes and/or waypoints. These restrictions may be required for tactical airspace operations or as part of a procedure. When speed restrictions are assigned at a waypoint, the system should support “AT”, “AT or ABOVE” and “AT or BELOW” types as required by Table I-Att A-1. Flight phase affects the way the speed restriction is applied before and after the waypoint. The RNP system may support speed restrictions through system automation or by suitable information and cues to the flight crew.

5.5.2 Table I-Att A-1 and the following describe the expected equipment operation and the operational applicability of the respective speed restriction types:

a) for an "AT" speed restriction, the aircraft airspeed should be at the speed restriction when the waypoint is sequenced;

b) for an "AT or ABOVE" speed restriction, the aircraft airspeed should be at or above the restriction when the waypoint is sequenced;

c) for an "AT or BELOW" speed restriction, the aircraft airspeed should be at or below the restriction when the waypoint is sequenced; and

d) when the same "AT" speed restriction is used between any two waypoints in the same flight phase, the aircraft should treat the leg(s) between those waypoints as a constant speed segment at the restriction speed.

Table I-Att A-1. Operational applicability of speed restrictions

Speed restriction type	Speed applicability by operation	
	Departure / Missed approach (CLIMB)	Arrival / Approach (DESCENT)
AT or BELOW	Do not exceed PRIOR to and AT	Do not exceed AT and AFTER
AT	Do not exceed PRIOR, do not go below AFTER, cross AT	Do not go below PRIOR, do not exceed AFTER, cross AT
AT or ABOVE	Do not go below AT and AFTER	Do not go below PRIOR to and AT

Note.— The capability described above is not widely available in existing RNP systems. The requirements are contained in RTCA DO-236() and EUROCAE ED-75() as the standard needed to ensure reliable, repeatable and predictable performance necessary for emerging flow, merging/spacing 3D and time control 4D operations.

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Attachment B

DATA PROCESSES

1. AERONAUTICAL DATA

1.1 All RNAV and RNP applications use aeronautical data to define, inter alia, ground-based NAVAIDs, runways, gates, waypoints and the route/procedure to be flown. The safety of the application is contingent upon the accuracy, resolution and integrity of the data. The accuracy of the data depends upon the processes applied during the data origination. The resolution depends upon the processes applied at the point of origination and during the subsequent data processing, including the publication by the State. The integrity of the data depends upon the entire aeronautical data chain from the point of origin to the point of use.

1.2 An aeronautical data chain is a conceptual representation of the path that a set, or element, of aeronautical data takes from origination to end use. A number of different aeronautical data chains may contribute to a collection of data that are used by an RNAV or RNP application. The main components of the chain are illustrated below and include data origin, data collators, data publishers, database suppliers, data packers and data users (see Figure I-Att B-1).

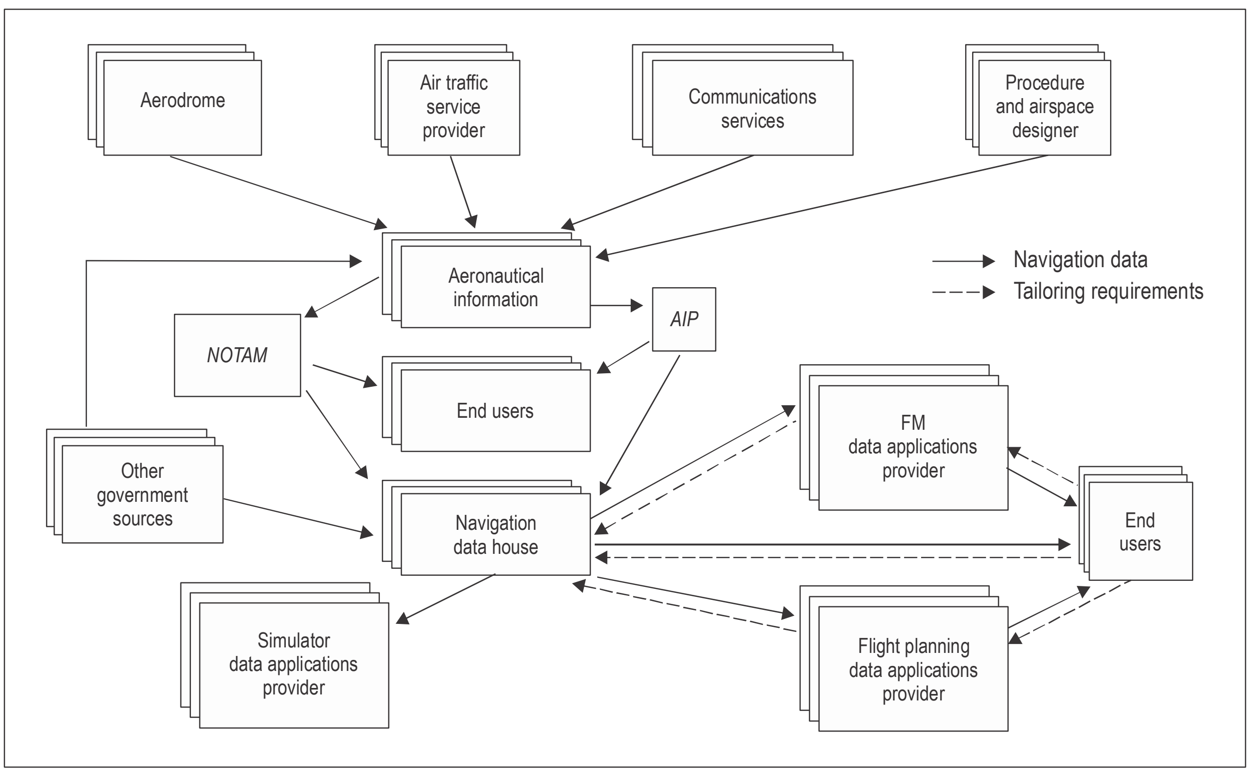

Figure I-Att B-1. The data chain

2. DATA ACCURACY AND INTEGRITY

2.1 The accuracy, resolution and integrity requirements of individual data items processed by the aeronautical data chain are detailed in the Aeronautical Data Catalogue contained in –the *Procedures for Air Navigation Services – Aeronautical Information Management* (PANS-AIM, Doc 10066)*,* which requires Member States to take all necessary measures to ensure that the aeronautical information/data it provides is adequate, of required quality (accuracy, resolution and integrity), and is provided in a timely manner for the entire territory for which the State is responsible.

2.2 Annex 15 – *Aeronautical Information Services* requires Member States to introduce a properly organized quality system in conformance with the ISO 9000 series of quality standards.

2.3 Annex 6 – *Operation of Aircraft* requires that the operator not employ electronic navigation data products, unless the State of the Operator has approved the operator's procedures for ensuring that the process applied and the products delivered have met acceptable standards of integrity, and that the products are compatible with the intended function of the equipment. Additional guidance is provided in RTCA document DO-200() and EUROCAE document ED76(), both entitled "Standards for Processing Aeronautical Data".

2.4 While procedures to ensure the quality of the data process are required to be in place, the validity of the *original* data submission is not guaranteed. Its accuracy should be verified by established data quality evaluation processes.

3. PROVISION OF AERONAUTICAL DATA

3.1 Each national aviation authority in each State should arrange for the timely provision of required aeronautical information to the aeronautical information service (AIS) associated with aircraft operations. Information provided under the aeronautical information regulation and control (AIRAC) process must be distributed at least 42 days prior to the effective date and major changes should be published at least 56 days prior to the effective date, according to Annex 15 – *Aeronautical Information Services*, Chapter 6.

3.2 The processing cycle for the airborne navigation databases requires that the database is delivered to the end user at least seven days before the effective date. The RNAV or RNP system provider requires at least eight days to pack the data prior to delivery to the end user, and the navigation data houses generally exercise a cut-off 20 days prior to the effective date in order to ensure that the subsequent milestones are met. Data supplied after the 20-day cut-off will generally not be included in the database for the next cycle. The timeline is illustrated in Figure I-Att B-2.

3.3 The quality of data obtained from another link in the aeronautical data chain must be either validated to the required level or guaranteed through an assurance of data quality from the supplier. In most cases, there is no benchmark against which the quality of such data can be validated and the need to obtain assurance of the data quality will generally flow back through the system until it reaches the originator of each data element. Consequently, reliance must be placed upon the use of appropriate procedures at every point along the aeronautical data chain.

3.4 Navigation data may originate from survey observations, from equipment specifications/settings or from the airspace and procedure design process. Whatever the source, the generation and the subsequent processing of the data must take account of the following provisions in Annex 15:

a) coordinate data references to the World Geodetic System – 1984 (WGS-84);

b) surveys based upon the International Terrestrial Reference Frame;

c) data traceability;

d) equipment used for surveys must be adequately calibrated;

e) software tools used for surveys, procedure design or airspace design must be suitably qualified;

f) standard criteria and algorithms must be used in all designs;

g) surveyors and designers must be properly trained;

h) comprehensive verification and validation routines must be used by all data originators;

i) instrument flight procedures must be subjected to validation prior to publication. For guidance on the validation process see *The Quality Assurance Manual for Flight Procedure Design* (Doc 9906), Volume 5 – *Validation of Instrument Flight Procedures;*

j) aeronautical navigation data must be published in a standard format, with an appropriate level of detail and to the required resolution; and

k) all data originators and data processors must implement a quality management process which includes:

1) a requirement to maintain quality records; and

2) a procedure for managing feedback and error reporting from users and other processors in the data chain.

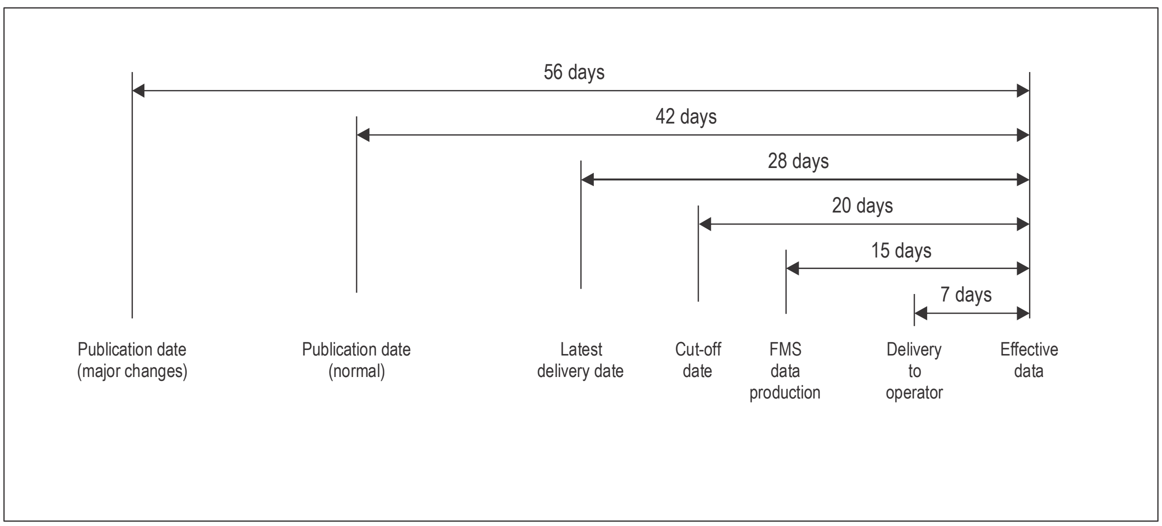

Figure I-Att B-2. Data processing timeline

4. ALTERING AERONAUTICAL DATA

4.1 A data processor or data user must not alter any data without informing the originator of the alteration and receiving concurrence. Altered data must not be transmitted to a user if the originator rejects the alteration. Records shall be kept of all alterations and must be made available upon request.

4.2 Wherever possible, data handling processes should be automated, and human intervention should be kept to a minimum. Integrity-checking devices such as cyclic redundancy check (CRC) algorithms should be used wherever possible throughout the navigation data chain.

VOLUME II

IMPLEMENTING RNAV AND RNP OPERATIONS

Part A

GENERAL

Chapter 1

INTRODUCTION

1.1 PERFORMANCE-BASED NAVIGATION CONCEPT REVIEW

1.1.1 The performance-based navigation (PBN) concept is made up of three interrelated elements: the navigation specification, the NAVAID infrastructure and the navigation application.

Note.— A detailed explanation of the PBN concept is presented in Volume I, Chapter 1.

1.1.2 Navigation specifications are guidance used by States to develop certification and operational authorization material. Navigation specifications describe, in detail, the requirements placed on the area navigation system for operation along a particular route, procedure or within an airspace where authorization for the navigation specification is prescribed. These requirements include:

a) the performance required of the area navigation system in terms of accuracy, integrity and continuity;

b) the functions available in the area navigation system so as to achieve the required performance;

c) the navigation sensors, integrated into the area navigation system, that may be used to achieve the required performance;

d) the flight crew and other procedures needed to achieve the performance mentioned of the area navigation system.

1.1.3 Navigation specifications include implementation considerations for States and service providers to aid in the implementation of navigation applications based upon associated navigation specification.

1.1.4 The NAVAID infrastructure relates to space or ground-based NAVAIDs that are mentioned in each navigation specification.

1.1.5 Navigation specifications that require OBPMA are termed RNP navigation specifications. Those that do not require OBPMA are known as RNAV navigation specifications.

1.1.6 A navigation application is when a navigation specification and associated NAVAID infrastructure are applied to ATS routes, instrument approaches and/or user-defined routeing in a defined airspace volume, in accordance with the airspace concept. Examples of how the navigation specification and NAVAID infrastructure may be used together in a navigation application include RNAV or RNP departures and arrivals, RNAV or RNP ATS routes, and RNP approach procedures.

1.2 CONTEXT, SCOPE AND USE OF NAVIGATION SPECIFICATIONS

1.2.1 Context and scope

1.2.1.1 Most of the navigation specifications contained in this volume were originally developed for regional use to respond to the operational requirements of specific airspace concepts and associated flight phases. This is reflected in Table II-A-1-1 and these explanations are provided at the beginning of each navigation specification. Some navigation specifications are applied in airspace concepts for oceanic or remote continental airspace applications; others are used in continental or terminal airspace applications. The navigation specification's functional and operating requirements were selected as a function of the targeted airspace concept which includes, but is not limited to, the associated flight phase (oceanic or continental en-route, arrival, approach, departure), particular applications (such as fixed or random routeing, standard instrument departures (SIDs)/standard instrument arrivals (STARs) and/or instrument approach procedures) and the targeted CNS/ATM environment (such as procedural operating environment using ADS-C reporting or parallel route network in a radar environment with direct controller-pilot very high frequency (VHF) voice communications).

1.2.1.1.1 The flight phase for which a navigation specification was intended for use remains fixed, primarily because the technical and operational requirements in a navigation specification are flight phase specific, such as RNP value requirements, certain leg types and path terminators.

1.2.1.1.2 The operating environment is more flexible: while a specific operating environment may have been envisaged when the navigation specification was developed and implemented, the operating environment can be changed. Thus, a navigation specification originally envisaged for oceanic use (such as RNP 4) supported by ADS-C could continue to be used for oceanic (en-route) operations with reduced separation requirements supported by space-based ADS-B and RCP240.

Note.— For more information on performance-based communication requirements, see the Performance-Based Communication and Surveillance (PBCS) Manual *(Doc 9869).*

1.2.1.1.3 If a change from the originally intended operating environment occurs, then an implementation-specific safety assessment is needed to ensure the adequacy of safety requirements in the new operating environment. The requirements of the navigation specification may not be changed (see note under 1.2.1.2.1) and neither can the flight phase in which the specification can be used, that is, the RNP 4 (oceanic specification) cannot be used for terminal SIDs/STARs, and similarly RNP 1 cannot be used for oceanic operations.

1.2.1.2 Proliferation of regional or State navigation specifications is avoided by publishing these navigation specifications in this manual, which allow regions and States to use existing navigation specifications rather than developing new ones.

1.2.1.2.1 The navigation specifications included in Parts B and C of this volume do not address all the requirements that may be specified for operation in a particular airspace concept. Such additional requirements are specified in other documents such as operating rules, AIPs and the *Regional Supplementary Procedures* (Doc 7030). Before conducting flights into an airspace, the appropriate State regulations of that airspace require that operators and pilots take account of all operational documents relating thereto.

Note.— Mindful that navigation specifications seek to ensure interoperability and international standardization, States are strongly discouraged from diverging from requirements in the navigation specification when publishing their State regulatory material. If differences are published by States, these should not place any additional burden on the aircraft qualification and operational authorization. State regulatory material based on a navigation specification should include a specific section to highlight any difference from requirements in the reference navigation specification.

1.2.1.2.2 States should undertake a safety assessment in accordance with the provisions contained in Annex 19 – *Safety Management*, Annex 11 – *Air Traffic Services* and PANS-ATM (Doc 4444), Chapter 2.

1.2.1.3 A navigation specification published in this manual does not constitute regulatory guidance material against which either the aircraft or the operator will be assessed and authorized. National, or regional, certification and operations authorization documentation for PBN applications must be published, as necessary. The navigation specification provides the technical and operational criteria but does not imply a need for recertification. For example, with RNAV 2/RNAV 1 an operational authorization process is still needed. This could be either through a dedicated authorization document or through recognition that existing regional RNAV implementation certification documents can be applied with the necessary differences, to satisfy the objectives set out in the PBN specification. The applicable documents related to airworthiness and/or approval process are listed in Attachment E.

1.2.1.4 Compliance should be determined against each relevant navigation specification. Compliance with one navigation specification does not automatically imply compliance with another. Navigation specifications are not written to be automatically consistent with State-specific regulatory guidance or documentation processes and may be incomplete. The navigation specifications are not specifically intended to be invoked for compliance because a State must scrutinize the material to assure consistency between the navigation specification and the State-specific regulatory guidance (this could be as simple as a cover sheet and a reference to the navigation specification or as extensive as a regulatory circular containing all of the navigation specification material along with any State-specific guidance, processes or procedures).

1.2.2 Use of navigation specifications

1.2.2.1 Table II-A-1-1 shows the navigation specifications published in Parts B and C of this volume and that some navigation specifications are used in particular flight phases and/or routes or procedures, whilst other navigation specifications are more versatile.

Note.— Although this table uses the RNAV/RNP value (lateral navigation accuracy) requirement of a navigation specification to denote its applicability for a particular flight phase, the RNAV/RNP value is only one of several performance and functional requirements in a navigation specification and is often not the only determining characteristic.

Table II-A-1-1. Navigation specification, flight phase, navigation application, and associated RNAV/RNP value (lateral navigation accuracy) (NM)

		Navigation application, flight phase and RNAV/RNP value (NM)							
		ATS or user-defined routeing		*Arrival procedures*	*Approach procedures*				*Departure procedures*
Part, chapter	*Navigation specification*	*En-route oceanic/remote*	*En-route continental*	*Arrival*	*Initial*	*Intermediate*	*Final*	*Missed*[1]	*Departure*
B, Ch.1	RNAV 10	10							
B, Ch.2	RNAV 5[2]		5	5					
B, Ch.3	RNAV 2		2	2					2
B, Ch.3	RNAV 1		1	1	1	1		1	1
C, Ch.1	RNP 4	4							

		Navigation application, flight phase and RNAV/RNP value (NM)							
		ATS or user-defined routeing		*Arrival procedures*	*Approach procedures*				*Departure procedures*
Part, chapter	*Navigation specification*	*En-route oceanic/remote*	*En-route continental*	*Arrival*	*Initial*	*Intermediate*	*Final*	*Missed*[1]	*Departure*
C, Ch.2	RNP 2	2[3]	2						
C, Ch.3	RNP 1[7]			1	1	1		1	1
C, Ch.4	Advanced RNP (A-RNP)	2[3]	2 or 1	0.3	0.3	0.3		1[9]	0.3
C, Ch.5	RNP APCH[4]				1	1	0.3[5]	1[8]	
C, Ch.6	RNP AR				1-0.1	1-0.1	0.3-0.1	1-0.1	1-0.3
C, Ch.7	RNP 0.3[6]		0.3	0.3	0.3	0.3		0.3	0.3

Notes.
1. *The RNAV/RNP value (lateral navigation accuracy) applies from the start of climb and along the intermediate and final missed approach segments.*
2. *RNAV 5 is an en-route navigation specification, which may be used for the initial part of an arrival procedure outside 30 NM from the aerodrome reference point (ARP) and above minimum sector altitude.*
3. *Optional – requires higher continuity.*
4. *There are two sections to the RNP APCH specification: Section A is enabled by* global navigation satellite system *(GNSS*) *and baro-VNAV, Section B is enabled by SBAS.*
5. *An RNP value (lateral navigation accuracy) of 0.30 NM is applicable to RNP APCH Section A. Different angular performance requirements are applicable to RNP APCH Section B only.*
6. *The RNP 0.3 navigation specification is for helicopter operations only.*
7. *Potential alert limit limitations beyond 30 NM from the ARP and associated mitigations are described in Part C, Chapter 3 (Implementing RNP 1).*
8. *An RNP value (lateral navigation accuracy) of 1 NM is applicable to RNP APCH Part A all along the missed approach. An RNP value (lateral navigation accuracy) of 0.3 NM is applicable for RNP APCH Part B, along the first leg of the missed approach if it is a track to fix (TF) leg aligned within 3° of the final approach path (intermediate missed approach and until turn initiation point).*
9. *For missed approach considerations, including exceptions for use of an RNP value (lateral navigation accuracy) of 0.3 NM, see Part C, Chapter 4, 4.2.3.3.*

1.2.2.2 It is possible that a sequence of RNAV and RNP navigation specifications is used. A flight may commence in an airspace using an RNP 1 departure, transit through en-route continental and then oceanic airspace requiring RNAV 2 and RNP 4, respectively, and culminate with terminal and approach operations requiring RNAV 1 and RNP APCH (see Figure II-A-1-1 and Table II-A-1-1).

1.2.2.3 Table II-A-1-1 identifies a number of instances where different navigation specifications can be applied on the same phase of flight; for example, in the arrival, approach or missed approach phases of flight. However, since not all of the specifications provide the same functional capability for the particular phase of flight, this may limit the number of navigation specification options for a particular application. Consequently, it is important in the design of the procedures to appropriately identify the applicable navigation specification(s), and to require only the capability that is provided by those navigation specification(s).

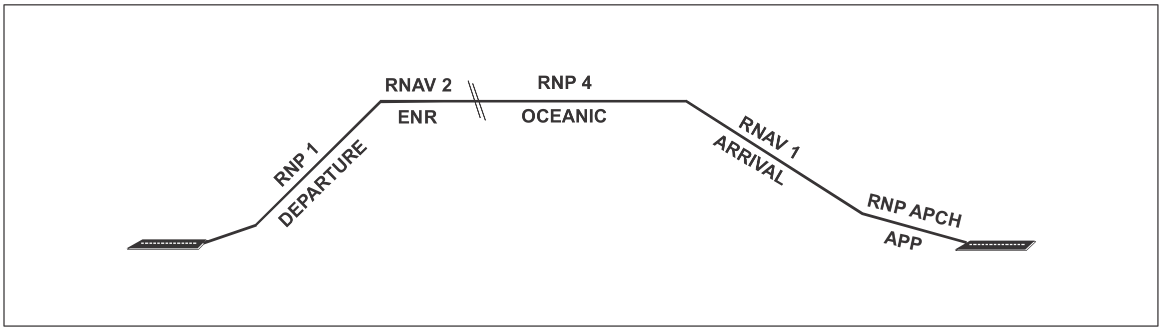

Figure II-A-1-1. Example of an application of RNAV and RNP navigation specifications

1.2.3 Navigation specifications and references

Each volume and navigation specification includes numerous document references to regulatory guidance and industry standards. Where references are invoked as a requirement, they will be shown with an open reference version (). Attachment E lists the applicable, specific version for each document.

1.3 NAVIGATION FUNCTIONS FOR PERFORMANCE-BASED NAVIGATION APPLICATIONS

1.3 1 RNAV navigation specifications are contained in Part B of this volume and RNP navigation specifications are in Part C. This volume also has additional attachments describing functions. Where appropriate, the navigation specification links to the relevant appendices in Part C and the matrix of normal applications is reflected in Table II-A-1-3 to connect additional functions with navigation specifications. These functionalities may be associated with more than one navigation specification.

1.3.1.1 “Parallel offset” and “holding” are navigation capabilities that can be considered within an airspace concept implementing a particular navigation specification. While many aircraft can have these capabilities, a lack of standardization means that consistent behaviour cannot be guaranteed.

1.3.1.1.1 “Parallel offset” functional requirements are only specified in three navigation specification chapters and reflect the application requirements (such as Volume II, Part C, Chapter 1, 1.3.3.7.2 and Volume I, Attachment A, 5.4). Parallel offset is listed in Table II-A-1-3 for those navigation specifications.

1.3.1.1.2 “Holding” is described in Volume I, Attachment A, 5.3 but in general, is not supported by functional requirements in the navigation specifications described in this manual. It is therefore not listed in Table II-A-1-3. However, holding can be associated with any navigation specification either through the requirement for flight crew capability to perform holds, or through the use of a navigation system that has a holding function.

Note.— In the case of A-RNP, the navigation specification includes a functional requirement for RNP holding. At present there are no operational concepts including RNP holding and RNP holding has not been published, even within an A-RNP application context. Until such a time as these concepts are developed, the RNP holding functionality may be used to fly the holding patterns as described above.

1.3.1.2 An airspace concept may include either of these two capabilities based on the assumption that the aircraft contains parallel offset and/or holding functions, or for those aircraft without parallel offset and/or holding functions, flight crews have the means, procedures and training to perform these aspects of flight operations.

1.3.2 The airspace concept discussed in Volume I is used to design the broad architecture of airspace, anchored around (PBN) navigation applications developed as the ATS routes departures, arrivals and approaches.

1.3.3 Successful PBN implementation starts with identifying the operational requirements in order to identify the PBN application that best responds to these requirements and match the fleet capability and NAVAID infrastructure available to provide positioning capability (see 1.4). For example, RNP 1 might meet the need of a particular departure/arrival requirement, but other considerations should be addressed such as the number of operators qualified for RNP 1 versus RNAV 1, and that global navigation satellite system (GNSS) reversion capability can provide continued PBN service during a short or prolonged GNSS outage. For example RNAV 1 might meet the need for the initial and missed approach segments of ILS approach to take into account the need to keep ILS approaches available in case of GNSS failure.

1.3.4 While the reliability of PBN applications is assured by aircraft/systems compliance with the performance requirements of the navigation specifications, it can be enhanced by requiring the use of specific RNP system functions that may be associated with some navigation specifications. Examples of these RNP system functions include: radius to fix (RF), FRT, parallel offset and vertical navigation (VNAV) (for final approach only).

1.3.5 There are several pre-requisites before requiring the use of any RNP system function:

a) the operational requirement(s) must be identified, analysed and validated and the RNP system function selected to respond to the particular requirement (see Table II-A-1-2);

b) the chosen RNP system function must be permitted for use with the selected navigation specification (see Table II-A-1-3); and

c) the targeted fleet must be certified to use the RNP system function in the context of the PBN application.

1.3.6 An example of how an RNP system function could evolve from identification to implementation is provided following the Tables below.

Table II-A-1-2. Example of airspace requirements and corresponding RNP system functions

Operational (airspace) requirement	*Enabling RNP system function with permitted navigation specification*
– Enabling operations on closely spaced/parallel routes with consistent and repeatable turns on SIDs/STARs. – Enabling curved approaches, particularly through terrain rich areas but also to support environmental mitigation.	– Radius to fix (RF) can be used on SIDs/STARs, with the following specifications: RNP 1, Advanced RNP, RNP 0.3 (for helicopters), RNP AR DP. – RF can be used outside the final approach, with the following specifications: RNP 1, Advanced RNP, RNP 0.3 (for helicopters), RNP APCH and RNP AR.

Operational (airspace) requirement	*Enabling RNP system function with permitted navigation specification*
	Note.— If there is a need to use the RF function inside the final approach segment, there is a mandatory requirement for the RNP AR APCH specification.
– Maintaining same spacing between ATS routes (excluding SIDs/STARs) on straight and curved segments without a need to increase route spacing on the turn.	– Fixed radius transition (FRT) can be used on ATS routes and associated with RNP 4, RNP 2 and Advanced RNP.
– Flying offset from the user-defined or ATS route, such as an alternative to vectoring.	– Parallel offset function can be applied 'tactically' (such as on instruction from ATC) or strategically. The function can only be used on user-defined routes and on ATS routes that are not SIDs/STARs. The tactical application is commonly referred to as tactical parallel offset and the offsets used are typically in increments of 1 NM, such as 5 NM offset. The strategic parallel offset function is included in the architecture of the airspace concept. The parallel offset function can be associated with RNP 4, RNP 2 and Advanced RNP.

Note.— Air navigation services providers (ANSPs) may include holding procedures in their airspace design, using a waypoint as a holding point. Aircraft can either hold manually over a waypoint when the aircraft holding function is not available and the pilot is expected to manually fly the holding pattern, or the navigation system's holding function can be used to execute the published hold.

1.3.7 In the following table, navigation specifications are listed in association with functions. If there is an R (required) or an O (optional) associated with a function for a navigation specification, it means that the related function must perform as the requirements specify. If there is no entry then the function, if it is available, may not meet any listed standards or requirements.

Table II-A-1-3. Navigation specifications and RNP system functions

		Additional functionalities (**R**equired or **O**ptional)				
		RF	FRT[3]	VNAV (Final segment)	Parallel offset[4]	Time of arrival control (TOAC)
Part, chapter	Navigation specification	*Volume II, Appendix 1 to Part C*	*Volume II, Appendix 2 to Part C*	*Volume II, Attachment A*	*Volume I, Attachment A*	*Volume II, Appendix 3 to Part C*
B, Ch.1	RNAV 10	N/A	N/A	N/A	N/A	
B, Ch.2	RNAV 5	N/A	N/A	N/A	N/A	

Part, chapter	Navigation specification	Additional functionalities (**R**equired or **O**ptional)				
		RF	FRT[3]	VNAV (Final segment)	Parallel offset[4]	Time of arrival control (TOAC)
		Volume II, Appendix 1 to Part C	*Volume II, Appendix 2 to Part C*	*Volume II, Attachment A*	*Volume I, Attachment A*	*Volume II, Appendix 3 to Part C*
B, Ch.3	RNAV 2	N/A	N/A	N/A	N/A	
B, Ch.3	RNAV 1	N/A	N/A	N/A	N/A	
C, Ch.1	RNP 4	N/A	O	N/A	R	
C, Ch.2	RNP 2	N/A	O	N/A	O	
C, Ch.3	RNP 1	O[1]	O	N/A	N/A	
C, Ch.4	Advanced RNP	R[1]	O	N/A	R	
C, Ch.5	RNP APCH	O[1]	N/A	O *(Baro or SBAS)*	N/A	
C, Ch.6	RNP AR	R[2]	N/A	R[5] *(Baro or SBAS)*	N/A	
C, Ch.7	RNP 0.3	O[1]	N/A	N/A	N/A	

Notes.
1. *RF can only be used for arrival, departure and instrument approach procedures excluding the final segment.*
2. *RF can be used with any segment of RNP AR APCH or for RNP AR DP.*
3. *FRT can only be used for RNP ATS routes, excluding departures and arrivals.*
4. *The parallel offset function may be used for user-defined routes and ATS routes, excluding arrivals and departures. This is an available in-service capability within some aircraft and systems that perform RNAV and RNP applications. No functional requirements exist except for RNP 4 and Advanced RNP. If lacking a standard for aircraft and system, general use of the parallel offset capability is at the discretion of the operator and their operating procedures. The parallel offset function identified within A-RNP is specified in accordance with DO-236()/ED-75() and provides a basis for the specification of airspace and ATS routes.*
5. *VNAV is only a requirement for RNP AR APCH and not for RNP AR DP. Attachment A provides general information on VNAV.*

Example

RNP system function (RF) transitioning from identification to implementation

RF legs are used to control ground track of a turn where obstructions prevent the design of a fly-by or fly-over turn, or to accommodate other operational requirements such as closely spaced parallel routes. Procedure designers are increasingly using RF legs to achieve operational advantages and track repeatability not driven by significant terrain/obstruction issues. Considerations for implementation extend beyond CNS/ATM concerns and include environmental issues, traffic participation, stakeholders' feedback and dependencies:

Planning considerations

– Identify potential participants, fleet analysis and equipage plans.

– RF equipage and authorization rates are expected to rise; however, operator business market strategies can influence local/regional fleet composition.

– Determine ANSP tolerance for mixed mode operations in airspace design: is traffic segregation possible considering traffic pressure and capacity?

– Check if ATM automation is capable to assign or suppress correct type procedure via filed flight plan PBN info (in the future).

– Confirm that the regulatory body is agreeable to the use of RF leg.

Cost-benefit analysis considerations

– Track mile savings due to use of RF can create significant efficiencies, partially shared with non-participants, feasible when airspace system can maintain acceptable throughput capacity during moderate to heavy traffic loading.

– Consider ATM operation enhancement, such as established on RNP AR APCH, for additional benefit including runway or airspace capacity increase.

– What is the service objective and core benefit? Is RF the only way to achieve it?

– What is RF procedure utilization rate planned, both initially and projected?

– Are the benefits appropriately distributed? Who can achieve the level of certification (equipage/authorizations)?

– Are all key stakeholders (air traffic control officers (ATCOs), airlines, regulators, etc.) committed to the change and do they understand system limitations?

– Some operators may intentionally bias collaborative deliberations due to company business interest concerns.

– What is the risk of building RF procedures that will never or rarely be used?

Unintended consequences of adding RF to a transition (RNP departure/arrival/approach)

– Instrument flight procedures with RF legs are only available in databases of users allowed to fly RF legs. Therefore, some States may require a regulator review prior to RF use, except for procedures/segments based on either A-RNP or RNP AR APCH/DP (RF required).

– Charting and navigation database service providers may block distribution of RF containing procedures, based on safety-related regulatory agreements; this will require separate procedure development to make similar alternatives available.

Some considerations on the use of RF

– RF is a repeatable path and can be beneficial for strict noise corridor application.

– Track dispersion may be a far more popular/tolerable choice for noise-sensitive communities.

– RF legs can be easily specified and flown by RNP aircraft with RF leg capability. If a procedure designer elects to define turns with multiple TF legs, this may require more testing and analysis considering the intended aircraft flying the turn.

– TF design turns at lower altitudes and slower airspeeds (such as intermediate approach segment) can approximate RF equivalent turn paths and flight times, allowing a greater population of aircraft and systems to conduct a procedure.

1.4 NAVIGATION INFRASTRUCTURE FOR NAVIGATION SPECIFICATIONS

1.4.1 The NAVAID infrastructure refers to ground- or space-based NAVAIDs. Conventional ground-based NAVAIDs include DME and VHF omnidirectional radio range (VOR), while space-based NAVAIDS include GNSS elements. The PBN concept requires that NAVAID infrastructure provides position information to the aircraft through an on-board area navigation system. Further guidance on implementing GNSS is given in the *Global Navigation Satellite System (GNSS) Manual* (Doc 9849). All NAVAID requirements are defined in Annex 10 – *Aeronautical Telecommunications*, and the *Manual on Testing of Radio Navigation Aids* (Doc 8071) contains information concerning the testing of navigation aids supporting PBN.

1.4.2 The NAVAID infrastructure provides position information to the aircraft through the on-board area navigation system. This may be supplemented by autonomous on-board inertial navigation systems and/or air data systems.

1.4.3 Most navigation specifications only make use of the lateral positioning provided by the NAVAID infrastructure. For those navigation specifications used in the final approach segment, lateral and vertical guidance may be obtained from a core constellation (such as GPS) augmented by satellite-based augmentation system (SBAS) or Barometric VNAV.

1.4.4 Each navigation specification stipulates which positioning sensors may be used for a particular navigation application, as seen in Table II-A-1-4. The table shows that the only navigation specification with maximum sensor flexibility is RNAV 5, since RNAV 5 was predicted on performance supported by a diverse existing navigation infrastructure. The flexibility and choices are reduced when the performance requirement is more stringent and sufficient ground NAVAID infrastructure cannot be affordably provided by the ANSP or State. Because of its broad coverage and availability, GNSS is easily able to meet the requirements of any navigation.

Table II-A-1-4. Navigation specifications and (required or optional) NAVAID infrastructure

	GNSS	GNSS/ inertial navigation system[3]	DME/DME	DME/DME/ inertial navigation system[3]	VOR/DME
RNAV 10[1, 4]	O	O			
RNAV 5[1]	O	O	O	O	O
RNAV 2[1] & 1[1]	O		O	O	
RNP 4	R				
RNP 2	R		O[2]	O[2]	
RNP 1	R		O[2]	O[2]	
ADVANCED RNP	R		O[2]	O[2]	
RNP APCH	R				
RNP AR	R	R			
RNP 0.3	R				

Notes.
1. *For these navigation specifications where there is a choice of navigation infrastructure/positioning sources, at least one NAVAID is required for the promulgated associated navigation application.*
2. *The use of DME/DME for this navigation specification requires a specific State authorization.*
3. *Inertial navigation systems may be integrated with the GNSS or DME/DME sensor to improve performance and continuity of the operation.*
4. *DME and/or VOR may be used to check aircraft navigation accuracy prior to entry into oceanic airspace. DME and/or VOR may also be used to extend the RNAV 10 navigation capability by updating the navigation system, when en-route.*

1.4.5 Freedom to use any available positioning source/sensor (such as navigation aid and/or aircraft integration with inertial navigation systems) is limited by the performance requirements for a particular navigation specification where only a specified set of sensor combinations has been determined suitable to achieve the performance requirements of a specific navigation specification.

1.4.6 As such, each usable aircraft positioning sensor must be matched by suitable and permitted NAVAID infrastructure to provide positioning within the desired coverage area.

1.4.7 Attachment E contains the document references for permitted sensors for each navigation specification.

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Chapter 2

ON-BOARD PERFORMANCE MONITORING AND ALERTING

2.1 INTRODUCTION

On-board performance monitoring and alerting (OBPMA) is the main functional element that determines whether the operation of the navigation system complies with the necessary acceptable level of safety risk associated with an RNP navigation specification. OBPMA can apply to the aircraft's lateral and longitudinal navigation performance. On-board performance monitoring and alerting (OBPMA) also helps the flight crew detect when the navigation system is not achieving or cannot guarantee the integrity and the navigation performance an RNP operation requires. This chapter addresses the requirements associated with OBPMA for RNP operations based on this manual's RNP navigation specifications. In order to do this, the chapter first provides an overview of the error sources associated with navigation systems.

2.2 NAVIGATION ERROR COMPONENTS AND ALERTING

2.2.1 Lateral navigation

2.2.1.1 The inability to achieve the required RNP value may be due to navigation errors in aircraft tracking and positioning. The three main errors that OBPMA deals with are path definition error (PDE), FTE and NSE. Total system error (TSE) is a function of PDE, NSE and FTE. The combination of the error monitoring by the aircraft's navigation system and the implementation requirements of a given performance-based navigation (PBN) specification (such as RNP procedure design lateral and vertical protected areas) then serve to allow some random error variables to occur during an individual aircraft's operation yet maintain a predetermined acceptable level of safety risk.

2.2.1.2 Of the three error sources:

a) PDE occurs when the defined path in the aircraft's navigation system does not correspond to the airspace planner's or procedure designer's desired path (the path ATC expects the aircraft to fly over the ground). Use of an RNAV or an RNP system for navigation requires the aircraft's on-board navigation database be loaded with and contain the defined path representing the PBN route or procedure's path. Where the database procedure contains segments or path terminators affected by magnetic variation (such as heading), altitude terminated, or fly-by/fly-over requirements, this will result in greater variability in the path flown and greater PDE.

   In contrast, when a PBN procedure or route includes an RF leg transition or an FRT, as some RNP navigation specifications permit, the aircraft's RNP system will define a reliable, continuous path matching the intent of the route or procedure design's ground-track. This is especially true for navigation systems using a standard Earth reference model for RNAV and RNP PBN implementations relying on global navigation satellite system (GNSS). Therefore, one can measure PDE and FTE directly and control the errors through a variety of means for these paths.

   The PDE is generally considered negligible but may need to be evaluated for specific procedures.

Note.— The World Geodetic System – 1984 (WGS-84), or an equivalent Earth reference model, should be the reference Earth model for error determination. If the data the aircraft's navigation system uses does not employ a WGS-84 model, then the navigation system must include any differences between the aircraft's selected Earth model and the WGS-84 Earth model as part of the PDE contribution to TSE. PDE should also include any data resolution errors the selected Earth reference introduces.

b) FTE relates to the flight crew or autopilot's ability to follow the aircraft navigation system's defined path or track, and this error includes any display error (such as course deviation indicator (CDI) centering error). The flight crew can monitor and control FTE through their use of the aircraft's FGS (such as coupling the autopilot to the steering commands from the navigation system) or through flight crew procedures and training requiring monitoring of the FTE displayed on the aircraft display system. Where flight crew monitoring procedures are used, support may be required from other means of monitoring and controlling FTE, depending on the phase of flight and the type of PBN operation. For example, many RNP navigation specifications require the aircraft to provide support for a flight crew by requiring a moving map display showing the desired route or path and the aircraft's own-ship relative to the path as an aid to situation and position awareness, while also **requiring** a deviation display in each pilot's primary field of view.

Note 1.— FTE is sometimes referred to as path steering error.

Note 2.— FAA AC20-138D and EASA CS-ACNS provide industry and regulator accepted FTE assumptions for defined navigation specifications, and these rely on the expectations that the flight crew will make every effort to keep the aircraft on the route or procedure centre line. Manufacturers and operators can use the FTE values in DO-208, Appendix E, to justify eligibility for almost all of this manual's navigation specifications as long as their use is consistent with the DO-208's guidance and standards.

c) NSE refers to the difference between the aircraft's estimated position and actual position (see Figure II-A-2-1).

Note.— NSE is sometimes referred to as positioning estimation error (PEE).

2.2.2 Longitudinal navigation

2.2.2.1 Longitudinal performance implies navigation relative to a position along the defined track (such as 4-D control). However, at the time of publication of this manual, there are no navigation specifications requiring 4-D control, and there is no consideration for FTE in the longitudinal or along-track dimension. The current navigation specifications define requirements for along-track accuracy, which includes just NSE when the manufacturer shows PDE is negligible (such as through gaining acceptance of their database handling and management practices). However, assumptions of along-track error, consistent with PBN operation's 95 per cent accuracy requirement, can affect requirements for position reporting (such as "10 NM to ABC") and route and procedure design criteria (such as minimum segment altitudes where the aircraft can begin a descent once crossing a fix).

2.2.2.2 The accuracy requirements of the RNP navigation specifications in Part C consider both the lateral and along-track dimensions. The RNP navigation specifications define aircraft's on-board performance monitoring and alerting requirements for just the lateral dimension for the purpose of assessing an aircraft's performance compliance. When then combined with the NSE, the RNP system provides on-board performance monitoring and alerting for the lateral and along-track directions (see Figure II-A-2-2).

Note.— The figure is intended to illustrate the relationship of the lateral errors. In determining TSE, the errors are assumed to be independent and combined by root sum square.

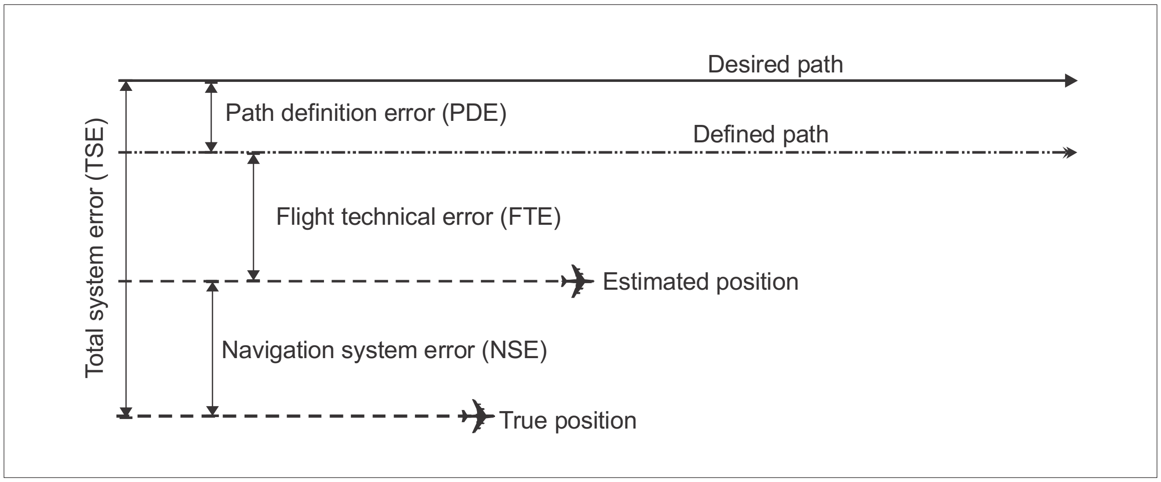

Figure II-A-2-1. Lateral navigation errors (95 per cent)

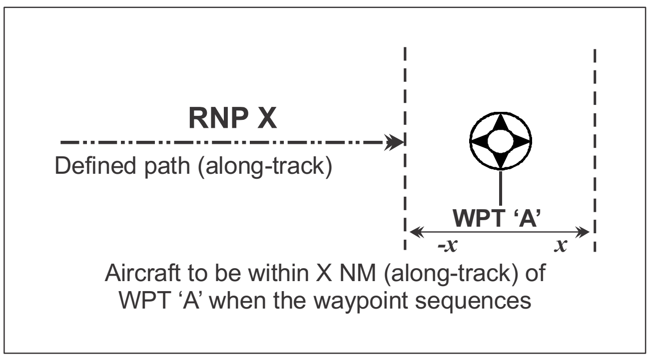

Figure II-A-2-2. Along-track navigation errors (95 per cent)

2.3 ROLE OF ON-BOARD PERFORMANCE MONITORING AND ALERTING

2.3.1 Overview

2.3.1.1 On-board performance monitoring and alerting (OBPMA) capabilities fulfil two interrelated needs, one on-board the aircraft and one within the airspace design:

a) on-board the aircraft, RNP systems provide for consistency in functionality, assurance of aircraft and system performance, that together result in reliable, repeatable and predictable flight operations; and

b) for airspace design, OBPMA allows for the allocation of airspace and procedure design based upon a specified RNP. This supports more efficient use of airspace resulting from RNP procedures and route design criteria.

Note.— RNAV systems may have similar or nearly identical functional capabilities but lack OBPMA capabilities.

2.3.1.2 On-board performance monitoring and alerting is a capability that allows the air crew to detect whether or not the RNP system satisfies the navigation performance required in the navigation specification. On-board performance monitoring and alerting relates to both lateral and longitudinal navigation performance.

2.3.1.3 On-board performance monitoring and alerting is concerned with the performance of the area navigation system:

a) "On-board" explicitly means that the performance monitoring and alerting is on board the aircraft and does not rely on external resources, like a ground-based route monitor or ATS surveillance. The monitoring element of OBPMA relates to FTE and NSE, while navigation database integrity and functional requirements constrain PDE so that it may be considered negligible.

b) "Monitoring" refers to the monitoring of the aircraft's performance with respect to positioning error and the ability of the aircraft to maintain the desired path.

c) "Alerting" relates to monitoring with predefined performance limits; and, if the aircraft does not perform well enough, the systems and displays in the aircraft will alert the pilot.

2.3.1.4 The monitoring and alerting requirements could be satisfied by:

a) an aircraft navigation system having an NSE monitoring and alerting capability (such as the monitoring of a protection level ensuring integrity of the position versus an alarm limit depending on the RNP value for the phase of flight) plus a lateral path deviation display indicator (such as a course deviation indicator (CDI)) enabling the crew to monitor the FTE. Given the assumption PDE is negligible, an aircraft can meet the OBPMA requirements because when NSE and FTE are both monitored, then the aircraft has TSE monitoring; or

b) an airborne navigation system having a TSE monitoring and alerting capability.

2.3.1.5 The net effect of OBPMA on TSE is displayed in Table II-A-2-1.

2.3.1.6 PBN operations also use the term OBPMA instead of the term "containment area" or "containment alert". OBPMA is a descriptive term and avoids confusion with existing uses of "containment" in various documents by different areas of expertise. For example:

a) The term "containment" often refers to the region within which the aircraft will remain 95 per cent of the time. In this instance, the associated terms "containment value" and "containment distance" relate to the airspace protection on either side of a PBN ATS route.

b) Within the industry standards for RNP systems in RTCA/DO-236 and EUROCAE/ED-75, "containment" refers to the region that the aircraft will remain when there is no alert (0.99999 probability) and defines a requirement for how often an alert occurs (0.9999). The associated terms from this use are: "containment limit", "containment integrity", "containment continuity" and "containment region".

c) Within PANS-OPS procedure and route design criteria material, "containment" refers to the lateral and vertical surfaces defining obstacle clearance, and the design criteria assumes the normal performance of the aircraft, with no failures, will remain within or above those lateral and vertical surfaces with very high probability. The terms often associated with design criteria are: "containment area", "airspace containment", "obstacle clearance containment" and "related obstacle protection areas".

2.3.1.7 For the purposes of this manual, the navigation accuracy component of TSE expressed in NM replaces the previous ICAO expressions of "containment value" and "containment distance".

2.3.2 On-board performance monitoring and alerting requirements for RNP

2.3.2.1 The on-board performance monitoring and alerting requirements for RNP 4, RNP 2, A-RNP, RNP 1, RNP APCH, RNP AR, and RNP 0.3 use common terminology in their navigation specifications. Each of these RNP navigation specifications include requirements for the characteristics shown in Table II-A-2-1.

Table II-A-2-1. Performance Monitoring and Alerting Effects on TSE

	RNAV navigation specifications	*RNP navigation specifications*	
		RNP X navigation specifications not requiring RF or FRT	*RNP X navigation specifications requiring RF or FRT*
NSE (monitoring and alerting)	Requires no alerting on position error or pilot cross-check of NSE.	Alerting on position accuracy and integrity.	
FTE (monitoring)	Managed by on-board system or pilot procedure.	Managed by on-board system or pilot procedure. More specific display scaling.	
PDE (monitoring)	Assumed to be zero; the desired path is not defined for non-fixed radius turns.		Assumed to be zero; path defined on RF and FRT.
NET EFFECT ON TSE	TSE monitoring does not apply to RNAV operations.	The RNP operations bound the TSE consistent with the RNP value. RNP route and procedure design requires extra protection for fly-by and fly-over turns;	The RNP operations bound the TSE consistent with the RNP value. RNP route and procedure design require no extra protection when using either FRT or RF turns.

Note.— RNAV navigation specifications do not require OBPMA, and this table includes RNAV for comparison to RNP.

2.3.2.1.1 RNP system performance

– *Accuracy*. The RNP value (such as RNP 1.0) expressed in NM defines the 95 per cent accuracy requirement in the RNP navigation specifications. Each RNP navigation specification's requirements also ensure monitoring of compliance with the accuracy requirement occurs during RNP operations.

– *Integrity*. During RNP operations the malfunction of the aircraft's RNP equipment is a major failure condition. Under airworthiness regulations, the probability of a malfunction affecting the RNP equipment is remote (that is, less than 1×10^{-5} per flight hour). For RNP APCH down to localiser performance with vertical guidance (LPV) minima and RNP AR APCH, malfunction of the aircraft's RNP equipment is considered a hazardous failure condition.

– *Continuity*. Airworthiness regulations consider loss of function a minor failure condition when the operator can revert to a different means of navigation (such as revert to conventional VHF omnidirectional radio range (VOR) navigation) or another navigation system (such as a second GPS receiver) and then safely proceed to a suitable airport. For RNP APCH down to LPV minima and RNP AR operations, loss of continuity is considered a major failure condition.

2.3.2.1.2 Airworthiness regulations address the aircraft's equipment requirements as they relate to RNP operations. These regulations characterize aircraft failures by the severity of the failure on the aircraft's operation and, as result, the aircraft systems' design must reduce the likelihood of the failure occurring or mitigate the effect of the failure. Typically, airworthiness requirements address both malfunction (equipment operating but failing to provide proper outputs) and loss of function (equipment ceases to function). Likewise, desires for operational continuity in such areas as oceanic and remote operations drives requirements for dual equipage to mitigate both malfunction and loss of equipment. The airworthiness requirements addressing aircraft failure characteristics are also not unique to RNP operations.

2.3.2.1.3 The RNP system must provide a means to support TSE monitoring. The system must provide an alert to the flight crew when the accuracy requirement is not met or when the probability that the TSE exceeds two times the RNP value (such as 2 × RNP) is greater than one in 100,000 (that is, 1×10^{-5}).

Note 1.— Some aircraft require the flight crew to monitor FTE. This requirement supports the monitoring of TSE performance when the aircraft offers an alert on the 95 per cent estimated lateral navigation accuracy, ensuring that the risk of the overall TSE (including the monitored NSE) exceeding 2 RNP will remain below one in 100,000 (that is, 1×10^{-5}*).*

Note 2.— Operators can use flight crew procedures and training, unique equipment characteristics in their aircraft and the installation characteristics to satisfy the TSE performance requirement of an RNP operation.

2.3.2.2 The on-board performance monitoring requirement is unique to RNP navigation specifications. RNP navigation specifications bound the permitted TSE performance of all aircraft conducting a given RNP operation. Since PDE is assumed to be negligible, the monitoring requirement is reduced to the other components of TSE (that is, FTE plus NSE). FTE can vary by the means of flight control in the aircraft (such as autopilot-coupled navigation). However, in contrast, the NSE can vary for a variety of reasons, most notably:

a) selected navigation sensors: the navigation sensors the aircraft uses to estimate position, such as GNSS or DME/DME navigation, where authorized by the State;

b) the relative geometry of the aircraft position to the supporting NAVAIDs: all radio NAVAIDs have this basic variability, although the specific characteristics and impacts of geometry vary depending on the NAVAID in use. For example, the relative geometry of the GNSS satellites to the aircraft affects an aircraft's GNSS performance. Likewise, the inclusion angle between the two or more DMEs relative to the aircraft (90 degrees being optimal) and the distance to the DMEs affects an RNP system's DME/DME navigation solution, since the aircraft DME equipment can have increasing range errors with increasing distance; and

c) inertial navigation system drift characteristics that increase over time depending on the aircraft's capability to update the inertial navigation system using an alternate available navigation sensor (such as the DME or GNSS sensor).

2.3.3 Application of on-board performance monitoring and alerting to aircraft

2.3.3.1 Although the TSE can change significantly over time for a number of reasons, including those above, the application of RNP navigation specifications can assure the TSE distribution remains suitable to the RNP operation. This can result from meeting two requirements associated with the TSE distribution, namely:

a) the requirement the lateral navigation accuracy remains equal to or less than the required accuracy (that is, less than 1 × RNP) for 95 per cent of the total flight time; and

b) the probability the TSE of each aircraft might exceed the specified TSE limit (equal to two times the accuracy value, or 2 × RNP) without annunciation is less than one in 100,000 (that is, 1×10^{-5}).

2.3.3.2 Typically, when using GNSS navigation, the aircraft's resulting performance satisfies the requirements in 2.3.3.1.

2.3.3.3 In meeting the OBPMA requirement for the aircraft, there can be significant variability in how each aircraft type manages individual errors:

a) Some navigation systems monitor the actual cross-track and along-track errors individually, whereas other systems monitor the radial NSE to simplify the monitoring and eliminate dependency on the aircraft track (such as, statistically, a typical elliptical 2-D error distribution).

b) Some navigation systems include TSE monitoring by adding the current value of FTE to the current value of NSE (such as current FTE + current NSE = current TSE).

c) For GNSS-based navigation systems, the accuracy requirement and the integrity requirement are met as a by-product of the aircraft-based augmentation system (ABAS) requirements defined in the GNSS equipment standards (that is, RTCA DO-229()) and a means to monitor FTE (such as a CDI display).

2.3.3.4 On-board performance monitoring and alerting (OBPMA) is not error monitoring. An installed RNP system will issue a performance monitoring alert when the system cannot guarantee, with sufficient integrity, the aircraft's current position meets the accuracy requirement (that is, 1 × RNP). When the RNP system issues an alert, the probable reason is the loss of ability to validate the aircraft's current position (such as insufficient GNSS satellites in view being one potential reason). When the RNP system issues the alert, the most likely position of the aircraft at that time is the exact same position indicated on the navigation display. Assuming the aircraft is on the desired track, the aircraft's FTE should be within the required limits, and, therefore, the likelihood of the TSE exceeding 2 × RNP just prior to the alert is less than one in 100,000 (that is, less than 1×10^{-5}). As a result, the installed RNP system protects the performance and integrity of the RNP operation.

2.3.4 Sample system performance monitoring and alerting requirements for RNP 1

2.3.4.1 The following is a simplified extract of how RNP system performance monitoring and alerting requirements apply to the RNP 1 navigation specification from Part C. The detailed RNP navigation specifications in this volume may contain additional information and contextual notes, along with specific functional and performance requirements tailored to the RNP navigation specification's required navigation sensors, airworthiness and operations compliance requirements, etc., consistent with the original guidance from State and industry standards (such as advisory circulars, technical standard orders (TSOs), DO- (RTCA) or ED-documents (EUROCAE), notices of proposed amendment).

2.3.4.2 The following requirements are taken from the RNP 1 navigation specification RNP system performance:

a) *Accuracy.* During operations in airspace or on routes designated as RNP 1, the lateral TSE must be within ±1 NM for at least 95 per cent of the total flight time. The along-track error must also be within ±1 NM for at least 95 per cent of the total flight time.

b) *Integrity.* Malfunction of the aircraft navigation equipment is classified as a major failure condition under airworthiness regulations (that is, 1×10^{-5} per flight hour).

c) *Continuity.* Loss of function is classified as a minor failure condition if the operator can revert to a different navigation system and proceed to a suitable airport.

d) *On-board performance monitoring and alerting.* The installed RNP system is required to provide an alert if the accuracy requirement is not met, or if the probability that the lateral TSE exceeds 2 NM is greater than 1×10^{-5} per flight hour. The alert must be consistent with RTCA DO-236(), DO-283(), DO-229(), and EUROCAE ED-75().

2.3.4.3 All of the navigation specifications in this volume have similar RNAV or RNP system performance requirements.

Chapter 3

SAFETY ASSESSMENT CONSIDERATIONS

3.1 The airspace concept is comprised of multiple elements, including the airspace organisation (routes and procedures and sectorization), bundled into an operational concept that relies on airspace classification, traffic assignment, communication, navigation, and surveillance enablers as well as ATM system tools and pilot and flight crew procedures.

3.1.1 Several varying airspace concepts exist, even though they may use the same enablers and/or procedures. Common enablers such as ATS surveillance, RNAV 5 and direct controller-pilot very high frequency (VHF) voice communications could produce an airspace concept for free route operations, and another for high-density continental operations based on a parallel track system of segregated routes, or, be used for arrival routes to position arriving aircraft into holding patterns.

3.1.2 At the heart of any airspace concept are the aircraft operating therein. It is critical that the avionics, navigation systems and associated failures of these aircraft be understood in the operating context of a complex system comprised of multiple enablers with their own systems, sub-systems, sub-components and safety considerations.

3.2 The aircraft itself, as well as each enabler and contributor to an airspace concept, undergoes a safety evaluation and assessment. If ADS-B is used to provide surveillance in the airspace concept, then it must meet the strict surveillance requirements of the relevant provisions. This is equally true if data communications are used within the airspace concept. PBN, in its role as contributor to the airspace concept, is also subject to such stringent requirements.

3.2.1 Understanding the relationship between the aircraft and CNS/ATM enablers, and the potential failure of any part of the system, is crucial to the overall safety assessment. For example, in an ATS surveillance environment, one aircraft with a failure of navigation capability could normally be handled successfully by ATC. Where there is no ATS surveillance, it is necessary to consider two situations:

a) the complete failure of the RNAV or RNP system; and

b) the potential that an aircraft's RNAV or RNP system has an unreported position error.

3.2.2 In either case, mitigations will need to be identified and incorporated into the operating procedures to implement the navigation application and ensure the safety of the envisaged airspace concept.

3.3 When an airspace concept is to be implemented, it relies upon various layers of safety assessments (that is, technological, operational, procedural). The airspace concept in its totality must also demonstrate that it is safe for implementation. The safety assessments of different components, including the aircraft and its systems and failures, form the foundation of the cumulative safety assessment for the overall airspace concept.

3.4 Along with communication, surveillance and ATM, navigation is one of multiple enablers of an airspace concept. In the context of this manual, *navigation* refers to PBN, whose three elements are subject to safety assessment processes:

a) the navigation specification's safety and performance requirements are embedded in the chapters entitled "Implementing RNAV" or "Implementing RNP" in parts B and C;

b) the NAVAID infrastructure's technical performance standards are prescribed in Annex 10 – *Aeronautical Telecommunications*, Volume I – *Radio Navigation* Aids, and

c) the navigation application's design criteria are enabled by Annex 6 and supported by PANS-OPS, Volume II (Doc 8168).

3.5 The overarching safety assessment requirements for airspace changes enabled by PBN, are prescribed in Annex 11 – *Air Traffic* Services, PANS-ATM (Doc 4444) and more generically in the *Safety Management Manual* (Doc 9859). Sample airspace concepts, each the result of a comprehensive safety assessment for specific implementations, are provided in Attachment C.

3.6 This chapter can only provide a high-level overview and should not be considered as an exhaustive description of the safety assessment. It presents key reference safety documentation associated primarily with the airspace concept, navigation applications, some navigation specifications and the NAVAID infrastructure (see Table II-A-3-1) that support a detailed safety assessment.

Table II-A-3-1. References to support safety assessment of PBN operations

Safety assessment references	*PBN related elements*
Annex 6, Operation of Aircraft	All navigation applications/specifications
Annex 11, Air Traffic Services	All navigation applications and airspace concepts
Annex 14, Aerodromes	RNP APCH and RNP AR operations
Annex 19, Safety Management	All CNS/ATM applications
Doc 4444, Procedures for Air Navigation Services – Air Traffic Management (PANS ATM)	Airspace concept
Doc 8168, Procedures for Air Navigation Services – Aircraft Operations (PANS-OPS, Volume II)	All navigation applications
Doc 9689, Manual on Airspace Planning Methodology for the Determination of Separation Minima	Airspace concept
Doc 9859, Safety Management Manual	All CNS/ATM applications
Doc 9905, Required Navigation Performance Authorization Required (RNP AR) Procedure Design Manual	RNP AR OPERATIONS
Doc 9997, Performance-based Navigation (PBN) Operational Authorization Manual[1], Appendix E	RNP AR OPERATIONS

1. Formerly the *Performance-based Navigation Operational Approval Manual*, renamed in its third (forthcoming) edition.

Safety assessment references	*PBN related elements*
Doc 9849, Global Navigation Satellite System (GNSS) Manual	NAVAIDs and applications
Doc 7030, Regional Supplementary Procedures	RNAV 10; RNAV 5; RNP 4 applications and airspace concepts;
EUR Doc 025, EUR RNP APCH Guidance Material	RNP APCH applications in Europe
Circular 324, Guidelines for lateral separation of arriving and departing aircraft on published adjacent instrument flight procedures	RNAV 1; RNP 1; RNP APCH; ADVANCED RNP; RNP AR – separation minima
Circular 353, Transition Planning for Change to Instrument Flight Procedure Approach Chart Identification from RNAV to RNP	RNP APCH and RNP AR APCH applications

Chapter 4

NAVIGATION SERVICE MONITORING

4.1 CONTEXT AND INTRODUCTION

The different navigation specifications presented in this volume contain statements on navigation service monitoring. This chapter provides guidance on how this monitoring may be practically implemented by States and ANSPs.

Note.— Within this section, the term air navigation services provider (ANSP) *refers to the entity owning a specific procedure/route, and conventional NAVAID signal service provider or global navigation satellite system (GNSS*) *signal service provider refers to the entity owning the navigation system.*

4.2 TYPES OF NAVIGATION SERVICE MONITORING

4.2.1 Navigation service monitoring for conventional navigation

When designing a navigation application based on signals from conventional beacons (such as a VHF omnidirectional radio range (VOR) route, or an ILS approach), there is usually a direct correlation between the loss of the beacon signal and the loss of the navigation service. In this case, the ANSP and the signal service provider of the ground-based NAVAIDs are frequently contained in the same organization. A monitoring service usually consists of monitoring the availability of conventional radio navigation beacon signals.

4.2.2 Navigation service monitoring for RNAV and RNP applications

In the context of area navigation, which is the basis of performance-based navigation (PBN), the one-to-one correlation between the loss of individual signals (such as one core GNSS satellite, or one distance measuring equipment (DME)) and the loss of the navigation service is much less direct. Experience has shown that the status of the navigation service may vary with the number of redundant ranging sources available, the relative geometry between the user and ranging sources, and the level of sophistication of the avionics. Another significant difference in such cases is that the ANSP may not be the same organization as the signals service provider, particularly when the individual navigation sources are part of a GNSS constellation. This may require establishing specific agreements between the GNSS (particularly in the case of satellite-based augmentation system (SBAS)) or DME signals service providers and the ANSP in support of a navigation service status monitoring. Another practical source of information about GNSS constellation status is available from the GNSS provider user support centre.

4.3 IMPLEMENTING NAVIGATION SERVICE MONITORING

4.3.1 Implementing an area navigation service monitoring for GNSS

4.3.1.1 The four main types of GNSS monitoring functions serve different purposes:

a) GNSS performance assessment;

b) GNSS data recording;

c) GNSS interference monitoring; and

d) GNSS operational status monitoring - an activity performed by a State or delegated entity, with the main objective of providing timely information to technical staff and ATC services on the operational status of GNSS services in relation to a defined operation in a particular airspace (and to therefore inform the user of any operating restrictions that may be required),

4.3.1.2 Functions a), b) and c) are described in the *Global Navigation Satellite System (GNSS) Manual* (Doc 9849) and are therefore not discussed in this document. This section focuses on specific aspects of function d): ground based operational status monitoring for PBN approach applications with respect to requirements for the status monitoring of navigation services. The provision of relevant information to ATS services are provided in Annex 10 – *Aeronautical* Telecommunications, Volume I – *Radio Navigation Aids* and Annex 11 – *Air Traffic* Services.

4.3.1.3 It should be noted that Annex 10, Volume I, Chapter 2, *Standard on Provision of information on the operational status of radio navigation services*, initially designed for ground-based navigation services, refers to approach control services only, as opposed to ATC service in the whole airspace, and this is also in line with the current operational use of PBN outside of approaches. Also, it does not address the status monitoring of individual GNSS signals, but rather of essential radio navigation services. Annex 10 defines an essential radio navigation service as a radio navigation service whose disruption has a significant impact on operations in the affected airspace or aerodrome.

4.3.1.4 There are a number of specific features of PBN approaches that render real-time operational status monitoring neither practical nor required for PBN operations, whether the service is assessed as essential or non-essential.

4.3.1.4.1 Impracticability of real-time service monitoring for PBN operations

4.3.1.4.1.1 As noted in the GNSS Manual, Chapter 7:

"Given the variety of avionics designs, one service status model cannot meet all operators' requirements. A conservative model would produce false alarms for some aircraft. A less conservative model would lead to missed detection of a service outage for some and false alarms for others. Regardless, only the aircrew, not ATC, is in a position to determine whether, for example, it is possible to continue an ABAS-based instrument approach. In contrast, ATC has access to ILS monitor data and can deny an ILS approach clearance based on a failure indication. The real-time monitor concept is neither practical nor required for GNSS ABAS operations."

4.3.1.4.1.2 For PBN approach operations supporting SBAS minima, building an SBAS real-time monitor could be more practical than for ABAS. However, PBN approach procedures supporting SBAS (LPV) minima also support ABAS (lateral navigation (LNAV) and/or lateral navigation or vertical navigation (LNAV/VNAV)) minima in most cases. Since the ATC clears the aircraft to a PBN procedure chart identification and not to a specific line of minima, this specific SBAS monitor would not help ATC to manage the PBN approach procedure unavailability, unless all aircraft are SBAS equipped. Consequently, there has been no operational need for this interface to date.

4.3.1.4.2 Mitigating the absence of service monitoring for PBN operations

4.3.1.4.2.1 Whereas the availability of ground-based navigation services is directly related to failures of the electronic equipment, the availability of PBN services depends mostly on the geometry of the GNSS constellation, as interpreted by the specific airborne augmentation layer. Where PBN is implemented as an essential service, one active mitigation to the impracticability of building operational status information is to ensure a high availability at the airspace user level of the PBN approach procedure through the requirement of a pre-flight prediction of the GNSS constellation geometry. Airspace users are then required to delay departure until the predicted geometry is sufficient.

4.3.1.4.2.2 Another mitigation measure, applicable to both essential and non-essential PBN approaches, is the advisory predictive GNSS service availability NOTAMs broadcast to users and ATC services. These are based on the status information provided by the core satellites or augmentation system operator. Finally, since only the aircrew are able to determine the availability of a particular PBN operation, real-time information to ATC is provided by pilots' reports based on the status information provided by the PBN avionics.

4.3.1.5 It is important that airspace users notify ATC of interference events and ,as a consequence, ATC should consider notifying other airspace users of these events through automatic terminal information service (ATIS), NOTAMs or other means.

4.3.2 Implementing an area navigation service monitoring for DME/DME

4.3.2.1 In this case, monitoring consists mainly of assessing the operational status of any "critical distance measuring equipment (DME)". Additional guidance material is available on the ICAO PBN public website[1], notably in the document *Navigation Infrastructure Assessment in Support of PBN,* and PANS-OPS, Volume II (Doc 8168).

4.3.2.2 *Redundancy and critical NAVAIDs*. If DME is the approved navigation infrastructure to support RNAV 1 standard instrument departures (SIDs) / standard instrument arrivals (STARs), adequate redundancy can be provided by two independent DME pairs, either of which are able to provide positioning anywhere along the flight path. A common DME in the two DME pairs is sometimes referred to as limited redundancy. When there is only one DME pair providing positioning, there is no redundancy. In such cases, either of the DME stations in the pair becomes a critical NAVAID. The loss either of this (only) DME pair, means that the standard instrument departure (SID)/standard instrument arrival (STAR) cannot be flown using DME/DME.

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1. https://www.icao.int/safety/pbn/Pages/Documentation.aspx

Part B

IMPLEMENTING RNAV OPERATIONS

Chapter 1

IMPLEMENTING RNAV 10
(DESIGNATED AND AUTHORIZED AS RNP 10)

1.1 INTRODUCTION

1.1.1 Background

This chapter addresses the implementation of RNP 10 to support the 50 NM lateral and the 50 NM longitudinal distance-based separation minima in procedural oceanic or remote area airspace. This guidance has been titled RNAV 10 for consistency with the other chapters in this manual. This designation and version of the material do not change any requirements, and do not affect operators who obtained an RNP 10 authorization from their relevant State regulatory authority. RNAV 10 does not require on-board performance monitoring and alerting. However, the designation of the airworthiness and operational authorization as well as airspace/route designation remains “RNP 10” in order to retain the validity of the present publications and extensive authorizations. Recognizing the extent of existing airspace designations and operational authorizations under RNP 10 designation, it is anticipated that any new airspace designations and aircraft approvals will continue to use the “RNP 10” term while the required PBN application will now be known as “RNAV 10.”

1.1.2 Purpose

1.1.2.1 This chapter provides guidance for implementing RNP 10 routes and developing an RNP 10 operational authorization process. This material includes guidance on airworthiness and operational issues. The information enables an operator to be approved as capable of meeting the navigation element requirements for RNP 10 operations. It also provides a means by which an operator can lengthen any navigation time limit associated with the RNP 10 authorization.

1.1.2.2 While RNP 10 operational authorization primarily relates to the navigation requirements of the airspace, operators and pilots are still required to take account of all operational documents relating to the airspace, which are required by the appropriate State authority, before conducting flights into that airspace.

1.2 IMPLEMENTATION CONSIDERATIONS

1.2.1 NAVAID infrastructure

RNP 10 was developed for operation in oceanic and remote areas and does not require any ground-based NAVAID infrastructure or assessment.

1.2.2 Communications and air traffic services surveillance

1.2.2.1 This guidance material does not specifically address communications and ATS surveillance requirements associated with implementation of route systems and lateral separation minima utilizing RNP 10. Those requirements are normally determined in the implementation process taking into account any local and regional characteristics. For example, procedural-pilot position reports and voice communications through a third party have been demonstrated to be acceptable in some implementations; however, direct very high frequency (VHF) controller/pilot voice communications may be required in certain areas, such as those of known convective weather.

1.2.2.2 Communications and ATS surveillance requirements for distance-based longitudinal separation utilizing RNP 10 are specified in the *Procedures for Air Navigation Services – Air Traffic Management* (PANS-ATM, Doc 4444), Chapter 5.

1.2.2.3 When global navigation satellite system (GNSS) is used as the sole basis for both ATS surveillance and aircraft navigation, the risks and requirement for mitigation techniques associated with the loss of GNSS potentially resulting in the loss of both navigation and surveillance capability, should be considered. This should typically be addressed through the regional or local State safety case prepared in support of the application.

1.2.3 Obstacle clearance and route spacing

1.2.3.1 Detailed guidance on obstacle clearance is provided in the *Procedures for Air Navigation Services – Aircraft Operations*, Volume II – *Construction of Visual and Instrument Flight Procedures* (PANS-OPS, Doc 8168); the general criteria in Parts I and III apply and assume normal operations.

1.2.3.2 The rationale for having chosen the RNP 10 navigation specification can apply in oceanic and remote areas where the availability of NAVAIDs, communications and ATS surveillance is limited.

1.2.3.3 The minimum route spacing where this navigation specification is utilized is 50 NM.

1.2.4 Additional considerations

1.2.4.1 Guidance in this chapter does not supersede appropriate State operating requirements for equipage.

1.2.4.2 Although this navigation specification does not include requirements for holding function, ANSPs may include holding procedures in their airspace design using a waypoint as a holding point.

1.2.4.3 Many aircraft have a holding capability. Aircraft can either hold manually over a waypoint when the aircraft holding functionality is not available and the pilot is expected to manually fly the holding pattern, or the navigation system's holding functionality can be used to execute the published hold (see Volume I, Attachment A, 5.3, Holding pattern).

1.2.5 Publication

1.2.5.1 The AIP should clearly indicate that the navigation application is RNP 10, where reference is to existing routes. The route should identify minimum segment altitude requirements.

1.2.5.2 The navigation data published in the State AIP for the routes and supporting NAVAIDs must meet the requirements of Annex 15 – *Aeronautical Information Services*. All routes must be based upon WGS-84 coordinates.

1.2.5.3 Where holding patterns are established, they should comply with the criteria and publication requirements in PANS-OPS, Volume II, Part 3, Section 3, Chapter 7.

1.2.6 Air traffic controller training

It is recommended that air traffic controllers providing control service in airspace where RNAV 10 is implemented should have completed training in the following areas:

1.2.6.1 Core training

a) How area navigation systems work (in the context of this navigation specification):

   1) functional capabilities and limitations of this navigation specification;

   2) accuracy, integrity, availability and continuity; and

   3) GPS receiver, receiver autonomous integrity monitoring (RAIM), fault detection and exclusion (FDE), and integrity alerts;

b) flight plan requirements;

c) air traffic control (ATC) procedures:

   1) ATC contingency procedures;

   2) separation minima;

   3) mixed equipage environment (impact of manual VHF omnidirectional radio range (VOR) tuning);

   4) transition between different operating environments; and

   5) phraseology.

1.2.6.2 Training specific to a navigation specification

Reporting of gross navigation errors.

1.2.7 Navigation service monitoring

Navigation service monitoring should be consistent with Volume II, Part A, Chapter 4.

1.2.8 Air traffic services system monitoring

1.2.8.1 The RNAV value provides a primary parameter for determining lateral route spacing and separation minima necessary for traffic operating on a given route. Accordingly, lateral and longitudinal navigation errors are monitored (that is, through monitoring programmes that use oceanic navigation error reports, oceanic altitude deviation reports or navigation error reports) and then investigated to prevent their recurrence. To date, radar observations of each aircraft's proximity to track and altitude, before coming into coverage of short-range NAVAIDs at the end of the oceanic route segment, are typically noted by ATS facilities.

1.2.8.2 If an observation indicates an aircraft is not within the established limit, the reason for the apparent deviation from track or altitude may need to be determined and steps taken to prevent a recurrence. Additionally, it is a condition of the authorization that pilots/operators notify the relevant regulatory authority of any of the following:

a) lateral navigation errors of 27.8 km (15 NM) or greater;

b) longitudinal navigational errors of 18.5 km (10 NM) or greater;

c) longitudinal navigational errors of three minutes or more variation between the aircraft's estimated time of arrival at a reporting point and its actual time of arrival; and

d) navigation system failures.

1.2.8.3 Overall system safety needs to be monitored to confirm that the ATS system meets the required system safety requirements.

1.2.8.4 The introduction of new ATS surveillance systems could affect the monitoring process.

1.3 NAVIGATION SPECIFICATION

1.3.1 Background

1.3.1.1 This section identifies the airworthiness and operational requirements for RNP 10 operations. Operational compliance with these requirements must be addressed through national operational regulations and may require an operational authorization in some cases. For example, some States require operators to apply to their national authority (State of the Operator/Registry) for operational authorization.

1.3.1.2 This chapter addresses only the lateral part of the navigation system.

1.3.1.3 The United States Department of Transportation published FAA Order 8400.12 – Required Navigation Performance 10 (RNP 10) Operational Authorization on 24 January 1997. Based on the comments received from operators, States, and aviation regulatory authorities, a new version, 8400.12A, was published on 9 February 1998. Subsequently, EASA issued "AMC 20-12 Recognition of FAA Order 8400.12A for RNP-10 Operations" for European operators. The Civil Aviation Safety Authority (CASA) of Australia, in coordination with the United States, used FAA Order 8400.12A (as amended) to develop Civil Aviation Advisory Publication (CAAP) RNP 10-1, detailing the authorization process for Australian operators. This has since been replaced with Advisory Circular (AC) 91U-2(0). The airworthiness and operational requirements contained in this navigation specification are based upon past ICAO material and have been updated accordingly. The preceding documents have been superseded by FAA 20-138D (or later) and EASA CS-ACNS.

1.3.2 Authorization process

1.3.2.1 This navigation specification does not in itself constitute regulatory guidance material against which either the aircraft or the operator will be assessed and approved. Aircraft are certified by their State of manufacture. Operators are approved in accordance with their national operating rules. The navigation specification provides the technical and operational criteria and does not imply a need for recertification.

1.3.2.2 The following steps must be completed before conducting RNP 10 operations:

a) aircraft equipment eligibility must be determined and documented;

b) operating procedures for the navigation systems to be used and the operator navigation database process must be documented;

c) pilot training based upon the operating procedures must be documented, if necessary;

d) the above material must be accepted by the state regulatory authority; and

e) operational authorization must then be obtained in accordance with national operating rules.

1.3.3 Contents of an application for an RNP 10 operational authorization

1.3.3.1 Aircraft eligibility

1.3.3.1.1 Many aircraft and navigation systems currently in use in oceanic or remote area operations will qualify for RNP 10 based on one or more provisions of the existing certification criteria. Thus, additional aircraft certification action may not be necessary for the majority of RNP 10 operational authorizations. Additional aircraft certification will only be necessary if the operator chooses to claim additional performance beyond that originally certified or stated in the AFM but cannot demonstrate the desired performance through data collection. Three methods of determining aircraft eligibility have been defined.

1.3.3.1.2 ***Method 1 – RNP certification***

1.3.3.1.2.1 Method 1 can be used to approve aircraft that have been formally certificated and approved for RNP operations. RNP compliance is documented in the flight manual and is typically not limited to RNP 10. The flight manual addresses RNP levels that have been demonstrated to meet the certification criteria and any related provisions applicable to their use (such as NAVAID sensor requirements). Operational authorization will be based upon the performance stated in the flight manual.

1.3.3.1.2.2 Airworthiness approval specifically addressing RNP 10 performance may be obtained. Sample wording that could be used in the flight manual, when an RNP 10 approval is granted for a change in the approved inertial navigation system's performance, is as follows:

> "The XXX navigation system has been demonstrated to meet the criteria of [State's guidance material document] as a primary means of navigation for flights up to YYY hours' duration without inertial navigation system updating. The determination of flight duration starts when the inertial navigation system is placed in the navigation mode. For flights that include airborne updating of the inertial navigation system's position, the operator must address the effect that updating has on position accuracy and any associated time limits for RNP operations pertinent to the updating NAVAID facilities used and the area, routes or procedures to be flown. Demonstration of performance in accordance with the provisions of [State's guidance material document] does not constitute authorization to conduct RNP operations."

Note.— The above wording is based upon performance approval by the aviation authority and is only one element of the authorization process. Aircraft with this wording in their flight manual are eligible for authorization, if all other criteria are met. The YYY hours specified in the flight manual do not include updating. When the operator proposes a credit for updating, the proposal must address the effect the updating has on the position accuracy and any associated time limits for RNP operations pertinent to the updating of the NAVAID facilities used and the area, routes or procedures to be flown.

1.3.3.1.3 ***Method 2 – Aircraft eligibility through prior navigation system certification***

Method 2 can be used to approve aircraft whose level of performance, under other/previous standards, can be equated to the RNP 10 criteria. The Standards listed in 1.3.4 can be used to qualify an aircraft. Other standards may also be used if they are sufficient to ensure that the RNP 10 requirements are met. If other standards are to be used, the applicant must propose an acceptable means of compliance.

1.3.3.1.4 ***Method 3 – Aircraft eligibility through data collection***

1.3.3.1.4.1 Method 3 requires that operators collect data to gain an RNP 10 authorization for a specified period of time. The data collection programme must address the appropriate navigational accuracy requirements for RNP 10. The data collection must ensure that the applicant demonstrate to the aviation authority that the aircraft and the navigation system provide the pilot with navigation situational awareness relative to the intended RNP 10 route. The data collection must also ensure that a clear understanding of the status of the navigation system is provided, and that failure indications and procedures are consistent with maintaining the navigation performance.

1.3.3.1.4.2 There are two data collection methods for Method 3:

a) the sequential method is a data collection programme meeting the provisions of FAA booklet, RNP 10 Qualification through Data Collection. This method allows the operator to collect a set of data and plot it against the "pass-fail" graphs to determine whether the operator's aircraft inertial navigation system will meet the RNP 10 requirements for the length of time needed by the operator; and

b) the periodic method of data collection uses of a hand-held GNSS receiver as a baseline for collected inertial navigation system data (as described in FAA booklet, RNP 10 Qualification through Data Collection). The data collected are then analysed to determine whether the system is capable of maintaining the navigation performance for the length of time needed by the operator.

1.3.3.1.4.3 Relevant documentation for the selected qualification method must be available to establish that the aircraft is equipped with long range navigation systems (LRNSs) that meet the requirements of RNP 10 (such as the flight manual). The applicant must provide a configuration list that details pertinent components and equipment to be used for long-range navigation and RNP 10 operations. The applicant's proposed RNP 10-time limit for the aircraft's inertial navigation system must be provided. The applicant must consider the effect of headwinds in the area in which RNP 10 operations are intended to be carried out (see 1.3.4) to determine the feasibility of the proposed operation.

1.3.3.2 Operational authorization

This navigation specification does not in itself constitute regulatory guidance material against which either the aircraft or the operator will be assessed and approved. Aircraft are certified by their State of Manufacture. Operators are approved in accordance with their national operating rules. This navigation specification provides the technical and operational criteria and does not necessarily imply a need for recertification.

Note 1.— Detailed information on operational authorizations is provided in the Performance-based Navigation (PBN) Operational Authorization Manual (Doc 9997)[1].

Note 2.— Where appropriate, States may refer to previous operational authorizations in order to expedite this process for individual operators where performance and functionality are applicable to the current request for operational authorization.

1.3.3.2.1 ***Aircraft eligibility***

The aircraft eligibility must be determined through demonstration of compliance against the relevant airworthiness criteria and the requirements of 1.3.4. The original equipment manufacturer (OEM) or the holder of installation approval for the aircraft, such as the supplemental Type Certificate (STC) holder, will demonstrate compliance to their regulatory authority (such as EASA, FAA) and the approval can be documented in manufacturer documentation (such as service letters). AFM entries are not required provided the State accepts manufacturer documentation.

1.3.3.2.2 ***Operational authorization***

1.3.3.2.2.1 *Description of aircraft equipment*

The operator must have a configuration list and, if necessary, an MEL detailing the required aircraft equipment for RNAV 10 operations.

1.3.3.2.2.2 *Training documentation*

1.3.3.2.2.2.1 Commercial operators must have a training programme addressing the operational practices, procedures and training items related to RNAV 10 operations (such as initial, upgrade or recurrent training for pilots, dispatchers and maintenance personnel).

Note.— Operators need not establish a separate training programme or regimen if they already integrate RNAV training as an element of their training programme. However, the operator should be able to identify the aspects of RNAV 10 covered within their training programme.

1.3.3.2.2.2.2 Private operators must be familiar with the practices and procedures identified in 1.3.10, “Pilot knowledge and training”.

1.3.3.2.2.3 *Operations manuals and checklists*

1.3.3.2.2.3.1 Operations manuals (OMs) and checklists for commercial operators must address information/guidance on the standard operating procedures (SOPs) detailed in 1.3.5. The appropriate manuals should contain navigation operating instructions and contingency procedures, where specified. When required by the State of the Operator/Registry, the operator must submit their manuals and checklists for review as part of the application process.

1.3.3.2.2.3.2 Private operators should operate using the practices and procedures identified in 1.3.10, “Pilot knowledge and training”.

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1. Formerly the *Performance-based Navigation Operational Approval Manual*, renamed in its third (forthcoming) edition.

1.3.3.2.2.4 *Minimum equipment list considerations*

Any MEL revisions necessary to address RNAV 10 provisions must be approved. Operators must adjust the MEL, or equivalent, and specify the required dispatch conditions.

1.3.3.2.2.5 *Continuing airworthiness*

The operator must submit the continuing airworthiness instructions applicable to the aircraft's configuration and the aircraft's qualification for this navigation specification. Additionally, there is a requirement for the operator to submit their maintenance programme, including a reliability programme for monitoring the equipment.

Note.— The operator should confirm with the OEM, or the holder of installation approval for the aircraft, that acceptance of subsequent changes in the aircraft configuration, such as service bulletins, do not invalidate current operational authorizations.

1.3.3.2.2.6 *Past performance*

An operating history of the operator must be included in the application. The applicant must address any events or incidents related to navigation errors for that operator (such as reported on a State's navigation error investigation form) that have been covered by training, procedures and maintenance, or the aircraft/navigation system modifications which are to be used.

1.3.4 Aircraft requirements

RNP 10 requires that aircraft operating in oceanic and remote areas be equipped with at least two independent and serviceable LRNSs comprising an inertial navigation system or a GNSS system.

1.3.4.1 System performance

1.3.4.1.1 RNAV System Performance: RNAV systems have no monitoring and alerting requirement during an RNAV operation.

1.3.4.1.1.1 *Accuracy*. During operations in airspace or on routes designated as RNP 10, the lateral navigation system error (NSE) must be within ±10 NM for at least 95 per cent of the total flight time.

Note 1.— For RNP 10, operational authorization of aircraft capable of coupling the RNAV system to the flight director or autopilot, a navigational positioning error is considered to be the dominant contributor to cross-track and along-track error. Flight technical error (FTE), path definition error (PDE) and display errors are considered to be insignificant for the purposes of RNP 10 authorization.

Note 2.— When the sequential data collection method described in FAA booklet, RNP 10 Qualification through Data Collection, *is used as the basis for an RNP 10 operational authorization, these error types are included in the analysis. However, when the periodic data collection method described in FAA booklet,* RNP 10 Qualification through Data Collection, *is used, these errors are not included since that method is more conservative. The periodic method uses radial error instead of cross-track and along-track error.*

1.3.4.1.1.2 *Integrity.* Malfunction of the aircraft's long range navigation systems (LRNS) without annunciation is a major failure condition (that is, the probability of a malfunction with no annunciation must be less than 1×10^{-5} per flight hour).

1.3.4.1.1.3 *Continuity*. Loss of function is classified as a major failure condition for oceanic and remote navigation. The continuity requirement is satisfied by the carriage of dual independent LRNSs.

1.3.4.2 Criteria for specific navigation services

1.3.4.2.1 ***Aircraft incorporating dual GNSS***

1.3.4.2.1.1 Aircraft approved to use GNSS as a primary means of navigation for oceanic and remote operations, in accordance with the appropriate aviation authority's requirements, also meet the RNP 10 requirements without time limitations.

1.3.4.2.1.2 Multi-sensor systems integrating GNSS with FDE that are approved using the guidance contained in the United States FAA Advisory Circular AC 20-138(), or its equivalent, also meet RNP 10 requirements without time limitations.

1.3.4.2.1.3 FAA Advisory Circular AC 20-138() provides an acceptable means of complying with installation requirements for aircraft that use GNSS but do not integrate it with other sensors. FAA AC 20-138() describes an acceptable means of compliance for multi-sensor navigation systems that incorporate GNSS. Aircraft that intend to use GNSS as the only navigation system (such as no inertial navigation system (INS) or inertial navigation system) on RNP 10 routes or in RNP 10 airspace must also comply with the regulations and related advisory documentation of the relevant aviation authority, except for specific GNSS requirements described in this guidance material. This includes use of GNSS approved for primary oceanic/remote performance.

1.3.4.2.1.4 The flight manual must indicate that a particular GNSS installation meets the appropriate aviation authority's requirements. Dual technical standard order (TSO)-approved GNSS equipment must be fitted and an approved FDE availability prediction programme must be used. The maximum allowable time for which FDE capability is projected to be unavailable is 34 minutes for any one occasion. The maximum outage time must be included as a condition of the RNP 10 authorization.

Note.— If predictions indicate that the maximum FDE outage time for the intended RNP 10 operation will be exceeded, then the operation must be rescheduled when FDE is available, or RNP 10 must be predicated on an alternate means of navigation.

1.3.4.2.2 ***Aircraft incorporating dual inertial navigation systems – standard time limit***

1.3.4.2.2.1 Aircraft equipped with dual inertial navigation systems approved in accordance with any of the following standards have been determined to meet RNP 10 requirements for up to 6.2 hours of flight time:

a) United States 14 CFR, Part 121, Appendix G (or a State's equivalent);

Note.— GNSS-inertial navigation system integrations meeting the performance requirements of RTCA DO-384 (Minimum Operational Performance Standards (MOPS) for GNSS Aided Inertial Systems) for Category A equipment can meet the performance requirements of 14 CFR, Part 121, Appendix G.

b) approved for RNAV operations in Australia; and

c) FAA AC 20-138D, Chapter 10 or EASA CS-ACNS, Appendix B to subpart C.

1.3.4.2.2.2 The timing starts from when the inertial navigation systems are placed in navigation mode or at the last point at which the inertial navigation systems receive a position update.

Note.— The 6.2 hours of flight time are based on an approved inertial navigation system with a 95 per cent radial position error rate (circular error rate) of 3.7 km/h (2.0 NM/h), which is statistically equivalent to individual 95 per cent cross-track and 95 per cent along-track position error rates (orthogonal error rates) of 2.9678 km/h (1.6015 NM/h) each, and 95 per cent cross-track and 95 per cent along-track position error limits of 18.5 km (10 NM) each (such as 18.5 km (10 NM)/2.9678 km/h (1.6015 NM/h) = 6.2 hours)).

1.3.4.2.2.3 If the inertial navigation systems are updated en-route, the operator must show the effect that the accuracy of the update has on the time limit (see FAA 20-138D, Chapter 10 or EASA CS-ACNS, Appendix B to subpart C for information on the adjustment factors for systems that are updated en-route).

Note.— FAA 20-138D, Chapter 10 or EASA CS-ACNS, Appendix B to subpart C *provide information on the acceptable means of compliance for operators who wish to increase the 6.2-hour time limitation specified.*

1.3.4.2.3 ***Aircraft incorporating inertial navigation systems – extended time limit***

Aircraft with an airworthiness approval recognizing inertial navigation system performance meeting United States 14 CFR, Part 121, Appendix G, require an additional airworthiness approval to demonstrate inertial navigation accuracy to better than 3.7 km/hr (2 NM/hr) radial error (2.9678 km/hr (1.6015 NM/hr) cross-track error). When an airworthiness applicant desires this additional approval, the following conditions apply:

a) the airworthiness approval of inertial navigation system performance must address all issues associated with maintaining the required accuracy, including accuracy and reliability, acceptance test procedures, maintenance procedures and training programmes; and

b) the airworthiness applicant must identify the inertial navigation system performance standard they desire to demonstrate. This standard may be a regulatory (that is, United States 14 CFR, Part 121, Appendix G), an industry standard (that is, RTCA DO-384 Minimum Operational Performance Standards (MOPS) for GNSS Aided Inertial Systems) or an applicant-unique specification. Upon airworthiness approval, the approving authority and applicant must add a statement to the flight manual (AFM/AFMS) identifying the demonstrated accuracy and any limitations (see FAA AC90-105A, G.4.320-138D, 10-2.1, or EASA CS-ACNS, Appendix B to Subpart C).

Note.— GNSS-inertial navigation system integrations meeting the performance requirements of RTCA DO-384 Category A equipment may offer performance equivalent to or better than the requirements of 14 CFR, Part 121, Appendix G. An airworthiness approval demonstrating compliance to this public standard should identify the demonstrated accuracy of the aircraft's inertial-only navigation and any limitations associated with the accuracy (such as a time limit greater than 6.2 flight hours).

1.3.4.2.4 ***Aircraft equipped with a single inertial navigation system and a single GPS sensor approved for primary means of navigation in oceanic and remote areas***

Aircraft equipped with a single inertial navigation system and a single GPS meet the RNP 10 requirements without time limitations. The inertial navigation system must be approved to 14 CFR, Part 121, Appendix G or an equivalent standard accepted by the State of registry (such as a GNSS-inertial navigation system integration meeting or exceeding the performance requirements of RTCA DO-384 for Category A equipment). TSO-C129() GPS equipment installations must meet the requirements of AC20-138() for oceanic and remote continental operations. The aircraft flight manual (AFM/AFMS) must indicate that the particular inertial navigation system installation meets the appropriate aviation authority's acceptable means of compliance.

Note.— Some TSO-C129() GPS equipment may not support oceanic and remote operations. FAA AC 20-138D, Appendix 1, describes additional criteria defining an acceptable means of compliance for TSO-C129() GPS equipment to support operations eligibility for oceanic and remote operations.

1.3.5 Operating procedures

1.3.5.1 To satisfy the requirements for RNP 10 operations in oceanic and remote areas, an operator must also comply with the relevant requirements of Annex 2 – *Rules of the Air*.

1.3.5.2 Flight planning

During flight planning, the pilot should pay particular attention to conditions affecting operations in RNP 10 airspace (or on RNP 10 routes), including:

a) verifying that the RNP 10 time limit has been accounted for;

b) verifying the requirements for GNSS, such as FDE, if appropriate for the operation; and

c) accounting for any operating restriction related to RNP 10 authorization, if required for a specific navigation system.

1.3.5.3 Pre-flight procedures

The following actions should be completed during pre-flight:

a) review maintenance logs and forms to ascertain the condition of the equipment required for flight in RNP 10 airspace or on an RNP 10 route. Ensure that maintenance action has been taken to correct defects in the required equipment;

b) during the external inspection of an aircraft, if possible, check the condition of the navigation antennas and the condition of the fuselage skin in the vicinity of each of these antennas (this check may be accomplished by a qualified and authorized person other than the pilot, such as a flight engineer or maintenance person); and

c) review the emergency procedures for operations in RNP 10 airspace or on RNP 10 routes. These are no different than normal oceanic emergency procedures with one exception – crews must be able to recognize when the aircraft is no longer able to navigate to its RNP 10 authorization capability and ATC must be advised.

1.3.6 Navigation equipment

1.3.6.1 Aircraft operating in RNP 10 oceanic and remote airspace typically require two fully serviceable, independent LRNSs. However, some regions may permit RNP 10 operations where the aircraft is equipped with a single inertial navigation system or a single GNSS navigation system. FAA AC 20-138D, Chapter 10, contains guidance and acceptable means of compliance for the various combinations of aircraft navigation equipment eligible for RNP 10 operations.

Note.— The Gulf of Mexico offers RNP 10 operations for aircraft equipped with either a single inertial navigation system or a single GNNS navigation system. Eligibility for these RNP 10 operations is predicated on the air traffic surveillance provided in the Gulf of Mexico.

1.3.6.2 A State authority may approve the operational use of a single LRNS in specific circumstances (such as Gulf of Mexico RNP 10 operations). Use of a single LRNS should require specific RNP 10 authorization limiting the use of a single LRNS to a specific region or airspace.

1.3.7 Flight plan designation

Operators should use the appropriate flight plan designation specified for the RNP route flown.

1.3.8 Availability of NAVAIDs

1.3.8.1 At dispatch or during flight planning, the operator must ensure that adequate NAVAIDs are available en-route to enable the aircraft to navigate to RNP 10 for the duration of the planned RNP 10 operation.

1.3.8.2 For GNSS systems, the operator should ensure during dispatch or flight planning that adequate navigation capability is available en-route for the aircraft to navigate to RNP 10, including the availability of FDE, if appropriate for the operation.

1.3.9 En-route

1.3.9.1 At least two LRNSs capable of satisfying this navigation specification must be operational at the oceanic entry point. If this is not the case, then the pilot should consider an alternate route that does not require that particular equipment or having to make a diversion for repairs.

1.3.9.2 Before entering oceanic airspace, the position of the aircraft must be checked as accurately as possible by using external NAVAIDs. This may require (DME/DME and/or VHF omnidirectional radio range (VOR) checks to determine NSEs through displayed and actual positions. If the system must be updated, the proper procedures should be followed with the aid of a prepared checklist.

1.3.9.3 Operator in-flight operating drills must include mandatory cross-checking procedures to identify navigation errors in sufficient time to prevent aircraft from inadvertent deviation from ATC-cleared routes.

1.3.9.4 Crews must advise ATC of any deterioration or failure of the navigation equipment below the navigation performance requirements or of any deviations required for a contingency procedure.

1.3.9.5 Pilots should use a lateral deviation indicator, flight director, or autopilot in lateral navigation mode on RNP 10 operations. All pilots are expected to maintain route centre lines, as depicted by on-board lateral deviation indicators and/or flight guidance, during all RNP operations described in this manual unless authorized to deviate by ATC or under emergency conditions. For normal operations, cross-track error/deviation (the difference between the RNAV system computed path and the aircraft position relative to the path) should be limited to ±½ the navigation accuracy associated with the route (that is, 5 NM). Brief deviations from this standard (such as overshoots or undershoots) during and immediately after route turns, up to a maximum of one times the navigation accuracy (that is, 10 NM), are allowable.

Note.— Some aircraft do not display or compute a path during turns. Pilots of these aircraft may not be able to adhere to the ±½ accuracy standard during route turns but are still expected to satisfy the standard during intercepts following turns and on straight segments.

1.3.9.6 Route evaluation for RNP 10 time limits for aircraft equipped only with an inertial navigation system

1.3.9.6.1 An RNP 10 time limit must be established for aircraft equipped only with an inertial navigation system. When planning operations in areas where RNP 10 is applied, the operator must establish that the aircraft will comply with the time limitation on the routes that it intends to fly.

1.3.9.6.2 In making this evaluation, the operator must consider the effect of headwinds and, for aircraft not capable of coupling the navigation system or flight director to the autopilot, the operator may choose to make this evaluation on a one-time basis or on a per-flight basis. The operator should consider the points listed in the following subsections in making this evaluation.

1.3.9.6.3 ***Route evaluation***

The operator must establish the capability of the aircraft to satisfy the RNP 10 time limit established for dispatch or departure into RNP 10 airspace.

1.3.9.6.4 ***Start point for calculation***

The calculation must start at the point where the system is placed in navigation mode or the last point at which the system is expected to be updated.

1.3.9.6.5 ***Stop point for calculation***

The stop point may be one of the following:

a) the point at which the aircraft will begin to navigate by reference to ICAO standard NAVAIDs (VOR, DME, NDB) and/or comes under ATS surveillance; or

b) the first point at which the navigation system is expected to be updated.

1.3.9.6.6 ***Sources of wind component data***

The headwind component to be considered for the route may be obtained from any source acceptable to the aviation authority. Acceptable sources for wind data include: the State's Bureau of Meteorology, National Weather Service, Bracknell, industry sources such as Boeing Winds on World Air Routes, and historical data supplied by the operator.

1.3.9.6.7 ***One-time calculation based on 75 per cent probability wind components***

Certain sources of wind data establish the probability of experiencing a given wind component on routes between city pairs on an annual basis. If an operator chooses to make a one-time calculation of RNP 10 time limit compliance, the operator may use the annual 75 per cent probability level to calculate the effect of headwinds (this level has been found to be a reasonable estimation of wind components).

1.3.9.6.8 ***Calculation of time limit for each specific flight***

The operator may choose to evaluate each individual flight using flight plan winds to determine whether the aircraft will comply with the specified time limit. If it is determined that the time limit will be exceeded, then the aircraft must fly an alternate route or delay the flight until the time limit can be met. This evaluation is a flight planning or dispatch task.

1.3.9.7 Effect of en-route updates

Operators may extend their RNP 10 navigation capability time by updating. Authorizations for various updating procedures are based upon the baseline for which they have been approved minus the time factors shown below:

a) automatic updating using DME/DME = baseline minus 0.3 hours (such as, an aircraft that has been approved for 6.2 hours can gain 5.9 hours following an automatic DME/DME update);

b) automatic updating using DME/DME/VHF omnidirectional radio range (VOR) = baseline minus 0.5 hours; and

c) manual updating using a method similar to that contained in FAA Order 8400.12A (as amended), Appendix 7 or approved by the aviation authority = baseline minus 1 hour.

1.3.9.8 Automatic radio position updating

1.3.9.8.1 Automatic updating is any updating procedure that does not require the pilot to manually insert coordinates. Automatic updating is acceptable provided that:

a) procedures for automatic updating are included in an operator’s training programme; and

b) pilots are knowledgeable of the updating procedures and of the effect of the update on the navigation solution.

1.3.9.8.2 An acceptable procedure for automatic updating may be used as the basis for an RNP 10 authorization for an extended time as indicated by data presented to the aviation authority. This data must present a clear indication of the accuracy of the update and the effect of the update on the navigation capabilities for the remainder of the flight.

1.3.9.9 Manual radio position updating

If manual radio position updating is not specifically approved, manual radio position updates are not permitted in RNP 10 operations. Manual radio updating may be considered acceptable for operations in airspace where RNP 10 is applied provided that:

a) the procedures for manual radio position updating are reviewed by the aviation authority on a case-by-case basis. An acceptable procedure for manual updating is described in FAA Order 8400.12A (as amended), Appendix 7 and may be used as the basis for an RNP 10 authorization for an extended time when supported by acceptable data;

b) operators show that their updating and training procedures include measures/cross-checking to prevent Human Factors errors and the pilot qualification syllabus is found to provide effective pilot training; and

c) the operator provides data that establish the accuracy with which the aircraft inertial navigation system position can be updated using manual procedures and representative NAVAIDs. Data should show the update accuracy achieved in in-service operations. This factor must be considered when establishing the RNP 10 time limit for the aircraft's inertial navigation system.

1.3.10 Pilot knowledge and training

1.3.10.1 The following items should be standardized and incorporated into training programmes and operating practices and procedures. Certain items may already be adequately standardized in existing operator programmes and procedures. New technologies may also eliminate the need for certain crew actions. If this is found to be the case, then the intent of this attachment can be considered to have been met.

Note.— This guidance material has been written for a wide variety of operator types, therefore, certain items that have been included may not apply to all operators.

1.3.10.2 Commercial operators should ensure that pilots have been trained so that they are knowledgeable of the topics contained in this guidance material, the limits of their RNP 10 navigation capabilities, the effects of updating, and RNP 10 contingency procedures.

1.3.10.3 Non-commercial operators should show the aviation authority that their pilots are knowledgeable of RNP 10 operations. However, some States might not require non-commercial operators to have formal training programmes for some types of operations (such as FAA Order 8900.1, Flight Standards Information Management System). The aviation authority, in determining whether a non-commercial operator's training is adequate, might:

a) accept a training centre certificate without further evaluation;

b) evaluate a training course before accepting a training centre certificate from a specific centre;

c) accept a statement in the operator's application for an RNP 10 authorization that the operator has ensured and will continue to ensure that pilots are knowledgeable of the RNP 10 operating practices and procedures; or

d) accept an operator's in-house training programme.

1.3.11 Navigation database

If a navigation database is carried, it must be current and appropriate for the operations and must include the NAVAIDs and waypoints required for the route.

1.3.12 Oversight of operators

1.3.12.1 An aviation authority may consider any navigation error reports in determining remedial action. Repeated navigation error occurrences attributed to a specific piece of navigation equipment or operational procedure may result in cancellation of the operational authorization, pending replacement or modifications to the navigation equipment or changes in the operator's operational procedures.

1.3.12.2 Information that indicates the potential for repeated errors may require modification of an operator's training programme, maintenance programme or specific equipment certification. Information that attributes multiple errors to a particular pilot crew may necessitate remedial training or crew licence review.

1.4 REFERENCES

The applicable versions of industry and regulatory references, standards and guidance included in this chapter, shown as open reference (), are listed in Attachment E. Some references contained in the chapter are part of background or historical information, and not included in Attachment E.

Chapter 2

IMPLEMENTING RNAV 5

2.1 INTRODUCTION

2.1.1 Background

2.1.1.1 Joint Aviation Authorities (JAA) Temporary Guidance Leaflet No. 2 was first published in July 1996, containing Advisory Material for the Airworthiness Approval of Navigation Systems for use in European Airspace designated for Basic RNAV operations. Following the adoption of AMC material by JAA and, subsequently, responsibility being assigned to European Union Aviation Safety Agency (EASA), this document was re-issued as AMC 20-4.

2.1.1.2 The Federal Aviation Administration (FAA) published comparable material under AC 90-96 on 20 March 1998. These two documents provide identical functional and operational requirements. The two documents have been superseded by FAA AC90-105() and EASA CS-ACNS.

2.1.1.3 In the context of the terminology adopted by this manual, basic RNAV (B-RNAV) requirements are termed RNAV 5.

2.1.1.4 The concept envisaged by both original European and American navigation standards, which became RNAV 5, was to enable continental en-route operations using area navigation in a radar surveillance environment (as reflected in 2.2.3, below). This targeted surveillance environment does not preclude the use of this specification in other ATS surveillance environments or in procedural environments. An implementation safety assessment would be needed to ensure that adequate safety requirements are addressed when implementing this specification in a different environment. Where this was applied, an increase in route spacings resulted. See also Part A, Chapter 1, 1.2.1 for more information.

2.1.2 Purpose

2.1.2.1 This chapter provides ICAO guidance for implementing RNAV 5 in the en-route phase of flight and provides the ANSP with an ICAO recommendation on the implementation requirements, avoiding the proliferation of standards and the need for multiple regional authorizations. It provides the operator with criteria to enable operation in airspace where the carriage of RNAV meeting 5 NM lateral accuracy is already required (such as the European Civil Aviation Conference (ECAC) B-RNAV). It avoids the need for further authorizations in other regions or areas needing to implement RNAV with the same lateral accuracy and functional requirements.

2.1.2.2 The RNAV 5 specification does not require an alert to the pilot in the event of excessive navigation errors. Since the specification does not require the carriage of dual RNAV systems, the potential for loss of RNAV capability requires an alternative navigation source.

2.1.2.3 This chapter does not address all requirements that may be specified for a particular operation. These requirements are specified in other documents, such as operating rules, AIPs and, where appropriate, the *Regional Supplementary Procedures* (Doc 7030). While operational authorization primarily relates to the navigation requirements of the airspace, operators and pilots are still required to take account of all operational documents relating to the airspace, which are required by the appropriate State authority, before conducting flights into that airspace.

2.2 IMPLEMENTATION CONSIDERATIONS

2.2.1 NAVAID infrastructure

2.2.1.1 States may prescribe the carriage of RNAV 5 on specific routes.

2.2.1.2 RNAV 5 systems permit aircraft navigation along any desired flight path within the coverage of station-referenced NAVAIDs (space or terrestrial) or within the limits of the capability of self-contained aids, or a combination of both methods.

2.2.1.3 RNAV 5 operations are based on the use of RNAV equipment, which automatically determines the aircraft position in the horizontal plane using input from one or a combination of the following types of position sensors, together with the means to establish and follow a desired path:

a) VOR/DME;

b) DME/DME;

c) INS or IRS; and

d) global navigation satellite system (GNSS).

2.2.1.4 The ANSP must assess the NAVAID infrastructure in order to ensure that it is sufficient for the proposed operations, including reversionary modes. It is acceptable for gaps in NAVAID coverage to be present; when this occurs, route spacing and obstacle clearance surfaces need to take account of the expected increase in lateral track-keeping errors during the “dead reckoning” phase of flight.

2.2.2 Communications and air traffic services surveillance

2.2.2.1 In the context of the original airspace concept described in 2.1.1, the following requirements apply:

2.2.2.1.1 Direct pilot to ATC (voice) communications is required.

2.2.2.1.2 ATS surveillance service may be used to assist contingency procedures, to mitigate the effect of blunder errors and to reduce route spacing. When ATS surveillance services are relied upon to these ends, the system’s performance should be fit for purpose, ensuring that the routes lie within the ATS surveillance and communications service volumes and the ATS resources are sufficient for these tasks.

2.2.2.1.3 When GNSS is used as the sole basis for both ATS surveillance and aircraft navigation, the risks and requirement for mitigation techniques associated with the loss of GNSS, potentially resulting in the loss of both navigation and surveillance capability, should be considered. This should typically be addressed through the regional or local State safety case prepared in support of the application.

2.2.3 Obstacle clearance and route spacing

2.2.3.1 Detailed guidance on obstacle clearance is provided in PANS-OPS (Doc 8168), Volume II; the general criteria in Parts I and III apply and assume normal operations.

2.2.3.2 The State is responsible for route spacing and should have ATS surveillance and monitoring tools to support detection and correction of navigation errors. The State should refer to applicable ICAO guidance material regarding route spacing between RNAV 5 routes or between RNAV 5 routes and conventional routes – see Attachment A to Annex 11 – *Air Traffic Services*, and Attachment C to this volume. One State demonstrated a route spacing of 30 NM to meet the safety targets of 5×10^{-9} fatal accidents per flight hour in a procedural environment and in a high traffic density environment.

2.2.3.3 Where traffic density is lower, route spacing may be reduced. In an ATS surveillance environment, the route spacing will depend on acceptable ATC workload and availability of controller tools. One regional RNAV 5 implementation adopted a standard route spacing of 16.5 NM for same-direction traffic and 18 NM for opposite-direction traffic in an ATS surveillance environment. Moreover, route spacing as low as 10 NM has been used in a radar environment where ATC intervention capability permits (see Attachment C to this volume).

2.2.3.4 The route design should account for the navigation performance achievable using the available NAVAID infrastructure, as well as the functional capabilities required by the navigation specification. Two aspects are of particular importance: spacing between routes in turns and along track distance between leg changes.

2.2.3.4.1 ***Spacing between routes in turns***

Automatic leg sequencing and associated turn anticipation is only a recommended function for RNAV 5. The track followed in executing turns depends upon the true airspeed, applied bank angle limits and wind. These factors, together with the different turn initiation criteria used by manufacturers, result in a large spread of turn performance. Studies have shown that for a track change of as little as 20 degrees, the actual path flown can vary by as much as 2 NM. This variability of turn performance needs to be taken into account in the design of the route structure where closely spaced routes are proposed.

2.2.3.4.2 ***A long track distance between leg changes***

2.2.3.4.2.1 The turn can start as early as 20 NM before the waypoint in the case of a large track angle change with a "fly-by" turn; manually initiated turns may overshoot the following track.

2.2.3.4.2.2 The track structure design needs to ensure leg changes do not occur too closely together. The required track length between turns depends upon the required turn angle.

2.2.4 Additional considerations

2.2.4.1 Many aircraft have the capability to fly a path parallel to, but offset left or right from, the original active route. The purpose of this function is to enable offsets for tactical operations authorized by ATC.

2.2.4.2 Although this navigation specification does not include requirements for a holding function, ANSPs may include holding procedures in their airspace design using a waypoint as a holding point.

2.2.4.3 Many aircraft have a holding capability: aircraft can either hold manually over a waypoint when the aircraft holding functionality is not available and the pilot is expected to manually fly the holding pattern, or the navigation system's holding functionality can be used to execute the published hold (see Volume I, Attachment A, 5.3).

2.2.4.4 Guidance in this chapter does not supersede appropriate State operating requirements for equipage.

2.2.5 Publication

2.2.5.1 The AIP should clearly indicate the navigation application is RNAV 5. The requirement for the carriage of RNAV 5 equipment in specific airspace or on identified routes should be published in the AIP. The route should rely on normal descent profiles and identify minimum segment altitude requirements. The navigation data published in the State AIP for the routes and supporting NAVAIDs must meet the requirements of Annex 15 – *Aeronautical Information Services*. All routes must be based upon WGS-84 coordinates.

2.2.5.2 The available NAVAID infrastructure should be clearly designated on all appropriate charts (such as GNSS, DME/DME, VOR/DME). Any navigation facilities that are critical to RNAV 5 operations should be identified in the relevant publications.

2.2.5.3 A navigation database does not form part of the required functionality of RNAV 5. The absence of such a database necessitates manual waypoint entry, which significantly increases the potential for waypoint errors. En-route charts should support gross error checking by the pilot by publishing fix data for selected waypoints on RNAV 5 routes.

2.2.5.4 Where holding patterns are established, they are to comply with the criteria and publication requirements in PANS-OPS, Volume II, Part 3, Section 3, Chapter 7.

2.2.6 Controller training

2.2.6.1 It is recommended that air traffic controllers providing control services in airspace where RNAV 5 is implemented, complete training in the following areas:

2.2.6.2 Core training

a) How area navigation systems work (in the context of this navigation specification):

   1) include functional capabilities and limitations of this navigation specification;

   2) accuracy, integrity, availability and continuity; and

   3) Global Positioning System (GPS) receiver, receiver autonomous integrity monitoring (RAIM), FDE and integrity alerts;

b) flight plan requirements;

c) ATC procedures:

   1) ATC contingency procedures;

   2) separation minima;

   3) mixed equipage environment (impact of manual VOR tuning);

   4) transition between different operating environments; and

   5) phraseology.

2.2.7 Navigation service monitoring

Navigation service monitoring should be consistent with Volume II, Part A, Chapter 4.

2.2.8 Air traffic services system monitoring

2.2.8.1 Monitoring of navigation performance is required for two reasons:

a) demonstrated "typical" navigation accuracy provides a basis for determining whether the performance of the ensemble of aircraft operating on the RNAV routes meets the required performance; and

b) the lateral route spacing and separation minima necessary for traffic operating on a given route are determined both by the core performance and upon normally rare system failures.

2.2.8.2 If an observation/analysis indicates that a loss of separation or obstacle clearance has occurred, the reason for the apparent deviation from track or altitude should be determined and steps should be taken to prevent a recurrence. Overall system safety needs to be monitored to confirm that the ATS system meets the required system safety requirements.

2.2.8.3 ATS surveillance observations of each aircraft's proximity to track and altitude are typically noted by ATS facilities and aircraft track-keeping capabilities are analysed.

2.2.8.4 A process should be established allowing pilots and controllers to report incidents where navigation errors are observed. If an observation/analysis indicates that a loss of separation or obstacle clearance has occurred, the reason for the apparent deviation from track or altitude should be determined and steps taken to prevent a recurrence.

2.3 NAVIGATION SPECIFICATION

2.3.1 Background

2.3.1.1 This section identifies the operational requirements for RNAV 5 operations. Operational compliance with these requirements should be addressed through national operational regulations and may require operational authorization in some cases. Operators will be approved against their national operating rules. For example, in the European Union, EASA AIR OPS requires operators to apply to their national authority for operational authorization. The equivalence of the technical requirements of RNAV 5 and B-RNAV means that equipment approved against existing national rules for B-RNAV will not normally require further technical authorization.

2.3.1.2 RNAV 5 does not require the carriage of a navigation database. Because of the specific limitations (such as workload and potential for data input errors) associated with manual insertion of waypoint coordinate data, RNAV 5 operations should be restricted to the en-route phase of flight.

2.3.2 Authorization process

This navigation specification does not in itself constitute regulatory guidance material against which either the aircraft or the operator will be assessed and approved. Aircraft are certified by their State of Manufacture. Operators are approved in accordance with their national operating rules. This navigation specification provides the technical and operational criteria and does not necessarily imply a need for recertification.

Note 1.— Detailed information on operational authorizations is provided in the Performance-based Navigation (PBN) Operational Authorization Manual *(Doc 9997)*[1].

Note 2.— Where appropriate, States may refer to previous operational authorizations in order to expedite this process for individual operators where performance and functionality are applicable to the current request for operational authorization.

2.3.2.1 Aircraft eligibility

The aircraft eligibility must be determined through demonstration of compliance against the relevant airworthiness criteria and the requirements of 2.3.3. The OEM or the holder of installation approval for the aircraft, such as the STC holder, will demonstrate compliance to their regulatory authority (such as EASA, FAA) and the approval can be documented in manufacturer documentation (such as service letters). AFM entries are not required provided the State accepts manufacturer documentation.

2.3.2.2 Operational authorization

2.3.2.2.1 ***Description of aircraft equipment***

The operator must have a configuration list and, if necessary, an MEL detailing the required aircraft equipment for RNAV 5 operations.

2.3.2.2.2 ***Training documentation***

2.3.2.2.2.1 Commercial operators must have a training programme addressing the operational practices, procedures and training items related to RNAV 5 operations (such as initial, upgrade or recurrent training for pilots, dispatchers or maintenance personnel).

Note.— Operators need not establish a separate training programme or regimen if they already integrate RNAV training as an element of their training programme. However, the operator should be able to identify the aspects of RNAV 5 covered in their training programme.

2.3.2.2.2.2 Private operators must be familiar with the practices and procedures identified in 2.3.5.

2.3.2.2.3 ***OMs and checklists***

2.3.2.2.3.1 Operations manuals (OMs) and checklists for commercial operators must address information/guidance on the standard operating procedure (SOP) detailed in 2.3.4. The appropriate manuals should contain navigation operating instructions and contingency procedures, where specified. When required by the State of the Operator/Registry, the operator must submit their manuals and checklists for review as part of the application process.

2.3.2.2.3.2 Private operators should operate using the practices and procedures identified in 2.3.5.

1, Formerly the *Performance-based Navigation Operational Approval Manual*, renamed in its third (forthcoming) edition.

2.3.2.2.4 ***MEL considerations***

Any MEL revisions necessary to address RNAV 5 provisions must be approved. Operators must adjust the MEL, or equivalent, and specify the required dispatch conditions.

2.3.2.2.5 ***Continuing airworthiness***

The operator must submit the continuing airworthiness instructions applicable to the aircraft's configuration and the aircraft's qualification for this navigation specification. Additionally, there is a requirement for the operator to submit their maintenance programme, including a reliability programme for monitoring the equipment.

Note.— The operator should confirm with the OEM, or the holder of installation approval for the aircraft, that acceptance of subsequent changes in the aircraft configuration, such as service bulletins (SBs), do not invalidate current operational authorizations.

2.3.2.3 Migration path to RNAV 5

The requirements of B-RNAV are identical to RNAV 5. National regulatory material is expected to take this equivalence into account. No additional migration path is required. This does not relieve the operator of the responsibility, in relation to all operations, to consult and comply with regional and national specific procedures or regulations.

2.3.3 Aircraft requirements

RNAV 5 operations are based on the use of RNAV equipment, which automatically determines the aircraft position using input from one or a combination of the following types of position sensors, together with the means to establish and follow a desired path:

a) VOR/DME;

b) DME/DME;

c) INS; and

d) GNSS.

2.3.3.1 System performance

2.3.3.1.1 *RNAV system performance.* RNAV systems have no monitoring and alerting requirement during an RNAV operation.

2.3.3.1.1.1 *Accuracy.* During operations in airspace or on routes designated as RNAV 5, the lateral NSE must be within +/-5 NM for at least 95 per cent of the total flight time.

2.3.3.1.1.2 *Integrity.* Malfunction of the aircraft navigation equipment is classified as a major failure condition under airworthiness regulations (that is, 10^{-5} per hour).

2.3.3.1.1.3 *Continuity.* Loss of function is classified as a minor failure condition if the operator can revert to a different navigation system and proceed to a suitable airport.

Note.— The minimum level of integrity and continuity required for RNAV 5 systems for use in airspace designated for RNAV 5 would normally be met by a single installed system comprising one or more sensors, an RNAV computer, a control display unit and navigation display(s) (such as CDI), provided that the system is monitored by the pilot and that, in the event of a system failure, the aircraft retains the capability to navigate relative to ground-based NAVAIDs (such as VOR/DME or NDB).

2.3.3.2 Criteria for specific navigation services

2.3.3.2.1 ***Inertial navigation systems***

2.3.3.2.1.1 Inertial navigation systems may be used either as a stand-alone inertial navigation system or as an approved inertial sensor integrated as part of a multi-sensor RNP system, where inertial navigation sensors provide augmentation to the basic position sensors, as well as a reversionary position data source when out of cover of radio navigation sources.

2.3.3.2.1.2 When complying with the functional criteria of this specification, an inertial navigation system installation approved in accordance with FAA AC 20-138D, but lacking automatic radio updating of the inertial position during flight, may support RNAV operations for a maximum of two hours from the last full inertial alignment or the last position update performed on the ground. Specific inertial systems configurations (such as integrating triple inertial systems) where either the inertial system manufacturers or the aircraft manufacturer’s data justifies extended use of more than two hours from the last position update, may be considered.

2.3.3.2.1.3 Inertial navigation systems with automatic radio updating of the inertial position from ground-based NAVAIDs, including those installations where the flight crew manually selects radio channels in accordance with flight crew procedures, should be meet an approved means of compliance in FAA AC 20-138() EASA CS-ACNS or equivalent material.

2.3.3.2.2 **VOR**

VOR accuracy can typically meet the accuracy requirements for RNAV 5 up to 60 NM (75 NM for Doppler VOR) from the NAVAID. Specific regions within the VOR coverage may experience larger errors due to propagation effects (such as multipath). Where such errors exist, this can be resolved by prescribing areas where the affected VOR may not be used. Alternative action could be to take account of lower VOR performance in the setting up of the proposed RNAV routes by, for example, increasing additional route spacing. Account must be taken of the availability of other NAVAIDs that can provide coverage in the affected area and that not all aircraft may be using the VOR concerned and may therefore not exhibit the same track-keeping performance.

2.3.3.2.3 ***DME***

2.3.3.2.3.1 DME signals are considered sufficient to meet the requirements of RNAV 5 whenever the signals are received and there is no closer DME on the same channel, regardless of the published coverage volume. When the RNAV 5 system does not take account of published “Designated Operational Coverage” of the DME, the RNAV system must execute data integrity checks to confirm that the correct DME signal is being received. The NAVAID infrastructure should be validated by modelling, and the anticipated performance should be adequately assessed and verified by flight inspection. The assessments should consider the aircraft capability described in this specification. For example, a DME signal can only be used if the aircraft is between 3 NM and 160 NM from the facility, below 40 degrees above the horizon (as viewed from the facility) and if the DME/DME include angle is between 30 degrees and 150 degrees. The DME infrastructure assessment is simplified when using a screening tool that accurately matches ground infrastructure and aircraft performance, as well as an accurate representation of the terrain.

Note.— Guidance material concerning this assessment can be found in PANS-OPS, Volume II (Doc 8168) and the Manual on Testing of Radio Navigation Aids *(Doc 8071).*

2.3.3.2.3.2 The individual components of the NAVAID infrastructure must meet the performance requirements detailed in Annex 10, Volume I. NAVAIDs that are not compliant with Annex 10 should not be published in the State AIP.

2.3.3.2.4 ***GNSS***

2.3.3.2.4.1 GNSS equipment may be used to perform RNAV 5 operations when approved in accordance with ETSO-C129(), ETSO-C145(), ETSO-C146(), FAA TSO-C145(), TSO-C146(), and TSO-C129() or equivalent, and include the minimum system functions specified in 2.3.4.3.

2.3.3.2.4.2 Integrity should be provided by SBAS GNSS or RAIM or an equivalent means within a multi-sensor navigation system. In addition, GPS stand-alone equipment should include the following functions:

a) pseudo-range step detection; and

b) health word checking.

Note.— These two additional functions are required to be implemented in accordance with TSO-C129a/ETSO-C129a or equivalent criteria.

2.3.3.2.4.3 Where authorization for RNAV 5 operations requires the use of traditional navigation equipment as a back-up in the event of loss of GNSS, the required NAVAID capability, as defined in the authorization (that is, VOR, DME, and/or ADF), will need to be installed and be serviceable.

2.3.3.2.4.4 Positioning data from other types of navigation sensors may be integrated with the GNSS data provided other positioning data do not cause position errors exceeding the track-keeping accuracy requirements.

2.3.3.3 Functional requirements

2.3.3.3.1 The following system functions are the minimum required to conduct RNAV 5 operations:

a) continuous indication of aircraft position relative to track to be displayed to the pilot flying the aircraft, on a navigation display situated in his/her primary field of view;

b) where the minimum flight crew is two pilots, indication of the aircraft position relative to track to be displayed to the pilot not flying the aircraft, on a navigation display situated in his/her primary field of view;

c) display of distance and bearing to the active (To) waypoint;

d) display of ground-speed or time to the active (To) waypoint;

e) storage of waypoints; minimum of four; and

f) appropriate failure indication of the RNAV system, including the sensors.

2.3.3.3.2 ***RNAV 5 navigation displays***

2.3.3.3.2.1 Navigation data must be available for display either on a display forming part of the RNAV equipment or on a lateral deviation display (such as CDI, electronic horizontal situation indicator (EHSI), or a navigation map display).

2.3.3.3.2.2 These must be used as primary flight instruments for the navigation of the aircraft, for manoeuvre anticipation and for failure/status/integrity indication. They should meet the following requirements:

a) the displays must be in the pilot's primary field of view;

b) the lateral deviation display scaling should be compatible with any alerting and annunciation limits, where implemented; and

c) the lateral deviation display must have a scaling and full-scale deflection suitable for the RNAV 5 operation.

2.3.4 Operating procedures

2.3.4.1 *General*

Airworthiness certification alone does not authorize flights in airspace or along routes for which RNAV 5 authorization is required. Operational authorization is also required to confirm the adequacy of the operator's normal and contingency procedures for the particular equipment installation.

2.3.4.2 Pre-flight planning

2.3.4.2.1 Operators and pilots intending to conduct operations on RNAV 5 routes should file the appropriate flight plan suffixes indicating their authorization for operation on the routes.

2.3.4.2.2 During the pre-flight planning phase, the availability of the NAVAID infrastructure, required for the intended routes, including any non-RNAV contingencies, must be confirmed for the period of intended operations. The pilot must also confirm availability of the on-board navigation equipment necessary for the operation.

2.3.4.2.3 Where a navigation database is used, it should be current and appropriate for the region of intended operation and must include the NAVAIDs and waypoints required for the route.

2.3.4.2.4 The availability of the NAVAID infrastructure, required for the intended routes, including any non-RNAV contingencies, must be confirmed for the period of intended operations using all available information. Since GNSS integrity (RAIM or SBAS signal) is required by Annex 10, Volume I, the availability of these should also be determined as appropriate. For aircraft navigating with SBAS receivers (all TSO-C145()/C146()), operators should check appropriate GPS RAIM availability in areas where SBAS signal is unavailable.

2.3.4.3 ABAS availability

2.3.4.3.1 When GNSS is used, en-route RAIM levels are required for RNAV 5 and can be verified either through NOTAMs (where available) or through prediction services. The operating authority may provide specific guidance on how to comply with this requirement (such as if sufficient satellites are available, a prediction may not be necessary). Operators should be familiar with the prediction information available for the intended route.

2.3.4.3.2 RAIM availability prediction should take into account the latest GPS constellation NOTAMs and avionics model. The service may be provided by the ANSP, avionics manufacturer, other entities or through an airborne receiver RAIM prediction capability.

2.3.4.3.3 In the event of a predicted, continuous loss of appropriate level of fault detection of more than five minutes for any part of the RNAV 5 operation, the flight planning should be revised (that is, delaying the departure or planning a different departure procedure).

2.3.4.3.4 RAIM availability prediction software is a tool used to assess the expected capability of meeting the navigation performance. Due to unplanned failure of some GNSS elements, pilots/ANSP must realize that RAIM or GPS navigation may be lost altogether while airborne, which may require reversion to an alternative means of navigation. Therefore, pilots should assess their capability to navigate (potentially to an alternate destination) in case of failure of GPS navigation.

2.3.4.4 General operating procedures

2.3.4.4.1 Operators and pilots should not request or file RNAV 5 routes unless they satisfy all the criteria in the relevant documents. If an aircraft not meeting these criteria receives a clearance from ATC to conduct an RNAV procedure, the pilot must advise ATC that he/she is unable to accept the clearance and must request alternate instructions.

2.3.4.4.2 The pilot should comply with any instructions or procedures identified by the manufacturer as being necessary to comply with the performance requirements in this manual.

2.3.4.4.3 Pilots of RNAV 5 aircraft must adhere to any AFM limitations or operating procedures required to maintain the navigation accuracy specified for the procedure.

2.3.4.4.4 Where installed, pilots must confirm that the navigation database is up to date.

2.3.4.4.5 The pilots should cross-check the current flight plan by comparing charts or other applicable resources with the navigation system textual display and the aircraft map display, if applicable. If required, the exclusion of specific NAVAIDs should be confirmed.

2.3.4.4.6 During the flight, where feasible, the flight progress should be monitored for navigational reasonableness by cross-checks with conventional NAVAIDs using the primary displays in conjunction with the RNAV control and display unit (CDU).

2.3.4.4.7 For RNAV 5, pilots should use a lateral deviation indicator, flight director or autopilot in lateral navigation mode. Pilots may use a navigation map display as described in 2.3.3.3.2, without a flight director or autopilot. Pilots of aircraft with a lateral deviation display must ensure that lateral deviation scaling is suitable for the navigation accuracy associated with the route/procedure (such as full-scale deflection: ±5 NM).

2.3.4.4.8 All pilots are expected to maintain route centre lines, as depicted by on-board lateral deviation indicators and/or flight guidance, during all RNAV operations described in this manual, unless authorized to deviate by ATC or under emergency conditions. For normal operations, cross-track error/deviation (the difference between the RNAV system-computed path and the aircraft position relative to the path) should be limited to ±½ the navigation accuracy associated with the procedure or route (that is, 2.5 NM). Brief deviations from this standard (such as overshoots or undershoots) during and immediately after procedure/route turns, up to a maximum of one times the navigation accuracy (that is, 5 NM), are allowable.

Note.— Some aircraft do not display or compute a path during turns; pilots of these aircraft may not be able to adhere to the ±½ accuracy standard during route turns but are still expected to satisfy the standard during intercepts of the final track following the turn and on straight segments.

2.3.4.4.9 If ATS issues a heading assignment taking the aircraft off a route, the pilot should not modify the flight plan in the RNAV system until a clearance is received to rejoin the route or the controller confirms a new clearance. When the aircraft is not on the published route, the specified accuracy requirement does not apply.

2.3.4.5 Contingency procedures

2.3.4.5.1 The pilot must notify ATC when the RNAV performance ceases to meet the requirements for RNAV 5. The communications to ATC must be in accordance with the authorized procedures (PANS-ATM, Doc 4444 or the *Regional Supplementary Procedures* (Doc 7030), as appropriate).

2.3.4.5.2 In the event of communications failure, the pilot should continue with the current flight plan in accordance with the published "lost communications" procedure.

2.3.4.5.3 Where stand-alone GNSS equipment is used:

a) In the event of a loss of the RAIM detection function, the GNSS position may continue to be used for navigation. The pilot should attempt to cross-check the aircraft position with other sources of position information (such as VOR, DME and/or NDB information) to confirm an acceptable level of navigation performance. Otherwise, the pilot should revert to an alternative means of navigation and advise ATC.

b) In the event that the navigation display is flagged invalid due to a RAIM alert, the pilot should revert to an alternative means of navigation and advise ATC.

2.3.5 Pilot knowledge and training

The pilot training programme should address the following items:

a) the capabilities and limitations of the RNAV system installed;

b) the operations and airspace for which the RNAV system is approved to operate;

c) the NAVAID limitations with respect to the RNAV system to be used for the RNAV 5 operation;

d) contingency procedures for RNAV failures;

e) the radio/telephony phraseology for the airspace, in accordance with PANS-ATM, Doc 4444 and Doc 7030, as appropriate;

f) the flight planning requirements for the RNAV operation;

g) RNAV requirements as determined from chart depiction and textual description;

h) RNAV system-specific information, including:

    1) levels of automation, mode annunciations, changes, alerts, interactions, reversions and degradation;

2) functional integration with other aircraft systems;

3) monitoring procedures for each phase of the flight (such as monitor PROG or LEGS page);

4) types of navigation sensors (such as, DME, inertial navigation system or GNSS) utilized by the RNAV system and associated system prioritization/weighting/logic;

5) turn anticipation with consideration to speed and altitude effects; and

6) interpretation of electronic displays and symbols;

i) RNAV equipment operating procedures, as applicable, including how to perform the following actions:

1) verify that the aircraft navigation data is current;

2) verify the successful completion of RNAV system self-tests;

3) initialize RNAV system position;

4) fly direct to a waypoint;

5) intercept a course/track;

6) be vectored off and rejoin a procedure;

7) determine cross-track error/deviation;

8) remove and reselect navigation sensor input;

9) when required, confirm exclusion of a specific NAVAID or NAVAID type; and

10) perform gross navigation error checks using conventional NAVAIDs.

2.3.6 Navigation database

Where a navigation database is carried and used, it must be current and appropriate for the region of intended operation and must include the NAVAIDs and waypoints required for the route.

Note.— Navigation databases are expected to be current for the duration of the flight. If the AIRAC cycle is due to change during flight, operators and pilots should establish procedures to ensure the accuracy of the navigation data, including the suitability of navigation facilities used to define the routes for the flight. Traditionally, this has been accomplished by verifying electronic data against paper products.

2.3.7 Oversight of operators

2.3.7.1 A process needs to be established whereby navigation error reports can be submitted and analysed in order to establish the need for remedial action. Repeated navigation error occurrences attributed to a specific piece of navigation equipment need to be followed up and action taken to remove the causal factor(s).

2.3.7.2 The nature of the error cause will determine the remedial action, which could include the need for remedial training, restrictions in the application of the system or requirements for software changes in the navigation system.

2.3.7.3 The nature and severity of the error may result in temporary cancellation of the authorization for use of that equipment until the cause of the problem has been identified and rectified.

2.4 REFERENCES

The applicable versions of industry and regulatory references, standards and guidance included in this chapter, shown as open reference (), are listed in Attachment E to this volume. Some references contained in the chapter are part of background or historical information, and not included in Attachment E.

Chapter 3

IMPLEMENTING RNAV 1 AND RNAV 2

3.1 INTRODUCTION

3.1.1 Background

3.1.1.1 The Joint Aviation Authorities (JAA) published airworthiness and operational authorization for precision area navigation (P-RNAV) on 1 November 2000 through TGL-10. The Federal Aviation Administration (FAA) published AC 90-100 U.S. terminal and en-route area navigation (RNAV) operations on 7 January 2005, updated on 1 March 2007 through AC 90-100A. While similar in functional requirements, differences exist between these two documents. These regulatory documents are superseded by FAA AC90-105A, AC20-138D, EASA CS-ACNS and European Union Regulation 965/2012. This specification is the result of the harmonization of European and United States RNAV criteria into a single ICAO RNAV 1 and 2 specification.

3.1.1.2 The concept envisaged by both the original European and the American navigation standards, which became RNAV 1 and RNAV 2, was to enable continental terminal route operations using RNAV in a radar surveillance environment. This targeted surveillance environment does not preclude use of this specification in other ATS surveillance environments or in procedural environments. An implementation safety assessment would be needed to ensure that adequate safety requirements are addressed when implementing this specification in a different environment. See Part A, Chapter 1, 1.2.1.

3.1.2 Purpose

3.1.2.1 This chapter provides guidance for the implementation of this navigation specification and references to the applicable guidance material that supports the implementation of RNAV 1 and RNAV 2. Systems that have demonstrated compliance with both P-RNAV (TGL-10) and U.S. RNAV (FAA AC 90-100) may be considered compliant with this ICAO specification. Operators with demonstrated compliance to only TGL-10 or AC 90-100 should refer to FAA AC90-105(), AC20-138(), EASA CS-ACNS and EU Regulation 965/2012, as appropriate to determine whether or not their system complies with RNAV 1 and RNAV 2 requirements. Aircraft, systems and operators intending to demonstrate compliance and obtain approval or authorization for ICAO RNAV 1 and 2 navigation applications should refer to FAA AC90-105(), AC20-138(), EASA CS-ACNS and EU Regulation 965/2012, as appropriate. Prior approvals/authorizations are not affected by these documents. Compliance with ICAO RNAV 1 and 2 through any one of the above obviates the need for further assessment or AFM documentation. The aircraft requirements for RNAV 1 and 2 are identical, while some operating procedures are different.

3.1.2.2 The RNAV 1 and 2 specification is applicable to all ATS routes, including routes in the en-route domain, standard instrument departures (SIDs) and standard terminal arrival routes (STARs). It also applies to RNAV 1 IAPs up to the final approach fix (FAF).

Note.— RNAV 1 can also be used to define the missed approach segment following an ILS/MLS final approach.

3.1.2.3 RNAV 1 and RNAV 2 routes are intended to be conducted in direct VHF controller/pilot voice communications environments.

3.1.2.4 This chapter does not address all requirements that may be specified for particular operations. These requirements are specified in other documents, such as operating rules, AIPs and the *Regional Supplementary Procedures* (Doc 7030). While operational authorization primarily relates to the navigation requirements of the airspace, the pilot is still required to take account of all operational documents relating to that airspace before conducting flights into it.

3.2 IMPLEMENTATION CONSIDERATIONS

The ANSP is responsible for the development of the route as described in Volume I, Chapter 2. Changes in the route or available NAVAID infrastructure should be accomplished in accordance with the guidance in that chapter.

3.2.1 NAVAID infrastructure

3.2.1.1 The route design should take account of the navigation performance, which can be achieved with the available NAVAID infrastructure, and the functional capabilities required by this document. While the aircraft's navigation equipment requirements for RNAV 1 and RNAV 2 are identical, NAVAID infrastructure impacts the achievable performance. Accommodation of existing user equipment should be considered a primary goal. The following navigation criteria are defined: global navigation satellite system (GNSS), DME/DME and DME/DME/inertial. Where DME is the only navigation service used for position updates, gaps in DME coverage can prevent position update. Integration of approved inertial navigation systems can permit extended gaps in coverage.

Note.— Based on evaluated inertial navigation system performance, the growth in position error after reverting to inertial coasting can be expected to be less than 2 NM per 15 minutes.

3.2.1.2 If an approved inertial navigation system is not carried, then the aircraft may revert to dead reckoning. In such cases, additional protection, in accordance with PANS-OPS (Doc 8168, Volume II), will be needed to cater for the increased error. GNSS should be authorized whenever possible and limitations on the use of specific system elements should be avoided.

Note.— Most modern RNAV systems prioritize input from GNSS and then DME/DME positioning. Although VHF omnidirectional radio range (VOR)/DME positioning is usually performed within a flight management computer when DME/DME positioning criteria cannot be met, avionics and infrastructure variability pose serious challenges to standardization. Therefore, the criteria in this document only cover GNSS, DME/DME and DME/DME/inertial. This does not preclude the conduct of operations by systems that also use VOR provided they satisfy the criteria in 3.3.

3.2.1.3 The NAVAID infrastructure should be validated by modelling, and the anticipated performance should be adequately assessed and verified by flight inspection. The assessments should consider the aircraft capability described in this specification. For example, in some RNAV and RNP systems, a DME signal may only be used if the aircraft is between 3 NM and 160 NM from the facility, below 40 degrees above the horizon (as viewed from the facility) and if the DME/DME include angle is between 30 degrees and 150 degrees. The DME infrastructure assessment is simplified when using a DME facility screening tool, which accurately matches ground infrastructure and conservatively represents the aircraft performance, as well as an accurate representation of the terrain.

Note.— Guidance material concerning this assessment can be found in PANS-OPS, Volume II *(Doc 8168), the* Manual on Testing of Radio Navigation Aids *(Doc 8071) and EUROCONTROL Guidelines for RNAV 1 Infrastructure Assessment (Doc EUROCONTROL-GUID-114).*

3.2.1.4 DME signals are considered to meet signal-in-space (SIS) accuracy tolerances where signals are received, regardless of the published coverage volume. Field strengths below the minimum requirement, or where co-channel or adjacent channel interference may exist, are considered receiver errors and are addressed in 3.3.3. Errors resulting from multi-path of the DME signal should be identified by the ANSP. Where such errors exist and are not acceptable to the operation, the ANSP may identify such NAVAIDs as not appropriate for RNAV 1 and RNAV 2 applications (to be inhibited by the pilot) or may not authorize the use of DME/DME or DME/DME/inertial. The individual components of the NAVAID infrastructure must meet the performance requirements detailed in Annex 10 – *Aeronautical Telecommunications*. NAVAIDs that are not compliant with Annex 10 should not be published in the State AIP. If significant performance differences are measured for a published DME facility, RNAV 1 and RNAV 2 operations in airspace affected by that facility may need to be limited to GNSS.

3.2.1.5 For an RNAV 1 or RNAV 2 operation where reliance is placed on an approved inertial navigation system, some aircraft RNAV systems will revert to VOR/DME-based navigation before reverting to inertial coasting. The impact of VOR radial accuracy, when the VOR is within 40 NM from the route and there is insufficient DME/DME NAVAID infrastructure, must be evaluated by the ANSP to ensure that it does not affect aircraft position accuracy.

3.2.1.6 Air navigation services providers (ANSPs) should ensure that operators of GNSS-equipped aircraft and, where applicable, SBAS-equipped aircraft, have access to a means of predicting the availability of fault detection using ABAS (such as receiver autonomous integrity monitoring (RAIM)). This prediction service may be provided by the ANSP, airborne equipment manufacturers or other entities. Prediction services can be for receivers meeting only the minimum technical standard order (TSO) performance or be specific to the receiver design. The prediction service should use status information on GNSS satellites and should use a horizontal alert limit appropriate to the operation (1 NM for RNAV 1 and 2 NM for RNAV 2). Outages should be identified in the event of a predicted, continuous loss of ABAS fault detection of more than five minutes for any part of the RNAV 1 and RNAV 2 operations. If the prediction service is temporarily unavailable, ANSPs may still allow RNAV 1 and RNAV 2 operations to be conducted, considering the operational impact of aircraft reporting outages or the potential risk associated with an undetected satellite failure when fault detection is not available.

3.2.1.7 Since RNAV systems conducting DME/DME navigation should only use DME facilities identified in State AIPs, the State should indicate facilities inappropriate for RNAV 1 and RNAV 2 operations in their AIP.

Note.— Where temporary restrictions occur, the publication of restrictions on the use of a DME facility should be accomplished by use of a NOTAM to identify the need to exclude that specific DME facility.

3.2.2 Communications and air traffic services surveillance

3.2.2.1 Direct pilot to ATC (voice) communications is required.

3.2.2.2 ATS surveillance service may be used to assist contingency procedures to mitigate the effect of blunder errors and to reduce route spacing. When ATS surveillance services are relied upon to these ends, the system's performance should be fit for purpose, ensuring that the routes lie within the ATS surveillance and communications service volumes and the ATS resources are sufficient for these tasks.

3.2.2.3 Where GNSS is used as the sole basis for both ATS surveillance and aircraft navigation, the risks and requirement for mitigation techniques associated with the loss of GNSS, potentially resulting in the loss of both navigation and surveillance capability, should be considered. This should typically be addressed through the regional or local State safety case prepared in support of the application.

3.2.3 Obstacle clearance, route spacing and separation minima

3.2.3.1 Obstacle clearance guidance is provided in PANS-OPS (Doc 8168, Volume II, Part III); the general criteria in Part I apply and assume normal operations.

3.2.3.2 States may prescribe either an RNAV 1 or an RNAV 2 ATS route. Route spacing for RNAV 1 and RNAV 2 depends on the route configuration, air traffic density and the availability of ATS surveillance to provide intervention capability – see the *Performance-based Navigation (PBN) Operational Authorization Manual* (Doc 9997)[1]. Separation Minima for RNAV 1 are included in PANS-ATM (Doc 4444, Chapter 5).

3.2.4 Additional considerations

3.2.4.1 For procedure design and infrastructure evaluation, the normal FTE limits of 0.5 NM (RNAV 1) and 1 NM (RNAV 2) defined in the operating procedures are assumed to be 95 per cent values.

3.2.4.2 Many aircraft have the capability to fly a path parallel to, but offset left or right from, the original active route. The purpose of this function is to enable offsets for tactical operations authorized by ATC.

3.2.4.3 Although this navigation specification does not include requirements for a holding function, ANSPs may include holding procedures in their airspace design using a waypoint as a holding point.

3.2.4.4 Many aircraft have a holding capability: aircraft can either hold manually over a waypoint when its holding functionality is not available and the pilot is expected to manually fly the holding pattern, or the navigation system's holding functionality can be used to execute the published hold (see Volume I, Attachment A, 5.3).

3.2.4.5 Guidance in this chapter does not supersede appropriate State operating requirements for equipage.

3.2.5 Procedure validation

3.2.5.1 Guidance on procedure validation is provided in *The Quality Assurance Manual for Flight Procedure Design* (Doc 9906), Volume I – *Flight Procedure Design Quality Assurance System*, and Volume V – *Validation of in Flight Procedures*.

Note.— Guidance on flight inspection is provided in the Manual on Testing of Radio Navigation Aids *(Doc 8071).*

3.2.6 Publication

3.2.6.1 The AIP should clearly indicate whether the navigation application is RNAV 1 or RNAV 2. The route should rely on normal descent profiles and identify minimum segment altitude requirements. The navigation data published in the State AIP for the routes and supporting NAVAIDs must meet the requirements of Annex 15 – *Aeronautical Information* Services. All routes must be based upon WGS-84 coordinates.

3.2.6.2 The available NAVAID infrastructure should be clearly designated on all appropriate charts (such as GNSS, DME/DME or DME/DME/inertial).

3.2.6.3 Any DME facilities that are critical to RNAV 1 or RNAV 2 operations should be identified in the relevant publications.

1. Formerly the *Performance-based Navigation Operational Approval Manual*, renamed in its third (forthcoming) edition.

3.2.6.4 Where holding patterns are established, they are to comply with the criteria and publication requirements in PANS-OPS, Volume II, Part 3, Section 3, Chapter 7. For the content of the PBN Requirement Box published on the chart, see also PANS-OPS, Volume II, Part 3, Section 5, Chapter 1.

3.2.7 Controller training

3.2.7.1 Air traffic controllers providing RNAV terminal and approach control services in airspace where RNAV 1 and RNAV 2 are implemented should complete training covering the items listed below.

3.2.7.2 Core training

a) How area navigation systems work (in the context of this navigation specification):

 1) include functional capabilities and limitations of this navigation specification;

 2) accuracy, integrity, availability and continuity;

 3) GPS receiver, RAIM, FDE and integrity alerts; and

 4) waypoint fly-by versus fly-over concept (and differences in turn performance);

b) flight plan requirements; and

c) ATC procedures:

 1) ATC contingency procedures;

 2) separation minima;

 3) mixed equipage environment (impact of manual VOR tuning);

 4) transition between different operating environments; and

 5) phraseology.

3.2.7.3 Training specific to this navigation specification

a) RNAV STARs:

 1) related control procedures;

 2) radar vectoring techniques;

 3) open and closed STARs;

 4) altitude constraints; and

 5) descend and climb clearances;

b) transitions to approach and related procedures;

c) RNAV 1 and RNAV 2 related phraseology; and

d) impact of requesting a change to routing during a procedure.

3.2.8 Navigation service monitoring

Navigation service monitoring should be consistent with Part A, Chapter 4.

3.2.9 Air traffic services system monitoring

3.2.9.1 The RNAV value provides a basis for determining the lateral route spacing and separation minima necessary for traffic operating on a given route. When available, ATS surveillance observations of each aircraft's proximity to track and altitude are typically noted by ATS facilities and aircraft track-keeping capabilities are analysed.

3.2.9.2 If an observation/analysis indicates that a loss of separation or obstacle clearance has occurred, the reason for the apparent deviation from track or altitude should be determined and steps taken to prevent a recurrence. Overall system safety needs to be monitored to confirm that the ATS system meets the required System Safety Requirements.

3.3 NAVIGATION SPECIFICATION

3.3.1 Background

3.3.1.1 This section identifies the aircraft requirements and operating procedures for RNAV 1 and RNAV 2 operations. Operational compliance with these requirements should be addressed through national operational regulations, and, in some cases, may require an operational authorization. For example, JAR-OPS 1 requires operators to apply to the State of the Operator/Registry, as appropriate, for operational authorization.

3.3.1.2 RNAV 1 and RNAV 2 specifications constitute harmonization between EASA CS-ACNS and FAA AC 20-138D (or later). Aircraft approved for RNAV 1 and RNAV 2 operations are automatically approved to operate within the United States or airspace of the Member States of the European Civil Aviation Conference (ECAC).

3.3.2 Authorization process

3.3.2.1 This navigation specification does not in itself constitute regulatory guidance material against which either the aircraft or the operator will be assessed and approved. Aircraft are certified by their State of Manufacture. Operators are approved in accordance with their national operating rules. This navigation specification provides the technical and operational criteria and does not necessarily imply a need for recertification.

Note 1.— Detailed information on operational authorizations is provided in the Performance-based Navigation (PBN) Operational Authorization Manual *(Doc 9997)*[2].

2. Formerly the *Performance-based Navigation Operational Approval Manual*, renamed in its third (forthcoming) edition.

Note 2.— Where appropriate, States may refer to previous operational authorizations in order to expedite this process for individual operators where performance and functionality are applicable to the current request for operational authorization.

3.3.2.2 Aircraft eligibility

The aircraft eligibility must be determined through demonstration of compliance against the relevant airworthiness criteria and the requirements of 2.3.3. The OEM or the holder of installation approval for the aircraft, such as STC holder, will demonstrate compliance to their regulatory authority (such as EASA, FAA) and the approval can be documented in manufacturer documentation (such as service letters). AFM entries are not required provided the State accepts certificate holders' documentation.

3.3.2.3 Operational authorization

3.3.2.3.1 ***Description of aircraft equipment***

The operator must have a configuration list and, if necessary, an MEL detailing the required aircraft equipment for RNAV 1 and/or RNAV 2 operations.

3.3.2.3.2 ***Training documentation***

3.3.2.3.2.1 Commercial operators must have a training programme addressing the operational practices, procedures and training items related to RNAV 1 and/or RNAV 2 operations (such as initial, upgrade or recurrent training for pilots, dispatchers or maintenance personnel).

Note.— Operators need not establish a separate training programme if they already integrate RNAV training as an element of their training programme. However, the operator should be able to identify the aspects of RNAV 1 and/or RNAV 2 covered within their training programme.

3.3.2.3.2.2 Private operators must be familiar with the practices and procedures identified in 3.3.5.

3.3.2.3.3 ***OMs and checklists***

3.3.2.3.3.1 Operations manuals (OMs) and checklists for commercial operators must address information/guidance on the SOP detailed in 3.3.4. The appropriate manuals should contain navigation operating instructions and contingency procedures, where specified. When required by the State of Operator/Registry, operators must submit their manuals and checklists for review as part of the application process.

3.3.2.3.3.2 Private operators should operate using the practices and procedures identified in 3.3.5.

3.3.2.3.4 ***MEL considerations***

Any MEL revisions necessary to address RNAV 1 and/or RNAV 2 provisions must be approved. Operators must adjust the MEL, or equivalent, and specify the required dispatch conditions.

3.3.2.3.5 ***Continuing airworthiness***

The operator must submit the continuing airworthiness instructions applicable to the aircraft configuration and the aircraft qualification for this navigation specification. Additionally, there is a requirement for operators to submit their maintenance program, including a reliability program for monitoring the equipment.

Note.— The operator should confirm with the OEM, or the certificate holder (Type Certificate (TC)/STC) for the aircraft, that acceptance of subsequent changes in the aircraft configuration, such as SBs, do not invalidate current operational authorizations.

3.3.3 Aircraft requirements

RNAV 1 and RNAV 2 operations are based upon the use of RNAV equipment that automatically determines the aircraft position in the horizontal plane using input from the following types of position sensors (no specific priority):

a) GNSS in accordance with FAA TSO-C145(), TSO-C146(), or TSO-C129(). Positioning data from other types of navigation sensors may be integrated with the GNSS data provided other position data do not cause position errors exceeding the total system accuracy requirements. GPS equipment approved to TSO-C129() are acceptable if they include the minimum functions specified in 3.3.3.3. As a minimum, integrity should be provided by an ABAS. In addition, TSO-C129 equipment should include the following functions:

   1) pseudo-range step detection;

   2) health word checking;

b) RNAV systems with an approved DME/DME navigation capability complying with the criteria listed in 3.3.3.2.2; and

c) RNAV systems with an approved DME/DME/Inertial navigation capability complying with the criteria listed in 3.3.3.2.3.

3.3.3.1 RNAV system performance

3.3.3.1.1 *RNAV system performance.* RNAV systems have no monitoring and alerting requirement during an RNAV operation.

3.3.3.1.1.1 *Accuracy.* During operations in airspace or on routes designated as RNAV 1, the lateral NSE must be within ±1 NM for at least 95 per cent of the total flight time. During operations in airspace or on routes designated as RNAV 2, the lateral NSE must be within ±2 NM for at least 95 per cent of the total flight time.

3.3.3.1.1.2 *Integrity.* Malfunction of the aircraft navigation equipment is classified as a major failure condition under airworthiness regulations (that is, 10^{-5} per hour).

3.3.3.1.1.3 *Continuity.* Loss of function is classified as a minor failure condition if the operator can revert to a different navigation system and proceed to a suitable airport.

3.3.3.2 Criteria for specific navigation services

3.3.3.2.1 ***Criteria for use of GNSS during RNAV 1 or RNAV 2 operations***

3.3.3.2.1.1 The following installed aircraft systems meet the accuracy requirements of these criteria:

a) aircraft with a GPS sensor (Class B or C) with a TSO-C129() award integrated in an FMS with a TSO-C115() award that has airworthiness approval, for use under instrument flight rules (IFR) and is installed in accordance with FAA AC 20-130A;

b) aircraft with an SBAS sensor with a TSO-C145() award integrated in an FMS with a TSO-C115() award, that has an airworthiness approval for use under IFR and is installed in accordance with FAA AC 20-130A or AC 20-138B;

c) aircraft with a GPS sensor with a TSO-C129() Class A1 award with an airworthiness approval for use under IFR meeting the installed performance and functional requirements in FAA AC 20-138() without deviating from the functionality described in 3.3.3.3; and

d) aircraft with an SBAS TSO-C146() Class Delta award with an airworthiness approval for use under IFR meeting the installed performance and functional requirements in AC 20-138() without deviating from the functionality described in 3.3.3.3 of this document.

3.3.3.2.1.2 For routes and/or aircraft authorizations requiring GNSS, if the navigation system does not automatically alert the pilot to a loss of GNSS, the operator must develop procedures to verify correct GNSS operation.

3.3.3.2.1.3 Positioning data from other types of navigation sensors may be integrated with the GNSS data, provided other positioning data do not cause position errors exceeding the TSE budget. Otherwise, means should be provided to deselect the other navigation sensor types.

3.3.3.2.2 ***Criteria for RNAV systems approved for DME/DME***

Paragraph	*Criteria*	*Explanation*
a)	Accuracy is based on the performance standards of TSO-C66c.	The accuracy required by TSO-C66c is adequate to support RNAV 1 and RNAV 2 operations. DME equipment approved to earlier TSO revisions may follow processes such as those in AC20-138() Chapter 6, Section 6-4.2 to establish more accurate performance than originally credited in their TSO award in support of eligibility for RNAV 1 and RNAV 2 operations.
b)	Tuning and updating position of DME facilities	The RNAV system with DME/DME navigation: 1) position updates within 30 seconds of tuning DME navigation facilities; 2) auto-tunes multiple DME facilities; and 3) provides continuous DME/DME position updating, and there must be no interruption in DME/DME positioning when the RNAV system switches between DME stations/pairs.

Paragraph	*Criteria*	*Explanation*
c)	Using facilities in the State AIPs	RNAV systems must only use DME facilities identified in State AIPs. The RNAV systems must not use facilities indicated by the State as inappropriate for RNAV 1 and/or RNAV 2 operations in the AIP. This may be accomplished by: 1) excluding specific DME facilities, which are known to have an adverse effect on the navigation solution, from use by the RNAV system, when the RNAV routes are within reception range of these DME facilities; and 2) using an RNAV system that performs reasonableness checks to detect errors from all received DME facilities and excludes these facilities from the navigation position solution, when appropriate (such as preclude tuning co-channel DME facilities when the DME facilities signals-in-space overlap) (see the guidance on testing of reasonableness checks beginning in 3.3.3.2.2 l)).
d)	DME facility relative angles	As a minimum, when offering DME/DME positioning, the RNAV system must use DME facilities with a relative include angle between 30° and 150° to the path of the aircraft (left and right of the aircraft's path).
e)	RNAV system use of DMEs	The RNAV system may use any valid receivable DME facility (listed in the AIP) regardless of its location. A valid DME facility: 1) broadcasts an accurate facility identifier signal; 2) satisfies the minimum field strength requirements; and 3) is protected from other interfering DME signals according to the co-channel and adjacent channel requirements. When needed to generate a DME/DME position, as a minimum, the RNAV system must use an available and valid terminal (low altitude) and/or en-route (high altitude) DME anywhere within the following region around the DME facility: 1) greater than or equal to 3 NM from the facility; and 2) less than 40 degrees above the horizon when viewed from the DME facility and out to 160 NM. *Note.— The use of a figure-of-merit in approximating the designated operational coverage (*DOC*) of a particular facility is accepted, provided precautions are taken to ensure that the figure-of-merit is coded so that the aircraft will use the facility everywhere within the DOC relative to the aircraft's path. The use of DMEs associated with ILS or MLS is not required.* *For facilities with an ARINC 424 figure of merit (FOM), the RNAV system may use the FOM from the following table as the acceptable, usable region.*

<table>
<tr><th>Paragraph</th><th>Criteria</th><th>Explanation</th></tr>
<tr><td></td><td></td><td>
<table>
<tr><th rowspan="2">If the ARINC 424 FOM is:</th><th colspan="2">The aircraft's DME/DME RNAV system must be:</th></tr>
<tr><th>Less than or equal to:</th><th>And less than:</th></tr>
<tr><td>0</td><td>40 NM from the facility</td><td>12,000 ft above facility elevation</td></tr>
<tr><td>1</td><td>70 NM from the facility</td><td>18,000 ft above facility elevation</td></tr>
<tr><td>2</td><td>130 NM from the facility</td><td>--</td></tr>
<tr><td>3</td><td>160 NM from the facility</td><td>--</td></tr>
</table>
Note 1.— RNAV systems need not use the FOM value to conduct DME/DME-based RNAV. Many RNAV and RNP systems use reasonableness checks in lieu of the FOM values to validate range replies from DME facilities.
Note 2.— RNAV systems may use additional DME facilities that do not use these FOM values (such as the RNAV system may use a localizer-DME facility). RNAV systems are not required to use the FOM value.
Note 3.— DME facilities supporting RNAV routes and procedures may include new FOMs when a State expands or contracts a DME facility's service volumes. The State will record the new FOM in their AIP and, when the RNAV system relies on the FOM for DME/DME positioning, the aircraft's on-board navigation database will contain the new FOM value for the system's use.
</td></tr>
<tr><td>f)</td><td>No requirement to use VOR, NDB, LOC, inertial navigation system or altitude and heading referencing system (AHRS)</td><td>There is no requirement to use VOR, LOC, NDB or an approved inertial navigation system during normal operation of the DME/DME RNAV system.</td></tr>
<tr><td>g)</td><td>Position estimation error</td><td>When using a minimum of two DME facilities meeting the criteria in 3.3.3.2.2 e), and any other DME facilities not meeting that criteria, the 95 per cent position estimation error must be better than or equal to 1.75 NM. An FTE contribution not exceeding 1.0 NM (95 per cent) may be assumed for RNAV 2 operations.</td></tr>
<tr><td>h)</td><td>Preventing erroneous guidance from other facilities</td><td>The RNAV system must ensure that the use of co-channel DME facilities outside their service volume (where the minimum field strength, co-channel and adjacent-channel interference requirements may not be satisfied) do not cause erroneous guidance. The RNAV system can accomplish this through the use of VOR reasonableness checks.</td></tr>
</table>

Paragraph	*Criteria*	*Explanation*
i)	Preventing erroneous VOR SIS	An RNAV system may use a VOR SIS for RNAV positioning. However, the RNAV system must ensure a positional accuracy from an erroneous VOR SIS will not exceed 1.75 NM for RNAV 2 operations and 0.87 NM for RNAV 1 operations. The RNAV system can do so by not using the VOR SIS when DME/DME positioning is available or by weighting and/or monitoring the VOR SIS while using reasonableness checks (see 3.3.3.2.2 l).
j)	Ensuring RNAV systems use operational facilities	The RNAV system must use operational DME and VOR facilities. DME and VOR facilities listed by NOTAM as unavailable (such as under test or other maintenance) may still reply to an airborne interrogation or be broadcasting a SIS, therefore, the RNAV system must not use unavailable DME or VOR facilities. An RNAV system may exclude unavailable facilities by checking the identification or providing a means to inhibit (that is, disable) the use of specific unavailable facilities.
k)	Operational mitigations	Operational mitigations defining a means to qualify the aircraft equipment as eligible for RNAV 1 or RNAV 2 operations should not require pilot monitoring of the RNAV system's navigation updating source(s) during the operation, nor require time-intensive programming/deselection of multiple DME or VOR facilities prior to, or during, an RNAV route or procedure that increases pilot workload. *Note 1.— Deselecting single DME or VOR facilities listed by NOTAM as out-of-service and/or programming route-defined "critical" DME is acceptable when this mitigation requires an acceptable pilot workload and does not occur during a critical phase of flight.* *Note 2.— The critical phase of flight is normally from the final approach fix on an approach procedure through missed approach, or from field elevation to 2,500 ft above airport elevation on a departure.*
l)	Reasonableness checks	Many RNAV systems perform a reasonableness check to verify valid DME measurements. Reasonableness checks are very effective against database errors or erroneous system acquisition (such as co-channel facilities), and typically fall into two classes: 1) reasonableness checks that the RNAV system uses upon acquiring a reply from a new DME facility, where it compares the aircraft's position to the aircraft's range to the DME before using the new DME; and 2) reasonableness checks that the RNAV system continuously uses, based on redundant information (such as additional DME facilities' replies or the present position of the inertial navigation system). *General requirements.* The reasonableness checks are intended to prevent the RNAV system's use of NAVAIDs that could cause position fix errors due to co-channel interference, multipath and direct signal screening. In lieu of using the published service volume of the radio NAVAID, the navigation system should provide reasonableness checks that preclude the use of duplicate frequency NAVAIDs within range, over-the-horizon NAVAIDs, and use of NAVAIDs with poor geometry relative to the path of the aircraft.

Paragraph	*Criteria*	*Explanation*
		Assumptions. Under the following conditions, the RNAV system's reasonableness checks may be invalid: 1) when the previously valid DME facility interrogation and reply is no longer valid; and 2) when additional DME facilities are not available. *Note.— The intent of this specification is to support RNAV operations where the NAVAID infrastructure is minimal (such as where only two DME facilities are available for parts of the RNAV route or procedure).*

3.3.3.2.3 ***Criteria for DME and inertial navigation system integration (DME/DME/inertial)***

This section defines the RNAV system's minimum requirements for DME/DME/inertial (or D/D/I) positioning.

Paragraph	*Criteria*	*Explanation*
a)	Inertial navigation system performance must satisfy the criteria of US 14 CFR Part 121, Appendix G or an equivalent standard (such as RTCA DO-384, Category A equipment).	
	The 95 per cent position estimation error must be better than or equal to the value referred to in 3.3.3.2.2g) Note 2.	*Note.— Based on an evaluation of inertial navigation system performance, the growth in position error after reverting to inertial coasting can be expected to be less than 2 NM per 15 minutes.*
b)	Automatic position updating capability from the DME/DME solution is required.	*Note.— Operators/pilots should contact manufacturers to discern if any annunciation of inertial coasting is suppressed following loss of radio updating.*
c)	Since some aircraft systems revert to VOR/DME-based navigation before reverting to inertial coasting, the impact of VOR radial accuracy, when the VOR is greater than 40 NM from the aircraft, must not affect aircraft position accuracy.	*Note.— One means of accomplishing this objective is for RNAV systems to exclude VORs greater than 40 NM from the aircraft or to disable VOR/DME updating altogether through some means.*
d)	The RNAV system must be able to accept a position update immediately prior to take-off.	

Paragraph	*Criteria*	*Explanation*
e)	The total system error must be less than or equal to 1.0 NM (95 per cent) throughout the route. To maximize the available RNAV performance relying on inertial coasting, the flight technical error for D/D/I on terminal procedures should be limited to 0.5 NM (95 per cent).	

3.3.3.3 Functional requirements – navigation displays and functions

Paragraph	*Functional requirement*	*Explanation*
a)	Navigation data, including a "to/from" indication and a failure indicator, must be displayed on a lateral deviation display (CDI, EHSI) and/or a navigation map display. These must be used as primary flight instruments for the navigation of the aircraft, for manoeuvre anticipation and for failure/status/integrity indication. They must meet the following requirements:	Non-numeric lateral deviation display (such as CDI, EHSI), with a to/from indication and a failure annunciation, for use as primary flight instruments for navigation of the aircraft, for manoeuvre anticipation and for failure/status/integrity indication, with the following five attributes: 1) the displays must be visible to the pilot and located in the primary field of view (±15 degrees from the pilot's normal line-of-sight) when looking forward along the flight path; 2) the lateral deviation display scaling should agree with any alerting and annunciation limits, if implemented; 3) the lateral deviation display must also have a full-scale deflection suitable for the current phase of flight and must be based on the required total system accuracy; 4) the display scaling may be set automatically by default logic or set to a value obtained from a navigation database. The full-scale deflection value must be known or must be available for display to the pilot commensurate with en-route, terminal, or approach values; and 5) the lateral deviation display must be automatically slaved to the RNAV computed path. The course selector of the deviation display should be automatically slewed to the RNAV computed path. As an alternate means, a navigation map display should give equivalent functionality to a lateral deviation display as described in 3.3.3.3 a) (1-5), with appropriate map scales (scaling may be set manually by the pilot) and giving equivalent functionality to a lateral deviation display.

Paragraph	*Functional requirement*	*Explanation*
		Note.— A number of modern aircraft eligible for this specification utilize a map display as an acceptable method to satisfy the stated requirements.
b)	The following system functions are required as a minimum within any RNAV 1 or RNAV 2 equipment:	1) the capability to continuously display to the pilot flying, on the primary flight instruments for navigation of the aircraft (primary navigation display), the RNAV computed desired path and aircraft position relative to the path. For operations where the required minimum flight crew is two pilots, the means for the pilot not flying to verify the desired path and the aircraft position relative to the path must also be provided; 2) a navigation database, containing current navigation data officially promulgated for civil aviation, which can be updated in accordance with the AIRAC cycle and from which ATS routes can be retrieved and loaded into the RNAV system. The stored resolution of the data must be sufficient to achieve negligible PDE. The database must be protected against pilot modification of the stored data; 3) the means to display the validity period of the navigation data to the pilot; 4) the means to retrieve and display data stored in the navigation database relating to individual waypoints and NAVAIDs, to enable the pilot to verify the route to be flown; and 5) the capacity to load from the database into the RNAV system the entire RNAV segment of the SID or STAR to be flown. *Note.— Due to variability in RNAV systems, this document defines the RNAV segment from the first occurrence of a named waypoint, track or course to the last occurrence of a named waypoint, track or course. Heading legs prior to the first named waypoint or after the last-named waypoint do not have to be loaded from the database.*
c)	The means to display the following items, either in the pilot's primary field of view, or on a readily accessible display page:	1) the active navigation sensor type; 2) the identification of the active (To) waypoint; 3) the ground speed or time to the active (To) waypoint; and 4) the distance and bearing to the active (To) waypoint.
d)	The capability to execute a "direct to" function.	

Paragraph	*Functional requirement*	*Explanation*
e)	The capability for automatic leg sequencing with the display of sequencing to the pilot.	
f)	The capability to execute SIDs or STARs extracted from the on-board database, including the capability to execute fly-over and fly-by turns.	
g)	The aircraft must have the capability to automatically execute leg transitions and maintain tracks consistent with the following ARINC 424 path terminators, or their equivalent. – intermediate fix (IF) – course to fix (CF) – course to altitude (CA) – direct to fix (DF) – TF	*Note 1.— Path terminators are defined in ARINC 424, and their application is described in more detail in RTCA documents DO-236() and DO-201(), and EUROCAE ED-75() and ED-77().* *Note 2.— Numeric values for courses and tracks must be automatically loaded from the RNAV system database*.
h)	The aircraft must have the capability to automatically execute leg transitions consistent with heading to an altitude (VA), VM and VI ARINC 424 path terminators, or must be able to be manually flown on a heading to intercept a course or to go direct to another fix after reaching a procedure-specified altitude.	
i)	The aircraft must have the capability to automatically execute leg transitions consistent with CA and fix to manual termination (FM) ARINC 424 path terminators, or the RNAV system must permit the pilot to readily designate a waypoint and select a desired course to or from a designated waypoint.	

Paragraph	*Functional requirement*	*Explanation*
j)	The capability to load an RNAV SID or STAR from the database, by route name, into the RNAV system is a recommended function. However, if all or part of the RNAV SID or STAR is entered through the manual entry of waypoints from the navigation database, the paths between a manually entered waypoint and the preceding and following waypoints must be flown in the same manner as a TF leg in terminal airspace.	
k)	The capability to display an indication of the RNAV system failure, including the associated sensors, in the pilot's primary field of view.	
l)	For multi-sensor systems, the capability for automatic reversion to an alternate RNAV sensor if the primary RNAV sensor fails. This does not preclude providing a means for manual navigation source selection.	The manufacturer's documentation should describe what navigation sensors are selected, how the sensor data is used in the determination of aircraft position (including how the data may be combined), and the effects on calculation of aircraft position and it's display in the cockpit.
m)	Database integrity	The navigation database should be obtained from a supplier that complies with RTCA DO 200()/EUROCAE document ED 76(), Standards for Processing Aeronautical Data. A letter of authorization (LOA) issued by the appropriate regulatory authority demonstrates compliance with this requirement (such as FAA LOA issued in accordance with FAA AC 20-153() or EASA certification of data services provider in accordance with Regulation (EU) 2017/373 (Part DAT). Discrepancies that invalidate a route must be reported to the navigation database supplier and affected routes must be prohibited by an operator's notice to its pilots. Aircraft operators should consider the need to conduct periodic checks of the operational navigation databases in order to meet existing quality system requirements.
n)	The navigation sensors in use must be clearly and unambiguously indicated.	

Paragraph	*Functional requirement*	*Explanation*
o)	For terminal and approach operations, the bearing and distance to the active fix must be displayed with a minimum resolution of 1 degree and 0.1 NM up to a range of 99.99 NM. Alternate means may be a moving map display where fix passage is clearly indicated. A moving map could obviate the need for numerical output provided there is adequate resolution.	

3.3.4 Operating procedures

3.3.4.1 Airworthiness certification alone does not authorize flight in airspace or along routes for which RNAV 1 or RNAV 2 authorization is required. Operational authorization is also required to confirm the adequacy of the operator's normal and contingency procedures for the particular equipment installation.

3.3.4.2 Preflight planning

3.3.4.2.1 Operators and pilots intending to conduct operations on RNAV 1 and RNAV 2 routes should file the appropriate flight plan suffixes.

3.3.4.2.2 The on-board navigation data must be current and appropriate for the region of intended operation and must include the NAVAIDs, waypoints, and relevant coded ATS routes for departure, arrival, and alternate airfields.

Note.— Navigation databases are expected to be current for the duration of the flight. If the AIRAC cycle is due to change during flight, operators and pilots should establish procedures to ensure the accuracy of the navigation data, including the suitability of navigation facilities used to define the routes and procedures for flight.

3.3.4.2.3 The availability of the NAVAID infrastructure required for the intended routes, including any non-RNAV contingencies, must be confirmed for the period of intended operations using all available information. Since GNSS integrity (RAIM or SBAS signal) is required by Annex 10, Volume I, the availability of these should also be determined as appropriate. For aircraft navigating with the SBAS receivers (all TSO-C145/C146), operators should check appropriate GPS RAIM availability in areas where the SBAS signal is unavailable.

3.3.4.3 ABAS availability

3.3.4.3.1 RAIM levels required for RNAV 1 and RNAV 2 can be verified either through NOTAMs (where available) or through prediction services. The operating authority may provide specific guidance on how to comply with this requirement (such as if sufficient satellites are available, a prediction may not be necessary). Operators should be familiar with the prediction information available for the intended route.

3.3.4.3.2 RAIM availability prediction should take into account the latest GPS constellation NOTAMs and avionics model (when available). The service may be provided by the ANSP, avionics manufacturer, other entities or through an airborne receiver RAIM prediction capability.

3.3.4.3.3 In the event of a predicted, continuous loss of appropriate level of fault detection of more than five minutes for any part of the RNAV 1 or RNAV 2 operation, the filed flight plan should be revised (such as delaying the departure or planning a different departure procedure).

3.3.4.3.4 RAIM availability prediction software does not guarantee a service; such tools assess the RNAV system's ability to meet the navigation performance. Because of unplanned failure of some GNSS elements, pilots/ANSP must realize that RAIM or GPS navigation altogether may be lost while airborne, which may require reversion to an alternative means of navigation. Therefore, pilots should assess their capability to navigate (potentially to an alternate destination) in case of failure of GPS navigation.

3.3.4.4 DME availability

For navigation relying on DME, NOTAMs should be checked to verify the condition of critical DMEs. Pilots should assess their capability to navigate (potentially to an alternate destination) in case of failure of critical DME while airborne.

3.3.4.5 General operating procedures

3.3.4.5.1 The pilot should comply with any instructions or procedures identified by the manufacturer as necessary to comply with the performance requirements in this chapter.

3.3.4.5.2 Operators and pilots should not request or file RNAV 1 and RNAV 2 routes unless they satisfy all the criteria in the relevant State documents. If an aircraft not meeting these criteria receives a clearance from ATC to conduct an RNAV route, the pilot must advise ATC that he/she is unable to accept the clearance and must request alternate instructions.

3.3.4.5.3 At system initialization, pilots must confirm the navigation database is current and verify that the aircraft position has been entered correctly. Pilots must verify proper entry of their ATC assigned route upon initial clearance and any subsequent change of route. Pilots must ensure the waypoints sequence, depicted by their navigation system, matches the route depicted on the appropriate chart(s) and their assigned route.

3.3.4.5.4 Pilots must not fly an RNAV 1 or RNAV 2 SID or STAR unless it is retrievable by route name from the on-board navigation database and conforms to the charted route. However, the route may subsequently be modified through the insertion or deletion of specific waypoints in response to ATC clearances. The manual entry, or creation of new waypoints by manual entry, of latitude and longitude or rho/theta values is not permitted. Additionally, pilots must not change any RNAV SID or STAR database waypoint type from a fly-by to a fly-over or vice versa.

3.3.4.5.5 Whenever possible, RNAV 1 and RNAV 2 routes in the en-route domain should be extracted from the database in their entirety, rather than loading individual waypoints from the database into the flight plan. However, it is permitted to select and insert individual, named fixes/waypoints from the navigation database, provided all fixes along the published route to be flown are inserted. Moreover, the route may subsequently be modified through the insertion or deletion of specific waypoints in response to ATC clearances. The creation of new waypoints by manual entry of latitude and longitude or rho/theta values is not permitted.

3.3.4.5.6 Pilots should cross-check the current flight plan by comparing charts or other applicable resources with the navigation system textual display and the aircraft map display, if applicable. If required, the exclusion of specific NAVAIDs should be confirmed.

Note.— Pilots may notice a slight difference between the navigation information portrayed on the chart and their primary navigation display. Differences of 3 degrees or less may result from the equipment manufacturer's application of magnetic variation and are operationally acceptable.

3.3.4.5.7 During the flight, where feasible, the pilot should use available data from ground-based NAVAIDs to confirm navigational reasonableness.

3.3.4.5.8 For RNAV 2 routes, pilots should use a lateral deviation indicator, flight director or autopilot in lateral navigation mode. Pilots may use a navigation map display with equivalent functionality as a lateral deviation indicator, as described in 3.3.3.3 a) (1-5), without a flight director or autopilot.

3.3.4.5.9 For RNAV 1 routes, pilots must use a lateral deviation indicator, flight director or autopilot in lateral navigation mode.

3.3.4.5.10 Pilots of aircraft with a lateral deviation display must ensure that lateral deviation scaling is suitable for the navigation accuracy associated with the route/procedure (such as full-scale deflection: ±1 NM for RNAV 1, ±2 NM for RNAV 2, or ±5 NM for TSO-C129() equipment on RNAV 2 routes).

3.3.4.5.11 All pilots are expected to maintain route centre lines, as depicted by on-board lateral deviation indicators and/or flight guidance during all RNAV operations described in this manual, unless authorized to deviate by ATC or under emergency conditions. For normal operations, cross-track error/deviation (the difference between the RNAV system computed path and the aircraft position relative to the path, that is, FTE) should be limited to ±½ the navigation accuracy associated with the procedure or route (that is, 0.5 NM for RNAV 1, 1.0 NM for RNAV 2). Brief deviations from this standard (such as overshoots or undershoots) during and immediately after procedure/route turns, up to a maximum of one times the navigation accuracy (that is, 1.0 NM for RNAV 1, 2.0 NM for RNAV), are allowable.

Note.— Some aircraft do not display or compute a path during turns, therefore, pilots of these aircraft may not be able to adhere to the ±½ RNAV value during procedural/route turns but are still expected to satisfy the standard during intercepts following turns and on straight segments.

3.3.4.5.12 If ATC issues a heading assignment taking the aircraft off a route, the pilot should not modify the flight plan in the RNAV system until a clearance is received to rejoin the route or the controller confirms a new route clearance. When the aircraft is not on the published route, the specified accuracy requirement does not apply.

3.3.4.5.13 Manually selecting aircraft bank limiting functions may reduce the aircraft's ability to maintain its desired track and is not recommended. Pilots should recognize that manually selectable aircraft bank-limiting functions might reduce their ability to satisfy ATC path expectations, especially when executing large angle turns. This should not be construed as a requirement to deviate from aeroplane flight manual procedures; rather, pilots should be encouraged to limit the selection of such functions within accepted procedures.

3.3.4.6 RNAV SID specific requirements

3.3.4.6.1 Prior to commencing take-off, the pilot must verify the aircraft's RNAV system is available, operating correctly, and the correct airport and runway data are loaded. Prior to flight, pilots must verify their aircraft navigation system is operating correctly and the correct runway and departure procedure (including any applicable en-route transition) are entered and properly depicted. Pilots who are assigned an RNAV departure procedure and subsequently receive a change of runway, procedure or transition must verify the appropriate changes are entered and available for navigation prior to take-off. A final check of proper runway entry and correct route depiction, shortly before take-off, is recommended.

3.3.4.6.2 *RNAV engagement altitude.* The pilot must be able to use RNAV equipment to follow flight guidance for lateral navigation, such as lateral navigation no later than 153 m (500 ft) above the airport elevation. The altitude at which RNAV guidance begins on a given route may be higher (such as climb to 304 m (1 000 ft) then direct to […]).

3.3.4.6.3 Pilots must use an authorized method (lateral deviation indicator/navigation map display/flight director/autopilot) to achieve an appropriate level of performance for RNAV 1.

3.3.4.6.4 *DME/DME aircraft*. Pilots of aircraft without GPS, using DME/DME sensors without an inertial navigation system input, cannot use their RNAV system until the aircraft has entered adequate DME coverage. The ANSP will ensure adequate DME coverage is available on each RNAV (DME/DME) SID at an acceptable altitude. The initial legs of the SID may be defined based on heading.

3.3.4.6.5 *DME/DME/inertial (D/D/I) aircraft*. Pilots of aircraft without GPS, using DME/DME RNAV systems with an approved inertial navigation system (DME/DME/inertial), should ensure the aircrafts inertial navigation system position is confirmed, within 304 m (1 000 ft) (0.17 NM) of a known position, at the starting point of the take-off roll. This is usually achieved by the use of an automatic or manual runway update function. A navigation map may also be used to confirm aircraft position when the pilot procedures and the display resolution allow for compliance with the 304 m (1 000 ft) tolerance requirement.

Note 1.— To be eligible for D/D/I positioning during RNAV operations, the aircraft requires an approved inertial navigation system. These specifications assume an aircraft with D/D/I positioning has an airworthiness approval for use of D/D/I positioning for flight under IFR during RNAV operations.

Note 2.— Based on the airworthiness approval of the inertial navigation system, the growth in position error after reverting to inertial coasting can be expected to be less than 2 NM per 15 minutes.

3.3.4.6.6 GNSS aircraft. When using GNSS, the signal must be acquired before the take-off roll commences. For aircraft using TSO-C129/C129A equipment, the departure airport must be loaded into the flight plan in order to achieve the appropriate navigation system monitoring and sensitivity. For aircraft using TSO-C145()/C146() avionics, if the departure begins at a runway waypoint, then the departure airport does not need to be in the flight plan to obtain appropriate monitoring and sensitivity.

3.3.4.7 RNAV STAR specific requirements

3.3.4.7.1 Prior to the arrival phase, the pilot should verify that the correct terminal route has been loaded. The active flight plan should be checked by comparing the charts with the map display (if applicable) and the multifunction control and display unit (MCDU). This includes confirmation of the waypoint sequence, reasonableness of track angles and distances, any altitude or speed constraints, and, where possible, which waypoints are fly-by, and which are fly-over. If required by a route, a check will need to be made to confirm that updating will exclude a particular NAVAID. A route must not be used if doubt exists as to the validity of the route in the navigation database.

Note.— As a minimum, the arrival checks could be a simple inspection of a suitable map display that achieves the objectives of this paragraph.

3.3.4.7.2 The creation of new waypoints by manual entry into the RNAV system by the pilot would invalidate the route and is not permitted.

3.3.4.7.3 Where the contingency procedure requires reversion to a conventional arrival route, necessary preparations must be completed before commencing the RNAV route.

3.3.4.7.4 Route modifications in the terminal area may take the form of vectors or “direct to” clearances and the pilot must be capable of reacting in a timely fashion. This may include the insertion of tactical waypoints loaded from the database. Manual entry or modification by the pilot of the loaded route, using temporary waypoints or fixes not provided in the database, is not permitted.

3.3.4.7.5 Pilots must verify their aircraft navigation system is operating correctly and the correct arrival procedure and runway (including any applicable transition) are entered and properly depicted.

3.3.4.7.6 Although a particular method is not mandated, any published altitude and speed constraints must be observed.

3.3.4.8 Contingency procedures

3.3.4.8.1 The pilot must notify ATC of any loss of the RNAV capability, together with the proposed course of action. If unable to comply with the requirements of an RNAV route, pilots must advise ATS as soon as possible. The loss of RNAV capability includes any failure or event causing the aircraft to no longer satisfy the RNAV requirements of the route.

3.3.4.8.2 In the event of communications failure, the pilot should continue with the RNAV route in accordance with established lost communications procedures.

3.3.5 Pilot knowledge and training

The following items should be addressed in the pilot training programme (such as simulator, training device or aircraft) for the aircraft's RNAV system:

a) the information in this chapter;

b) the meaning and proper use of aircraft equipment/navigation suffixes;

c) procedure characteristics as determined from chart depiction and textual description;

d) depiction of waypoint types (fly-over and fly-by) and path terminators (provided in 3.3.3.3, ARINC 424 path terminators) and any other types used by the operator, as well as associated aircraft flight paths;

e) required navigation equipment for operation on RNAV routes/SIDs/STARs, such as DME/DME, DME/DME/inertial, and GNSS;

f) RNAV system-specific information:

   1) levels of automation, mode annunciations, changes, alerts, interactions, reversions and degradation;

   2) functional integration with other aircraft systems;

   3) the meaning and appropriateness of route discontinuities as well as related flight crew procedures;

   4) pilot procedures consistent with the operation;

   5) types of navigation sensors (such as DME, inertial navigation system, GNSS) utilized by the RNAV system and associated system prioritization/weighting/logic;

   6) turn anticipation with consideration to speed and altitude effects;

   7) interpretation of electronic displays and symbols;

   8) understanding of the aircraft configuration and operational conditions required to support RNAV operations, that is, appropriate selection of CDI scaling (lateral deviation display scaling);

g) RNAV equipment operating procedures, as applicable, including how to perform the following actions:

1) verify currency and integrity of the aircraft navigation data;

2) verify the successful completion of RNAV system self-tests;

3) initialize navigation system position;

4) retrieve and fly a SID or a STAR with appropriate transition;

5) adhere to speed and/or altitude constraints associated with a SID or STAR;

6) select the appropriate STAR or SID for the active runway in use and be familiar with procedures to deal with a runway change;

7) perform a manual or automatic update (with take-off point shift, if applicable);

8) verify waypoints and flight plan programming;

9) fly direct to a waypoint;

10) fly a course/track to a waypoint;

11) intercept a course/track;

12) following vectors and rejoining an RNAV route from “heading” mode;

13) determine cross-track error/deviation. More specifically, the maximum deviations allowed to support RNAV must be understood and respected;

14) resolve route discontinuities;

15) remove and reselect navigation sensor input;

16) when required, confirm exclusion of a specific NAVAID or NAVAID type;

17) when required by the State aviation authority, perform gross navigation error checks using conventional NAVAIDs;

18) change arrival airport and alternate airport;

19) perform parallel offset functions if capability exists. Pilots should know how offsets are applied, the functionality of their particular RNAV system and the need to advise ATC if this functionality is not available;

20) perform RNAV holding;

h) operator-recommended levels of automation for phase of flight and workload, including methods to minimize cross-track error to maintain route centre line;

i) radiotelephony (R/T) phraseology for RNAV applications; and

j) contingency procedures for RNAV applications.

3.3.6 Navigation database

3.3.6.1 The navigation database should be obtained from a supplier that complies with RTCA DO 200()/EUROCAE document ED 76(), Standards for Processing Aeronautical Data. An LOA issued by the appropriate regulatory authority demonstrates compliance with this requirement (such as FAA LOA issued in accordance with FAA AC 20-153() or EASA certification of data services provider in accordance with Regulation (EU) 2017/373 (Part DAT)).

3.3.6.2 Discrepancies that invalidate a route must be reported to the navigation database supplier and affected routes must be prohibited by an operator's notice to its pilots.

3.3.6.3 Aircraft operators should consider the need to conduct periodic checks of the operational navigation databases in order to meet existing quality system requirements. DME/DME RNAV systems must only use DME facilities identified in State AIPs. Systems must not use facilities indicated by the State as inappropriate for RNAV 1 and RNAV 2 operations in the AIP or facilities associated with an ILS or MLS that uses a range offset. This may be accomplished by excluding specific DME facilities, which are known to have a deleterious effect on the navigation solution, from the aircraft's navigation database, when the RNAV routes are within reception range of these DME facilities.

3.3.6.4 For the RNAV system to perform as intended, the database configuration, as specified by the equipment manufacturer's data qualify requirements, must be consistent with the equipment capability. Procedures not supported by the RNAV system should not be accessible to the flight crew.

3.3.7 Oversight of operators

3.3.7.1 A regulatory authority may consider any navigation error reports in determining remedial action. Repeated navigation error occurrences attributed to a specific piece of navigation equipment may result in cancellation of the authorization for use of that equipment.

3.3.7.2 Information that indicates the potential for repeated errors may require modification of an operator's training programme. Information that attributes multiple errors to a particular pilot crew may necessitate remedial training or licence review.

3.4 REFERENCES

The applicable versions of industry and regulatory references, standards and guidance included in this chapter, shown as open reference (), are listed in Attachment E to this volume. Some references contained in the chapter are part of background or historical information, and not included in Attachment E.

Part C

IMPLEMENTING RNP OPERATIONS

Chapter 1

IMPLEMENTING RNP 4

1.1 INTRODUCTION

1.1.1 Background

1.1.1.1 This chapter addresses the implementation of RNP 4, originally developed to support 30 NM lateral and the 30 NM longitudinal distance-based separation minima in a procedural oceanic or remote area airspace.

1.1.1.2 The introduction of new ATS surveillance systems (such as space-based ADS-B) and new communication standards (such as RCP240), enables a range of new airspace concepts. See Part A, Chapter 1, 1.2.1.

Note.— For more information on performance-based communication and surveillance requirements, see the Performance-Based Communication and Surveillance (PBCS) Manual *(Doc 9869)*.

1.1.2 Purpose

1.1.2.1 This chapter provides ICAO guidance for implementing RNP 4. The operational authorization process described herein is limited to aircraft that have received airworthiness certification, indicating the installed navigation systems meet the performance requirements for RNP 4. This certification may have been issued at the time of manufacture, or where aircraft have been retrofitted in order to meet the requirements for RNP 4, by the granting of an appropriate STC.

1.1.2.2 This chapter does not address all requirements that may be specified for particular operations. These requirements are specified in other documents, such as national operating rules, AIPs and the *Regional Supplementary Procedures* (Doc 7030). While operational authorization primarily relates to the navigation requirements of the airspace, operators and pilots are still required to take account of all operational documents relating to the airspace, which are required by the appropriate State authority, before conducting flights into that airspace.

1.1.2.3 RNP 4 can be associated with FRT – see Appendix 2.

1.2 IMPLEMENTATION CONSIDERATIONS

1.2.1 NAVAID infrastructure considerations

RNP 4 was developed for operations in oceanic and remote airspace, therefore, it does not require any ground-based NAVAID infrastructure. Global navigation satellite system (GNSS) is the primary navigation sensor to support RNP 4, either as a stand-alone navigation system or as part of a multi-sensor system.

1.2.2 Communications and air traffic services surveillance considerations

1.2.2.1 This guidance material does not specifically address communications and ATS surveillance requirements associated with implementation of route systems and lateral separation minima utilizing RNP 4. Those requirements are normally determined in the implementation process taking into account any local and regional characteristics.

1.2.2.2 The provisions relating to separation minima, including the communications and ATS surveillance requirements, can be found in Annex 11 – *Air Traffic Services* and the *Procedures for Air Navigation Services – Air Traffic Management* (PANS-ATM, Doc 4444) for the appropriate application. Controller-pilot data link communications (CPDLC) (FANS1/A) and either ADS-C or ADS-B, or CPDLC (ATN) and ADS-B may be used providing they support the reporting rate require applications.

1.2.2.3 When GNSS is used as the sole basis for both ATS surveillance and aircraft navigation, the risks and requirement for mitigation techniques associated with the loss of GNSS potentially resulting in the loss of both navigation and surveillance capability, should be considered. This should typically be addressed through the regional or local State safety case prepared in support of the application.

1.2.3 Obstacle clearance, route spacing and separation minima

1.2.3.1 Detailed guidance on obstacle clearance is provided in the *Procedures for Air Navigation Services – Aircraft Operations*, Volume II – *Construction of Visual and Instrument Flight Procedures* (PANS-OPS, Doc 8168); the general criteria in Parts I and III apply and assume normal operations.

1.2.3.2 The separation minima are described in PANS-ATM (Doc 4444), Chapter 5.

1.2.3.3 RNP 4 may be used to support the application of separation standards/route spacing less than 23 NM in continental airspace provided a State has undertaken the necessary safety assessments outlined in PANS-ATM (Doc 4444). However, the communications and ATS surveillance parameters that support the application of the new separation standards will be different from those for a 23 NM standard. See also Attachment C to this volume.

1.2.4 Additional considerations

1.2.4.1 Many aircraft have the capability to fly a path parallel to, but offset left or right from, the original active route. The purpose of this function is to enable offsets for tactical operations authorized by ATC.

1.2.4.2 Although this navigation specification does not include requirements for a holding function, ANSPs may include holding procedures in their airspace design using a waypoint as a holding point. Aircraft can either hold manually over a waypoint when the aircraft holding functionality is not available and the pilot is expected to manually fly the holding pattern, or the navigation system's holding functionality can be used to execute the published hold.

1.2.4.3 Many aircraft have a holding capability. Aircraft can either hold manually over a waypoint when the aircraft holding functionality is not available and the pilot is expected to manually fly the holding pattern, or the navigation system's holding functionality can be used to execute the published hold. (see Volume I, Attachment A, 5.3).

1.2.4.4 Guidance in this chapter does not supersede appropriate State operating requirements for equipage.

1.2.5 Publication

1.2.5.1 The AIP should clearly indicate the navigation application is RNP 4. The route should identify minimum segment altitude requirements. The navigation data published in the State AIP for the routes and supporting NAVAIDs must meet the requirements of Annex 15 – *Aeronautical Information Services*. All routes must be based upon WGS-84 coordinates.

1.2.5.2 Where holding patterns are established, they are to comply with the criteria and publication requirements in PANS-OPS, Volume II, Part 3, Section 3, Chapter 7.

1.2.6 Controller training

1.2.6.1 Air traffic controllers providing control services in airspace where RNP 4 is implemented should have completed training in the following areas:

1.2.6.2 Core training

a) How area navigation systems work (in the context of this navigation specification):

   1) functional capabilities and limitations of this navigation specification;

   2) accuracy, integrity, availability and continuity including on-board performance monitoring and alerting;

   3) Global Positioning System (GPS) receiver, receiver autonomous integrity monitoring (RAIM), FDE, and integrity alerts; and

   4) waypoint fly-by versus fly-over concept (and different turn performance);

b) flight plan requirements;

c) ATC procedures:

   1) ATC contingency procedures;

   2) separation minima;

   3) mixed equipage environment (impact of manual VHF omnidirectional radio range (VOR) tuning);

   4) transition between different operating environments; and

   5) phraseology.

1.2.6.3 Training specific to this navigation specification

For application of performance-based separation defined in PANS-ATM:

a) CPDLC communications;

b) ADS-C system and simulation training;

c) performance-based communication and surveillance; and

d) effect of periodic reporting delay/failure on longitudinal separation.

1.2.7 Navigation service monitoring

Navigation service monitoring should be consistent with Volume II, Part A, Chapter 4.

1.2.8 Air traffic services system monitoring

1.2.8.1 The RNP value provides a basis for determining the lateral route spacing and separation minima necessary for traffic operating on a given route. Accordingly, lateral and longitudinal navigation errors are monitored through monitoring programmes. To date, radar observations of each aircraft's proximity to track and altitude, before coming into coverage of short-range NAVAIDs at the end of the oceanic route segment, are noted by ATS facilities. If an observation indicates that an aircraft is not within the established limit, a navigation error report is submitted, and an investigation undertaken to determine the reason for the apparent deviation from track or altitude, in order that steps may be taken to prevent a recurrence.

1.2.8.2 The introduction of new ATS surveillance systems could affect the monitoring process.

1.3 NAVIGATION SPECIFICATION

1.3.1 Background

1.3.1.1 This section identifies the airworthiness and operational requirements for RNP 4 operations. Operational compliance with these requirements must be addressed through national operational regulations and may require an operational authorization in some cases. For example, certain operational regulations require operators to apply to their national authority (State of Registry) for operational authorization.

1.3.1.2 This chapter addresses only the lateral part of the navigation system.

1.3.2 Authorization process

1.3.2.1 This navigation specification does not in itself constitute regulatory guidance material against which either the aircraft or the operator will be assessed and approved. Aircraft are certified by their State of Manufacture. Operators are approved in accordance with their national operating rules. This navigation specification provides the technical and operational criteria and does not necessarily imply a need for recertification.

Note 1.— Detailed information on operational authorizations is provided in Doc 9997[1]*.*

Note 2.— Where appropriate, States may refer to previous operational authorizations in order to expedite this process for individual operators where performance and functionality are applicable to the current request for operational authorization.

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[1] Formerly the *Performance-based Navigation Operational Approval Manual*, renamed in its third (forthcoming) edition.

1.3.2.2 Aircraft eligibility

1.3.2.2.1 The aircraft eligibility must be determined through demonstration of compliance against the relevant airworthiness criteria and the requirements of 1.3.3. The original equipment manufacturer (OEM) or the holder of installation approval for the aircraft, such as STC holder, will demonstrate compliance to their regulatory authority (such as European Union Aviation Safety Agency (EASA), Federal Aviation Administration (FAA)) and the approval can be documented in manufacturer documentation (such as service letters). Aircraft flight manual (AFM) entries are not required provided the State accepts manufacturer documentation.

1.3.2.2.2 Aircraft eligibility groups:

a) Group 1: RNP certification:

1) Group 1 aircraft are those with formal certification and approval of RNP integration in the aircraft. RNP compliance is documented in the aircraft's flight manual.

2) The certification will not necessarily be limited to a specific RNP navigation specification. The flight manual must address the RNP levels that have been demonstrated and any related provisions applicable to their use (such as NAVAID sensor requirements). Operational authorization is based upon the performance stated in the flight manual.

3) This method also applies in cases where certification is received through an STC issued to cover retrofitting of equipment, such as GNSS receivers, to enable the aircraft to meet RNP 4 requirements in oceanic and remote area airspace.

b) Group 2: prior navigation system certification:

Group 2 aircraft are those that can equate their certified level of performance, given under previous standards, to RNP 4 criteria. Standards listed in 1) to 3) can be used to qualify aircraft under Group 2:

1) *GNSS*. Aircraft fitted with GNSS only as an approved long-range navigation system for oceanic and remote airspace operations must meet the technical requirements specified in 1.3.3. The flight manual must indicate that dual GNSS equipment approved under an appropriate standard is required. Appropriate standards are FAA TSOs C129a or C146(), and EASA ETSOs C129a or C146(). In addition, an approved dispatch FDE availability prediction programme must be used. The maximum allowable time for which FDE capability is projected to be unavailable on any one event is 25 minutes. This maximum outage time must be included as a condition of the RNP 4 operational authorization. If predictions indicate that the maximum allowable FDE outage will be exceeded, the operation must be rescheduled to a time when FDE is available.

2) *Multi-sensor systems integrating GNSS with integrity provided by RAIM.* Multi-sensor systems incorporating GPS with RAIM and FDE approved under FAA AC20-138(), or other equivalent documents, meet the technical requirements specified in 1.3.3.

Note.— There is no requirement to use dispatch FDE availability prediction programmes when multi-sensor systems are fitted and used.

3) *Aircraft autonomous integrity monitoring (AAIM).* AAIM uses the redundancy of position estimates from multiple sensors, including GNSS, to provide integrity performance that is at least equivalent to RAIM. These airborne augmentations must be certified in accordance with TSO C-115(), ETSO C-115() or other equivalent documents. An example is the use of an inertial navigation system (INS) or other navigation sensors as an integrity check on GNSS data when RAIM is unavailable but GNSS positioning information continues to be valid.

c) Group 3: new technology:

This group has been provided to cover new navigation systems that meet the technical requirements for operations in airspace where RNP 4 is specified.

1.3.2.3 Operational authorization

1.3.2.3.1 ***Description of aircraft equipment***

The operator must have a configuration list and, if necessary, an MEL detailing the required aircraft equipment for RNP 4 operations.

1.3.2.3.2 ***Training documentation***

1.3.2.3.2.1 Commercial operators must have a training programme addressing the operational practices, procedures and training items related to RNP 4 operations (such as initial, upgrade or recurrent training for pilots, dispatchers or maintenance personnel).

Note.— Operators need not establish a separate training programme or regimen if they already integrate RNAV training as an element of their training programme. However, the operator should be able to identify the aspects of RNP 4 covered within their training programme.

1.3.2.3.2.2 Private operators must be familiar with the practices and procedures identified in 1.3.5.

1.3.2.3.3 ***OMs and checklists***

1.3.2.3.3.1 Operations manuals (OMs) and checklists for commercial operators must address information/guidance on the SOP detailed in 1.3.4. The appropriate manuals should contain navigation operating instructions and contingency procedures, where specified. When required by the State of the Operator/Registry, the operator must submit their manuals and checklists for review as part of the application process.

1.3.2.3.3.2 Private operators should operate using the practices and procedures identified in 1.3.5.

1.3.2.3.4 ***MEL considerations***

Any MEL revisions necessary to address RNP 4 provisions must be approved. Operators must adjust the MEL, or equivalent, and specify the required dispatch conditions.

1.3.2.3.5 ***Continuing airworthiness***

The operator must submit the continuing airworthiness instructions applicable to the aircraft's configuration and the aircraft's qualification for this navigation specification. Additionally, there is a requirement for the operator to submit their maintenance programme, including a reliability programme for monitoring the equipment.

Note.— The operator should confirm with the OEM, or the holder of installation approval for the aircraft, that acceptance of subsequent changes in the aircraft configuration, such as SBs do not invalidate current operational authorizations.

1.3.3 Aircraft requirements

1.3.3.1 For RNP 4 operations in oceanic or remote airspace, at least two fully serviceable independent long range navigation systems (LRNSs), with integrity such that the navigation system does not provide misleading information, must be fitted to the aircraft and form part of the basis upon which RNP 4 operational authorization is granted. GNSS must be used and can be used as either a stand-alone navigation system or as one of the sensors in a multi-sensor system.

1.3.3.2 FAA Advisory Circular AC 20-138(), or equivalent documents, provides an acceptable means of complying with installation requirements for aircraft that use, but do not integrate, the GNSS output with that of other sensors. FAA AC 20-138() also describes an acceptable means of compliance for multi-sensor navigation systems that incorporate GNSS.

1.3.3.3 The equipment configuration used to demonstrate the required accuracy must be identical to the configuration specified in the MEL or flight manual.

1.3.3.4 The design of the installation must comply with the design standards that are applicable to the aircraft being modified and changes must be reflected in the flight manual prior to commencing operations requiring an RNP 4 authorization.

1.3.3.5 System performance monitoring and alerting

1.3.3.5.1 ***RNP system performance***

1.3.3.5.1.1 *Accuracy.* During operations in airspace or on routes designated as RNP 4, the lateral total system error (TSE) must be within ±4 NM for at least 95 per cent of the total flight time. The along-track error must also be within ±4 NM for at least 95 per cent of the total flight time.

1.3.3.5.1.2 *Integrity.* Malfunction of the aircraft navigation equipment is classified as a major failure condition under airworthiness regulations (that is, 10^{-5} per hour).

1.3.3.5.1.3 *Continuity.* Loss of function is classified as a major failure condition for oceanic and remote navigation. The continuity requirement is satisfied by the carriage of dual independent long-range navigation systems.

1.3.3.5.2 ***On-board performance monitoring and alerting***

The installed RNP system must provide an alert if the accuracy requirement is not met, or if the probability that the lateral TSE exceeds 8 NM is greater than 10^{-5}. The alert should be consistent with RTCA DO-236(), DO-283(), DO-229() and EUROCAE ED-75().

Note.— Compliance with the on-board performance monitoring and alerting requirement does not imply an automatic monitor of FTE. The on-board monitoring and alerting function should consist at least of an NSE monitoring and alerting algorithm and a lateral deviation display enabling the crew to monitor the FTE. To the extent operational procedures are used to monitor FTE, the crew procedure, equipment characteristics and installation are evaluated for their effectiveness and equivalence, as described in the functional requirements and operating procedures. PDE is considered negligible due to the quality assurance process (1.3.6) and crew procedures (1.3.4).

1.3.3.6 Functional requirements

The on-board navigation system must have the following functionalities:

a) display of navigation data;

b) TF;

c) DF;

d) direct to function;

e) CF;

f) parallel offset;

g) fly-by transition criteria;

h) user interface displays;

i) flight planning path selection;

j) flight planning fix sequencing;

k) user defined CF;

l) path steering;

m) alerting requirements;

n) navigation database access;

o) WGS-84 geodetic reference system; and

p) automatic radio position updating.

1.3.3.7 Explanation of required functionalities

1.3.3.7.1 ***Display of navigation data***

The display of navigation data must use either a lateral deviation display (see a) below) or a navigation map display (see b) below) that meets the following requirements:

a) a non-numeric lateral deviation display (such as CDI, EHSI), with a to/from indication and failure annunciation, for use as a primary flight instrument for navigation of the aircraft, for manoeuvre anticipation, and for failure/status/integrity indication, with the following attributes:

1) the display must be visible to the pilot and located in the primary view (±15 degrees from the pilot's normal line of sight) when looking forward along the flight path;

2) lateral deviation scaling must agree with any alerting and annunciation limits, if implemented;

3) lateral deviation display must be automatically slaved to the RNAV computed path. The lateral deviation display also must have full-scale deflection suitable for the current phase of flight and must be based on the required track-keeping accuracy. The course selector of the lateral deviation display should be automatically slewed to the RNAV computed path, or the pilot must adjust the CDI or horizontal situation indicator (HSI) selected course to the computed desired track; and

Note.— The normal function of stand-alone GNSS equipment meets this requirement.

4) display scaling may be set automatically by default logic or set to a value obtained from the navigation database. The full-scale deflection value must be known or must be available to the pilot and must be commensurate with en-route, terminal or approach phase values; and

b) a navigation map display, readily visible to the pilot, with appropriate map scales (scaling may be set manually by the pilot) and giving equivalent functionality to a lateral deviation display.

1.3.3.7.2 ***Parallel offset***

The system must have the capability to fly parallel tracks at a selected offset distance. When executing a parallel offset, the navigation accuracy and all performance requirements of the original route in the active flight plan must be applicable to the offset route. The system must provide for entry of offset distances in increments of 1 NM, left or right of course. The system must be capable of offsets of at least 20 NM. When in use, system offset mode operation must be clearly indicated to the pilot. When in offset mode, the system must provide reference parameters (such as cross-track deviation, distance-to-go, time-to-go) relative to the offset path and offset reference points. An offset must not be propagated through route discontinuities, unreasonable path geometries or beyond the initial approach fix (IAF). Annunciation must be given to the pilot prior to the end of the offset path, with sufficient time to return to the original path. Once a parallel offset is activated, the offset must remain active for all flight plan route segments until removed automatically, until the pilot enters a direct-to routing, or until pilot (manual) cancellation. The parallel offset function must be available for en-route TF and the geodesic portion of DF leg types.

1.3.3.7.3 ***Fly-by transition criteria***

The navigation system must be capable of accomplishing fly-by transitions. No predictable and repeatable path is specified because the optimum path varies with airspeed and bank angle. However, the boundary of the transition area is as described in Volume I, Attachment A, Figure I-Att A-6. Path definition error (PDE) is defined as the difference between the defined path and the condition-based limit for the theoretical transition area. If the path lies within the transition area, there is no PDE. Fly-by transitions must be the default transition when the transition type is not specified. The theoretical transition area requirements are applicable for the following assumptions:

a) course changes do not exceed 120 degrees for low altitude transitions (aircraft barometric altitude is less than FL 195); and

b) course changes do not exceed 70 degrees for high altitude transitions (aircraft barometric altitude is equal to or greater than FL 195).

1.3.3.7.4 ***User interface displays***

General user interface display features must clearly present information, provide situational awareness and be designed and implemented to accommodate human factors considerations. Essential design considerations include:

a) minimizing reliance on pilot memory for any system operating procedure or task;

b) developing a clear and unambiguous display of system modes/sub-modes and navigational data with emphasis on enhanced situational awareness requirements for any automatic mode changes, if provided;

c) the use of context-sensitive help capability and error messages (such as invalid input or invalid data entry messages should provide a simple means to determine how to enter "valid" data);

d) fault-tolerant data entry methods rather than rigid rule-based concepts;

e) placing particular emphasis on the number of steps and minimizing the time required to accomplish flight plan modifications to accommodate ATS clearances, holding procedures, runway and instrument approach changes, missed approaches and diversions to alternate destinations; and

f) minimizing the number of nuisance alerts so the pilot will recognize and react appropriately, when required.

1.3.3.7.5 ***Displays and controls***

1.3.3.7.5.1 Each display element used as a primary flight instrument in the guidance and control of the aircraft, for manoeuvre anticipation, or for failure/status/integrity annunciation, must be located where it is clearly visible to the pilot (in the pilot's primary field of view) with the least practicable deviation from the pilot's normal position and line of vision when looking forward along the flight path. For those aircraft meeting the requirements of FAR/CS/JAR 25, compliance with the provisions of certification documents, such as AC 25-11, AMJ 25-11 and other applicable documents, should be met.

1.3.3.7.5.2 All system displays, controls and annunciations must be readable under normal cockpit conditions and expected ambient light conditions. Night lighting provisions must be compatible with other cockpit lighting.

1.3.3.7.5.3 All displays and controls must be arranged to facilitate pilot accessibility and usage. Controls that are normally adjusted in flight must be readily accessible with standardized labelling as to their function. System controls and displays must be designed to maximize operational suitability and minimize pilot workload. Controls intended for use during flight must be designed to minimize errors and, when operated in all possible combinations and sequences, must not result in a condition that would be detrimental to the continued performance of the system. System controls must be arranged to provide adequate protection against inadvertent system shutdown.

1.3.3.7.6 ***Flight planning path selection***

The navigation system must provide the crew the capability to create, review and activate a flight plan. The system must provide the capability for modification (such as deletion and addition of fixes and creation of along-track fixes), review and user acceptance of changes to the flight plans. When this capability is exercised, guidance output must not be affected until the modification(s) is activated. Activation of any flight plan modification must require positive action by the pilot after input and verification by the pilot.

1.3.3.7.7 ***Flight planning fix sequencing***

The navigation system must provide the capability for automatic sequencing of fixes.

1.3.3.7.8 ***User-defined CF***

The navigation system must provide the capability to define a user-defined course to a fix. The pilot must be able to intercept the user-defined course.

1.3.3.7.9 ***Flight technical error***

The system must provide data to enable the generation of command signals for autopilot/flight director/CDI, as applicable. In all cases, an FTE must be defined at the time of certification, which will meet the requirements of the desired RNP operation in combination with the other system errors. During the certification process, the ability of the crew to operate the aircraft within the specified FTE must be demonstrated. Aircraft type, operating envelope, displays, autopilot performance, and leg transitioning guidance (specifically between arc legs) should be accounted for in the demonstration of FTE compliance. A measured value of FTE may be used to monitor system compliance to RNP requirements. For operation on all leg types, this value must be the distance to the defined path. For cross-track deviation compliance, any inaccuracies in the cross-track error computation (such as resolution) must be accounted for in the TSE.

1.3.3.7.10 ***Alerting requirements***

The system must also provide an annunciation if the manually entered navigation accuracy is larger than the navigation accuracy associated with the current active leg segment of the route or procedure as defined in the navigation database. Any subsequent reduction of the navigation accuracy must reinstate this annunciation. When approaching RNP airspace from non-RNP airspace, alerting must be enabled when the cross-track to the desired path is equal to or less than one-half the navigation accuracy and the aircraft has passed the first fix in the RNP airspace.

1.3.3.7.11 ***Navigation database access***

The navigation database must provide access to navigation information in support of the navigation systems reference and flight planning features. Manual modification of the data in the navigation database must not be possible. This requirement does not preclude the storage of “user-defined data” within the equipment (such as for flex-track routes). When data are recalled from storage they must also be retained in storage. The system must provide a means to identify the navigation database version and valid operating period.

1.3.3.7.12 ***Geodetic reference system***

The World Geodetic System – 1984 (WGS-84) or an equivalent Earth reference model must be the reference Earth model for error determination. If WGS-84 is not employed, any differences between the selected Earth model and the WGS-84 Earth model must be included as part of the PDE. Errors induced by data resolution must also be considered.

1.3.4 Operating procedures

1.3.4.1 Airworthiness certification alone does not authorize RNP 4 operations. Operational authorization is also required to confirm the adequacy of the operator’s normal and contingency procedures for the particular equipment installation.

1.3.4.2 Preflight planning

1.3.4.2.1 Operators should use the appropriate ICAO flight plan designation specified for the RNP route. The letter "R" should be placed in block 10 of the ICAO flight plan to indicate the pilot has reviewed the planned route of flight and determined the RNP requirements and the aircraft and operator authorization for RNP routes. Additional information should be displayed in the remarks section indicating the accuracy capability, such as RNP 4 versus RNP 10. It is important to understand that additional requirements will have to be met for operational authorization in RNP 4 airspace or on RNP 4 routes. CPDLC and ADS-C systems will also be required when the separation standard is 30 NM lateral and/or longitudinal. The on-board navigation data must be current and include appropriate procedures.

Note.— Navigation databases are expected to be current for the duration of the flight. If the AIRAC cycle is due to change during flight, operators and pilots should establish procedures to ensure the accuracy of navigation data, including suitability of navigation facilities used to define the routes and procedures for flight.

1.3.4.2.2 The pilot must:

a) review maintenance logs and forms to ascertain the condition of the equipment required for flight in RNP 4 airspace or on routes requiring RNP 4 navigation capability;

b) ensure that maintenance action has been taken to correct defects in the required equipment; and

c) review the contingency procedures for operations in RNP 4 airspace or on routes requiring an RNP 4 navigation capability. These are no different than normal oceanic contingency procedures with one exception: crews must be able to recognize, and ATC must be advised, when the aircraft is no longer able to navigate to its RNP 4 navigational capability.

1.3.4.3 Availability of GNSS

At dispatch or during flight planning, the operator must ensure that adequate navigation capability is available en-route to enable the aircraft to navigate to RNP 4 and to include the availability of FDE, if appropriate for the operation.

1.3.4.4 En-route

1.3.4.4.1 At least two LRNSs, capable of navigating to RNP 4, and listed in the flight manual, must be operational at the entry point of the RNP airspace. If an item of equipment required for RNP 4 operations is unserviceable, then the pilot should consider an alternate route or diversion for repairs.

1.3.4.4.2 In flight operating procedures must include mandatory cross-checking procedures to identify navigation errors in sufficient time to prevent inadvertent deviation from ATC-cleared routes.

1.3.4.4.3 Crews must advise ATC of any deterioration or failure of the navigation equipment that cause navigation performance to fall below the required level, and/or any deviations required for a contingency procedure.

1.3.4.4.4 Pilots should use a lateral deviation indicator, flight director or autopilot in lateral navigation mode on RNP 4 routes. Pilots may use a navigation map display with equivalent functionality to a lateral deviation indicator as described in 1.3.3.7.1 b). Pilots of aircraft with a lateral deviation indicator must ensure that the lateral deviation indicator scaling (full-scale deflection) is suitable for the navigation accuracy associated with the route (that is, ±4 NM). All pilots are expected to maintain route centre lines, as depicted by on-board lateral deviation indicators and/or flight guidance during all RNP operations described in this manual, unless authorized to deviate by ATC or under emergency conditions. For normal operations, cross-track error/deviation (the difference between the RNAV system computed path and the aircraft position relative to the path) should be limited to ±½ the navigation accuracy associated with the route (that is, 2 NM). Brief deviations from this standard (such as overshoots or undershoots) during and immediately after route turns, up to a maximum of one-times the navigation accuracy (that is, 4 NM), are allowable.

1.3.5 Pilot knowledge and training

1.3.5.1 Operators/owners must ensure that pilots are trained and have appropriate knowledge of the topics contained in this guidance material, the limits of their RNP 4 navigation capabilities, the effects of updating and RNP 4 contingency procedures.

1.3.5.2 In determining whether training is adequate, an approving authority might:

a) evaluate a training course before accepting a training centre certificate from a specific centre;

b) accept a statement by the operator/owner in the application for an RNP 4 authorization that the operator/owner has ensured and will continue to ensure that pilots are familiar with the RNP 4 operating practices and procedures contained in this chapter; or

c) accept a statement by the operator that it has conducted or will conduct an RNP 4 training programme utilizing the guidance contained in this chapter.

1.3.6 Navigation database

1.3.6.1 The navigation database should be obtained from a supplier that complies with RTCA DO 200()/EUROCAE document ED 76(), Standards for Processing Aeronautical Data. A letter of authorization (LOA) issued by the appropriate regulatory authority demonstrates compliance with this requirement (such as FAA LOA issued in accordance with FAA AC 20-153() or EASA certification of data services provider in accordance with Regulation (EU) 2017/373 (Part DAT)).

1.3.6.2 Discrepancies that invalidate the route must be reported to the navigation database supplier and the affected route must be prohibited by an operator’s notice to its pilots.

1.3.6.3 Aircraft operators should consider the need to conduct periodic checks of the operational navigation databases in order to meet existing quality system requirements.

Note.— To minimize PDE, the database should comply with DO-200()/ED-76(), or an equivalent operational means must be in place to ensure database integrity for the RNP 4.

1.3.7 Oversight of operators

1.3.7.1 An aviation authority should consider any navigation error reports in determining remedial action. Repeated navigation error occurrences attributed to a specific piece of navigation equipment or operational procedure may result in cancellation of the operational authorization pending replacement or modifications on the navigation equipment or changes in the operator’s operational procedures.

1.3.7.2 Information that indicates the potential for repeated errors may require modification of an operator’s training programme, maintenance programme or specific equipment certification. Information that attributes multiple errors to a particular pilot crew may necessitate remedial training or crew licence review.

1.4 REFERENCES

The applicable versions of industry and regulatory references, standards and guidance included in this chapter, shown as open reference (), are listed in Attachment E to this volume. Some references contained in the chapter are part of background or historical information, and not included in Attachment E.

Chapter 2

IMPLEMENTING RNP 2

2.1 INTRODUCTION

2.1.1 Background

2.1.1.1 RNP 2 is primarily intended for a diverse set of en-route applications, particularly in geographic areas with little or no ground NAVAID infrastructure. Use of RNP 2 in continental applications requires a lower continuity requirement than used in oceanic/remote applications. In the latter application, the target traffic is primarily transport category aircraft operating at high altitude, whereas continental applications may include a significant percentage of general aviation aircraft.

2.1.1.2 This navigation specification can be applied for applications in oceanic, continental and in airspace considered by a State to be remote. Such remote airspace may require different considerations for aircraft eligibility based on whether the remote areas are covered by ATS surveillance or support suitable landing airports for the target aircraft population, or support reversion to an alternate means of navigation. Thus for remote airspace applications, a State may choose to designate either continental or oceanic/remote aircraft eligibility.

2.1.2 Purpose

2.1.2.1 This chapter provides guidance to States implementing RNP 2 for en-route airspace. It does not address all the requirements that may be specified for particular operations. These requirements are specified in other documents, such as national operating rules, AIPs and the *Regional Supplementary Procedures* (Doc 7030). While operational authorization primarily relates to the navigation requirements of the airspace, operators and pilots are still required to take account of all operational documents relating to the airspace, which are required by the appropriate State authority, before conducting flights into that airspace.

2.1.2.2 RNP 2 can be associated with FRT – see Appendix 2 to Part C.

2.2 IMPLEMENTATION CONSIDERATIONS

2.2.1 NAVAID infrastructure considerations

2.2.1.1 The RNP 2 specification is based upon global navigation satellite system (GNSS).

2.2.1.2 Operators relying on GNSS are required to have the means to predict the availability of GNSS fault detection (such as ABAS receiver autonomous integrity monitoring (RAIM)) to support operations along the RNP 2 ATS route. The on-board RNP system, GNSS avionics, the ANSP or other entities may provide a prediction capability. The AIP should clearly indicate when prediction capability is required and an acceptable means to satisfy that requirement.

2.2.1.3 RNP 2 should not be used in areas of known GNSS signal interference.

2.2.1.4 The ANSP must undertake an assessment of the NAVAID infrastructure. The infrastructure should be sufficient for the proposed operations, including reversionary navigation modes the aircraft may apply.

2.2.2 Communications and air traffic services surveillance considerations

2.2.2.1 The need for direct pilot to ATC (voice) communications and ATS surveillance will be determined by the airspace concept and the operating environment.

2.2.2.2 The ATS surveillance service may compliment contingency procedures to mitigate the effect of blunder errors and to reduce route spacing. When ATS surveillance services are relied upon to these ends, the performance of the system should be fit for purpose: the routes lie within the ATS surveillance and communications service volumes and the ATS resources are sufficient for these tasks.

2.2.2.3 When GNSS is used as the sole basis for both ATS surveillance and aircraft navigation, the risks and requirement for mitigation techniques associated with loss of GNSS potentially resulting in the loss of both navigation and surveillance capability, should be considered. This should typically be addressed through the regional or local State safety case prepared in support of the application.

2.2.2.4 The provisions relating to separation minima, including the communications and ATS surveillance requirements can be found in Annex 11 – *Air Traffic Services* and the *Procedures for Air Navigation Services – Air Traffic Management* (PANS-ATM, Doc 4444) for the appropriate application. Controller-pilot data link communications (CPDLC) (FANS1/A) and either ADS-C or ADS-B, or CPDLC (ATN) and ADS-B may be used providing they support the reporting rate require applications.

2.2.3 Obstacle clearance, route spacing and separation minima

2.2.3.1 Guidance on obstacle clearance is provided in the *Procedures for Air Navigation Services – Aircraft Operations*, Volume II – *Construction of Visual and Instrument Flight Procedures* (PANS-OPS, Doc 8168); the general criteria in Parts I and III apply and assume normal operations.

2.2.3.2 The route spacing supported by this chapter will be determined by a safety study for the intended operations, which will depend on the route configuration, air traffic density and intervention capability, etc. Horizontal separation standards are published in PANS-ATM (Doc 4444).

2.2.4 Additional considerations

2.2.4.1 It is important that the ANSP, in establishing the RNP 2 routes, consider the factors determining the location of routes, the availability of diversions, etc. These factors determine whether the ATS routes are being applied in continental or oceanic/remote airspace, and this must be clearly identified in the State's AIP. The area of application (that is, continental or oceanic/remote) will determine the applicable RNP continuity requirement. An aircraft configuration that does not meet the higher continuity requirements for oceanic/remote will be limited to operate on continental RNP 2 routes only.

2.2.4.2 Although this navigation specification does not include requirements for a holding function, ANSPs may include holding procedures in their airspace design using a waypoint as a holding point.

2.2.4.3 Many aircraft have a holding capability: aircraft can either hold manually over a waypoint when the aircraft holding functionality is not available and the pilot is expected to manually fly the holding pattern, or the navigation system's holding functionality can be used to execute the published hold (see Volume I, Attachment A, 5.3).

2.2.5 Publication

2.2.5.1 An RNP 2 route should rely on normal flight profiles and identify minimum segment altitude requirements. The navigation data published in the State AIP for the routes must meet the requirements of Annex 15 – *Aeronautical Information Services*. The State should define all RNP 2 routes using WGS-84 coordinates.

2.2.5.2 Where holding patterns are established, they are to comply with the criteria and publication requirements in PANS-OPS, Volume II, Part 3, Chapter 7.

2.2.6 Controller training

2.2.6.1 Air traffic controllers providing services where RNP 2 operations are implemented should complete training covering the following items.

2.2.6.2 Core training

a) How area navigation systems work (in the context of this navigation specification):

   1) functional capabilities and limitations of this navigation specification;

   2) accuracy, integrity and continuity, including on-board performance monitoring and alerting; and

   3) GNSS receiver, RAIM, fault detection and integrity alerts;

b) flight plan requirements;

c) ATC procedures:

   1) ATC contingency procedures;

   2) separation minima;

   3) mixed equipage environment;

   4) transition between different operating environments; and

   5) phraseology.

2.2.6.3 Training specific to this navigation specification

a) RNP 2 ATS route control requirements (in either ATS surveillance or procedural control environments):

   1) descend/climb clearances; and

   2) route reporting points;

b) RNP 2 related phraseology; and

c) impact of requesting an in-flight change to route.

2.2.7 Navigation service monitoring

Navigation service monitoring should be consistent with Part A, Chapter 4.

2.2.8 Monitoring and investigation of navigation and system errors

2.2.8.1 The RNP value provides a basis for determining the lateral route spacing and horizontal separation minima necessary for traffic operating on a given route. When available, observations of each aircraft's proximity to track and altitude, based on ATS surveillance (such as radar, multilateration or ADS-B), are typically noted by ATS facilities, and aircraft track-keeping capabilities are analysed.

2.2.8.2 If an observation/analysis indicates that a loss of separation or obstacle clearance has occurred, the reason for the apparent deviation from track or altitude should be determined and steps taken to prevent a recurrence. Overall system safety needs to be monitored to confirm that the ATS system meets the required system safety requirements.

2.3 NAVIGATION SPECIFICATION

2.3.1 Background

This section identifies the operational requirements for RNP 2 operations. Operational compliance with these requirements should be addressed through national operational regulations and may require an operational authorization from the State of the Operator/Registry for commercial operations, as applicable, and non-commercial operations when required.

2.3.2 Authorization process

2.3.2.1 This navigation specification does not in itself constitute regulatory guidance material against which either the aircraft or the operator will be assessed and approved. Aircraft are certified by their State of Manufacture. Operators are approved in accordance with their national operating rules. This navigation specification provides the technical and operational criteria and does not necessarily imply a need for recertification.

Note 1.— Detailed information on operational authorizations is provided in the Performance-based Navigation (PBN) Operational Authorization Manual *(Doc 9997)*[1]*.*

Note 2.— Where appropriate, States may refer to previous operational authorizations in order to expedite this process for individual operators where performance and functionality are applicable to the current request for operational authorization.

2.3.2.2 Aircraft eligibility

2.3.2.2.1 The aircraft eligibility must be determined through demonstration of compliance against the relevant airworthiness criteria and the requirements of 2.3.3. The original equipment manufacturer (OEM) or the holder of installation approval for the aircraft, such as the STC holder, will demonstrate compliance to their regulatory authority (such as European Union Aviation Safety Agency (EASA), Federal Aviation Administration (FAA)) and the approval can

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1 Formerly the *Performance-based Navigation Operational Approval Manual*, renamed in its third (forthcoming) edition.

be documented in manufacturer documentation (such as service letters). Aircraft flight manual (AFM) entries are not required provided the State accepts manufacturer documentation.

2.3.2.2.2 In this navigation specification, the continuity requirements for oceanic/remote and continental applications are different – see 2.3.3. Where an aircraft is eligible for continental applications only, such a limitation must be clearly identified to support operational authorizations. Aircraft meeting the oceanic/remote continuity requirement also meet the continental continuity requirement.

2.3.2.2.3 Advanced RNP (A-RNP) systems are considered as qualified for RNP 2 continental applications without further examination, and for RNP 2 oceanic/remote applications provided the oceanic/remote continuity requirement has been met.

Note.— Requests for authorization to use optional functionality (such as radius to fix (RF) legs, FRT) should address the aircraft and operational requirements as described in the appropriate functional attachment to this volume.

2.3.2.3 Operational authorization

2.3.2.3.1 ***Description of aircraft equipment***

The operator must have a configuration list and, if necessary, an MEL detailing the required aircraft equipment for RNP 2 operations.

2.3.2.3.2 ***Training documentation***

2.3.2.3.2.1 Commercial operators must have a training programme addressing the operational practices, procedures and training items related to RNP 2 operations (such as, initial, upgrade or recurrent training for pilots, dispatchers or maintenance personnel).

Note.— Operators need not establish a separate training programme if they already integrate RNAV training as an element of their training programme. However, the operator should be able to identify the aspects of RNP 2 covered within their training programme.

2.3.2.3.2.2 Private operators must be familiar with the practices and procedures identified in 2.3.5.

2.3.2.3.3 ***OMs and checklists***

2.3.2.3.3.1 Operations manuals (OMs) and checklists for commercial operators must address information/guidance on the SOP detailed in 2.3.4. The appropriate manuals should contain navigation operating instructions and contingency procedures, where specified. When required by the State of the Operator/Registry, the operator must submit their manuals and checklists for review as part of the application process.

2.3.2.3.3.2 Private operators should operate using the practices and procedures identified in 2.3.5.

2.3.2.3.4 ***MEL considerations***

Any MEL revisions necessary to address RNP 2 provisions must be approved. Operators must adjust the MEL, or equivalent, and specify the required dispatch conditions.

2.3.2.3.5 ***Continuing airworthiness***

The operator must submit the continuing airworthiness instructions applicable to the aircraft's configuration and the aircraft's qualification for this navigation specification. Additionally, there is a requirement for the operator to submit their maintenance programme, including a reliability programme for monitoring the equipment.

Note.— The operator should confirm with the OEM, or the holder of installation approval for the aircraft, that acceptance of subsequent changes in the aircraft configuration, such as SBs, does not invalidate current operational authorizations.

2.3.3 Aircraft requirements

2.3.3.1 *General*

2.3.3.1.1 On-board performance monitoring and alerting is required. This section provides the criteria for a total system error (TSE) form of performance monitoring and alerting that will ensure a consistent evaluation and assessment of compliance for RNP 2 applications (as described in Part A, Chapter 2, 2.3.3).

2.3.3.1.2 The aircraft navigation system, or aircraft navigation system and pilot in combination, is required to monitor the TSE, and to provide an alert if the accuracy requirement is not met or if the probability that the lateral TSE exceeds two times the accuracy value is larger than 1×10^{-5}. To the extent operational procedures are used to satisfy this requirement, the crew procedure, equipment characteristics and installation should be evaluated for their effectiveness and equivalence. Examples of information provided to the pilot for awareness of navigation system performance include estimated position uncertainty (EPU), "ACTUAL", "ANP" and estimated position error (EPE). Examples of indications and alerts provided when the operational requirement is or can be determined as not being met include "UNABLE RNP", "Nav Accur Downgrad", GNSS alert limit, loss of GNSS integrity, TSE monitoring (real time monitoring of NSE and FTE combined), etc. The navigation system is not required to provide both performance and sensor-based alerts, such as if a TSE-based alert is provided, a GNSS alert may not be necessary.

2.3.3.2 The following systems meet the accuracy and integrity requirements of these criteria:

a) aircraft with E/TSO-C129a sensor (Class B or C), E/TSO-C145() and the requirements of E/TSO-C115() FMS, installed for instrument flight rules (IFR) use in accordance with FAA AC 20-138(); and

b) aircraft with E/TSO-C129a Class A1 or E/TSO-C146() equipment installed for IFR use in accordance with FAA AC 20-138();

2.3.3.3 System performance monitoring and alerting

2.3.3.3.1 ***RNP system performance***

2.3.3.3.1.1 *Accuracy.* During operations in airspace or on routes designated as RNP 2, the lateral TSE must be within ±2 NM for at least 95 per cent of the total flight time. The along-track error must also be within ±2 NM for at least 95 per cent of the total flight time. To satisfy the accuracy requirement, the 95 per cent FTE should not exceed 1 NM.

Note.— The use of a deviation indicator with 2 NM full-scale deflection is an acceptable means of compliance.

2.3.3.3.1.2 *Integrity.* Malfunction of the aircraft navigation equipment is classified as a major failure condition under airworthiness guidance material (that is, 10^{-5} per hour).

2.3.3.3.1.3 *Continuity.* For RNP 2 oceanic/remote continental airspace applications, loss of function is a major failure condition. For RNP 2 continental applications, loss of function is a minor failure condition if the operator can revert to a different navigation system and proceed to a suitable airport. If a single aircraft configuration is to support all potential applications of RNP 2, the more stringent continuity requirement applies. The AFM limitations section must reflect restrictions in capability to aid in operational authorizations.

2.3.3.3.2 ***On-board performance monitoring and alerting***

The installed RNP system is required to provide an alert if the accuracy requirement is not met, or if the probability that the lateral TSE exceeds 4 NM is greater than 10^{-5}. The alert must be consistent with RTCA DO-236(), DO-283(), DO-229() and EUROCAE ED-75().

2.3.3.4 Flight technical error

2.3.3.4.1 During the aircraft certification process, the manufacturer must demonstrate the ability of the pilot to operate the aircraft within the allowable FTE. The demonstration of FTE should account for the aircraft type, the operating envelope, aircraft displays, autopilot performance and flight guidance characteristics. When this is done, the pilot may use the demonstrated value of FTE to monitor compliance to the RNP requirements. This value must be the cross-track distance to the defined path. For cross-track deviation compliance, the demonstration should account for any inaccuracies in the cross-track error computation (such as resolution) in the TSE.

2.3.3.4.2 Path definition error (PDE) is considered negligible because a quality assurance process is applied at the navigation database level.

2.3.3.5 Functional requirements

The following navigation displays and functions installed per AC 20-138(), or equivalent airworthiness installation advisory material, are required.

Note.— These functional requirements, while consistent with the equivalent requirements in the RNAV and the other RNP navigation specifications, have been customized for the en-route application and editorially revised for clarification.

Paragraph	*Functional requirement*	*Explanation*
a)	Navigation data, including a failure indicator, must be displayed on a lateral deviation display (CDI, EHSI) and/or a navigation map display. These must be used as primary flight instruments for the navigation of the aircraft, for manoeuvre anticipation and for failure/status/integrity indication.	Non-numeric lateral deviation display (such as CDI, EHSI), a failure annunciation, for use as primary flight instruments for navigation of the aircraft, for manoeuvre anticipation, and for failure/status/integrity indication, with the following six attributes: 1) the capability to continuously display to the pilot flying, on the primary flight instruments for navigation of the aircraft (primary navigation display), the computed path and aircraft position relative to the path. For operations where the required minimum flight crew is two pilots, the means for the pilot not flying to verify the desired path and the aircraft position relative to the path must also be provided;

Paragraph	*Functional requirement*	*Explanation*
		2) each display must be visible to the pilot and located in the primary field of view (±15° from the pilot's normal line of sight) when looking forward along the flight path; 3) the lateral deviation display scaling should agree with any implemented alerting and annunciation limits; 4) the lateral deviation display must also have a full-scale deflection suitable for the current phase of flight and must be based on the required track-keeping accuracy; 5) the display scaling may be set automatically by default logic, automatically to a value obtained from a navigation database, or manually by flight crew procedures. The full-scale deflection value must be known or must be available for display to the pilot commensurate with the required track-keeping accuracy; and 6) the lateral deviation display must be automatically slaved to the computed path. The course selector of the deviation display should be automatically slewed to the computed path or the pilot must adjust the CDI or HSI selected course to the computed desired track. As an alternate means of compliance, a navigation map display can provide equivalent functionality to a lateral deviation display as described in 1–6 above, with appropriate map scales and giving equivalent functionality to a lateral deviation display. The map scale should be set manually to a value appropriate for the RNP 2 operation.
b)	The RNP 2 operation requires the following minimum system and equipment functions:	1) a navigation database, containing current navigation data officially promulgated for civil aviation, which can be updated in accordance with the AIRAC cycle and from which RNP 2 routes can be retrieved and loaded into the RNP system. The stored resolution of the data must be sufficient to achieve negligible PDE. Database protections must prevent pilot modification of the on-board stored data; 2) a means to display the validity period of the navigation data to the pilot; 3) a means to retrieve and display data stored in the navigation database relating to individual waypoints and NAVAIDs (when applicable), to enable the pilot to verify the RNP 2 route to be flown; and

Paragraph	*Functional requirement*	*Explanation*
		4) for RNP 2 tracks in oceanic/remote continental airspace using flexible (such as organized) tracks, a means to enter the unique waypoints required to build a track assigned by the ATS provider.
c)	The means to display the following items, either in the pilot's primary field of view, or on a readily accessible display:	1) the active navigation sensor type; 2) the identification of the active (To) waypoint; 3) the groundspeed or time to the active (To) waypoint; and 4) the distance and bearing to the active (To) waypoint.
d)	The capability to execute a "direct to" function.	The aircraft and avionics manufacturers should identify any limitations associated with conducting the "direct to" function during RNP 2 operations in the manufacturer's documentation.
e)	The capability for automatic leg sequencing with the display of sequencing to the pilot.	
f)	The capability to automatically execute waypoint transitions and maintain track consistent with the RNP 2 performance requirements.	*Note.— A waypoint transition will be performed consistent with the conduct of a fly-by turn manoeuvre and the fly-by transition described in Volume I, Attachment A, 5.2.*
g)	The capability to display an indication of RNP 2 system failure in the pilot's primary field of view.	
h)	Parallel offset function (optional).	If implemented: 1) the system must have the capability to fly parallel tracks at a selected offset distance; 2) when executing a parallel offset, the navigation accuracy and all performance requirements of the original route in the active flight plan apply to the offset route; 3) the system must provide for entry of offset distances in increments of 1 NM, left or right of course; 4) the system must be capable of offsets of at least 20 NM; 5) when in use, the system must clearly annunciate the operation of offset mode; 6) when in offset mode, the system must provide reference parameters (such as cross-track deviation, distance-to-go, time-to-go) relative to the offset path and offset reference points;

Paragraph	*Functional requirement*	*Explanation*
		7) the system must annunciate the upcoming end of the offset path and allow sufficient time for the aircraft to return to the original flight plan path; and 8) once the pilot activates a parallel offset, the offset must remain active for all flight plan route segments until the system deletes the offset automatically, the pilot enters a new direct-to routing, or the pilot manually cancels the offset.

2.3.4 Operating procedures

2.3.4.1 Airworthiness certification and recognition of RNP 2 aircraft qualification together do not authorize RNP 2 operations. Operational authorization is also required to confirm the adequacy of the operator’s normal and contingency procedures for the particular equipment installation.

2.3.4.2 Preflight planning

2.3.4.2.1 Operators and pilots intending to conduct operations on RNP 2 routes must file the appropriate flight plan suffixes.

2.3.4.2.2 The on-board navigation data must be current and include appropriate procedures. Navigation databases should be current for the duration of the flight. If the AIRAC cycle is due to change during flight, operators and pilots should establish procedures to ensure the accuracy of the navigation data, including the suitability of navigation facilities defining the routes and procedures for flight.

2.3.4.2.3 The operator must confirm the availability of the NAVAID infrastructure required for the intended routes, including those for use in a non-GNSS contingency, for the period of intended operations using all available information. Since Annex 10 requires GNSS integrity (RAIM or SBAS signal), the procedures should determine the availability of these services and functions as appropriate. For aircraft navigating with SBAS capability (all TSO-C145()/C146()), operators should check appropriate GNSS RAIM availability in areas where the SBAS signal is unavailable.

2.3.4.3 ABAS availability

2.3.4.3.1 Operators can verify the availability of RAIM to support RNP 2 operations via NOTAMs (where available) or through GNSS prediction services. The operating authority may provide specific guidance on how to comply with this requirement. Operators should be familiar with the prediction information available for the intended route.

2.3.4.3.2 RAIM availability prediction should take into account the latest GNSS constellation NOTAMs and avionics model (when available). The ANSP, avionics manufacturer or the RNP system may provide this service.

2.3.4.3.3 In the event of a predicted, continuous loss of appropriate level of fault detection of more than five minutes for any part of the RNP 2 operation, the operator should revise the filed flight plan (such as delay the departure or plan a different route).

2.3.4.3.4 RAIM availability prediction software does not guarantee the service; rather, RAIM prediction tools assess the expected capability to meet the RNP. Because of unplanned failure of some GNSS elements, pilots and ANSPs must realize that RAIM or GNSS navigation may be lost while airborne, and this may require reversion to an alternative means of navigation. Therefore, pilots should prepare to assess their capability to navigate (potentially to an alternate destination) in case of failure of GNSS navigation.

2.3.4.4 General operating procedures

2.3.4.4.1 The pilot should comply with any instructions or procedures the manufacturer of the aircraft or avionics identifies as necessary to comply with the RNP 2 performance requirements. Pilots must adhere to any AFM limitations or operating procedures the manufacturer requires to maintain RNP 2 performance.

2.3.4.4.2 Operators and pilots should not request or file for RNP 2 routes unless they satisfy all the criteria in the relevant State documents. If an aircraft does not meet these criteria and receives a clearance from ATC to operate on an RNP 2 route, the pilot must advise ATC that they are unable to accept the clearance and must request an alternate clearance.

2.3.4.4.3 At system initialization, pilots must confirm the navigation database is current and verify proper aircraft position. Pilots must also verify proper entry of their ATC assigned route upon initial clearance and any subsequent change of route. Pilots must then ensure that the waypoint sequence depicted by their navigation system matches the route depicted on the appropriate chart(s) and their assigned route.

Note.— Pilots may notice a slight difference between the navigation information portrayed on the chart and their primary navigation display. Differences of three degrees or less may result from the equipment manufacturer's application of magnetic variation and are operationally acceptable.

2.3.4.4.4 Pilots must not fly a published RNP 2 route unless they can retrieve the route by name from the on-board navigation database and confirm it matches the charted route. However, pilots may subsequently modify the route through the insertion or deletion of specific waypoints in response to ATC requests and clearances. Pilots must not make manual entries or create new waypoints by manual entry of latitude and longitude or rho/theta values for fixed, published routes. Additionally, pilots must not change any route database waypoint type from a fly-by to a fly-over or vice versa. For flexible route structures, entry of latitude and longitude may also be permitted provided the potential for entry error by pilots is accounted for during associated safety analyses.

Note.— When the waypoints that make up an RNP 2 route are available by name in the aircraft's on-board navigation database, the operational authority may permit pilots to make a manual entry of the waypoints to define a published RNP 2 route in their navigation system.

2.3.4.4.5 The pilot need not cross-check the lateral navigation guidance with conventional NAVAIDs, as the absence of an integrity alert is sufficient to meet the integrity requirements.

2.3.4.4.6 For RNP 2 routes, pilots must use a lateral deviation indicator, flight director or autopilot in lateral navigation mode. Pilots of aircraft with a lateral deviation display must ensure that the lateral deviation scaling is suitable for the navigation accuracy associated with the route (such as full-scale deflection: ±2 NM for RNP 2 or ±5 NM in the case of some TSO-C129a equipment) and know their allowable lateral deviation limits.

Note.— An appropriately scaled map display, as provided for in 2.3.3.5 a), may also be used.

2.3.4.4.7 All pilots must maintain a centre line, as depicted by on-board lateral deviation indicators and/or flight guidance during all RNP 2 operations described in this manual, unless authorized to deviate by ATC or under emergency conditions. For normal operations, cross-track error/deviation (the difference between the system computed path and the aircraft position relative to the path, that is, FTE) should be limited to ±½ the navigation accuracy associated with the route (that is, 1 NM for RNP 2). Brief deviations from this standard (such as overshoots or undershoots) during and immediately after turns, up to a maximum of one times the navigation accuracy (that is, 2 NM for RNP 2) are allowable. Some aircraft do not display or compute a path during turns; therefore, pilots of these aircraft may not be able to confirm adherence to the ±½ RNP value during turns but must satisfy the standard during intercepts following turns and on straight segments.

2.3.4.4.8 Manual selection, or use of, default aircraft bank limiting functions may reduce the aircraft's ability to maintain desired track and the pilot should not use these functions. Pilots should understand manually selecting aircraft bank-limiting functions may reduce their ability to satisfy ATC path expectations, especially when executing large track changes. However, pilots should not deviate from AFM procedures and should limit the use of such functions within accepted procedures that meet the requirements for operation on an RNP 2 route.

2.3.4.4.9 If ATC issues a heading assignment that takes an aircraft off a route, the pilot should not modify the flight plan in the RNP system until they receive a clearance to rejoin the route, or the controller confirms a new route clearance. When the aircraft is not on the RNP 2 route, the RNP 2 performance requirements do not apply.

2.3.4.4.10 Pilots of aircraft with RNP input selection capability should select a navigation accuracy value of 2 NM, or lower. The selection of the navigation accuracy value should ensure the RNP system offers appropriate lateral deviation scaling permitting the pilot to monitor lateral deviation and meet the requirements of the RNP 2 operation.

2.3.4.5 Contingency procedures

The pilot must notify ATC of any loss of the RNP 2 capability (integrity alerts or loss of navigation). If unable to comply with the requirements of an RNP 2 route for any reason, pilots must advise ATC as soon as possible. The loss of RNP 2 capability includes any failure or event causing the aircraft to no longer satisfy the RNP 2 requirements.

2.3.5 Pilot knowledge and training

The training programme should provide sufficient training (such as simulator, training device, or aircraft) on the aircraft's RNP system to the extent that the pilots are familiar with the following:

a) the information in this chapter;

b) the meaning and proper use of aircraft equipment/navigation suffixes;

c) route and airspace characteristics as determined from chart depiction and textual description;

d) required navigation equipment on RNP 2 operations;

e) RNP system-specific information:

   1) levels of automation, mode annunciations, changes, alerts, interactions, reversions and degradation;

   2) functional integration with other aircraft systems;

   3) the meaning and appropriateness of route discontinuities as well as related flight crew procedures;

   4) pilot procedures consistent with the operation;

5) types of navigation sensors utilized by the RNP system and associated system prioritization/weighting/logic/limitations;

6) turn anticipation with consideration to speed and altitude effects;

7) interpretation of electronic displays and symbols used to conduct an RNP 2 operation; and

8) understanding of the aircraft configuration and operational conditions required to support RNP 2 operations, such as appropriate selection of CDI scaling (lateral deviation display scaling);

f) RNP system operating procedures, as applicable, including how to perform the following actions:

1) verify currency and integrity of the aircraft navigation data;

2) verify the successful completion of RNP system self-tests;

3) initialize navigation system position;

4) retrieve/manually enter and fly an RNP 2 route;

5) adhere to speed and/or altitude constraints associated with an RNP 2 route;

6) verify waypoints and flight plan programming;

7) fly direct to a waypoint;

8) fly a course/track to a waypoint;

9) intercept a course/track (flying assigned vectors and rejoining an RNP 2 route from "heading" mode);

10) determine cross-track error/deviation. More specifically, the maximum deviations allowed to support RNP 2 must be understood and respected;

11) resolve route discontinuities;

12) remove and reselect navigation sensor input; and

13) perform parallel offset function during RNP 2 operations if capability exists. Pilots should know how offsets are applied, the functionality of their particular RNP system and the need to advise ATC if this functionality is not available;

g) operator-recommended levels of automation for phase of flight and workload, including methods to minimize cross-track error to maintain route centre line;

h) R/T phraseology for RNP applications; and

i) contingency procedures for RNP failures.

2.3.6 Navigation database

2.3.6.1 Navigation data management is addressed in Annex 6 – *Operation of* Aircraft, Part I – *International Commercial Air Transport – Aeroplanes* , Chapter 7. The navigation database should be obtained from a supplier that complies with RTCA DO 200()/EUROCAE document ED 76(), Standards for Processing Aeronautical Data. A letter of authorization (LOA) issued by the appropriate regulatory authority demonstrates compliance with this requirement (such as, FAA LOA issued in accordance with FAA AC 20-153() or EASA certification of data services provider in accordance with Regulation (EU) 2017/373 (Part DAT)).

2.3.6.2 The operator must report any discrepancies invalidating an ATS route to the navigation database supplier, and the operator must take actions to prohibit their pilots from flying the affected ATS route.

2.3.6.3 Aircraft operators should consider the need to conduct periodic checks of the operational navigation databases in order to meet existing quality system requirements.

2.3.7 Oversight of operators

2.3.7.1 A regulatory authority should consider any navigation error reports in determining remedial action for an operator. Repeated navigation error occurrences attributed to specific navigation equipment should result in cancellation of the operational authorization permitting use of that equipment during RNP 2 operations.

2.3.7.2 Information indicating the potential for repeated errors may require modification of an operator's training programme. Information attributing multiple errors to a particular pilot may necessitate remedial training or licence review.

2.4 REFERENCES

The applicable versions of industry and regulatory references, standards and guidance included in this chapter, shown as open reference (), are listed in Attachment E to this volume. Some references contained in the chapter are part of background or historical information, and not included in Attachment E.

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Chapter 3

IMPLEMENTING RNP 1

3.1 INTRODUCTION

3.1.1 Background

3.1.1.1 The RNP 1 specification provides a means to develop RNP routes for connectivity between the en-route structure and terminal airspace and to develop standard instrument departures (SIDs) and standard instrument arrivals (STARs).

3.1.1.2 It may be used in a procedural or ATS surveillance environment, including in geographic areas having an extensive, modest or no ground NAVAID infrastructure.

Note.— When originally published, this navigation specification included the prefix "basic" because an Advanced RNP 1 specification was planned. Advanced RNP 1 evolved into the A-RNP navigation specification, so the need to include the prefix "basic" is no longer necessary. Existing authorizations granted under the original nomenclature remain valid.

3.1.2 Purpose

3.1.2.1 This chapter provides ICAO guidance for implementing RNP 1 for arrival and departure procedures. Within this chapter, arrival and departure procedures are referred to as SIDs and STARs, but are intended to also apply to initial, intermediate and missed approach segments. This chapter does not address all the requirements that may be specified for particular operations. These requirements are specified in other documents, such as national operating rules, AIPs and the *Regional Supplementary Procedures* (Doc 7030). While operational authorization primarily relates to the navigation requirements of the airspace, operators and pilots are still required to take account of all operational documents relating to the airspace, which are required by the appropriate State authority, before conducting flights into that airspace.

3.1.2.2 RNP 1 may be used for extended terminal operations, where it may be applied in the en-route continental flight phase on ATS routes or SIDs/STARs. It also applies to RNP 1 IAPs up to the FAF.

3.1.2.3 The radius to fix (RF) path terminator can be associated with RNP 1 SIDs/STARS and RNP 1 IAPs.

3.2 IMPLEMENTATION CONSIDERATIONS

3.2.1 NAVAID infrastructure considerations

3.2.1.1 The RNP 1 specification is based upon global navigation satellite system (GNSS). While DME/DME-based RNAV systems are capable of RNP 1 accuracy, this navigation specification is primarily intended for environments where the DME infrastructure cannot support DME/DME area navigation to the required performance.

Note.— The DME infrastructure requirements and assessment can support DME/DME and DME/DME/inertial positioning where there is an operational need (such as reversion for loss of GNSS over a wide area).

3.2.1.2 Air navigation services providers (ANSPs) should ensure operators of GNSS-equipped aircraft have the means to predict fault detection using ABAS (such as receiver autonomous integrity monitoring (RAIM)). Where applicable, ANSPs should also ensure operators of satellite-based augmentation system (SBAS)-equipped aircraft have the means to predict fault detection. This prediction service may be provided by the ANSP, airborne equipment manufacturers or other entities. Prediction services can be available for receivers meeting only the minimum technical standard order (TSO) performance or be specific to the receiver design. The prediction service should use status information on GNSS satellites and should use a horizontal alert limit appropriate to the operation (1 NM within 30 NM from the airport and 2 NM otherwise). Outages should be identified in the event of a predicted, continuous loss of ABAS fault detection of more than five minutes for any part of the RNP 1 operation.

3.2.1.3 RNP 1 should not be used in areas of known navigation signal (GNSS) interference.

3.2.1.4 The ANSP must undertake an assessment of the NAVAID infrastructure. It should be shown to be sufficient for the proposed operations, including reversionary modes.

3.2.2 Communications and air traffic services surveillance considerations

3.2.2.1 RNP 1 SIDs/STARs are primarily intended to be conducted in direct very high frequency (VHF) controller/pilot voice communications environments.

3.2.2.2 ATS surveillance service may be used to assist contingency procedures, to mitigate the effect of blunder errors and to reduce route spacing. When ATS surveillance services are relied upon to these ends, the system's performance should be fit for purpose, ensuring that the routes lie within the ATS surveillance and communications service volumes and the ATS resources are sufficient for these tasks.

3.2.2.3 When GNSS is used as the sole basis for both ATS surveillance and aircraft navigation, the risks and requirement for mitigation techniques associated with the loss of GNSS, potentially resulting in the loss of both navigation and surveillance capability, should be considered. This should typically be addressed through the regional or local State safety case prepared in support of the application.

3.2.3 Obstacle clearance, route spacing and separation minima

3.2.3.1 Detailed guidance on obstacle clearance is provided in PANS-OPS (Doc 8168, Volume II); the general criteria in Parts I and III apply and assume normal operations.

3.2.3.2 Route spacing for RNP 1 depends on the route configuration, air traffic density and the availability of ATS Surveillance to provide intervention capability – see Attachment C of this volume. Horizontal separation minima are published in PANS-ATM (Doc 4444, Chapter 5).

3.2.4 Additional considerations

3.2.4.1 For procedure design and infrastructure evaluation, the normal FTE limit of 0.5 NM defined in the operating procedures is assumed to be a 95 per cent value.

3.2.4.2 The default alerting functionality of a TSO-C129a sensor (stand-alone or integrated), switches between terminal alerting (±1 NM) and en-route alerting (±2 NM) at 30 miles from the aerodrome reference point (ARP).

3.2.4.3 Although this navigation specification does not include requirements for a holding function, ANSPs may include holding procedures in their airspace design using a waypoint as a holding point.

3.2.4.4 Many aircraft have a holding capability: Aircraft can either hold manually over a waypoint when the aircraft holding functionality is not available and the pilot is expected to manually fly the holding pattern, or the navigation system's holding functionality can be used to execute the published hold (see Volume I, Attachment A, 5.3).

3.2.5 Procedure validation

3.2.5.1 Guidance on procedure validation is provided in *The Quality Assurance Manual for Flight Procedure Design* (Doc 9906), Volume 1 – *Flight Procedure Design Quality Assurance System*, and Volume 5 – *Validation of in Flight Procedures*.

Note.— Guidance on the flight inspection is provided in the Manual on Testing of Radio Navigation Aids *(Doc 8071).*

3.2.6 Publication

3.2.6.1 The procedure should rely on normal descent profiles and identify minimum segment altitude requirements. The navigation data published in the State AIP for the procedures and supporting NAVAIDs must meet the requirements of Annex 15 – *Aeronautical Information Services*. All procedures must be based upon WGS-84 coordinates.

3.2.6.2 Where holding patterns are established, they are to comply with the criteria and publication requirements in PANS-OPS, Volume II, Part 3, Section 3, Chapter 7. For the content of the PBN Requirement Box published on the chart, see also PANS-OPS, Volume II, Part 3, Section 5, Chapter 1.

3.2.7 Controller training

3.2.7.1 Air traffic controllers who provide RNP terminal and approach control services, where RNP 1 is implemented, should have completed training that covers the items listed below.

3.2.7.2 Core training

a) How area navigation systems work (in the context of this navigation specification):

   1) functional capabilities and limitations of this navigation specification;

   2) accuracy, integrity, availability and continuity including on-board performance monitoring and alerting;

   3) GPS receiver, RAIM, FDE and integrity alerts; and

   4) waypoint fly-by versus fly-over concept (and different turn performance);

b) flight plan requirements;

c) ATC procedures;

1) ATC contingency procedures;

2) separation minima;

3) mixed equipage environment (impact of manual VOR tuning);

4) transition between different operating environments; and

5) phraseology.

3.2.7.3 Training specific to this navigation specification

a) RNP 1 STARs, SIDs, related control procedures:

   1) vectoring techniques (where appropriate);

   2) open and closed STARs;

   3) altitude constraints; and

   4) descend and climb clearances;

b) RNP approach and related procedures;

c) RNP 1 related phraseology; and

d) impact of requesting a change to routing during a procedure.

3.2.8 Navigation service monitoring

Navigation service monitoring should be consistent with Part A, Chapter 4.

3.2.9 Air traffic services system monitoring

3.2.9.1 The RNP value provides a basis for determining the lateral route spacing and horizontal separation minima necessary for traffic operating on a particular procedure. When available, ATS surveillance observations of each aircraft's proximity to track and altitude are typically noted by ATS facilities and aircraft track-keeping capabilities are analysed.

3.2.9.2 If an observation/analysis indicates that a loss of separation or obstacle clearance has occurred, the reason for the apparent deviation from track or altitude should be determined and steps taken to prevent a recurrence. Overall system safety needs to be monitored to confirm that the ATS system meets the required system safety requirements.

3.3 NAVIGATION SPECIFICATION

3.3.1 Background

This chapter identifies the operational requirements for RNP 1 operations. Operational compliance with these requirements should be addressed through national operational regulations and may require an operational authorization in some cases. For example, EU OPS requires operators to apply to the State of the Operator/Registry, as appropriate, for operational authorization.

3.3.2 Authorization process

3.3.2.1 This navigation specification does not in itself constitute regulatory guidance material against which either the aircraft or the operator will be assessed and approved. Aircraft are certified by their State of Manufacture. Operators are approved in accordance with their national operating rules. This navigation specification provides the technical and operational criteria and does not necessarily imply a need for recertification.

Note 1.— Detailed information on operational authorizations is provided in the Performance-based Navigation (PBN) Operational authorization Manual *(Doc 9997)*[1].

Note 2.— Where appropriate, States may refer to previous operational authorizations in order to expedite this process for individual operators where performance and functionality are applicable to the current request for operational authorization.

3.3.2.2 Aircraft eligibility

The aircraft eligibility must be determined through demonstration of compliance against the relevant airworthiness criteria and the requirements of 3.3.3. The OEM or the holder of installation approval for the aircraft, such as the STC holder, will demonstrate compliance to their regulatory authority (such as European Union Aviation Safety Agency (EASA), Federal Aviation Administration (FAA)), and the approval can be documented in manufacturer documentation (such as service letters). Aircraft flight manual (AFM) entries are not required, provided the State accepts manufacturer documentation.

Note.— Requests for authorization to use optional functionality (such as radius to fix (RF) legs) should address the aircraft requirements as described in the appropriate functional attachment to this volume.

3.3.2.3 Operational authorization

3.3.2.3.1 ***Description of aircraft equipment***

The operator must have a configuration list and, if necessary, an MEL detailing the required aircraft equipment for RNP 1 operations.

1. Formerly the *Performance-based Navigation Operational Approval Manual*, renamed in its third (forthcoming) edition.

3.3.2.3.2 ***Training documentation***

3.3.2.3.2.1 Commercial operators must have a training programme addressing the operational practices, procedures and training items related to RNP 1 operations (such as initial, upgrade or recurrent training for pilots, dispatchers or maintenance personnel).

Note 1.— Operators need not establish a separate training programme if they already integrate RNAV training as an element of their training programme. However, the operator should be able to identify the aspects of RNP 1 covered within their training programme.

Note 2.— Operators should document specific training provided for the use of instrument flight procedures containing the RF path terminator. See Appendix 1 to Part C, 5.2.

3.3.2.3.2.2 Private operators must be familiar with the practices and procedures identified in 3.3.5.

3.3.2.3.3 ***OMs and checklists***

3.3.2.3.3.1 Operations manuals (OMs) and checklists for commercial operators must address information/guidance on the SOP detailed in 3.3.4. The appropriate manuals should contain navigation operating instructions and contingency procedures, where specified. When required by the State of the Operator/Registry, the operator must submit their manuals and checklists for review as part of the application process.

3.3.2.3.3.2 Private operators should operate using the practices and procedures identified in 3.3.5.

3.3.2.3.4 ***MEL considerations***

Any MEL revisions necessary to address RNP 1 provisions must be approved. Operators must adjust the MEL, or equivalent, and specify the required dispatch conditions.

3.3.2.3.5 ***Continuing airworthiness***

The operator must submit the continuing airworthiness instructions applicable to the aircraft's configuration and the aircraft's qualification for this navigation specification. Additionally, there is a requirement for the operator to submit their maintenance programme, including a reliability programme for monitoring the equipment.

Note.— The operator should confirm with the OEM, or the holder of installation approval for the aircraft, that acceptance of subsequent changes in the aircraft configuration, such as SBs, do not invalidate current operational authorizations.

3.3.3 Aircraft requirements

3.3.3.1 The following systems meet the accuracy, integrity and continuity requirements of these criteria:

a) aircraft with E/TSO-C129a sensor (Class B or C), E/TSO-C145() and the requirements of E/TSO-C115() FMS, installed for instrument flight rules (IFR) use in accordance with FAA AC 20-138();

b) aircraft with E/TSO-C129a Class A1 or E/TSO-C146() equipment installed for IFR use in accordance with FAA AC 20-138(); and

c) aircraft with RNP capability certified or approved to equivalent standards.

Note.— For RNP procedures, the RNP system may only use DME updating when authorized by the State. The manufacturer should identify any operating constraints (such as manual inhibit of DME) in order for a given aircraft to comply with this requirement. This is in recognition of States where a DME infrastructure and capable equipped aircraft are available. Those States may establish a basis for aircraft qualification and operational authorization to enable use of DME. It is not intended to imply a requirement for implementation of DME infrastructure or the addition of RNP capability using DME for RNP operations. This requirement does not imply an equipment capability must exist providing a direct means of inhibiting DME updating. A procedural means for the pilots to inhibit DME updating or executing a missed approach if reverting to DME updating may meet this requirement.

3.3.3.2 System performance monitoring and alerting requirements

3.3.3.2.1 ***RNP system performance***

3.3.3.2.1.1 *Accuracy.* During operations in airspace or on routes designated as RNP 1, the lateral total system error (TSE) must be within ±1 NM for at least 95 per cent of the total flight time. The along-track error must also be within ±1 NM for at least 95 per cent of the total flight time. To satisfy the accuracy requirement, the 95 per cent FTE should not exceed 0.5 NM.

Note.— The use of a deviation indicator with 1 NM full-scale deflection has been found to be an acceptable means of compliance. The use of an autopilot or flight director has been found to be an acceptable means of compliance (roll stabilization systems do not qualify).

3.3.3.2.1.2 *Integrity.* Malfunction of the aircraft navigation equipment is classified as a major failure condition under airworthiness regulations (that is, 1×10^{-5} per hour).

3.3.3.2.1.3 *Continuity.* Loss of function is classified as a minor failure condition if the operator can revert to a different navigation system and proceed to a suitable airport.

3.3.3.2.2 ***On-board performance monitoring and alerting***

The installed RNP system is required to provide an alert if the accuracy requirement is not met, or if the probability that the lateral TSE exceeds 2 NM is greater than 1×10^{-5}. The alert must be consistent with RTCA DO-236(), DO-283(), DO-229() and EUROCAE ED-75().

Note 1.— Compliance with the on-board performance monitoring and alerting requirements does not imply automatic monitoring of FTEs. The on-board monitoring and alerting function should at least consist of an NSE monitoring and alerting algorithm and a lateral deviation display enabling the crew to monitor the FTE. To the extent operational procedures are used to monitor FTE, the crew procedure, equipment characteristics and installation are evaluated for their effectiveness and equivalence, as described in the functional requirements and operating procedures. Path definition error (PDE) is considered negligible due to the quality assurance process (3.3.6) and crew procedures (3.3.4).

Note 2.— If the installed RNP system does not automatically retrieve and set RNP 1.0 from the on-board navigation database for the entirety of the RNP 1 operation, the flight crew's operating procedures should manually set RNP 1.0.

3.3.3.3 Criteria for specific navigation systems

RNP 1 is based on GNSS positioning. Positioning data from other types of navigation sensors may be integrated with the GNSS data provided the other positioning data do not cause position errors exceeding the TSE budget. Otherwise, means should be provided to deselect the other navigation sensor types.

Note.— For RNP procedures, the RNP system may only use DME updating when authorized by the State. The manufacturer should identify any operating constraints (such as manual inhibit of DME) in order for a given aircraft to comply with this requirement. This is in recognition of States where a DME infrastructure and capable equipped aircraft are available. Those States may establish a basis for aircraft qualification and operational authorization to enable use of DME. It is not intended to imply a requirement for implementation of DME infrastructure or the addition of RNP capability using DME for RNP operations. This requirement does not imply an equipment capability must exist providing a direct means of inhibiting DME updating. A procedural means for the pilot to inhibit DME updating or executing a missed approach if reverting to DME updating may meet this requirement.

3.3.3.4 Functional requirements

The following navigation displays and functions installed per AC 20-138(), or equivalent airworthiness installation advisory material are required.

Paragraph	*Functional requirement*	*Explanation*
a)	Navigation data, including a failure indicator, must be displayed on a lateral deviation display (CDI, EHSI) and/or a navigation map display. These must be used as primary flight instruments for the navigation of the aircraft, for manoeuvre anticipation and for failure/status/integrity indication.	Non-numeric lateral deviation display (such as CDI, EHSI), with a to/from indication and a failure annunciation, for use as primary flight instruments for navigation of the aircraft, for manoeuvre anticipation, and for failure/status/integrity indication, with the following six attributes: 1) the capability to continuously display to the pilot flying, on the primary flight instruments for navigation of the aircraft (primary navigation display), the computed path and aircraft position relative to the path. For operations where the required minimum flight crew is two pilots, the means for the pilot not flying to verify the desired path and the aircraft position relative to the path must also be provided; 2) each display must be visible to the pilot and located in the primary field of view (±15° from the pilot's normal line of sight) when looking forward along the flight path; 3) the lateral deviation display scaling should agree with any implemented alerting and annunciation limits; 4) the lateral deviation display must also have a full-scale deflection suitable for the current phase of flight and must be based on the required track-keeping accuracy; 5) the display scale may be set:

Paragraph	*Functional requirement*	*Explanation*
		i) automatically by default logic; ii) automatically to a value obtained from navigation database; or iii) manually by pilot procedures. The full-scale deflection value must be known or must be available for display to the pilot commensurate with the required track keeping accuracy; and 6) the lateral deviation display must be automatically slaved to the computed path. The course selector of the deviation display should be automatically slewed to the computed path, or the pilot must adjust the CDI or HSI selected course to the computed desired track. As an alternate means of compliance, a navigation map display can provide equivalent functionality to a lateral deviation display as described in 1-6 above, with appropriate map scales and giving equivalent functionality to a lateral deviation display. The map scale should be set manually to a value appropriate for the RNP 1 operation.
b)	The following system functions are required as a minimum within any RNP 1 equipment:	1) a navigation database, containing current navigation data officially promulgated for civil aviation, which can be updated in accordance with the AIRAC cycle and from which ATS routes can be retrieved and loaded into the RNP system. The stored resolution of the data must be sufficient to achieve negligible PDE. The database must be protected against pilot modification of the stored data; 2) the means to display the validity period of the navigation data to the pilot; 3) the means to retrieve and display data stored in the navigation database relating to individual waypoints and NAVAIDs, to enable the pilot to verify the route to be flown; and 4) the capacity to load from the database into the RNP 1 system the entire segment of the SID or STAR to be flown. *Note.— Due to variability in systems, this document defines the RNAV segment from the first occurrence of a named waypoint, track or course to the last occurrence of a named waypoint, track or course. Heading legs prior to the first named waypoint or after the last-named waypoint do not have to be loaded from the database. The entire SID will still be considered an RNP 1 procedure.*

Paragraph	*Functional requirement*	*Explanation*
c)	The means to display the following items, either in the pilot's primary field of view, or on a readily accessible display page:	1) the active navigation sensor type; 2) the identification of the active (To) waypoint; 3) the ground speed or time to the active (To) waypoint; and 4) the distance and bearing to the active (To) waypoint.
d)	The capability to execute a "direct to" function.	
e)	The capability for automatic leg sequencing with the display of sequencing to the pilot.	
f)	The capability to load and execute an RNP 1 SID or STAR from the on-board database, by procedure name, into the RNP system.	
g)	The aircraft must have the capability to automatically execute leg transitions and maintain tracks consistent with the following ARINC 424 path terminators, or their equivalent: – IF – CF – CA – DF – TF	*Note 1.— Path terminators are defined in ARINC 424, and their application is described in more detail in RTCA documents DO-236()/EUROCAE ED-75() and DO-201()/EUROCAE ED-77().* *Note 2.— Numeric values for courses and tracks must be automatically loaded from the RNP system database.* *Note 3.— A leg transition will be performed consistent with the conduct of a fly-by turn manoeuvre and the fly-by transition described in Volume I, Attachment A, 5.2.*
h)	The aircraft must have the capability to automatically execute leg transitions consistent with VA, VM and VI ARINC 424 path terminators, or must be able to be manually flown on a heading to intercept a course or to go direct to another fix after reaching a procedure-specified altitude.	

Paragraph	*Functional requirement*	*Explanation*
i)	The aircraft must have the capability to automatically execute leg transitions consistent with CA and FM ARINC 424 path terminators, or the RNP system must permit the pilot to readily designate a waypoint and select a desired course to or from a designated waypoint.	
j)	The capability to display an indication of the RNP 1 system failure, in the pilot's primary field of view.	

3.3.4 Operating procedures

3.3.4.1 Airworthiness certification alone does not authorize RNP 1 operations. Operational authorization is also required to confirm the adequacy of the operator's normal and contingency procedures for the particular equipment installation.

3.3.4.2 Preflight planning

3.3.4.2.1 Operators and pilots intending to conduct operations on RNP 1 SIDs and STARs should file the appropriate flight plan suffixes.

3.3.4.2.2 The on-board navigation data must be current and include appropriate procedures.

Note.— Navigation databases are expected to be current for the duration of the flight. If the AIRAC cycle is due to change during flight, operators and pilots should establish procedures to ensure the accuracy of the navigation data, including the suitability of navigation facilities used to define the routes and procedures for flight.

3.3.4.2.3 The availability of the NAVAID infrastructure required for the intended routes, including any non-RNAV contingencies, must be confirmed for the period of intended operations using all available information. Since GNSS integrity (RAIM or SBAS signal) is required by Annex 10, the availability of these should also be determined as appropriate. For aircraft navigating with SBAS receivers (all TSO-C145()/C146()), operators should check appropriate GPS RAIM availability in areas where the SBAS signal is unavailable.

3.3.4.3 ABAS availability

3.3.4.3.1 RAIM levels required for RNP 1 can be verified either through NOTAMs (where available) or through prediction services. The operating authority may provide specific guidance on how to comply with this requirement (such as if sufficient satellites are available, a prediction may not be necessary). Operators should be familiar with the prediction information available for the intended route.

3.3.4.3.2 RAIM availability prediction should take into account the latest GPS constellation NOTAMs and avionics model (when available). The service may be provided by the ANSP, avionics manufacturer, other entities or through an airborne receiver RAIM prediction capability.

3.3.4.3.3 In the event of a predicted, continuous loss of appropriate level of fault detection of more than five minutes for any part of the RNP 1 operation, the filed flight plan should be revised (such as delaying the departure or planning a different departure procedure).

3.3.4.3.4 RAIM availability prediction software does not guarantee the service, rather, they are tools to assess the expected capability to meet the RNP. Because of unplanned failure of some GNSS elements, pilots/ANSP must realize that RAIM or GPS navigation altogether may be lost while airborne, which may require reversion to an alternative means of navigation. Therefore, pilots should assess their capability to navigate (potentially to an alternate destination) in case of failure of GPS navigation.

3.3.4.4 General operating procedures

3.3.4.4.1 The pilot should comply with any instructions or procedures identified by the manufacturer as necessary to comply with the performance requirements in this navigation specification.

3.3.4.4.2 Operators and pilots should not request or file RNP 1 procedures unless they satisfy all the criteria in the relevant State documents. If an aircraft not meeting these criteria receives a clearance from ATC to conduct an RNP 1 procedure, the pilot must advise ATC that he/she is unable to accept the clearance and must request alternate instructions.

3.3.4.4.3 At system initialization, pilots must confirm that the aircraft position has been entered correctly. Pilots must verify proper entry of their ATC assigned route upon initial clearance and any subsequent change of route. Pilots must ensure that the waypoint sequence depicted by their navigation system matches the route depicted on the appropriate chart(s) and their assigned route.

3.3.4.4.4 Pilots must not fly an RNP 1 SID or STAR unless it is retrievable by procedure name from the on-board navigation database and conforms to the charted procedure. However, the procedure may subsequently be modified through the insertion or deletion of specific waypoints in response to ATC clearances. The manual entry, or creation of new waypoints, by manual entry of latitude and longitude or rho/theta values is not permitted. Additionally, pilots must not change any SID or STAR database waypoint type from a fly-by to a fly-over or vice versa.

3.3.4.4.5 Pilots should cross-check the current flight plan by comparing charts or other applicable resources with the navigation system textual display and the aircraft map display, if applicable. If required, the exclusion of specific NAVAIDs should be confirmed.

Note.— Pilots may notice a slight difference between the navigation information portrayed on the chart and their primary navigation display. Differences of three degrees or less may result from the equipment manufacturer's application of magnetic variation and are operationally acceptable.

3.3.4.4.6 Cross-checking with conventional NAVAIDs is not required, as the absence of integrity alert is considered sufficient to meet the integrity requirements. However, monitoring of navigation reasonableness is suggested, and any loss of RNP capability must be reported to ATC.

3.3.4.4.7 For RNP 1 routes, pilots must use a lateral deviation indicator, flight director or autopilot in lateral navigation mode. Pilots of aircraft with a lateral deviation display must ensure that lateral deviation scaling is suitable for the navigation accuracy associated with the route/procedure (such as full-scale deflection: ±1 NM for RNP 1).

3.3.4.4.8 All pilots are expected to maintain centre lines, as depicted by on-board lateral deviation indicators and/or flight guidance during all RNP 1 operations described in this manual, unless authorized to deviate by ATC or under emergency conditions. For normal operations, cross-track error/deviation (the difference between the system computed path and the aircraft position relative to the path, that is, FTE) should be limited to ±½ the navigation accuracy associated with the procedure (that is, 0.5 NM for RNP 1). Brief deviations from this standard (such as overshoots or undershoots) during and immediately after turns, up to a maximum of one times the navigation accuracy (that is, 1.0 NM for RNP 1) are allowable.

Note.— Some aircraft do not display or compute a path during turns but are still expected to satisfy the above standard during intercepts following turns and on straight segments.

3.3.4.4.9 If ATC issues a heading assignment that takes an aircraft off of a route, the pilot should not modify the flight plan in the RNP system until a clearance is received to rejoin the route or the controller confirms a new route clearance. When the aircraft is not on the published RNP 1 route, the specified accuracy requirement does not apply.

3.3.4.4.10 Manually selecting aircraft bank limiting functions may reduce the aircraft's ability to maintain its desired track and is not recommended. Pilots should recognize that manually selectable aircraft bank-limiting functions might reduce their ability to satisfy ATC path expectations, especially when executing large angle turns. This should not be construed as a requirement to deviate from aeroplane flight manual procedures; pilots should be encouraged to limit the selection of such functions within accepted procedures.

3.3.4.5 Aircraft with RNP selection capability

Pilots of aircraft with RNP input selection capability should select RNP 1 or lower, for RNP 1 SIDs and STARs.

3.3.4.6 RNP 1 SID specific requirements

3.3.4.6.1 Prior to commencing take-off, the pilot must verify that the aircraft's RNP 1 system is available, operating correctly and that the correct airport and runway data are loaded. Prior to flight, pilots must verify their aircraft navigation system is operating correctly and the correct runway and departure procedure (including any applicable en-route transition) are entered and properly depicted. Pilots who are assigned an RNP 1 departure procedure and subsequently receive a change of runway, procedure or transition must verify that the appropriate changes are entered and available for navigation prior to take-off. A final check of proper runway entry and correct route depiction, shortly before take-off, is recommended.

3.3.4.6.2 *Engagement altitude*. The pilot must be able to use RNP 1 equipment to follow flight guidance for lateral navigation, such as lateral navigation, no later than 153 m (500 ft) above airport elevation.

3.3.4.6.3 Pilots must use an authorized method (lateral deviation indicator/navigation map display/flight director/autopilot) to achieve an appropriate level of performance for RNP 1.

3.3.4.6.4 *GNSS aircraft*. When using GNSS, the signal must be acquired before the take-off roll commences. For aircraft using TSO-C129a avionics, the departure airport must be loaded into the flight plan in order to achieve the appropriate navigation system monitoring and sensitivity. For aircraft using TSO-C145()/C146() avionics, if the departure begins at a runway waypoint, then the departure airport does not need to be in the flight plan to obtain appropriate monitoring and sensitivity. If the RNP 1 SID extends beyond 30 NM from the ARP and a lateral deviation indicator is used, its full-scale sensitivity must be selected to not greater than 1 NM between 30 NM from the ARP and the termination of the RNP 1 SID.

3.3.4.6.5 For aircraft using a lateral deviation display (that is, navigation map display), the scale must be set for the RNP 1 SID, and the flight director or autopilot should be used.

3.3.4.7 RNP 1 STAR specific requirements

3.3.4.7.1 Prior to the arrival phase, the pilot should verify that the correct terminal route has been loaded. The active flight plan should be checked by comparing the charts with the map display (if applicable) and the MCDU. This includes confirmation of the waypoint sequence, reasonableness of track angles and distances, any altitude or speed constraints, and, where possible, which waypoints are fly-by and which are fly-over. If required by a route, a check will need to be made to confirm that updating will exclude a particular NAVAID. A route must not be used if doubt exists as to the validity of the route in the navigation database.

Note.— As a minimum, the arrival checks could be a simple inspection of a suitable map display that achieves the objectives of this paragraph.

3.3.4.7.2 The creation of new waypoints by manual entry into the RNP 1 system by the pilot would invalidate the route and is not permitted.

3.3.4.7.3 Where the contingency procedure requires reversion to a conventional arrival route, necessary preparations must be completed before commencing the RNP 1 procedure.

3.3.4.7.4 Procedure modifications in the terminal area may take the form of vectoring or "direct to" clearances and the pilot must be capable of reacting in a timely fashion. This may include the insertion of tactical waypoints loaded from the database. Manual entry or modification by the pilot of the loaded route using temporary waypoints or fixes not provided in the database is not permitted.

3.3.4.7.5 Pilots must verify their aircraft navigation system is operating correctly, and the correct arrival procedure and runway (including any applicable transition) are entered and properly depicted.

3.3.4.7.6 Although a particular method is not mandated, any published altitude and speed constraints must be observed.

3.3.4.7.7 Aircraft with TSO-C129a GNSS RNP systems: If the RNP 1 STAR begins beyond 30 NM from the ARP and a lateral deviation indicator is used, then full scale sensitivity should be manually selected to not greater than 1 NM prior to commencing the STAR. For aircraft using a lateral deviation display (that is, navigation map display), the scale must be set for the RNP 1 STAR, and the flight director or autopilot should be used.

3.3.4.8 Contingency procedures

3.3.4.8.1 The pilot must notify ATC of any loss of the RNP capability (integrity alerts or loss of navigation), together with the proposed course of action. If unable to comply with the requirements of an RNP 1 SID or STAR for any reason, pilots must advise ATS as soon as possible. The loss of RNP capability includes any failure or event causing the aircraft to no longer satisfy the RNP 1 requirements of the route.

3.3.4.8.2 In the event of communications failure, the pilot should continue with the published lost communications procedure.

3.3.5 Pilot knowledge and training

The training programme should provide sufficient training (such as, simulator, training device or aircraft) on the aircraft's RNP system to the extent that the pilots are familiar with the following:

a) the information in this chapter;

b) the meaning and proper use of aircraft equipment/navigation suffixes;

c) procedure characteristics, as determined from chart depiction and textual description;

d) depiction of waypoint types (fly-over and fly-by) and path terminators (provided in 3.3.3.4 g), ARINC 424 path terminators) and any other types used by the operator, such as, RF legs), as well as associated aircraft flight paths;

e) required navigation equipment for operation on RNP 1 SIDs and STARs;

f) RNP system-specific information:

1) levels of automation, mode annunciations, changes, alerts, interactions, reversions and degradation;

2) functional integration with other aircraft systems;

3) the meaning and appropriateness of route discontinuities as well as related pilot procedures;

4) pilot procedures consistent with the operation;

5) types of navigation sensors utilized by the RNP system and associated system prioritization/weighting/logic;

6) turn anticipation with consideration to speed and altitude effects;

7) interpretation of electronic displays and symbols; and

8) understanding of the aircraft configuration and operational conditions required to support RNP 1 operations, that is, appropriate selection of CDI scaling (lateral deviation display scaling);

g) RNP system operating procedures, as applicable, including how to perform the following actions:

1) verify currency and integrity of the aircraft navigation data;

2) verify the successful completion of RNP system self-tests;

3) initialize navigation system position;

4) retrieve and fly an RNP 1 SID or a STAR with appropriate transition;

5) adhere to speed and/or altitude constraints associated with an RNP 1 SID or STAR;

6) select the appropriate RNP 1 SID or STAR for the active runway in use and be familiar with procedures to deal with a runway change;

7) verify waypoints and flight plan programming;

8) fly direct to a waypoint;

9) fly a course/track to a waypoint;

10) intercept a course/track;

11) follow vectors and rejoin an RNP 1 route from “heading” mode;

12) determine cross-track error/deviation. More specifically, the maximum deviations allowed to support RNP 1 must be understood and respected;

13) resolve route discontinuities;

14) remove and reselect navigation sensor input;

15) when required, confirm exclusion of a specific NAVAID or NAVAID type;

16) change arrival airport and alternate airport;

17) perform parallel offset function if capability exists. Pilots should know how offsets are applied, the functionality of their particular RNP system and the need to advise ATC if this functionality is not available;

18) perform RNAV holding; and

19) where applicable, execution of an RF leg;

h) operator-recommended levels of automation for phase of flight and workload, including methods to minimize cross-track error to maintain route centre line;

i) R/T phraseology for RNAV/RNP applications; and

j) contingency procedures for RNAV/RNP failures.

3.3.6 Navigation database

3.3.6.1 The navigation database should be obtained from a supplier that complies with RTCA DO 200()/EUROCAE document ED 76(), Standards for Processing Aeronautical Data. A letter of authorization (LOA) issued by the appropriate regulatory authority demonstrates compliance with this requirement (such as FAA LOA issued in accordance with FAA AC 20-153() or EASA certification of data services provider in accordance with Regulation (EU) 2017/373 (Part DAT)).

3.3.6.2 Discrepancies that invalidate a SID or STAR must be reported to the navigation database supplier and the affected SID or STAR must be prohibited by an operator’s notice to its pilots.

3.3.6.3 Aircraft operators should consider the need to conduct periodic checks of the operational navigation databases in order to meet existing quality system requirements.

Note.— To minimize PDE, the database should comply with DO 200(), or an equivalent operational means must be in place to ensure database integrity for the RNP 1 SIDs or STARs.

3.3.7 Oversight of operators

3.3.7.1 A regulatory authority should consider any navigation error reports in determining remedial action. Repeated navigation error occurrences attributed to a specific piece of navigation equipment may result in cancellation of the authorization for use of that equipment.

3.3.7.2 Information that indicates the potential for repeated errors may require modification of an operator's training programme. Information that attributes multiple errors to a particular pilot crew may necessitate remedial training or licence review.

3.4 REFERENCES

The applicable versions of industry and regulatory references, standards and guidance included in this chapter, shown as open reference (), are listed in Attachment E to this volume. Some references contained in the chapter are part of background or historical information, and not included in Attachment E.

Chapter 4

IMPLEMENTING ADVANCED RNP

4.1 INTRODUCTION

4.1.1 Background

Advanced RNP (A-RNP) is intended for a diverse set of applications across various flight phases. In en-route continental and terminal applications, it would be used in high density areas where ATS surveillance is provided based on radar. Depending on local implementation considerations, A-RNP can also be used in medium to low-density areas that do not provide an ATS surveillance service.

4.1.2 Purpose

4.1.2.1 This chapter provides guidance for implementing A-RNP routes and procedures. A-RNP recognizes and takes advantage of the multiple flight phase capabilities of modern aircraft navigation systems. A-RNP may be utilized in applications associated with other navigation specifications and has its own specific applications. A-RNP applications will provide environmental, capacity and efficiency benefits for en-route, oceanic/remote, continental, terminal, approach and missed approach, excluding the final approach.

4.1.2.2 Advanced RNP (A-RNP) applications offer multiple navigation accuracies for use as follows:

RNP value	*Applicable flight phases*
2 NM	En-route oceanic/remote and continental
1 NM	En-route continental
0.3 NM	Arrival, initial, intermediate and departure *Note.— The final approach segment is excluded.*
1 NM	Missed approach

Note.— For missed approach considerations including exceptions for use of an RNP value of 0.3 NM, see 4.2.3.3.

4.1.2.3 By design, A-RNP contains features and capabilities common with other navigation specifications, as well as some of its own specific performance and functional requirements. When these exclusive A-RNP performance and/or functional requirements are necessary for the operation, the term “Advanced RNP” will appear on an instrument approach chart in the PBN requirements box or in the aeronautical publication as the required navigation specification.

– *Performance.* The lateral navigation accuracies are 2 NM, 1 NM or 0.3 NM depending on the flight phase, with attendant integrity and continuity requirements;

Note 1.— In an instrument approach procedure, the A-RNP application is only used in the initial and intermediate segments and then in the missed approach. The final approach segment of an instrument approach procedure is defined using the RNP APCH specification. Alternatively, a non-performance-based navigation (PBN) final approach segment may be defined using ILS or GLS. The instrument approach procedure (IAP) contained in the RNP system navigation database, and selected by the flight crew, will contain all the procedure leg segments requirements of the associated navigation specification.

Note 2.— A-RNP can also be applied in the departure phase of flight.

– *Specific functions.* Parallel offset and RNP holding.

4.1.2.4 This chapter provides guidance to States implementing A-RNP applications for operations in en-route oceanic/remote, continental and terminal airspace. It is not intended to address all the requirements that may be specified for operation on a particular route or in a particular area. These requirements are specified in other documents such as operating rules, AIPs and the *Regional Supplementary Procedures* (Doc 7030). While operational authorization primarily relates to the navigation requirements of the airspace, operators and flight crew are still required to take account of all operational documents relating to the airspace that are required by the appropriate State authority before conducting flights into that airspace.

4.2 IMPLEMENTATION CONSIDERATIONS

4.2.1 NAVAID infrastructure considerations

4.2.1.1 Advanced RNP (A-RNP) is based upon GNSS. Multi-distance measuring equipment (DME) ground infrastructure is not required but may be provided based upon the State requirements, operational requirements and available services. The detailed requirements of the operation will be set out in the State AIP and, where regional requirements are appropriate, will be identified in Doc 7030.

4.2.1.2 Air navigation services providers (ANSPs) should ensure operators relying on GNSS are required to have the means to predict the availability of GNSS fault detection (such as ABAS) receiver autonomous integrity monitoring (RAIM)) to support the required navigation accuracy along the A-RNP route or procedure. The on-board RNP system, GNSS avionics, the ANSP or other entities may provide a prediction capability. The AIP should clearly indicate when prediction capability is required and acceptable means to satisfy that requirement.

4.2.2 Communications and air traffic services surveillance considerations

4.2.2.1 The need for direct very high frequency (VHF) controller/pilot voice communications and surveillance will be determined by the airspace concept and the operating environment. Advanced RNP standard instrument departures (SIDs)/standard instrument arrivals (STARs) are intended to be conducted where direct pilot to ATC (voice) communications is required.

4.2.2.2 ATS surveillance service may be used to assist contingency procedures, to mitigate the effect of blunder errors. The use of surveillance allows for controller intervention and therefore tighter route spacing than would otherwise be possible in an airspace where procedural separation is being applied. When ATS surveillance is relied upon to these ends, the system's performance should be fit for purpose, ensuring that the routes lie within the ATS surveillance and communications service volumes and the ATS resources are sufficient for these tasks.

4.2.2.3 When GNSS is used as the sole basis for both ATS surveillance and aircraft navigation, the risks and requirement for mitigation techniques associated with the loss of GNSS, potentially resulting in the loss of both navigation and surveillance capability, should be considered. This should typically be addressed through the regional or local State safety case prepared in support of the application.

4.2.2.4 The provisions relating to separation minima, including the direct VHF controller/pilot voice communications and ATS surveillance requirements can be found in Annex 11 – *Air Traffic Services* and the *Procedures for Air Navigation Services – Air Traffic* Management (PANS-ATM, Doc 4444) for the appropriate application. Controller-pilot data link communications (CPDLC) (FANS1/A) and ADS-C or ADS-B, or CPDLC (ATN) and ADS-B may be used providing they support the reporting rate required for the applications.

4.2.3 Obstacle clearance, route spacing and separation minima

4.2.3.1 General considerations

4.2.3.1.1 Advanced RNP (A-RNP) applications are intended for procedures where the obstacle/terrain environment, traffic density and aircraft separation, and runway access do not require RNP AR.

4.2.3.1.2 The overall safety of the operation can be managed in the terminal airspace through an ATM safety assessment, considering the use of surveillance services, departure intervals, wake vortex mitigations etc. A-RNP can also be applied to arrivals and departure procedures that are less complex and in a less demanding safety environment than RNP AR procedures, and that use standard instrument flight procedure design criteria.

4.2.3.2 Parallel offset considerations

Where parallel offsets are applied and a course change exceeds 120 degrees, the navigation system can be expected to terminate the offset no later than the fix where the course change occurs. The offset may also be terminated if the route segment ends at a hold fix.

Note.— Parallel offsets are typically applied in en-route airspace and not on SIDs/STARs and approaches. Where parallel offsets are applied, this may affect the spacing between routes.

4.2.3.3 Missed approach considerations

Advanced RNP (A-RNP) missed approach RNP value is normally 1 NM, but States may authorize 0.3 NM on an exceptional basis, subject to a safety assessment including at least the following items:

a) aircraft eligibility, such as inertial navigation system;

b) contingency procedures, including extraction considerations;

c) ATM infrastructure, including the available communications, navigation and satellite environment;

d) design of the missed approach path including the location of the first turn point and/or use of radius to fix (RF); and

e) publication and charting, including the navigation database.

4.2.4 Procedure validation

Guidance on procedure validation is provided in *The Quality Assurance Manual for Flight Procedure Design* (Doc 9906), Volume I – *Flight Procedure Design Quality Assurance System* and Volume V – *Validation of in Flight Procedures.*

Note.— Guidance on the flight inspection is provided in the Manual on Testing of Radio Navigation Aids *(Doc 8071).*

4.2.5 Publication

4.2.5.1 The State AIP should clearly indicate where A-RNP is being used in the publication of arrival or approach or departure procedures. This will be highlighted in the PBN requirements box.

4.2.5.2 The navigation data published in the State AIP for the procedures and supporting NAVAIDs must meet the requirements of Annex 15 – *Aeronautical Information Services* and Annex 4 – *Aeronautical Charts* (as appropriate). The original data defining the procedure should be available to the operators in a manner suitable to enable the operator to verify their navigation data.

4.2.6 Controller training

4.2.6.1 Air traffic controllers, who will provide control services for navigation applications using A-RNP, should have completed training that covers the items listed below.

4.2.6.2 Core training

a) How area navigation systems work (in the context of this navigation specification) in achieving reliable, repeatable and predictable procedures:

   1) include functional capabilities and limitations of this navigation specification;

   2) accuracy, integrity and continuity including on-board performance monitoring and alerting;

   3) availability of ATS and infrastructure;

   4) GNSS receiver, RAIM, FDE, and integrity alerts; and

   5) leg transitions, relative turn performance of waypoint fly-by versus fly-over concept;

b) flight plan requirements including the applicability of A-RNP to RNAV 1, RNAV 2, RNAV 5, RNP APCH, RNP 1 and RNP 2 applications;

c) ATC procedures:

1) ATC contingency procedures;

2) separation minima;

3) mixed equipage environment;

4) transition between different operating environments;

5) phraseology (consistency with PANS-ATM); and

6) ATC intervention considerations.

4.2.6.3 Training specific to this navigation specification

a) Related control procedures:

1) vectoring techniques (where appropriate);

2) RF leg limitations including ground speed constraints;

b) RNP approach related procedures:

1) approach minima;

2) potential negative impact of issuing an amended clearance for a procedure when the aircraft is already established on the procedure due to possible difficulty in complying with revised procedure requirements. Sufficient time needs to be allowed for the crew to accomplish navigation systems reprogramming requirements, such as a change to the en-route or runway transition;

c) RNP en-route:

1) FRT as a computed turn by the aircraft versus a unique en-route path segment;

d) parallel offsets: RNP systems termination of offsets and return to current flight plan; and

e) lateral performance associated with the route or procedure.

4.2.7 Navigation service monitoring

Navigation service monitoring should be consistent with Part A, Chapter 4.

4.2.8 Monitoring and investigation of navigation and system errors

The RNP value provides a basis for determining the lateral route spacing and horizontal separation minima necessary for traffic operating on a given route. When available, observations of each aircraft's proximity to track and altitude, based on ATS surveillance (such as radar, multilateration or automatic dependence surveillance), are typically noted by ATS facilities, and aircraft track-keeping capabilities are analysed. If an observation/analysis indicates that a loss of separation or obstacle clearance has occurred, the reason for the apparent deviation from track or altitude should be determined and steps taken to prevent a recurrence.

4.3 NAVIGATION SPECIFICATION

4.3.1 Background

This section identifies the operational requirements for A-RNP operations. Operational compliance with these requirements should be addressed through national operational regulations and may require a specific approval from the State of the Operator/Registry for commercial operations as applicable and non-commercial operations when required.

4.3.2 Authorization process

4.3.2.1 This navigation specification does not in itself constitute regulatory guidance material against which either the aircraft or the operator will be assessed and approved. Aircraft are certified by their State of Manufacture. Operators are approved in accordance with their national operating rules. This navigation specification provides the technical and operational criteria and does not necessarily imply a need for recertification.

Note 1.— Information related to certification and operational authorization is provided in the Appendix to this Chapter.

Note 2.— Where appropriate, States may refer to previous operational authorizations in order to expedite this process for individual operators where performance and functionality are applicable to the current request for operational authorization.

4.3.2.2 Aircraft eligibility

4.3.2.2.1 The aircraft eligibility should be determined through demonstration of compliance against the relevant airworthiness criteria and the requirements of 4.3.3. The aircraft original equipment manufacturer (OEM) or the holder of installation approval for the aircraft, such as the STC holder, will demonstrate compliance to their regulatory authority (such as the European Union Aviation Safety Agency (EASA) or the Federal Aviation Administration (FAA)), and the approval can be documented in manufacturer documentation (such as service letters). Aircraft flight manual (AFM) entries are not required provided the State accepts manufacturer documentation.

4.3.2.2.2 The aircraft OEM or the holder of installation approval for the aircraft should document demonstration of compliance with the A-RNP capability and highlight any limitations of functionality and performance.

Note.— Requests for approval to use optional functionality (such as FRT) should address the aircraft and operational requirements as described in the appropriate functional attachment to this volume.

4.3.2.3 Operational authorization

4.3.2.3.1 ***Description of aircraft equipment***

The operator must have a configuration list and, if necessary, an MEL detailing the required aircraft equipment for A-RNP operations. The optional time of arrival control (TOAC) capability must be documented if included in the approval.

4.3.2.3.2 ***Training documentation***

4.3.2.3.2.1 Commercial operators must have a training programme addressing the operational practices, procedures and training items related to A-RNP operations (such as initial, upgrade or recurrent training for flight crew, dispatchers or maintenance personnel).

Note.— Operators need not establish a separate training programme or regimen if they already integrate RNAV training as an element of their training programme. However, the operator should be able to identify the aspects of A-RNP covered within their training programme.

4.3.2.3.2.2 Private operators must be familiar with the practices and procedures identified in 4.3.6.

4.3.2.3.3 ***OMs and checklists***

4.3.2.3.3.1 Operations manuals (OMs) and checklists for commercial operators must address information/guidance on the SOP detailed in 4.3.4. The appropriate manuals should contain navigation operating instructions and contingency procedures, where specified. When required by the State of the Operator/Registry, the operator must submit their manuals and checklists for review as part of the application process. For each A-RNP application, equipment configurations, selected flight guidance modes and crew procedures are to be defined.

4.3.2.3.3.2 Private operators should operate using the practices and procedures identified in 4.3.6.

4.3.2.3.4 ***MEL considerations***

Any MEL revisions necessary to address A-RNP provisions must be approved. Operators must adjust the MEL, or equivalent, and specify the required dispatch conditions.

4.3.2.3.5 ***Continuing airworthiness***

The operator must submit the continuing airworthiness instructions applicable to the aircraft's configuration and the aircraft's qualification for this navigation specification. Additionally, there is a requirement for the operator to submit their maintenance programme, including a reliability programme for monitoring the equipment.

Note.— The operator should confirm with the OEM, or the holder of installation approval for the aircraft, that acceptance of subsequent changes in the aircraft configuration, such as SBs do not invalidate current operational authorization.

4.3.2.3.6 ***Approval documentation***

The approval should identify the equipment configuration and any limitations for each type of operations for which the operator is approved. A-RNP capabilities should be declared, including FRT, TOAC and higher continuity, such as dual independent navigation systems. The approval documentation should reflect any changes in aircraft configuration.

4.3.3 Aircraft requirements

4.3.3.1 This section describes the aircraft performance and functional criteria for aircraft to qualify for applications requiring A-RNP. Aircraft eligible for A-RNP operations must meet all the requirements of this chapter. The significant functional and performance requirements for A-RNP described herein are for RF legs, parallel offsets, RNP holding, and the options for higher continuity, FRTs and TOAC.

4.3.3.2 Approved RNP AR systems are considered to meet the system performance monitoring and alerting requirements without further examination. However, because of the broader application of this navigation specification, it contains additional functional requirements that are not included with the RNP AR navigation specification, such as RNP holding, parallel offset and FRT. If such capabilities have been demonstrated and are contained in an approved RNP AR system, documentation of compliance may be all that is necessary. If such capabilities are added to an RNP AR system or part of a new RNP system, they will be subject to typical regulatory reviews, demonstrations, tests and approval.

4.3.3.3 Communications and ATS surveillance equipment must be appropriate for the navigation application.

4.3.3.4 Some features/requirements may be required in one flight phase and optional or unnecessary in another. No distinctions are made regarding this flight phase association in providing a general set of criteria spanning all phases and navigation applications. Where such differences are deemed important, or the operational need is for one application, a more application-specific navigation specification, such as RNP 1 be used instead.

4.3.3.5 System performance, monitoring and alerting

4.3.3.5.1 ***RNP system performance***

4.3.3.5.1.1 *Accuracy.* During operations in airspace or on routes or procedures designated as A-RNP, the lateral total system error (TSE) must be within the applicable accuracy (±0.3 NM to ±2.0 NM) for at least 95 per cent of the total flight time. The along-track error must also be within ± the applicable accuracy for at least 95 per cent of the total flight time. To satisfy the accuracy requirement, the 95 per cent FTE should not exceed one half of the applicable accuracy.

Note.— The use of a deviation indicator is an acceptable means of compliance for satisfying the FTE part of the lateral TSE with the scaling commensurate with the navigation application.

4.3.3.5.1.2 *Integrity.* Malfunction of the aircraft navigation equipment is classified as a major failure condition under airworthiness guidance material (that is, 1×10^{-5} per flight hour).

4.3.3.5.1.3 *Continuity.* Loss of function is classified as a minor failure condition for applications predicated on this navigation specification. Where a State or application establishes a classification of “major”, the continuity requirement may be typically satisfied by carriage of dual independent navigation systems.

4.3.3.5.2 ***On-board performance monitoring and alerting***

4.3.3.5.2.1 On-board performance monitoring and alerting is required. This section provides the criteria for a TSE form of performance monitoring and alerting (as described in Part A, Chapter 2, 2.3.3) that will ensure a consistent evaluation and assessment of compliance that can be applied across all the possible applications in 4.1.1.

4.3.3.5.2.2 The aircraft navigation system, or aircraft navigation system and flight crew in combination, is required to monitor the TSE, and to provide an alert if the accuracy requirement is not met or if the probability that the TSE exceeds two times the accuracy value is larger than 10^{-5}. To the extent operational procedures are used to satisfy this requirement, the crew procedure, equipment characteristics and installation should be evaluated for their effectiveness and equivalence. Examples of information provided to the flight crew for awareness of navigation system performance include “EPU”, “ACTUAL”, “ANP” and “EPE”. Examples of indications and alerts provided when the operational requirement is or can be determined as not being met include “UNABLE RNP”, “Nav Accur Downgrad”, GNSS alert, loss of GNSS integrity, TSE monitoring (real time monitoring of NSE and FTE combined), etc. The navigation system is not required to provide both performance and sensor-based alerts, such as if a TSE-based alert is provided, a GNSS alert may not be necessary.

4.3.3.6 Criteria for specific navigation services

4.3.3.6.1 This section identifies unique issues for the navigation sensors.

4.3.3.6.2 *GNSS*. A-RNP operations are based on GNSS positioning. The aircraft’s RNP system may integrate GNSS positioning with positioning data from other types of navigation sensors during A-RNP operations as long as the positioning data from those other navigation sensors do not result in position errors exceeding the applicable TSE budget for the operation.

4.3.3.6.3 *Inertial navigation systems*. An inertial navigation system must satisfy the criteria of US 14 CFR Part 121, Appendix G, or equivalent (such as RTCA DO-384). While Appendix G defines the requirement for a 2 NM per hour drift rate (95 per cent) for flights up to 10 hours, this rate may not apply to an RNP system after loss of position updating. Systems that have demonstrated compliance with Part 121, Appendix G, can be assumed to have an initial drift rate of 4 NM/hour for the first 30 minutes (95 per cent) without further substantiation. Aircraft manufacturers and applicants can demonstrate improved inertial navigation system performance in accordance with the methods described in FAA AC 20-138D or the EASA CS ACNS.

Note.— The RNP system’s integration of the aircraft’s GNSS sensor with the aircraft’s approved inertial navigation system can enhance the availability of RNP after loss of GNSS. For “tightly coupled” GNSS/inertial integrations, see RTCA/DO-229(), Appendix R of RTCA/DO-384. For other categories of GNSS/inertial navigation system integration see RTCA/DO-384.

4.3.3.6.4 *DME*. For A-RNP procedures and routes, the RNP system may only use DME updating when authorized by the State. The manufacturer should identify any operating constraints (such as manual inhibit of DME) in order for a given aircraft to comply with this requirement.

Note 1.— This is in recognition of States where a DME infrastructure and capable equipped aircraft are available, those States may establish a basis for aircraft qualification and operational authorization to enable use of DME. It is not intended to imply a requirement for implementation of DME infrastructure or the addition of RNP capability using DME for RNP operations.

Note 2.— This does not imply an equipment capability must exist providing a direct means of inhibiting DME updating. A procedural means for the flight crew to inhibit DME updating or executing a missed approach if reverting to DME updating may meet this requirement.

4.3.3.6.5 *VHF omnidirectional radio range (VOR) station*. For A-RNP procedures, the RNP system must not use VOR updating. The manufacturer should identify any operating constraints (such as manual inhibit of VOR) in order for a given aircraft to comply with this requirement.

Note.— This does not imply an equipment capability must exist providing a direct means of inhibiting VOR updating. A procedural means for the flight crew to inhibit VOR updating may be acceptable.

4.3.3.6.6 For multi-sensor systems, there must be automatic reversion to an alternate RNP sensor if the primary RNP sensor fails. Automatic reversion from one multi-sensor system to another multi-sensor system is not required.

4.3.3.7 Functional requirements

The RNP aircraft and system functional requirements in this section are based on published standards within RTCA DO-236() and DO-283(), EUROCAE ED-75() and regulatory guidance including FAA AC 20-138() and EASA CS-ACNS. The set of A-RNP functional requirements are more extensive than those needed for the A-RNP navigation application shown in Table II-A-1-1, due to the need to encompass multiple navigation applications and enable RNP aircraft and systems capabilities for future applications.

4.3.3.7.1 ***Displays – guidance, situation and status***

Item	*Function/feature*	*Description*
a)	Continuous display of deviation	1) The navigation system must provide the capability to continuously display to the pilot flying, on the primary flight instruments for navigation of the aircraft, the aircraft position relative to the RNP defined path. 2) For operations where the required minimum flight crew is two pilots, the means for the pilot not flying to verify the desired path and the aircraft position relative to the path must also be provided. 3) The display must allow the pilot to readily distinguish whether the cross-track deviation exceeds the navigation accuracy (or a smaller value). 4) The numeric display of deviation on a map display with an appropriately scaled deviation indicator is generally considered acceptable for monitoring deviation. 5) Moving map displays without an appropriately scaled deviation indicator may be acceptable depending on the task, flight crew workload, display characteristics, flight crew procedures and training.
b)	Identification of the active (To) waypoint	The navigation system must provide a display identifying the active waypoint either in the pilot's primary optimum field of view, or on a readily accessible and visible display to the flight crew.

Item	*Function/feature*	*Description*
c)	Display of distance and bearing	The navigation system must provide a display of distance and bearing to the active (To) waypoint in the pilot's primary optimum field of view. Where not viable, a readily accessible page on a control display unit, readily visible to the flight crew, may display the data.
d)	Display of groundspeed and time	The navigation system must provide the display of groundspeed and time to the active (To) waypoint in the pilot's primary optimum field of view. Where not viable, a readily accessible page on a control display unit, readily visible to the flight crew, may display the data.
e)	Desired track display	The navigation system must have the capability to continuously display to the pilot flying the aircraft desired track. This display must be on the primary flight instruments for navigation of the aircraft.
f)	Display of aircraft track	The navigation system must provide a display of the actual aircraft track (or track angle error) either in the pilot's primary optimum field of view or on a readily accessible and visible display to the flight crew.
g)	Failure annunciation	The aircraft must provide a means to annunciate failures of any aircraft component of the RNP system, including navigation sensors. The annunciation must be visible to the pilot and located in the primary optimum field of view.
h)	Slaved course selector	The navigation system must provide a course selector automatically slaved to the RNP computed path.
i)	Display of distance to go	The navigation system must provide the ability to display distance to go to any waypoint selected by the flight crew.
j)	RNP selection	As a minimum, the RNP system must be capable of manual or automatic entry and display of navigation accuracies of 0.3 NM, 1 NM and 2 NM. The RNP system must provide lateral deviation displays and alerting appropriate to the selected navigation accuracy and application. *Notes:* 1. *One acceptable means of compliance is to implement RNP scalability and display in accordance with the Non-Numeric Display/Output Requirements contained within DO-236(), ED-75() and DO-283().* 2. *Another means of compliance is to develop a moving map display with appropriate map scales, and which provides equivalent functionality to a non-numeric lateral deviation display.*

Item	*Function/feature*	*Description*
		3. It is recognized that aircraft and equipment that are based upon GNSS standards such as RTCA DO-208() and DO-229() have RNP capabilities for lateral deviation and alerting that are generally associated with navigation accuracies of 0.3 NM, 1.0 NM and 2.0 NM only. Such capability exists in a large portion of the aircraft fleet but may not be extended to other navigation accuracies or the means of compliance specified herein. Additionally, some of this fleet does provide the capability to select other navigation accuracies. Therefore, before a manufacturer implements or an operator applies this functional capability, it is recommended that they determine the effects of the resolution of a number of issues including: *a) how their aircraft and systems will be affected or accommodated operationally when different navigation accuracy requirements are needed;* *b) is there a basis for implementing improved functionality or operating procedures; and* *c) how such systems will need to be qualified, used by the flight crew and operationally approved.*
k)	Display of distance between flight plan waypoints	The navigation system must provide the ability to display the distance between flight plan waypoints.
l)	Display of deviation	The navigation system must provide a numeric display of the lateral deviation with a resolution of 0.1 NM or less.
m)	Display of active sensors	The aircraft must display the current navigation sensor(s) in use. It is recommended that this display be provided in the primary optimum field of view. *Note.— This display is used to support operational contingency procedures. If such a display is not provided in the primary optimum field of view, crew procedures may mitigate the need for this display if the workload is determined acceptable.*

4.3.3.7.2 ***Path definition and flight planning***

<table>
<tr><th>Item</th><th>Function/feature</th><th>Description</th></tr>
<tr><td>a)</td><td>Maintaining tracks and leg transitions</td><td>
The aircraft must have the capability to execute leg transitions and maintain tracks consistent with the following ARINC 424 path terminators:
ARINC 424 path terminators
<table>
<tr><td>IF</td></tr>
<tr><td>CF</td></tr>
<tr><td>DF</td></tr>
<tr><td>TF</td></tr>
<tr><td>RF, see Appendix 1 to Part C, Volume II</td></tr>
<tr><td>CA</td></tr>
<tr><td>course from a fix to altitude (FA)</td></tr>
<tr><td>VA</td></tr>
<tr><td>course from an FM</td></tr>
<tr><td>VM</td></tr>
<tr><td>VI</td></tr>
<tr><td>HM</td></tr>
</table>
Where authorization is sought for FRT in association with this navigation specification, the RNP system must have the capability to create FRTs between route segments, based upon the data contained in the aircraft navigation system database – see Appendix 2 to Part C.
Notes:
1. Path terminators and the FRT are defined in ARINC 424, and their application is described in more detail in RTCA/EUROCAE documents DO-236()/ED-75() and DO-201()/ED-77().
2. The list of path terminators includes a number that introduce variability in the flight path to be flown by the aircraft. For all RNP applications, the preferred path terminators are IF, DF, TF, and RF. Other path terminators may be used on the understanding that they will introduce less repeatability, predictability and reliability of aircraft lateral path performance.
</td></tr>
</table>

Item	*Function/feature*	*Description*
		3. For the VA, VM and VI path terminators, if the aircraft is unable to automatically execute these leg transitions, they should be able to be manually flown on a heading to intercept a course or to go direct to another fix after reaching a procedure-specified altitude.
b)	Leg transition	Fly-by and fly-over fixes. The aircraft must have the capability to execute fly-by and fly-over fixes. For fly-by turns, the navigation system must limit the path definition within the theoretical turn transition area described in Volume I, Attachment A, 5.2. The fly-over turn is not compatible with RNP flight tracks and will only be used when there is no requirement for repeatable paths. FRTs: Where authorization is sought for FRTs, the aircraft must have the capability to execute the function in accordance with Appendix 2 to Part C.
c)	Intercepts	The RNP system should provide the ability to intercept the final approach at or before the FAF. This functional capability must provide the pilot with the ability to rejoin the published final approach track following a period when the aircraft has been flown manually, or in heading mode, following ATC vectors to support final approach sequencing. The implementation method and visual information (MCDU and primary displays (map display/ EHSI)) should be sufficient to enable the correct re-acquisition of the track with a minimum of manual intervention on the MCDU. Due account must be taken of the workload associated with the re-acquisition and the impact of errors in leg sequencing.
d)	RNP Holding	The system with the minimum of crew intervention must be capable of initiating, maintaining and discontinuing holding procedures at any point and at all altitudes. A holding procedure will only normally be required at defined holding points on entry to terminal airspace. However, holding may be required by ATC at any point. A hold is required to be defined by a point, the turn direction, an inbound track and an outbound time or distance. This data may be extracted from the database for published holds or may be manually entered for ad hoc ATC holds. *Notes:* *1. It is highly desirable that the RNP system provide a holding function that includes the computation of the hold flight path, guidance and/or cues to track the holding entry and path.*

Item	*Function/feature*	*Description*
		2. *One acceptable means of compliance is to implement holding in accordance with DO-236(), ED-75() and DO-283().*
e)	Parallel offset	Parallel offsets provide a capability to fly offset from the parent track, as defined by the series of waypoints. The turn defined for the parent track (fly-by or FRT) is required to be applied in the offset track. Parallel offsets are applicable only for en-route segments and are not foreseen to be applied on SIDs, STARs or approach procedures. The activation of an offset must be clearly displayed to the flight crew and the cross-track deviation indication during the operation of the offset will be to the offset track.
f)	Offset execution	Parallel offsets may be performed through the RNP system or manually, through flight crew action. The RNP system should be capable of flying tracks offset by up to 20 NM from the parent track. The presence of an offset should be continuously indicated. Tracks offset from the parent track should be continued for all ATS route segments and turns until either: a) removed by the crew; or b) automatically cancelled following: 1) amendment of the active flight plan by executing a “direct-to”; 2) commencement of a terminal procedure; and 3) where a course change exceeds 120°. In this case, the RNP system may terminate the offset at the fix where the course change occurs. The offset may also be terminated if the route segment ends at a hold fix. The flight crew should be given advance notice of this cancellation. The cross-track offset distance should be manually entered into the RNP system to a resolution of 1 NM or better. Where parallel offsets are applied, the lateral track-keeping requirement of RNP must be maintained referenced to the offset track.

Item	*Function/feature*	*Description*
		Where FRTs are applied, the offset track must be flown with the same turn radius as the parent track.
g)	Entry and recovery from offsets	Transitions to and from the offset track must maintain an intercept angle of 30°.
h)	Capability for a "direct-to" function	The navigation system must have a "direct-to" function the flight crew can activate at any time. This function must be available to any fix. The navigation system must also be capable of generating a geodesic path to the designated "To" fix without "S-turning" and without undue delay.
i)	Altitudes and/or speeds associated with published terminal procedures	Altitudes and/or speeds associated with published terminal procedures must be extracted from the navigation database.
j)	Capability to load procedures from the navigation database	The navigation system must have the capability to load the entire procedure(s) to be flown into the RNP system from the on-board navigation database.
k)	Means to retrieve and display navigation data	The navigation system must provide the ability for the flight crew to verify the procedure to be flown through review of the data stored in the on-board navigation database. This includes the ability to review the data for individual waypoints and for NAVAIDs.
l)	Magnetic variation	For paths defined by a course (such as CF and FA path terminators), the navigation system should use the appropriate magnetic variation value in the navigation database. See Attachment E.
m)	Changes in navigation accuracy	The RNP system should automatically retrieve and set the navigation accuracy for each leg segment of a route or procedure from the on-board navigation database. When a change occurs to a smaller navigation accuracy, such as from RNP 1.0 to RNP 0.3, the change must be complete by the first fix defining the leg with the smaller navigation accuracy requirement. The timing of this change must also consider any latency in alerting from the RNP system. When the RNP system cannot automatically set the navigation accuracy for each leg segment, any operational procedures necessary to accomplish this must be identified. *Note.— One acceptable means to meet this requirement may be to require the flight crew to manually set the smallest navigation accuracy the route or procedure uses before commencing the route or procedure (that is, prior to the IAF).* If the navigation accuracy for the RNP system has been set manually by the flight crew and following an RNP system change to the navigation accuracy required (such as the next flight path segment contains a different navigation accuracy), the RNP system should provide an alert to the flight crew.

Item	*Function/feature*	*Description*
n)	Automatic leg sequencing	The navigation system must provide the capability to automatically sequence to the next leg and display the sequencing to the flight crew in a readily visible manner.

4.3.3.7.3 ***System***

Item	*Function/feature*	*Description*
a)	*Design assurance*	The system design assurance must be consistent with at least a major failure condition for the display of misleading lateral or vertical guidance in RNP applications.
b)	*Navigation database*	The aircraft navigation system must use an on-board navigation database, containing current navigation data officially promulgated for civil aviation, which can be updated in accordance with the AIRAC cycle, and allow retrieval and loading of procedures into the RNP system. The stored resolution of the data must be sufficient to achieve negligible path definition error (PDE). The on-board navigation database must be protected against flight crew modification of the stored data. When a procedure is loaded from the database, the RNP system must fly the procedure as published. This does not preclude the flight crew from having the means to modify a procedure or route already loaded into the RNP system. However, the procedures stored in the navigation database must not be modified and must remain intact within the navigation database for future use and reference. The aircraft must provide a means to display the validity period for the on-board navigation database to the flight crew. The equipment should not permit the flight crew to either manually or automatically select a route that is not supported. A route is not supported if it incorporates an FRT and the equipment does not provide FRT capability. The RNP system should also restrict pilot access to routes requiring FRTs if the equipment can support the route, but the aircraft is not otherwise equipped (such as the aircraft does not have the required roll steering autopilot or flight director installed). *Note.— An alternate means of satisfying this requirement is to remove such routes from the navigation database.*

4.3.4 Operating procedures

Airworthiness certification alone does not authorize RNP operations. Operational authorization is also required to confirm the adequacy of the operator's normal and contingency procedures for the particular equipment installation.

4.3.4.1 Preflight planning

4.3.4.1.1 Operators and pilots intending to conduct RNP operations requiring A-RNP capability should indicate the appropriate application in the flight plan.

4.3.4.1.2 The on-board navigation data must be current and appropriate to the route being flown and for potential diversions. Navigation databases are expected to be current for the duration of the flight. If the AIRAC cycle is due to change during flight, operators and pilots should establish procedures to ensure the accuracy of navigation data, including suitability of navigation facilities used to define the routes and procedures for flight.

4.3.4.1.3 Operators using GNSS equipment should confirm the availability of RAIM by using RAIM availability prediction software taking account of the latest GNSS NOTAMs. Operators using SBAS augmentation should also check the relevant SBAS NOTAMs to determine the availability of SBAS. Notwithstanding preflight analysis results, because of unplanned failure of some GNSS or DME elements (or local interference), pilots must realize that integrity availability (or GNSS/DME navigation altogether) may be lost while airborne, which may require reversion to an alternate means of navigation. Therefore, pilots should assess their capability to navigate in case of failure of the primary sensor or the RNP system.

4.3.4.2 General operating procedures

4.3.4.2.1 Operators and pilots should not request or file RNP routes, SIDs, STARs or approaches unless they satisfy all the criteria in the relevant State documents. The pilot should comply with any instructions or procedures identified by the manufacturer, as necessary, to comply with the performance requirements in this chapter.

Note.— Pilots are expected to adhere to any AFM limitations or operating procedures required to maintain the RNP for the operation.

4.3.4.2.2 At system initialization, pilots must confirm the navigation database is current and verify that the aircraft position has been entered correctly. Pilots must not fly an A-RNP route, SID, STAR or approach unless it is retrievable by name from the on-board navigation database and conforms to the chart. An A-RNP route, SID, STAR or approach should not be used if doubt exists as to the validity of the procedure in the navigation database.

Note.— Flight crew may notice a slight difference between the navigation information portrayed on the chart and their primary navigation display. Differences of three degrees or less may result from equipment manufacturer's application of magnetic variation and are operationally acceptable.

4.3.4.2.3 Cross-checking with conventional NAVAIDs is not required as the absence of integrity alert is considered sufficient to meet the integrity requirements. However, monitoring of navigation reasonableness is suggested, and any loss of RNP capability must be reported to ATC. While operating on A-RNP routes, SIDs, STARs or approaches, pilots are encouraged to use flight director and/or autopilot in lateral navigation mode, if available. Flight crew should be aware of possible lateral deviations when using raw path steering data or Navigation Map Displays for lateral guidance in lieu of flight director. When the dispatch of a flight into A-RNP operations is predicated on use of the autopilot/flight director at the destination and/or alternate, the dispatcher/flight crew must determine that the autopilot/flight director is installed and operational.

4.3.4.3 Manual entry of required navigation accuracy

If the navigation system does not automatically retrieve and set the navigation accuracy from the on-board navigation database for each leg segment of a route or procedure, the flight crew's operating procedures should ensure the smallest navigation accuracy for the route or procedure is manually entered into the RNP system.

4.3.4.4 Departure specific requirements

4.3.4.4.1 Prior to flight, pilots must verify their aircraft navigation system is operating correctly and the correct runway and departure procedure (including any applicable en-route transition) are entered and properly depicted. Pilots who are assigned an A-RNP departure procedure and subsequently receive a change of runway, procedure or transition must verify the appropriate changes are entered and available for navigation prior to take-off. A final check of proper runway entry and correct route depiction, shortly before take-off, is recommended.

4.3.4.4.2 *Engagement altitude*. The pilot must be able to use RNP equipment to follow flight guidance for lateral navigation no later than 153 m (500 ft) above the airport elevation.

4.3.4.4.3 Pilots must use an authorized method (lateral deviation indicator/navigation map display/flight director/autopilot) to achieve an appropriate level of performance, including appropriate guidance in a RF turn during departure.

4.3.4.4.4 *GNSS aircraft.* When using GNSS, the signal must be acquired before the take-off roll commences. For aircraft using FAA TSO-C129a equipment, the departure airport must be loaded into the flight plan to achieve the appropriate navigation system monitoring and sensitivity. For aircraft using FAA TSO-C145()/C146() equipment, if the departure begins at a runway waypoint, then the departure airport does not need to be in the flight plan to obtain appropriate monitoring and sensitivity.

4.3.4.5 Arrival specific requirements

4.3.4.5.1 Prior to the arrival phase, the flight crew should verify that the correct terminal route has been loaded. The active flight plan should be checked by comparing the charts with the map display (if applicable) and the MCDU. This includes confirmation of the waypoint sequence, reasonableness of tracks and distances, any altitude or speed constraints, and, where possible, which waypoints are fly-by and which are fly-over. If required by a route, a check will need to be made to confirm that updating will exclude a particular NAVAID. A route must not be used if doubt exists as to the validity of the route in the navigation database.

Note.— As a minimum, the arrival checks could be a simple inspection of a suitable map display that achieves the objectives of 4.3.4.5.1.

4.3.4.5.2 The creation of new waypoints by manual entry into the RNP system by the flight crew would invalidate the route and is not permitted.

4.3.4.5.3 Where the contingency procedure requires reversion to a conventional arrival route, necessary preparations must be completed before commencing the RNP route.

4.3.4.5.4 Route modifications in the terminal area may take the form of headings or "direct to" clearances and the flight crew must be capable of reacting in a timely fashion. This may include the insertion of tactical waypoints loaded from the database. Manual entry or modification by the flight crew of the loaded route, using temporary waypoints or fixes not provided in the database, is not permitted.

4.3.4.5.5 Pilots must verify their aircraft navigation system is operating correctly, and the correct arrival procedure and runway (including any applicable transition) are entered and properly depicted.

4.3.4.5.6 Although a particular method is not mandated, any published altitude and speed constraints must be observed. Approaches using temporary waypoints or fixes not provided in the navigation database are not permitted.

4.3.4.6 Contingency procedures

4.3.4.6.1 The pilot must notify ATC of any loss of the RNP capability (integrity alerts or loss of navigation), together with the proposed course of action. If unable to comply with the requirements of an RNP SID or STAR, pilots must advise ATS as soon as possible. The loss of RNP capability includes any failure or event causing the aircraft to no longer satisfy the A-RNP requirements of the route.

4.3.4.6.2 In the event of communications failure, the flight crew should continue with the A-RNP SID or STAR in accordance with the published lost communications procedure.

4.3.5 Navigation database

4.3.5.1 Navigation data management is addressed in Annex 6 – *Operation of* Aircraft, Part I – *International Commercial Air Transport – Aeroplanes*, Chapter 7. The navigation database should be obtained from a supplier that complies with RTCA DO 200()/EUROCAE document ED 76(), Standards for Processing Aeronautical Data. A letter of authorization (LOA) issued by the appropriate regulatory authority demonstrates compliance with this requirement (such as FAA LOA issued in accordance with FAA AC 20-153() or EASA certification of data services provider in accordance with Regulation (EU) 2017/373 (Part DAT)).

4.3.5.2 Discrepancies that invalidate an A-RNP route, SID or STAR must be reported to the navigation database supplier and the affected route, SID or STAR must be prohibited by an operator's notice to its flight crew.

4.3.5.3 For A-RNP procedures, the database supplier is discouraged from substitution of path terminators in lieu of those specified in the original AIP data. Where this is necessary, there must be coordination with the State or service provider to gain operational acceptability and authorization for such substitutions.

4.3.5.4 Aircraft operators should consider the need to conduct ongoing checks of the operational navigation databases in order to meet existing quality system requirements.

4.3.6 Pilot knowledge and training

The training programme should provide sufficient training (such as simulator, training device, or aircraft) on the aircraft's RNP system to the extent that the pilots are familiar with the following:

a) the meaning and proper use of aircraft equipment/navigation suffixes;

b) procedure characteristics as determined from chart depiction and textual description:

   1) depiction of waypoint types (fly-over, fly-by, RF and FRT), altitude and speed restrictions and path terminators as well as associated aircraft flight paths; and

   2) required navigation equipment for operation on A-RNP routes, departure procedures, arrival procedures and instrument approach procedures including missed approaches;

c) RNP system-specific information:

1) levels of automation, mode annunciations, changes, alerts, interactions, reversions and degradation;

2) functional integration with other aircraft systems;

3) the meaning and appropriateness of route discontinuities as well as related flight crew procedures;

4) monitoring procedures for each phase of flight (for example, monitor PROG or LEGS page);

5) types of navigation sensors (GNSS) used by the RNP system and associated system prioritization/weighting/logic;

6) turn anticipation with consideration to speed and altitude effects;

7) interpretation of electronic displays and symbols; and

8) automatic and/or manual setting of the required navigation accuracy;

d) understand the performance requirement to couple the autopilot/flight director to the navigation system's lateral guidance on A-RNP procedures, if required;

e) the equipment should not permit the flight crew to select a procedure or route requiring particular functions (such as FRTs) that are not supported by the equipment;

f) RNP equipment operating procedures, as applicable, including how to perform the following actions:

1) verify currency and integrity of aircraft navigation data;

2) verify successful completion of RNP system self-tests;

3) initialize navigation system position;

4) retrieve and fly a SID or a STAR with appropriate transition;

5) adhere to speed and/or altitude constraints associated with a SID or STAR;

6) select the appropriate STAR or SID for the active runway in use and be familiar with procedures to deal with a runway change;

7) verify waypoints and flight plan programming;

8) perform a manual or automatic runway update (with take-off point shift, if applicable);

9) fly direct to a waypoint;

10) fly a course/track to a waypoint;

11) intercept a course/track (fly vectors, and rejoin an RNP route/procedure from the "heading" mode);

12) Determine cross-track error/deviation, more specifically, the maximum deviations allowed to support A-RNP must be understood and respected;

13) where applicable, the importance of maintaining the published path and maximum airspeeds while performing RNP operations with RF legs or FRTs;

14) insert and delete route discontinuity;

15) remove and reselect navigation sensor input;

16) when required, confirm exclusion of a specific NAVAID or NAVAID type;

17) when required by the State aviation authority, perform gross navigation error check using conventional NAVAIDs;

18) change arrival airport and alternate airport;

19) perform parallel offset function: pilots should know how offsets are applied, the functionality of their particular RNP system and the need to advise ATC if this functionality is not available;

20) perform RNP holding;

21) flight crew contingency procedures for a loss of RNP capability;

22) manual setting of the required navigation accuracy;

Note.— Operators are strongly encouraged to use manufacturer-recommended training and operating procedures.

g) operator-recommended levels of automation for phase of flight and workload, including methods to minimize cross-track error to maintain route centre line; and

h) R/T phraseology for RNAV/RNP applications.

4.3.7 Oversight of operators

4.3.7.1 A regulatory authority should consider any navigation error reports in determining remedial action. Repeated navigation error occurrences attributed to a specific piece of navigation equipment may result in the cancellation of the authorization for the use of that equipment.

4.3.7.2 Information that indicates the potential for repeated errors may require modification of an operator's training programme and, at the discretion of the approving State, may result in the establishment of operator RNP monitoring programmes.

4.4 REFERENCES

The applicable versions of industry and regulatory references, standards and guidance included in this chapter, shown as open reference (), are listed in Attachment E to this volume. Some references contained in the chapter are part of background or historical information, and not included in Attachment E.

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Appendix to Chapter 4

1. INTRODUCTION

1.1 A high-level description of the applicability, RNP value and select RNP features for all navigation specifications is contained in Part A, Chapter 1. These navigation specifications were developed to enable specific airspace concepts, with an associated infrastructure enabling a single navigation application – usually limited to one flight phase.

1.2 Advanced RNP (A-RNP) is different when compared to the other performance-based navigation (PBN) specifications. Aside from being a stand-alone specification, not having a one-to-one relationship with a particular flight phase, it also covers a variety of navigation applications from take-off to approach. Thus A-RNP offers unique functions creating alternatives for stakeholders in their ATM operations implementing PBN.

2. BACKGROUND

2.1 Advanced RNP (A-RNP) was conceived as a terminal solution to optimize airspace usage and facilitate operational capacity and efficiency.

2.2 A key aspect of A-RNP is the inclusion of more advanced capabilities, recognizing that these required functions reflect capable RNP systems in-service that may enable new navigation applications. The optional functions allow for evolving system implementation based upon changes for far term operational needs.

2.3 In developing the guidance and criteria, the possibility that future operational needs could lead to an increase in the number of future navigation specifications was foreseen. This would create the potential problem of too much complexity in both the navigation applications and authorizations for RNP systems and aircraft capabilities. A-RNP became a solution to enable a single airworthiness and multiple operational authorizations for an RNP system that spans a select number of RNAV and RNP applications and multiple flight phases, now and in the future. This is achieved in part by its broader set of performance requirements, capabilities and functionality included in the navigation specification.

3. A-RNP SCOPE AND APPLICABILITY

3.1 This section clarifies the relationship between the functions described in the navigation specification and the navigation applications.

3.2 Most navigation specifications have been derived from existing guidance material and criteria associated with specific types of applications, such as departure/arrival, approach, en-route, continental, oceanic or remote area. This results in a separate activity for all stakeholders for each navigation specification with regard to aircraft qualification. This is not the case for A-RNP.

3.3 Advanced RNP (A-RNP) has a dual purpose. Although A-RNP is firstly a navigation specification in its own right, it allows manufacturers to bundle optional capabilities along with required capabilities when qualifying an aircraft for a variety of navigation specifications and applications.

3.4 Advanced RNP (A-RNP) may be used for the certification of an RNP system when an RNP aircraft seeks multiple qualification covering RNP 2, RNP 1 and RNP APCH, as well as for RNAV 5, RNAV 2 RNAV 1 (see Table II-A-1-1). The A-RNP navigation specification must be used for applications requiring RNP value of 0.3 NM (outside of the final approach segment (FAS)) and exclusive A-RNP capabilities included in the A-RNP application.

3.5 Advanced RNP (A-RNP) describes a broad set of functions and options that can be applied to address operational needs across multiple flight phases stemming from ATM modernization, airspace redesign, capacity/efficiency improvements and others that cannot be addressed by other navigation specifications or their optional functions. The parallel offset function, which is defined by DO-236()/ED-75(), is exclusive to A-RNP.

Note.— Aircraft holding is an accepted pre-existing in-service capability for RNAV 5, RNAV 2, RNAV 1, RNP 1 and RNP APCH. There are no functional requirements for holding except in A-RNP where functional requirements, a path terminator and a means of compliance are specified.

Table II-C-4-App-1. Navigation specifications included by an A-RNP airworthiness approval

Navigation specification	*Volume II*
RNAV 5	Part B, Chapter 2
RNAV 1	Part B, Chapter 3
RNAV 2	Part B, Chapter 3
RNP 2	Part C, Chapter 2
RNP 1	Part C, Chapter 3
RNP APCH	Part C, Chapter 5

3.6 This navigation specification shares certain functions with other navigation specifications.

Table II-C-4-App-2. Functionalities A-RNP shares with other navigation specifications

Shared functionalities	*Advanced RNP Status*	*Reference*	*Association within other Navigation Specifications*
Higher continuity	Optional	4.3.3.5.1.3 of Chapter 4	See Part A, Chapter I, Table II-A-1-2
RF	Required	Appendix 1 to Part C	
FRT	Optional	Appendix 2 to Part C	

Shared functionalities	*Advanced RNP Status*	*Reference*	*Association within other Navigation Specifications*
TOAC	Optional	Appendix 3 to Part C	
Parallel offset[2]	Required	Chapter 4, 4.3.3.7.2 e), f) and g)	

Note.— The parallel offset function is a pre-existing in-service capability that is acknowledged in RNAV 2, RNAV 1, RNP 1 and RNP 0.3, even though these navigation specifications do not include it as a required function. Parallel offset is required for RNP 4, is optional in RNP 2 and reflects the regulatory acceptance of pre-existing in-service capability. The parallel offset function identified within A-RNP is specified in accordance with DO-236()/ED-75().

4. STAKEHOLDER CONSIDERATIONS

4.1 States and service providers

4.1.1 Application and performance requirements

4.1.1.1 Advanced RNP (A-RNP) would not be shown in any chart title. This said, it could be expected to appear in the PBN requirements box under certain circumstances. Examples include:

a) when an RNP SID or STAR requires A-RNP's exclusive functions or performance;

b) the final approach segment of any instrument approach procedure is preceded by an intermediate approach requiring exclusive A-RNP functionalities or performance; and

c) an instrument approach's missed approach segment requires A-RNP functionalities.

4.1.1.2 States and service providers should only implement and designate a procedure such as A-RNP based upon the application requirements shown in Table II-A-1-1 including any A-RNP required functions. A-RNP also provides a baseline for 4D evolutions and future airspace developments.

4.1.1.3 Different lateral navigation accuracies apply to A-RNP in different flight phases, as shown in Table II-A-1-1. These are as follows:

a) 2 NM is applicable in oceanic or remote continental;

b) 2 or 1 NM is applicable in en-route continental; and

c) 1.0 NM or 0.3 NM is applicable in the arrival and departure phases, and in the initial, intermediate and missed approach segments.

4.1.1.4 Advanced RNP (A-RNP) is a versatile navigation specification that does not invoke the more rigorous aircraft and operational requirements that require a specific approval. However, it does exploit modern aircraft capabilities to the greatest extent, including RNP value and functions within the standard procedure design criteria defined in the *Procedures for Air Navigation Services – Aircraft Operations*, Volume II – *Construction of Visual and Instrument Flight Procedures* (Doc 8168). Within a terminal environment, an RNP value of 0.3 NM is expected to support more closely spaced arrival and departure routes in complex, high density airspace where a surveillance service is an essential mitigating factor.

4.1.1.5 Aircraft are developed for a broad range of operations and applications. In the case of RNP applications, some may be intended to perform either or both A-RNP and RNP AR operations. An aircraft qualified to the A-RNP navigation specification in compliance with either FAA AC 20-138D, Change 2 or later, or EASA CS-ACNS, will have to demonstrate an RNP value of 0.3 NM in all of the terminal applications except in the missed approach, where an RNP value of 1 NM will have to be demonstrated.

4.1.1.6 Although most RNP AR APCH qualified aircraft are also A-RNP capable, some may not be and vice-versa. Therefore, it is essential to fully establish the aircraft eligibility requirements and which navigation specification can fulfil those particular requirements. Fleet capabilities and CNS infrastructure all feature in the assessment that must be made as part of any airspace design. The distinction between RNP AR and A-RNP cannot be assessed based on RNP value alone but has to be carefully considered within the operational context.

4.1.1.7 An aircraft eligible for A-RNP by means of its qualification for RNP AR APCH in accordance with Federal Aviation Administration (FAA) AC 20-138() and AC 90-101() or EASA CS-ACNS, is required to demonstrate an RNP value of 0.3 NM, with less than 0.3 NM as an option. Additionally, the aircraft may have an AFM limitation, restricting the RNP value for the missed approach segment to 1 NM. In all respects, the aircraft may meet the A-RNP requirements, but carry this limitation in the missed approach segment. For this reason, A-RNP applications use an RNP value of 1 NM in the missed approach. Exceptionally, an RNP value of 0.3 NM in the missed approach segment may be authorized, subject to an appropriate State safety assessment.

4.1.2 Advanced RNP functional capabilities

4.1.2.1 States and service providers should understand that the functional capabilities specified in the A-RNP navigation specification were specifically chosen to encompass those included in RNAV 5, RNAV 2, RNAV1, RNP 2, RNP 1 and RNP APCH applications (excluding the final approach segment) and as shown in Table II-A-1-1 and Table II-A-1-2.

4.1.2.2 ***Radius to fix legs***

Radius to fix (RF) legs are expected to be implemented where there is an operational requirement for reliable, repeatable and predictable turn performance from one flight plan fix to the next fix (the RF path terminator). This will require the specification of RF legs for charting information, AIP, etc. See the guidance for use of the RF leg contained in Volume II, Appendix 1 to Part C.

4.1.2.3 ***RNP holding***

The RNP holding operational concept is not yet defined. Upon its development, RNP holding should be specified when an operational need arises to aid airspace management, traffic flow, etc. with a racetrack holding pattern. This will require RNP holding to be identified on charts, AIP, etc.

4.1.2.4 ***Parallel offsets***

4.1.2.4.1 Parallel offsets can be applied tactically or strategically, depending on the operational need. These include supporting air traffic management consistent with traffic flow, separation and spacing, etc.

Note 1.— Strategic applications are planned as part of the airspace concept.

Note 2.— Tactical applications are initiated either by ATC or flight crew, on an ad hoc basis.

4.1.2.4.2 In either instance, a predictable manoeuvre and repeatable flight path is expected.

4.1.2.4.3 As part of the implementation process, the aircraft fleet should be assessed with regard to having this capability.

4.1.2.4.4 This capability is required for A-RNP and optional for RNP 2. The level of specification is different between the two navigation specifications. A-RNP references the detail specifications of DO-236()/ED-75(). For RNP 2, lacking a functional standard, the RNP system implementation may vary.

4.1.2.5 ***Fixed radius transitions***

Fixed radius transitions (FRTs) are expected to be implemented on ATS routes when there is an operational need for airspace management, traffic flow, separation, spacing, etc. that requires the specification of a transition from one track to the next track in a route through the requirement for an RNP system computed fixed radius turn. The FRT is also an optional function for RNP 2.

4.1.2.6 ***Time of arrival control***

Time of arrival control (TOAC) is an optional function in A-RNP. As the concept of time of arrival control is insufficiently mature, the appendix on the matter is solely a placeholder for the time being.

4.1.2.7 ***Higher continuity***

This is an optional function capability in A-RNP that the operators must satisfy to meet long range and remote operations.

4.1.2.8 ***Navigation infrastructure***

4.1.2.8.1 RNP is based upon global navigation satellite system (GNSS) and allows for use of DME/DME. However, the full range of operational applications and available navigation technology influence what sensors may be included in the aircraft.

4.1.2.8.2 The aircraft equipage may change over time, as some navigation infrastructure is phased out and new navigation sensors become available. As indicated in the A-RNP navigation specification, the State will determine what infrastructure will support their navigation applications.

4.1.2.9 ***Procedure naming and charting information***

Procedure naming and charting for PBN approaches has been updated through PANS-OPS, Volume II and the *Transition Planning for Change to Instrument Flight Procedure Approach Chart Identification from RNAV to RNP* (Cir 353). Both documents explain the correlation between operational applications and the navigation specifications for approach through the chart naming convention, as well as provide the information needed by the flight crew through the promulgation of the PBN requirements box on approach, arrival and departure charts. To compliment this update, work on phraseology adapted to the chart naming convention is on-going and will affect PANS-ATM, Doc 4444 and the *Manual of* Radiotelephony (Doc 9432).

4.1.2.10 ***Flight plan classification***

The A-RNP code is currently not part of the 2012 Flight Plan, but it will be included in a standardized set of codes for Item 18 (with the NAV/qualifier) for the flight plan.

Note.— For more information on flight plan codes for PBN, see the Manual on Flight and Flow – Information for a Collaborative Environment (FF-ICE) *(Doc 9965)*

4.2 Operators and airspace users

4.2.1 A-RNP qualification

4.2.1.1 An aircraft certified for A-RNP will be qualified for all the specification's required functions and any implemented options. Through this approval, an aircraft will be considered as compliant to all the navigation specifications shown in Table II-C-4-App-1 (see 3.5).

4.2.1.2 The elements of an RNP system approval that are allowed, by an airworthiness authority, to be bundled together by a manufacturer, can vary due to differences in regulatory requirements and implementation choices. For example, an airworthiness authority may stipulate that optional functionality (shown in 3.6), be prescribed as a required function for A-RNP certification by that particular authority. Similarly, what an operator chooses for the A-RNP functions for its intended operations may also differ from the total package of A-RNP capability of the RNP system – this would also require approval from the airworthiness authority. However, a certification for A-RNP must always include the required functions of the navigation specification.

Note 1.— Regulatory airworthiness approvals for A-RNP may vary for manufacturers, depending on the State in which they are granted. This aspect of PBN approvals is widely understood and already managed by the regulators.

Note 2.— These different bundling possibilities may impact the State, service provider and operator in terms of promulgation and operational authorization.

4.2.2 A-RNP authorization

4.2.2.1 Some regulators may choose to grant a wide range of authorizations for a single operator application for A-RNP. The bundling of authorizations will depend on their intended operations. This kind of bundling would be determined by the regulator, as the authorizations granted may not have a one-to-one relationship with the possible applications of A-RNP.

Note 1.— These different bundling possibilities may impact the ANSP, other service providers and operator in terms of promulgation, operational authorization and flight planning.

Note 2.— The operational authorization for A-RNP obtained by operators may vary from one State to another. This difference in authorizations applies not only with A-RNP, but to other navigation specifications as well (such as RNP AR APCH, RNP 1, etc.). These differences are understood and managed in processes, procedures and documentation among regulatory authorities, manufacturers and operators. It is crucial to be specific and clear to States and service providers when specifying A-RNP, its required functions and options for the intended navigation applications.

4.2.2.2 Operators should obtain operational authorization for the intended operation, however, with A-RNP, a benefit arises from obtaining only one aircraft qualification, potentially covering many operations. Operators may immediately benefit from having aircraft/systems whose qualification is broader than possible with the other single application navigation specifications. The broad qualification eliminates untimely and costly incremental support and documentation from manufacturers, while providing flexibility in the order they choose to obtain operational authorizations for their intended operations. This flexibility allows for additional capabilities required only by the A-RNP navigation specification (such as parallel offsets, RF legs and holding) and other options (such as, FRT, TOAC). The operator should understand these distinctions when planning for the intended operation of their aircraft and when appropriately identifying aircraft capability to those managing or controlling the airspace and procedures where the aircraft will be flown.

4.2.3 A-RNP function considerations

4.2.3.1 ***Radius to fix legs***

The RF legs provide for a fixed radius turn segment in an RNP arrival, departure and/or approach, excluding the final approach segment. The RF is not selectable as a unique element by the flight crew; it is defined and specified as part of the coded arrival, departure or approach procedure contained in the navigation database. The RF is often confused with the fixed radius transition (FRT), which is used to specify the radius of turn used in ATS routes. The RF differs as described in Appendix 1 to Part C. Its inclusion as a part of the arrival, departure or approach procedure is an indication to the flight crew that the operation warrants both a navigation accuracy requirement and a fixed turn path for the aircraft. The aircraft should have the equipment and displays to support this.

4.2.3.2 ***Holding***

A hold can be a part of the route/airway contained in the navigation database or via a datalink flight plan update or provided via an ATC instruction. The capability can be satisfied by a function in the RNP system or by providing information and cues to allow the flight crew to perform the manoeuvre. Its inclusion as a part of a route, arrival and/or approach procedure requires the flight crew and/or flight systems to have the capability that enables flying a race track shaped holding pattern.

Note.— RNP holding is a required function for A-RNP. This is different from other navigation specifications where qualified aircraft may have a holding function, which is not required or included by those specifications and associated applications.

4.2.3.3 ***Parallel offsets***

The flight crew and/or flight systems should have the capability to perform parallel offsets. A predictable manoeuvre and repeatable flight path are expected.

4.2.3.4 ***Fixed radius transitions***

4.2.3.4.1 FRTs are a method of transitioning from one straight leg segment to another via a pre-defined fixed radius turn path; it is only applicable en-route as part of an airway record. The FRT is not selectable by the flight crew, as it is defined and specified for a fix that is part of a route/airway contained in the navigation database. The FRT is often confused with the RF leg. Commonalities include their resulting in a defined curved path based upon a fixed radius. The FRT differentiations are described in Appendix 2 to Part C.

4.2.3.4.2 While an RF leg is a flight plan defined procedural leg segment between two waypoints, an FRT is a transition between two straight leg segments using a single reference waypoint. The FRT is a desired capability for some advanced route spacing and PBN operational concepts, but low implementation levels result in this being an optional capability for the foreseeable timeframe. The flight crew and flight systems not only have a navigation accuracy requirement that applies to the flight path, but a need for an RNP system computed fixed radius turn at such a track-to-track transition in the flight path. The aircraft must have an RNP system and suitable displays to support the applications that include the FRT.

4.2.3.5 ***Time of arrival control***

There are no known applications where this capability is required. As the concept of TOAC is insufficiently mature, the Appendix on the matter is solely a placeholder for the time being.

4.2.3.6 ***RNP system architecture***

4.2.3.6.1 All PBN applications may be typically performed with single system architecture. The requirement for higher continuity for an application would be influenced by:

a) operations and procedures that are long range over water or the navigation infrastructure is deemed insufficient; and

b) operations and procedures where RNP system performance and functionality is essential following a single system failure.

4.2.3.6.2 This is also an optional function for the RNP 2 navigation specification. Where long range navigation over water may be the application, current regulatory guidance could be expanded to require higher continuity of the navigation capability. This can usually be satisfied by dual system architecture.

4.3 Manufacturer and system integrator

4.3.1 General

In the implementation and certification to A-RNP, manufacturers and system integrators will gain the advantage of having aircraft only qualified to one aircraft certification standard (recognizing that by design A-RNP permits the bundling of optional and required functions) thus saving costs. This could therefore future-proof forthcoming airspace developments by allowing the operator to plan ahead and gain an immediate benefit from a single A-RNP airworthiness approval that can be applied to multiple applications.

4.3.2 Scope of certified A-RNP capabilities

A-RNP capable systems and aircraft have been in operation since 2004, with more being produced and/or evolving every day. Regulatory guidance is now available enabling a formal certification of A-RNP capabilities for the in-service aircraft RNP systems as well as those being produced for new aircraft or retrofit. Manufacturers can therefore bundle capabilities (such as RF plus FRT, scalability, etc.) into an approval that can be applied across multiple flight phases.

4.3.3 Alternatives for navigation specification authorization

In cases where other navigation specifications (or comparable regulatory guidance) have been used for individual airworthiness and operator authorizations, the cost impact to add the incremental capabilities of A-RNP to an RNP system or an additional A-RNP operational authorization in addition to those in place (such as RNAV 5, RNAV 2, RNAV 1, RNP APCH, etc.) may not be compelling enough to formalize a designation as A-RNP. The manufacturer and/or operator may just obtain authorization for adding incremental functionality to their existing system (such as RNP system with RNP 2, RNP 1, with add-on for RF legs and FRT only) to address specific operator needs or operational applications.

5. REGULATOR AND EQUIPMENT STANDARDS

5.1 Differences between States

A-RNP has a number of optional functions for its intended span of operations. This can lead to differences in how A-RNP is specified by a State. For example, the PBN manual requires RF legs, RNP holding and parallel offsets. United States regulatory guidance requires RF legs, parallel offsets, RNP holding and FRTs. This differentiation is not contained in the RTCA and EUROCAE standards, DO-236(), ED-75() and DO-283(). Choices such as this may help a State to better enforce a single operational standard; RNP APCH Part A or Part B is the applicable standard for the final approach. A-RNP aircraft, depending on the avionics equipment, will have certificated capability that enables operator authorizations to perform the operation. Regulatory differences that affect system capability and function are not unusual. It is the manufacturer’s responsibility to develop the necessary flexibility and adaptability suited to operational needs and regulatory constraints.

5.2 Technical standards and systems or equipment with A-RNP capability

Both RTCA in the United States and EUROCAE in Europe have issued their RNP systems and equipment standards, DO-236C/ED-75D MASPS, and DO-283B, MOPS. These standards and the systems/equipment built to them, are not tailored to specific application such as those contained in the navigation specifications of this manual. The standards include the minimum requirements for fixed radius turns (RF legs and fixed radius transitions), RNP holding, parallel offsets, scalability, vertical navigation (VNAV) and TOAC that are associated with A-RNP and other select navigation specifications, and many other requirements that are associated with all navigation specifications. RNP systems and equipment that align to A-RNP are already a part of the present fleet capabilities and going forward will have a much larger presence in operator fleets.

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Chapter 5

IMPLEMENTING RNP APCH

Note.— This chapter contains two sections – Section A and Section B – that describe the separate aircraft, operator and application requirements inherent to operations using the RNP APCH navigation specification. Section A describes which requirements apply to operations with LNAV and LNAV/VNAV minima and Section B describes which requirements apply to operations with LP and LPV minima. The paragraph numbering in both Sections A and B starts with 5.1.

SECTION A – RNP APCH OPERATIONS DOWN TO LNAV AND LNAV/VNAV MINIMA

5.1 INTRODUCTION

5.1.1 Background

5.1.1.1 Section A of this chapter addresses approach applications based on global navigation satellite system (GNSS), which are classified RNP APCH in accordance with the performance-based navigation (PBN) concept and give access to minima designated as LNAV or LNAV/VNAV.

5.1.1.2 RNP approach (RNP APCH) procedures include approach procedures designed with a straight final approach segment down to LNAV or LNAV/VNAV minima. The Federal Aviation Administration (FAA) AC20-138() contains airworthiness approval criteria for GNSS equipment and RNP systems that are eligible for such operations. The European Union Aviation Safety Agency (EASA) has developed certification material (CS-ACNS and EU 965/2012) for airworthiness approval and operational criteria for RNP APCH operations. While similar in functional requirements, there are slight differences between these two sets of airworthiness criteria. In order to achieve a global standard, the two sets of criteria were harmonized into a single navigation specification in this chapter.

5.1.2 Purpose

5.1.2.1 Section A also provides guidance to States implementing RNP APCH operations down to LNAV or LNAV/VNAV minima (excluding RNP AR APCH) and provides the ANSP with a recommendation on implementation requirements. It provides the operator with a combination of existing airworthiness and operational criteria. For existing stand-alone and multi-sensor RNP systems using GNSS, compliance with both European (EASA CS-ACNS) and United States (FAA AC 20-138()) guidance assures compliance with this specification, obviating the need for further assessment or AFM documentation. An operational authorization to this standard allows an operator to conduct RNP APCH operations down to LNAV or LNAV/VNAV minima globally.

Note 1.— RNP APCH operations authorization may be required by national authorities in the State of the intended operations.

Note 2.— Where authorized by the State, the multi-sensor systems may use other sensor combinations such as DME/DME or DME/DME/inertial that provide the navigation performance acceptable for RNP APCH. However, such cases are limited due to the increased complexity in the NAVAID infrastructure requirements and assessment and are not practical or cost-effective for widespread application.

Note 3.— The aircraft may also use GNSS-based vertical guidance to conduct RNP APCH operations down to LNAV/VNAV minima.

5.1.2.2 This chapter addresses only the requirement for the lateral navigation aspect (2D navigation) along straight final approach segments.

5.2 IMPLEMENTATION CONSIDERATIONS

5.2.1 NAVAID infrastructure

5.2.1.1 The RNP APCH navigation specification requires GNSS to support the entire RNP APCH operations.

5.2.1.2 The acceptability of the risk of loss of RNP APCH capability for multiple aircraft due to loss of the GNSS signal in space for any reason (such as jamming or interference), satellite failure, or loss of on-board monitoring and alerting functions (such as receiver autonomous integrity monitoring (RAIM) holes) must be considered by the responsible airspace authority.

Note.— The operator is responsible for developing flight crew contingency procedures for the loss of RNP APCH capability.

5.2.2 Communications and air traffic services surveillance

5.2.2.1 The need for direct pilot to ATC (voice) communications and surveillance will be determined by the airspace concept and the operating environment.

5.2.2.2 Air traffic services (ATS) surveillance may be used to assist contingency procedures. When ATS surveillance is relied upon to these ends, the system's performance should be fit for purpose, ensuring that the contingency procedures lie within the ATS surveillance and communications service volumes and the ATS resources are sufficient for these tasks.

5.2.2.3 When GNSS is used as the sole basis for both ATS surveillance and aircraft navigation, the risks and requirement for mitigation techniques associated with the loss of GNSS potentially resulting in the loss of both navigation and surveillance capability, should be considered. This should typically be addressed through the regional or local State safety risk assessment prepared in support of the application.

5.2.3 Obstacle clearance

5.2.3.1 Detailed guidance on obstacle clearance is provided in the *Procedures for Air Navigation Services – Aircraft Operations*, Volume II – *Construction of Visual and Instrument Flight Procedures* (PANS-OPS, Doc 8168). The general criteria in Parts I, III and IV apply, and assume normal operations.

5.2.3.2 Procedure design must take account of the absence of a VNAV capability in some aircraft eligible for RNP APCH.

5.2.4 Additional considerations

5.2.4.1 Many aircraft have an RNAV holding capability. Aircraft can either hold manually over a waypoint when the aircraft holding functionality is not available and the pilot is expected to manually fly the RNAV holding pattern, or the RNAV system's holding functionality can be used to execute the published RNAV hold (see Volume I, Attachment A, 5.3).

5.2.4.2 Although this navigation specification does not include requirements for an RNAV holding function, ANSPs may include holding procedures in their airspace design using a waypoint as a holding point.

5.2.4.3 Guidance in this chapter does not supersede appropriate State operating requirements for equipage.

5.2.5 Procedure validation

5.2.5.1 Guidance on procedure validation is provided in *The Quality Assurance Manual for Flight Procedure Design* (Doc 9906), Volume I – *Flight Procedure Design Quality Assurance System*, and Volume V – *Validation of in-Flight Procedures*.

Note.— Guidance on the flight inspection is provided in the Manual on Testing of Radio Navigation Aids *(Doc 8071).*

5.2.6 Publication

5.2.6.1 The AIP should clearly indicate that the navigation application is RNP APCH. The procedure design should rely on PANS-OPS procedure design criteria. If the missed approach segment is based on conventional means, NAVAID facilities that are necessary to conduct the approach must be identified in the relevant publications. The navigation data published in the State AIP for the procedures and supporting NAVAIDs must meet the requirements of Annex 4 – *Aeronautical Charts* and Annex 15 – *Aeronautical Information Services* (as appropriate). All procedures must be based upon WGS-84 coordinates.

5.2.6.2 Where holding patterns are published, they are to comply with the criteria and publication requirements in PANS-OPS, Volume II, Part 3, Section 3, Chapter 7. For the content of the PBN requirement box published on the chart, see also PANS-OPS, Volume II, Part 3, Section 5, Chapter 1.

5.2.7 Controller training

Air traffic controllers, who provide control services at airports where RNP APCH operations down to LNAV or LNAV/VNAV minima have been implemented should have completed training that covers the items listed below.

5.2.7.1 Core training

a) How area navigation systems work (in the context of this navigation specification):

   1) include functional capabilities and limitations of this navigation specification;

   2) accuracy, integrity, availability and continuity including on-board performance monitoring and alerting;

   3) GNSS receiver, RAIM, FDE and integrity alerts; and

4) waypoint fly-by versus fly-over concept (and different turn performances);

b) flight plan requirements;

c) ATC procedures;

1) ATC contingency procedures;

2) separation minima;

3) mixed equipage environment;

4) transition between different operating environments; and

5) phraseology.

5.2.7.2 Training specific to this navigation specification:

a) Related control procedures:

1) vectoring techniques (where appropriate);

b) RNP approach and related procedures:

1) including T and Y approaches; and

2) approach minima;

c) impact of requesting a change to routing during a procedure.

5.2.8 Navigation service monitoring

Navigation service monitoring should be consistent with Volume II, Part A, Chapter 4.

5.2.9 Air traffic services system monitoring

If an observation/analysis indicates that a loss of obstacle clearance has occurred, the reason for the apparent deviation from track or altitude should be determined and steps taken to prevent a recurrence.

5.3 NAVIGATION SPECIFICATION

5.3.1 Background

5.3.1.1 This section identifies the airworthiness and operational requirements for RNP APCH operations. Operational compliance with these requirements must be addressed through national operational regulations, and, in some cases, may require an operational authorization. For example, certain operational regulation requires operators to apply to the State of the Operator/Registry for operational authorization.

5.3.1.2 This chapter addresses only the lateral performance requirements of the RNP system outside the RNP APCH FAS. However, if the system is approved for an approach procedure with vertical guidance (APV)-barometric VNAV (such as "APV Baro-VNAV") instrument approach operation, the RNP system installation must be compliant with the Baro-VNAV equipment performance requirements for operations under instrument flight rules (IFR) in FAA AC 20-138() or an equivalent airworthiness approval basis offered by another State regulatory authority. In contrast, if the system is approved for APV with a space-based augmentation system (APV SBAS), the RNP system installation must be compliant with the requirements in Section B of this chapter or must demonstrate to an airworthiness regulatory authority performance at least equivalent to those described in Attachment A for a Baro-VNAV instrument approach capability.

5.3.2 Authorization process

5.3.2.1 This navigation specification does not in itself constitute regulatory guidance material against which either the aircraft or the operator will be assessed and approved. Aircraft are certified by their State of Manufacture. Operators are approved in accordance with their national operating rules. This navigation specification provides the technical and operational criteria and does not necessarily imply a need for recertification.

Note 1.— Detailed information on operational authorizations is provided in the Performance-based Navigation (PBN) Operational Authorization Manual *(Doc 9997)*[1].

Note 2.— Where appropriate, States may refer to previous operational authorizations in order to expedite this process for individual operators where performance and functionality are applicable to the current request for operational authorization.

5.3.2.2 Aircraft eligibility

The aircraft eligibility must be determined through demonstration of compliance against the relevant airworthiness criteria and the requirements of 5.3.3. The original equipment manufacturer (OEM) or the holder of installation approval for the aircraft, such as the STC holder, will demonstrate compliance to their regulatory authority (such as EASA, FAA) and the approval can be documented in manufacturer documentation (such as service letters). Aircraft flight manual (AFM) entries are not required, provided the State accepts manufacturer documentation.

Note.— Requests for approval to use optional functionality (such as RF legs) should address the aircraft and operational requirements as described in the appropriate functional attachment to this volume.

5.3.2.3 Operational authorization

5.3.2.3.1 ***Description of aircraft equipment***

The operator must have a configuration list and, if necessary, an MEL detailing the required aircraft equipment for RNP APCH operations to LNAV and/or LNAV/VNAV minima.

5.3.2.3.2 ***Training documentation***

5.3.2.3.2.1 Commercial operators must have a training programme addressing the operational practices, procedures and training items related to RNP APCH, Section A of this chapter, and operations (such as initial, upgrade or recurrent training for pilots, dispatchers or maintenance personnel).

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[1] Formerly the *Performance-based Navigation Operational Approval Manual*, renamed in its third (forthcoming) edition.

Note.— Operators need not establish a separate training programme if they already integrate RNAV training as an element of their training programme. However, the operator should be able to identify the aspects of RNP APCH operations to LNAV and/or LNAV/VNAV minima covered within their training programme.

5.3.2.3.2.2 Private operators must be familiar with the practices and procedures identified in Section A, 5.3.5.

5.3.2.3.3 ***OMs and checklists***

5.3.2.3.3.1 Operations manuals (OMs) and checklists for commercial operators must address information/guidance on the SOP detailed in Section A, 5.3.4. The appropriate manuals should contain navigation operating instructions and contingency procedures, where specified. When required by the State of the Operator/Registry, the operator must submit their manuals and checklists for review as part of the application process.

5.3.2.3.3.2 Private operators should operate using the practices and procedures identified in Section A, 5.3.5.

5.3.2.3.4 ***MEL considerations***

Any MEL revisions necessary to address provisions for RNP APCH operations to LNAV and/or LNAV/VNAV minima must be approved. Operators must adjust the MEL, or equivalent, and specify the required dispatch conditions.

5.3.2.3.5 ***Continuing airworthiness***

The operator must submit the continuing airworthiness instructions applicable to the aircraft's configuration and the aircraft's qualification for this navigation specification. Additionally, there is a requirement for the operator to submit their maintenance program, including a reliability program for monitoring the equipment.

Note.— The operator should confirm with the OEM, or the holder of installation approval for the aircraft, that acceptance of subsequent changes in the aircraft configuration, such as SBs, does not invalidate current operational authorizations.

5.3.3 Aircraft requirements

5.3.3.1 System performance monitoring and alerting requirements

5.3.3.1.1 ***RNP system performance***

5.3.3.1.1.1 *Accuracy.* During operations on the initial and intermediate segments, and for those missed approach procedures requiring RNP, the lateral total system error (TSE) must be within ±1 NM for at least 95 per cent of the total flight time. The along-track error must also be within ±1 NM for at least 95 per cent of the total flight time.

5.3.3.1.1.1.1 During operations on the FAS of an RNP APCH down to LNAV or LNAV/VNAV minima, the lateral TSE must be within ±0.3 NM for at least 95 per cent of the total flight time. The along-track error must also be within ±0.3 NM for at least 95 per cent of the total flight time.

5.3.3.1.1.1.2 To satisfy the accuracy requirement, the 95 per cent FTE should not exceed 0.5 NM on the initial, intermediate and missed approach segments. The 95 per cent FTE should not exceed 0.25 NM on the FAS of an RNP APCH.

Note.— The use of a deviation indicator with 1 NM full-scale deflection on the initial, intermediate and missed approach segments is acceptable. 0.3 NM full-scale deflection during the final approach segment is also an acceptable means of compliance. The use of an autopilot or flight director coupled to the RNP system's lateral and vertical guidance to aid in controlling FTE is an acceptable means of compliance (roll stabilization systems do not qualify).

5.3.3.1.1.2 *Integrity.* Malfunction of the aircraft navigation equipment is classified as a major failure condition under airworthiness regulations (that is, 10^{-5} per hour).

5.3.3.1.1.3 *Continuity.* Loss of function is classified as a minor failure condition if the operator can revert to a different navigation system and proceed to a suitable airport.

5.3.3.1.2 *On-board performance monitoring and alerting.* The installed RNP system is required to provide an alert if the accuracy requirement is not met, or if the probability that the lateral TSE exceed 2xRNP NM is greater than 1×10^{-5}per flight hour. The alert must be consistent with RTCA DO-236(), DO-283(), DO-229() and EUROCAE ED-75().

Note 1.— There are no RNP APCH requirements for the missed approach if it is based on conventional means (such as VOR, DME) or on dead reckoning.

Note 2.— Compliance with the on-board performance monitoring and alerting requirement does not imply automatic monitoring of an FTE. The on-board monitoring and alerting function should consist at least of an NSE monitoring and alerting algorithm and a lateral deviation display enabling the crew to monitor the FTE. To the extent operational procedures are used to monitor FTE, the crew procedure, equipment characteristics and installation are evaluated for their effectiveness and equivalence as described in the functional requirements and operating procedures. Path definition error (PDE) is considered negligible due to the navigation database quality assurance process (Section A, 5.3.6) and the operating procedures (Section A, 5.3.4).

Note 3.— The following systems meet the accuracy, integrity and continuity requirements of these criteria:

a) GNSS stand-alone systems, equipment should be approved in accordance with TSO C129a/ ETSO_C129a Class A, E/TSO-C146() Class Gamma and operational Class 1, 2 or 3, or TSO C-196();

b) GNSS sensors used in multi-sensor system (such as FMS) equipment should be approved in accordance with TSO C129()/ ETSO-C129() Class B1, C1, B3 C3 or E/TSO C145() Class 1, 2 or 3, or TSO C-196(). For GNSS receiver approved in accordance with E/TSO-C129(), capability for satellite FDE is recommended to improve continuity of function; and

c) multi-sensor systems using GNSS should be approved in accordance with AC20-138() or TSO-C115(), as well as having been demonstrated for RNP APCH capability.

Note 4.— For RNP procedures, the RNP system may only use DME updating when authorized by the State. The manufacturer should identify any operating constraints (such as manual inhibit of DME) in order for a given aircraft to comply with this requirement. This is in recognition of States where a DME infrastructure and capable equipped aircraft are available. Those States may establish a basis for aircraft qualification and operational authorization to enable use of DME. It is not intended to imply a requirement for implementation of DME infrastructure or the addition of RNP capability using DME for RNP operations. This requirement does not imply an equipment capability must exist providing a direct means of inhibiting DME updating. A procedural means for the pilot to inhibit DME updating or executing a missed approach if reverting to DME updating may meet this requirement.

5.3.3.2 Criteria for specific navigation systems

5.3.3.2.1 RNP APCH is based on GNSS positioning. Positioning data from other types of navigation sensors may be integrated with the GNSS data provided the other positioning data do not cause position errors exceeding the TSE budget, or if means are provided to deselect the other navigation sensor types.

5.3.3.2.2 *Automated temperature compensation systems.* RNP systems providing automated temperature-based compensation to RNP APCH procedural barometric altitudes must comply with RTCA/DO-236(), Appendix H.2 or an equivalent airworthiness approval basis. Manufacturers should document compliance to this standard.

Note 1.— Some RNP systems providing automated temperature compensation provide compensation only for deviation below International Standard Atmosphere (ISA) (that is, only for cold temperatures). A systems limitation should highlight this in the OEM's documentation of the aircraft's automated temperature compensation system.

Note 2.— Attachment B provides guidance on operational issues associated with RNP systems with automated temperature compensation.

5.3.3.3 Functional requirements

5.3.3.3.1 ***Navigation displays and required functions***

5.3.3.3.1.1 Navigation data, including a to/from indication and a failure indication, must be displayed on a lateral deviation display (CDI, EHSI) and/or a navigation map display. These must be used as primary flight instruments for the navigation of the aircraft, for manoeuvre anticipation and for failure/status/integrity indication:

a) the displays must be visible to the pilot and located in the primary field of view (±15 degrees from the pilot's normal line of sight) when looking forward along the flight path;

b) the lateral deviation display scaling should agree with any alerting and annunciation limits;

c) the lateral deviation display must also have a full-scale deflection suitable for the current phase of flight and must be based on the TSE requirement. Scaling is ±1 NM for the initial and intermediate segments and ±0.3 NM for the final segment;

Note.— When lateral or vertical deviation scaling or the deviation display are inadequate for monitoring and controlling deviation, the aircraft may require a flight director and/or autopilot to conduct an RNP APCH operation.

d) the display scaling may be set automatically by default logic or set to a value obtained from a navigation database. The full-scale deflection value must be known or must be available for display to the pilot commensurate with approach values;

e) as an alternate means, a navigation map display must give equivalent functionality to a lateral deviation display with appropriate map scales (scaling may be set manually by the pilot). To be approved, the navigation map display must be shown to meet the TSE requirements; and

f) the course selector of the deviation display should automatically slave to the computed path.

Note.— This does not apply for installations where an electronic map display contains a graphical display of the flight path and path deviation.

5.3.3.3.1.2 The following system functions are required as a minimum:

a) the capability to continuously display to the pilot flying, on the primary flight instruments for navigation of the aircraft (primary navigation display), the computed desired path and aircraft position relative to the path. For aircraft where the minimum flight crew is two pilots, the means for the pilot not flying to verify the desired path and the aircraft position relative to the path must also be provided;

b) a navigation database, containing current navigation data officially promulgated for civil aviation, which can be updated in accordance with the AIRAC cycle and from which approach procedures can be retrieved and loaded into the RNP system. The stored resolution of the data must be sufficient to achieve the required track-keeping accuracy. The database must be protected against pilot modification of the stored data;

Note.— Flight crew use of manual or automated temperature compensation during either hot or cold temperatures (that is, deviation above or below ISA) to correct the RNP system's flight plan procedural barometric altitude constraints is not a procedure modification and is operationally acceptable.

c) the means to display the validity period of the navigation data to the pilot;

d) the means to retrieve and display data stored in the navigation database relating to individual waypoints and NAVAIDs, to enable the pilot to verify the procedure to be flown;

e) capacity to load from the database into the RNP system the whole approach to be flown. The approach must be loaded from the database, into the RNP system, by its name;

f) the means to display the following items, either in the pilot's primary field of view, or on a readily accessible display page:

1) the identification of the active (To) waypoint;

2) the distance and bearing to the active (To) waypoint; and

3) The ground speed or time to the active (To) waypoint;

g) the means to display the following items on a readily accessible display page:

1) the display of distance between flight plan waypoints;

2) the display of distance to go;

3) the display of along-track distances; and

4) the active navigation sensor type, if there is another sensor in addition to the GNSS sensor;

h) the capability to execute a "direct to" function;

i) the capability for automatic leg sequencing with the display of sequencing to the pilot;

j) the capability to execute procedures extracted from the on-board database, including the capability to execute fly-over and fly-by turns;

Note.— For fly-by turns, the navigation system will limit the path definition within the theoretical turn transition area described in Volume I, Attachment A, 5.2. As a result, the navigation system must limit the path definition within this theoretical turn transition area. The fly-over turn is not compatible with RNP flight tracks and will only be used when there is no requirement for repeatable paths.

k) the capability to automatically execute leg transitions and maintain tracks consistent with the following ARINC 424 path terminators, or their equivalent:

1) CF;

2) CA;

3) IF;

4) TF; and

5) DF;

Note.— Path terminators are defined in ARINC 424, and their application is described in more detail in RTCA/EUROCAE documents DO 236()/ED-75() and DO-201()/ED-77().

l) the capability to display an indication of the RNP system failure, including the associated sensors, in the pilot's primary field of view;

m) the capability to indicate to the crew when NSE alert limit is exceeded (alert provided by the "on-board performance monitoring and alerting function"); and

n) the capability to automatically load numeric values for courses and tracks from the RNP system database.

5.3.4 Operating procedures

Airworthiness certification alone does not authorize an operator to conduct an RNP APCH operation down to LNAV or LNAV/VNAV minima. Operational authorization is also required to confirm the adequacy of the operator's normal and contingency procedures for the particular equipment installation.

5.3.4.1 Preflight planning

5.3.4.1.1 Operators and pilots intending to conduct operations using an RNP APCH procedure must file the appropriate flight plan suffixes and the on-board navigation data must be current and include appropriate procedures.

Note.— Navigation databases are expected to be current for the duration of the flight. If the AIRAC cycle is due to change during flight, operators and pilots should establish procedures to ensure the accuracy of navigation data, including the suitability of navigation facilities used to define the routes and procedures for the flight.

5.3.4.1.2 In addition to the normal preflight planning checks, the following must be included:

a) the pilot must ensure that approaches, which may be used for the intended flight (including alternate aerodromes), are selected from a valid navigation database (current AIRAC cycle), have been verified by the appropriate process (navigation database integrity process) and are not prohibited by a company instruction or NOTAM;

b) subject to a State's regulations, during the preflight phase, the pilot should ensure sufficient means are available to navigate and land at the destination or at an alternate aerodrome in the case of loss of RNP APCH airborne capability;

c) operators and pilots must take account of any NOTAMs or operator briefing material that could adversely affect the aircraft system operation, or the availability or suitability of the procedures at the airport of landing, or any alternate airport; and

d) for missed approach procedures, based on conventional means (such as VOR, DME), operators and pilots must ensure that the appropriate airborne equipment required for this procedure is installed in the aircraft and is operational and that the associated ground-based NAVAIDs are operational.

5.3.4.1.3 The availability of the NAVAID infrastructure, required for the intended routes, including any non-RNAV contingencies, must be confirmed for the period of intended operations using all available information. Since GNSS integrity (RAIM or satellite-based augmentation system (SBAS) signal) is required by Annex 10 – *Aeronautical* Telecommunications, Volume I – *Radio Navigation Aids*, the availability of these should also be determined as appropriate. For aircraft navigating with SBAS receivers (all TSO-C145()/C146()), operators should check appropriate GPS RAIM availability in areas where the SBAS signal is unavailable.

5.3.4.2 GNSS availability

5.3.4.2.1 ***ABAS availability***

5.3.4.2.1.1 RAIM levels required for RNP APCH down to LNAV or LNAV/VNAV minima can be verified either through NOTAMs (where available), the navigation system's RAIM function (when available) or through prediction services. The operating authority may provide specific guidance on how to comply with this requirement (such as if sufficient satellites are available, a prediction may not be necessary). Operators should be familiar with the prediction information available for the intended route.

5.3.4.2.1.2 RAIM availability prediction should take into account the latest GPS constellation NOTAMs and avionics model (when available). The service may be provided by the ANSP, avionics manufacturer, and other entities, or through an airborne receiver RAIM prediction capability.

5.3.4.2.1.3 In the event of a predicted, continuous loss of appropriate level of fault detection of more than five minutes for any part of the RNP APCH operation, the filed flight plan should be revised (such as delaying the departure or planning a different departure procedure).

5.3.4.2.1.4 RAIM availability prediction software does not guarantee the service, rather they are tools to assess the expected capability of meeting the RNP. Because of unplanned failure of some GNSS elements, pilots/ANSPs should realize that RAIM or GPS navigation altogether may be lost while airborne, which may require reversion to an alternative means of navigation. Therefore, pilots should assess their capability to navigate (potentially to an alternate destination) in case of failure of GPS navigation.

5.3.4.2.2 ***SBAS and other augmented GNSS availability***

5.3.4.2.2.1 Section B of this chapter contains criteria to assess GNSS SBAS guidance availability.

5.3.4.2.2.2 If the aircraft uses other SBAS, or any other enhancement to a basic GNSS capability (that is, use of multiple constellations, dual frequency, baro-aiding), the RNP APCH operation must be supported by a prediction capability based on the specific characteristics of these augmentations.

5.3.4.3 Prior to commencing the procedure

5.3.4.3.1 In addition to the normal procedure prior to commencing the approach (before the IAF and in compatibility with crew workload), the pilot must verify the correct procedure was loaded by comparison with the approach charts. This check must include:

a) the waypoint sequence; and

b) reasonableness of the tracks and distances of the approach legs, and the accuracy of the inbound course and length of the FAS; and

Note 1.— As a minimum, this check could be a simple inspection of a suitable map display that achieves the objectives of this paragraph.

Note 2.— Pilots may notice a slight difference between the navigation information portrayed on the chart and their map display. Differences of three degrees or less may result from the equipment manufacturer's application of magnetic variation and are operationally acceptable.

c) the vertical path angle.

5.3.4.3.2 The pilot must also check using the published charts, the map display or CDU, which waypoints are fly-by and which are fly-over.

5.3.4.3.3 For multi-sensor systems, the pilot must verify, during the approach, that the GNSS sensor is used for position computation.

5.3.4.3.4 For an RNP system with ABAS requiring barometric corrected altitude, the current airport barometric altimeter setting should be input at the appropriate time and location, consistent with the performance of the flight operation.

5.3.4.3.5 When the operation requires the availability of ABAS, the pilot should perform a new RAIM availability check if estimated time of arrival (ETA) is more than 15 minutes different from the ETA used during the pre-flight planning.

5.3.4.3.6 Air traffic control (ATC) tactical interventions in the terminal area may include heading assignments, "direct to" clearances that bypass the initial legs of an approach, interception of an initial or intermediate segment of an approach or the insertion of waypoints loaded from the database. In complying with ATC instructions, the pilot should be aware of the implications for the RNP system:

a) the manual entry of coordinates into the RNP system by the pilot for operation within the terminal area is not permitted; and

b) "direct to" clearances may be accepted to the IF provided that the resulting track change at the IF does not exceed 45 degrees.

Note.— A "direct to" clearance to the FAF, or vectors inside the FAF, is not acceptable.

5.3.4.3.7 The lateral definition of the flight path between the FAF and the MAP must not be revised by the pilot under any circumstances.

5.3.4.3.8 Operator use of temperature compensation may allow the flight crew to disregard the temperature limits published on RNP APCH procedures. If the operator intends to use temperature compensation, they should provide standardized flight crew training and procedures. In particular, flight crews should be familiar with how their aircraft's RNP system provides guidance to intercept the compensated path (the path using the corrected barometric altitude constraints) and pre-brief the fix where they will begin applying temperature compensation. More information on temperature compensation can be found in Attachment B.

Note.— A detailed description of an RNP system's automated temperature compensation function is found in EUROCAE ED-75()/ RTCA DO-236() Appendix H.

5.3.4.4 During the procedure

5.3.4.4.1 The aircraft must be established on the final approach course no later than the FAF before starting the descent (to ensure terrain and obstacle clearance).

5.3.4.4.2 The crew must check the approach mode annunciator (or equivalent) is properly indicating approach mode integrity within 2 NM before the FAF.

Note.— This will not apply for certain RNP systems (such as aircraft already approved with demonstrated RNP capability). For such systems, other means are available including electronic map displays, flight guidance mode indications, etc., which clearly indicate to the crew that the approach mode is activated.

5.3.4.4.3 The appropriate displays must be selected so that the following information can be monitored:

a) the desired path; and

b) the aircraft position relative to the path (cross-track deviation) for FTE monitoring.

5.3.4.4.4 The procedure must be discontinued:

a) if the navigation display is flagged invalid; or

b) in case of LOI alerting function; or

c) if integrity alerting function is annunciated as not available before passing the FAF; or
Note.— Discontinuing the procedure may not be necessary for a multi-sensor RNP system that includes demonstrated RNP capability without GNSS. Manufacturer documentation should be examined to determine the extent the system may be used in such configuration.

d) if FTE is excessive.

5.3.4.4.5 The missed approach must be flown in accordance with the published procedure. Use of the RNP system during the missed approach is acceptable, provided:

a) the RNP system is operational (such as no loss of function, no NSE alert, no failure indication); and

b) the whole procedure (including the missed approach) is loaded from the navigation database.

5.3.4.4.6 During the RNP APCH procedure, pilots must use a lateral deviation indicator, flight director and/or autopilot in lateral navigation mode. Pilots of aircraft with a lateral deviation indicator (such as CDI) must ensure that lateral deviation indicator scaling (full-scale deflection) is suitable for the navigation accuracy associated with the various segments of the procedure (that is, ±1.0 NM for the initial and intermediate segments, ±0.3 NM for the FAS down to LNAV or LNAV/VNAV minima, and ±1.0 NM for the missed approach segment). All pilots are expected to maintain procedure centre lines, as depicted by on-board lateral deviation indicators and/or flight guidance during the whole approach procedure, unless authorized to deviate by ATC or under emergency conditions. For normal operations, cross-track error/deviation (the difference between the RNP system computed path and the aircraft position relative to the path) should be limited to ±½ the navigation accuracy associated with the procedure (that is, 0.5 NM for the initial and intermediate segments, 0.15 NM for the FAS, and 0.5 NM for the missed approach segment). Brief deviations from this standard (such as overshoots or undershoots) during and immediately after turns, up to a maximum of one-times the navigation accuracy (that is, 1.0 NM for the initial and intermediate segments), are allowable.

Note.— Some aircraft do not display or compute a path during turns but are still expected to satisfy the above standard during intercepts following turns and on straight segments.

5.3.4.4.7 When Barometric VNAV is used for vertical path guidance during the FAS, deviations above and below the Barometric VNAV path must not exceed +22 m/–22 m (+75 ft/–75 ft), respectively.

5.3.4.4.8 Pilots must execute a missed approach if the lateral deviations or vertical deviations, if provided, exceed the criteria above, unless the pilot has in sight the visual references required to continue the approach.

5.3.4.5 General operating procedures

5.3.4.5.1 Operators and pilots must not request an RNP APCH procedure unless they satisfy all the criteria in the relevant State documents. If an aircraft not meeting these criteria receives a clearance from ATC to conduct an RNP APCH procedure, the pilot must advise ATC that he/she is unable to accept the clearance and must request alternate instructions.

5.3.4.5.2 The pilot must comply with any instructions or procedures identified by the manufacturer as necessary to comply with the performance requirements in this navigation specification.

5.3.4.5.3 If the missed approach procedure is based on conventional means (such as NDB, VOR, DME), related navigation equipment must be installed and be serviceable.

5.3.4.5.4 Pilots are encouraged to use flight director and/or autopilot in lateral navigation mode, if available.

5.3.4.6 Contingency procedures

5.3.4.6.1 The pilot must notify ATC of any loss of the RNP APCH capability, together with the proposed course of action. If unable to comply with the requirements of an RNP APCH procedure, pilots must advise ATS as soon as possible. The loss of RNP APCH capability includes any failure or event causing the aircraft to no longer satisfy the RNP APCH requirements of the procedure. The operator should develop contingency procedures in order to react safely following the loss of the RNP APCH capability during the approach.

5.3.4.6.2 In the event of communications failure, the pilot must continue with the RNP APCH in accordance with the published lost communications procedure.

5.3.5 Pilot knowledge and training

The training programme must provide sufficient training (such as simulator, training device, or aircraft) on the aircraft's RNP system to the extent that the pilots are not just task oriented, this includes:

a) the information in this chapter;

b) the meaning and proper use of RNP systems;

c) procedure characteristics as determined from chart depiction and textual description;

d) knowledge regarding depiction of waypoint types (fly-over and fly-by), required path terminators (IF, TF, DF) and any other types used by the operator as well as associated aircraft flight paths;

e) knowledge on the required navigation equipment in order to conduct RNP APCH operations (at least one RNP system based on GNSS);

f) knowledge of RNP system-specific information:

  1) levels of automation, mode annunciations, changes, alerts, interactions, reversions and degradation;

  2) functional integration with other aircraft systems;

  3) the meaning and appropriateness of route discontinuities as well as related pilot procedures;

  4) monitoring procedures for each phase of flight;

  5) types of navigation sensors utilized by the RNP system and associated system prioritization/weighting/logic;

  6) turn anticipation with consideration to speed and altitude effects;

  7) interpretation of electronic displays and symbols; and

  8) any limitations associated with the integration of barometric VNAV in their aircraft as it relates to conduct of an RNP APCH (that is, a limitation requiring the flight crew to confirm compliance with all procedural barometric altitudes through use of the primary barometric altimeter per FAA AC 20-138());

g) knowledge of the operating procedures, as applicable, including how to perform the following actions:

  1) verify currency of the aircraft navigation data;

  2) verify the successful completion of RNP system self-tests;

  3) initialize RNP system position;

  4) retrieve and fly an RNP APCH;

  5) adhere to speed and/or altitude constraints associated with an approach procedure;

6) fly interception of an initial or intermediate segment of an approach following ATC instruction;

7) verify waypoints and flight plan programming;

8) fly direct to a waypoint;

9) determine cross-track error/deviation;

10) insert and delete route discontinuity;

11) when required by the State aviation authority, perform gross navigation error check using conventional NAVAIDs; and

12) change arrival airport and alternate airport;

h) knowledge of operator-recommended levels of automation for phase of flight and workload, including methods to minimize cross-track error to maintain procedure centre line;

i) knowledge of radio telephony phraseology for RNP applications;

j) ability to conduct contingency procedures following RNP system failures; and

k) the manner by which the RNP system provides temperature compensation (if applicable).

5.3.6 Navigation database

5.3.6.1 The navigation database should be obtained from a supplier that complies with RTCA DO 200()/EUROCAE document ED 76(), Standards for Processing Aeronautical Data. A letter of authorization (LOA) issued by the appropriate regulatory authority demonstrates compliance with this requirement (such as FAA LOA issued in accordance with FAA AC 20-153() or EASA certification of data services provider in accordance with Regulation (EU) 2017/373 (Part DAT)).

5.3.6.2 Discrepancies that invalidate a procedure must be reported to the navigation database supplier and affected procedures must be prohibited by an operator's notice to its pilots.

5.3.6.3 Aircraft operators should consider the need to conduct ongoing checks of the operational navigation databases in order to meet existing quality system requirements.

5.3.7 Oversight of operators

5.3.7.1 A regulatory authority may consider any navigation error reports in determining remedial action. Repeated navigation error occurrences attributed to a specific piece of navigation equipment may result in cancelling of the authorization for use of that equipment.

5.3.7.2 Information that indicates the potential for repeated errors may require modification of an operator's training programme. Information that attributes multiple errors to a particular pilot crew may necessitate remedial training or licence review.

5.4 REFERENCES

The applicable versions of industry and regulatory references, standards and guidance included in this chapter, shown as open reference (), are listed in Attachment E to this volume. Some references contained in the chapter are part of background or historical information, and not included in Attachment E.

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SECTION B – RNP APCH OPERATIONS DOWN TO LP AND LPV MINIMA

5.1 INTRODUCTION

5.1.1 Background

5.1.1.1 Section B of this chapter addresses RNP APCH applications based on an integration of a global navigation satellite system (GNSS) space-based augmentation system (SBAS) in the aircraft's navigation system eligible for RNP APCH in accordance with the performance-based navigation (PBN) concept and authorized to use minima designated as LP and LPV. While SBAS is one means of compliance, other GNSS systems providing either lateral and/or vertical guidance performance in accordance with Annex 10 – *Aeronautical Telecommunications*, Volume I – *Radio Navigation Aids*, requirements (Table 3.7.2.4-1, APV I, APV II or Cat 1) may also be eligible to support RNP APCH down to LP or LPV minima, when installed in accordance with the provisions in this navigation specification.

5.1.1.2 RNP APCH procedures conducted down to localiser performance (LP) or localiser performance with vertical guidance (LPV) minima are authorized by a number of regulatory agencies including EASA and the United States Federal Aviation Administration (FAA). The FAA has issued airworthiness criteria, AC20-138(), for GNSS equipment and systems that are eligible for such operations. EASA has developed certification material (CS-ACNS) for airworthiness approval for RNP APCH operations consistent with FAA Advisory Circular AC 20-138() (LPV approach operation airworthiness approval section). In order to achieve a global standard, the two sets of criteria were harmonized into a single navigation standard.

5.1.1.3 RNP APCH down to LPV minima may give access to a different range of minima, depending on the performance of the navigation systems and the assessment of the responsible airspace authority. The provisions given in this navigation specification are consistent with these different sets of LPV minima, down to 60 m (200 ft).

5.1.2 Purpose

5.1.2.1 Section B also provides guidance to States implementing RNP APCH operations down to LP or LPV minima. For the ANSP, it provides a consistent ICAO recommendation on what to implement. For the operator, it provides a combination of existing airworthiness and operational criteria. For existing stand-alone and multi-sensor RNP systems using GNSS augmented by SBAS, compliance with both European (EASA CS-ACNS) and United States (FAA AC 20-138()) guidance assures compliance with this ICAO specification, obviating the need for further assessment or AFM documentation. An operational authorization to this standard allows an operator to conduct RNP APCH, Section B of this chapter, operations globally.

Note.— RNP APCH operations authorization may be required by national authorities in the State of the intended operations.

5.1.2.2 Section B addresses only the requirement for the navigation aspect along a final approach straight segment and the straight continuation of the final approach in the missed approach. The navigation requirements for the initial and intermediate segments, and other segments of the missed approach are addressed in Section A of this chapter. Curved approaches are addressed in RNP AR APCH.

Note.— At some airports, it may not be possible to meet the requirements to publish an LPV approach procedure with vertical guidance. This may be due to obstacles and terrain along the desired final approach path, airport infrastructure deficiencies, or the inability of SBAS to provide the desired availability of vertical guidance (that is, an airport *located on the fringe of the SBAS service area). When this occurs, a State may provide an LP approach procedure based on the lateral performance of SBAS. The LP approach procedure is a non-precision approach procedure with angular lateral guidance equivalent to an LPV lateral guidance and a localizer-only approach. As a non-precision approach, an LP approach procedure provides lateral navigation guidance to a minimum descent altitude (MDA); however, the SBAS integration may provide vertical guidance for advisory purposes to enable a continuous descent final approach (CDFA) operation to procedure's visual descent point (VDP) and MDA. With the notable exception of material directly related to SBAS vertical guidance for an RNP APCH conducted to LPV minima, the guidance material in Section B of this chapter applies to both LPV and LP approach operations.*

5.2 IMPLEMENTATION CONSIDERATIONS

5.2.1 NAVAID infrastructure

5.2.1.1 This RNP APCH specification is based on SBAS to support RNP APCH operations down to LP or LPV minima.

5.2.1.2 The acceptability of the risk of loss of RNP APCH approach capability for multiple aircraft due to satellite failure and/or SBAS system failure will be considered by the responsible airspace authority.

Note.— The operator is responsible for developing flight crew contingency procedures for the loss of RNP APCH capability.

5.2.2 Communications and air traffic services surveillance

5.2.2.1 The need for direct pilot to ATC (voice) communications and surveillance will be determined by the airspace concept and the operating environment.

5.2.2.2 Air traffic services (ATS) surveillance may be used to assist contingency procedures. When ATS surveillance services are relied upon to these ends, the system's performance should be fit for purpose, ensuring that the contingency procedures lie within the ATS surveillance and communications service volumes and the ATS resources are sufficient for these tasks.

5.2.2.3 When GNSS is used as the sole basis for both ATS surveillance and aircraft navigation, the risks and requirement for mitigation techniques associated with the loss of GNSS potentially resulting in the loss of both navigation and surveillance capability, should be considered. This should typically be addressed through the regional or local State safety risk assessment prepared in support of the application.

5.2.3 Obstacle clearance

5.2.3.1 Detailed guidance on obstacle clearance is provided in the *Procedures for Air Navigation Services – Aircraft* Operations, Volume II – *Construction of Visual and Instrument Flight Procedures* (Doc 8168). The general criteria in Parts I, III and IV apply, together with the approach criteria from PANS-OPS, Volume II, Part III, Section 1, Chapter 5 and Section 3, Chapter 5, regarding SBAS. The criteria assume normal operations.

5.2.4 Additional considerations

5.2.4.1 The State must verify that the SBAS system and the service provider of the GNSS system used to support RNP APCH operations are approved according to the appropriate regulation.

5.2.4.2 Guidance in this chapter does not supersede appropriate State operating requirements for equipage.

5.2.4.3 Many aircraft have an RNAV holding capability. Aircraft can either hold manually over a waypoint when the aircraft holding functionality is not available and the pilot is expected to manually fly the RNAV holding pattern, or the RNAV system's holding functionality can be used to execute the published RNAV hold (see Volume I, Attachment A 5.3).

5.2.4.4 Although this navigation specification does not include requirements for an RNAV holding function, ANSPs may include holding procedures in their airspace design using a waypoint as a holding point.

5.2.5 Procedure validation

5.2.5.1 Guidance on procedure validation is provided in *The Quality Assurance Manual for Flight Procedure Design* (Doc 9906), Volume I – *Flight Procedure Design Quality Assurance System*, and Volume V – *Validation of in-Flight Procedures*.

Note.— Guidance on the flight inspection is provided in the Manual on Testing of Radio Navigation Aids *(Doc 8071).*

5.2.6 Publication

5.2.6.1 The AIP should clearly indicate that the navigation application is RNP APCH. Charting will follow the standards of Annex 4 – *Aeronautical Charts*, for the designation of an RNAV procedure where the vertical path is geometrically specified by a final approach segment data block (FAS DB). The charting designation will remain consistent with the current convention and will be promulgated as an LP or LPV OCA(H).

Note.— An approach chart may contain LNAV, LNAV/VNAV and LPV minima. Where a final approach path cannot offer either LNAV/VNAV or LPV approach minima, a separate, distinct approach chart should provide LNAV and LP minima, when practical. Some RNP APCH charts may contain only an LP line of minima when the FAS requires SBAS angular lateral guidance to remain clear of obstacles and terrain.

5.2.6.2 If the missed approach segment is based on conventional means, NAVAID facilities that are necessary to conduct the missed approach procedure will be identified in the relevant AIP and charting.

5.2.6.3 The navigation data published in the State AIP for the procedures and supporting NAVAIDs will meet the requirements of Annex 4 and Annex 15 – *Aeronautical Information Services* (as appropriate).

5.2.6.4 All procedures will be based upon WGS-84 coordinates.

5.2.6.5 The FAS of RNP APCH operations down to LP or LPV minima is uniquely characterized by a geometrically defined FAS. The FAS is defined laterally by the FPAP and LTP/ fictitious threshold point (FTP) and defined vertically by the TCH and glide path angle. The procedural definition of the FAS will be promulgated using the FAS DB publication process. This FAS DB contains the lateral and vertical parameters, which define the LPV or LP approach to be flown. Each FAS DB includes a cyclic redundancy check (CRC) application, which wraps around and protects the FAS DB data from alteration or data corruption. SBAS avionics approved for LPV or LP approach operations include functionality to "unwrap" the CRC and extract the data from the FAS DB to generate the LPV or LP approach path.

5.2.6.6 The FAS may be intercepted by an approach transition (such as RNAV 1), or initial and intermediate segments of an RNP APCH approach, as described in Section A of this chapter, or through vectoring (such as interception of the extended FAS).

5.2.6.7 Where holding patterns are published, they are to comply with the criteria and publication requirements in PANS-OPS, Volume II, Part 3, Section 3, Chapter 7. For the content of the PBN requirement box published on the chart, see also PANS-OPS, Volume II, Part 3, Section 5, Chapter 1.

5.2.7 Controller training

5.2.7.1 Air traffic controllers, who will provide control services at airports where RNP APCH down to LP or LPV minima have been implemented, should have completed training that covers the items listed below.

5.2.7.2 Core training

a) How RNAV systems work (in the context of this navigation specification):

1) include functional capabilities and limitations of this navigation specification;

2) accuracy, integrity, availability and continuity including on-board performance monitoring and alerting;

3) GNSS and SBAS receivers, receiver autonomous integrity monitoring (RAIM), FDE, and integrity alerts;

4) waypoint fly-by versus fly-over concept (and different turn performance);

5) FAS DB; and

6) difference between barometric and geometric approach slopes;

b) flight plan requirements;

c) ATC procedures:

1) ATC contingency procedures;

2) separation minima;

3) mixed equipage environment;

4) transition between different operating environments; and

5) phraseology.

5.2.7.3 Training specific to this navigation specification

a) Related control procedures:

1) vectoring techniques (where appropriate);

b) RNP approach and related procedures:

1) including T and Y approaches; and

2) approach minima;

c) impact of requesting a change to routing during a procedure.

5.2.8 Navigation service monitoring

Navigation service monitoring should be consistent with Volume II, Part A, Chapter 4.

5.2.9 Air traffic services system monitoring

If an observation/analysis indicates that a loss of obstacle clearance has occurred, the reason for the apparent deviation from track or altitude should be determined and steps taken to prevent a recurrence.

5.3 NAVIGATION SPECIFICATION

5.3.1 Background

5.3.1.1 This section identifies the airworthiness and operational requirements for RNP APCH operations conducted using SBAS to enable use of LP or LPV minima. Operational compliance with these requirements must be addressed through national operational regulations and may require an operational authorization in some cases. For example, certain operational regulations require operators to apply to their national authority (State of Registry) for operational authorization.

5.3.1.2 This chapter addresses the lateral and vertical part of the navigation system.

5.3.2 Authorization process

5.3.2.1 This navigation specification does not in itself constitute regulatory guidance material against which either the aircraft or the operator will be assessed and approved. Aircraft are certified by their State of Manufacture. Operators are authorized in accordance with their national operating rules. This navigation specification provides the technical and operational criteria and does not necessarily imply a need for recertification.

Note 1.— Detailed information on operational authorizations is provided in the Performance-based Navigation (PBN) Operational Authorization Manual *(Doc 9997)*[1].

Note 2.— Where appropriate, States may refer to previous operational authorizations in order to expedite this process for individual operators where performance and functionality are applicable to the current request for operational authorization.

1 Formerly the *Performance-based Navigation Operational Approval Manual*, renamed in its third (forthcoming) edition.

5.3.2.2 Aircraft eligibility

The aircraft eligibility must be determined through demonstration of compliance against the relevant SBAS receiver airworthiness criteria and the requirements of Section B, 5.3.3. The OEM or the holder of installation approval for the aircraft, such as the STC holder, will demonstrate compliance to their regulatory authority and the approval can be documented in manufacturer documentation (such as service letters). Aircraft flight manual (AFM) entries are not required provided the State accepts manufacturer documentation.

Note.— Requests for approval to use optional functionality (such as radius to fix (RF) legs) should address the aircraft and operational requirements as described in the appropriate functional attachment to this volume.

5.3.2.3 Operational authorization

5.3.2.3.1 ***Description of aircraft equipment***

The operator must have a configuration list and, if necessary, an MEL detailing the required aircraft equipment for RNP APCH operations to LP or LPV minima.

5.3.2.3.2 ***Training documentation***

5.3.2.3.2.1 Commercial operators must have a training programme addressing the operational practices, procedures and training items related to RNP APCH operations to LP or LPV minima (such as initial, upgrade or recurrent training for pilots, dispatchers or maintenance personnel).

Note.— Operators need not establish a separate training programme or regimen if they already integrate RNP APCH training as an element of their training programme. However, the operator should be able to identify the aspects of RNP APCH operations using SBAS to LP or LPV minima covered within their training programme.

5.3.2.3.2.2 Private operators must be familiar with the practices and procedures identified in 5.3.5.

5.3.2.3.3 ***OMs and checklists***

5.3.2.3.3.1 Operations manuals (OMs) and checklists for commercial operators must address information/guidance on the SOP detailed in 5.3.4. The appropriate manuals should contain navigation operating instructions and contingency procedures, where specified. When required by the State of the Operator/Registry, the operator must submit their manuals and checklists for review as part of the application process.

5.3.2.3.3.2 Private operators should operate using the practices and procedures identified in 5.3.5.

5.3.2.3.4 ***MEL considerations***

Any MEL revisions necessary to address provisions for RNP APCH operations to LP or LPV minima must be approved. Operators must adjust the MEL, or equivalent, and specify the required dispatch conditions.

5.3.2.3.5 ***Continuing airworthiness***

The operator must submit the continuing airworthiness instructions applicable to the aircraft's configuration and the aircraft's qualification for this SBAS navigation specification. Additionally, there is a requirement for operators to submit their maintenance programme, including a reliability programme for monitoring the equipment.

Note.— The operator should confirm with the OEM, or the holder of installation approval for the aircraft, that acceptance of subsequent changes in the aircraft configuration, such as SBs, do not invalidate current operational authorizations.

5.3.3 Aircraft requirements

5.3.3.1 System performance monitoring and alerting

5.3.3.1.1 ***RNP system integrating SBAS performance***

5.3.3.1.1.1 *Accuracy.* Along the FAS and the straight continuation of the final approach in the missed approach, the lateral and vertical total system error (TSE) is dependent on the navigation system error (NSE), path definition error (PDE) and FTE:

a) *NSE*. The accuracy itself (the error bound with 95 per cent probability) changes due to different GNSS satellite geometries and whether SBAS is available. Assessment based on measurements within a sliding time window is not suitable for analysis of GNSS satellite geometries without SBAS availability. Therefore, GNSS accuracy is specified as a probability for each and every sample. NSE requirements are fulfilled without any demonstration if the equipment computes three dimensional positions using linearized, weighted least square solution in accordance with RTCA DO 229() Appendix J.

b) *FTE*. Performance during an RNP APCH flown to LPV or LP minima is considered acceptable if the lateral and vertical display full-scale deflection is compliant with the non-numeric lateral cross-track and vertical deviation requirements of RTCA DO 229() and if the crew maintains the aircraft within one-half the full-scale deflection for the lateral deviation and within one-half the full-scale deflection for the vertical deviation.

c) *PDE*. Considered negligible based upon the process of path specification to data specification and associated quality assurance that is included in the RNP APCH procedure production and SBAS FAS data-block generation process, which is a standardized process. The responsibilities for defining the SBAS FAS DB and its CRC generation lies with the ANSP.

Note.— FTE performance is considered acceptable if the approach mode of the aircraft's flight guidance system (FGS) demonstrates the ability to support an RNP APCH flown to LPV or LP minima.

5.3.3.1.1.2 *Integrity.* Simultaneously presenting misleading lateral and vertical guidance with misleading distance data during an RNP APCH operation down to LPV minima is considered a hazardous failure condition (extremely remote). Simultaneously presenting misleading lateral guidance with misleading distance data during an RNP APCH operation down to LP minima is considered a hazardous failure condition (extremely remote).

5.3.3.1.1.3 *Continuity.* Loss of approach capability is considered a minor failure condition if the operator can revert to a different navigation system (such as VHF omnidirectional radio range (VOR)) and proceed to a suitable airport. For RNP APCH operations down to LP or LPV minima at least one alternative system is required.

Note.— Most aircraft with an airworthiness approval to conduct an RNP APCH to LPV or LP minima also include a VOR installation. Thus, VOR can enable continued instrument flight operations when GNSS is lost for any reason. This enables the operator to safely obtain a new ATC clearance based on VOR navigation, achieving continuity.

5.3.3.1.2 ***On-board performance monitoring and alerting***

Operations on the FAS of an RNP APCH operation down to LP and LPV minima, the on-board performance monitoring and alerting function is fulfilled by:

a) NSE monitoring and alerting:

1) At a position between 2 NM from the FAP and the FAP, the aircraft navigation equipment is required to provide an alert within ten seconds if the probability that the NSE exceeds 0.6 NM is greater than $1x10^{-7}$ per flight hour.

2) After sequencing the FAP and during operations on the FAS of an RNP APCH operation down to LP or LPV minima:

i) the aircraft navigation equipment is required to provide an alert within six seconds if the NSE is greater than 40 m, with an integrity risk less than $2x10^{-7}$ in any approach (Annex 10, Volume I, Table 3.7.2.4-1); and

ii) the aircraft navigation equipment is required to provide an alert within six seconds if the probability that the vertical position error exceeds 50 m, for LPV minima down to 76 m (250 ft) height above touchdown (HAT), or 35 m, (115 ft) for LPV minima down to 60 m (200 ft) HAT, is greater than $2x10^{-7}$ in any approach (Annex 10, Volume I, Table 3.7.2.4-1).

b) FTE monitoring and alerting: LPV and LP approach guidance must be displayed on a lateral and vertical deviation display (HSI, EHSI), course deviation indicator/vertical deviation indicator (CDI/VDI) including a failure indicator, as applicable to the approach operation and aircraft's airworthiness approval integrating SBAS for LPV and LP approaches. The lateral and vertical deviation displays must have a suitable full-scale deflection based on the required track-keeping accuracy consistent with the SBAS installation's characteristics.

Note.— The lateral and vertical deviation scaling is angular during an LPV approach relative to the lateral and vertical path definitions the SBAS avionics generate based on the data contained in the FAS DB. In contrast, during an RNP APCH flown to LP minima, the SBAS avionics generate angular lateral path guidance consistent with the absence of a vertical path angle (VPA) in the FAS DB. Despite the absence of a VPA definition in the FAS DB, the integration of the SBAS avionics and RNP system in the aircraft can provide vertical guidance for advisory purposes during an LP final approach. The advisory vertical guidance can assist the flight crew by offering a means to conduct a CDFA operation to the LP approach procedure's VDP at the MDA, aiding in a smooth transition to landing.

c) Navigation database: the SBAS avionics run the FAS DB CRC to ensure the content of the data block retains its integrity and accuracy. If for any reason the SBAS avionics applies the CRC to the FAS DB and the CRC fails, the SBAS does not activate the LP or LPV approach mode and annunciates LPV or LP unavailable.

Note 1.— RNP requirements do not apply to the missed approach from an SBAS LPV or LP approach operation when the missed approach procedure relies on conventional navigation (such as VOR, DME) or on dead reckoning.

Note 2.— Compliance with the performance monitoring and alerting requirement does not imply automatic SBAS avionics monitoring of FTE. The on-board monitoring and alerting function should consist at least of an NSE monitoring and alerting algorithm and a lateral and vertical deviation display enabling the flight crew to monitor FTE. To the extent the SBAS installation in the aircraft relies on flight crew procedures to monitor FTE, the flight crew training and procedures, the SBAS and GNSS equipment characteristics, and the installation's characteristics are evaluated for their effectiveness and equivalence to other instrument approach procedures as described in the functional requirements and operating procedures. PDE is considered negligible due to the navigation database quality assurance process (5.3.6) and the operating procedures (5.3.4).

Note 3.—The following systems meet the accuracy, integrity and continuity requirements of these criteria:

1) *GNSS SBAS stand-alone equipment approved in accordance with E/TSO C146() (or subsequent version). Application of this SBAS standard guarantees the equipment is compliant with RTCA DO 229(). The equipment should be a Class Gamma, Operational Class 3;*

2) *for an integrated RNP system (such as FMS) incorporating a GNSS SBAS sensor, E/TSO C115() and AC 20-138() provide an acceptable means of compliance for the approval of this navigation system when the SBAS augmentation meets the following guidelines:*

   i) *demonstration to the performance requirements of E/TSO-C146() (or subsequent version) that apply to functional Class Gamma, Operational Class 3 or Delta 4; and*

   ii) *approval of the GNSS SBAS sensor in accordance with E/TSO C145() Class Beta, operational Class 3;*

3) *an RNP APCH system incorporating Class Delta GNSS SBAS equipment approved in accordance with E/TSO C146() (or subsequent version). This standard guarantees the equipment is compliant with RTCA DO 229(). The equipment should be a Class Delta 4; and*

4) *future SBAS systems are also expected to meet these requirements as a minimum.*

5.3.3.2 Criteria for specific navigation systems

RNP APCH operations down to LP or LPV minima are based on SBAS positioning. The RNP system may use positioning data from other types of navigation sensors and integrate that positioning data with the SBAS data provided it does not cause position errors exceeding the TSE budget**,** and when means are provided to deselect other, unacceptable navigation sensor types (such as VOR-updating).

5.3.3.3 Functional requirements

5.3.3.3.1 ***Navigation displays and required functions***

5.3.3.3.1.1 Approach guidance must be displayed on a lateral and vertical deviation display (HSI, EHSI, CDI/VDI), including a failure indicator, and must meet the following requirements:

a) this display must be used as primary flight instruments for the approach;

b) the display must be visible to the pilot and located in the primary field of view (±15 degrees from the pilot's normal line of sight) when looking forward along the flight path; and

c) the deviation display must have a suitable full-scale deflection based on the required track-keeping accuracy.

During an LPV approach operation, the lateral and vertical deviation scaling is angular and associated to the SBAS lateral and vertical path guidance derived from the sensor and the content of the FAS DB. During an LP approach operation, only the lateral deviation scaling is angular.

Note 1.— Where the minimum flight crew is two pilots, the pilot not flying should be able to verify the desired path and the aircraft position relative to the path.

Note 2.— For more details on lateral and vertical deviation display scales, see the non-numeric lateral cross-track and vertical deviation requirements of DO 229() (or subsequent version) and the SBAS installation requirements in FAA AC 20-138(), or other equivalent requirements from another State airworthiness authority.

5.3.3.3.1.2 The following GNSS and SBAS system functions are required as a minimum:

a) the capability to display the SBAS approach mode (such as LP, LPV, LNAV/VNAV, lateral navigation) in the primary field of view. This annunciation indicates to the crew the active approach mode in order to correlate it to the corresponding line of minima on the approach chart. It can also detect a level of service degradation (such as downgrade from LPV to LNAV-only). The airborne system should automatically provide the highest "level of service" available for the annunciation of the GNSS approach mode when the approach is selected;

Note.— Aircraft installation of an SBAS sensor may receive airworthiness approval for RNP APCH flown to LNAV/VNAV minima through use of SBAS vertical guidance in lieu of Baro-VNAV vertical guidance. RTCA DO-229() and FAA AC 20-138() provide guidance and an acceptable means of compliance for approval of RNP APCH flown to LNAV/VNAV minima when using SBAS vertical guidance.

b) once the SBAS installation successfully transitions to the LPV or LP approach mode prior to the FAF, the capability to continuously display the distance to the LTP/FTP;

c) the navigation database must contain all the necessary data/information to fly the published RNP APCH procedure, including the State-provided, CRC-wrapped FAS DB. Although there are many ways an on-board navigation database may store and transmit data to the RNP system installed in the aircraft, for RNP APCH operations relying on SBAS for use of LPV and LP minima, the database must support carriage of each procedure's FAS DB and support use of the FAS DB CRC. This is essential to ensure the aircraft integration of SBAS protects the integrity and accuracy of the content of the RNP APCH FAS DB;

d) the capacity to select from the on-board navigation database into the installed RNP system the whole RNP APCH procedure to be flown, to include all relevant information needed to enable use of SBAS positioning during the approach (such as SBAS "channel number" identifying the specific RNP APCH and content of the FAS DB);

e) the indication of the loss of navigation (such as system failure) in the pilot's primary field of view by means of a navigation warning flag or equivalent indicator on the vertical and/or lateral navigation display, including all displays required to enable an aircraft to be eligible to use SBAS during an RNP APCH;

f) the indication of the LOI function (such as loss of LPV vertical guidance) in the pilot's normal field of view by means of an appropriately located annunciation in accordance with the aircraft SBAS installation requirements; and

g) the capability to immediately provide track deviation indications relative to an extended FAS, in order to facilitate the interception of the extended FAS from a vector (such as vector to final (VTF) function).

Note.— These requirements are limited to the interception of the extended FAS lateral path. If the installed system is also able to fly the initial, intermediate and missed approach segments of the approach, the corresponding requirement (such as RNP APCH, Section A of this chapter, or RNAV1 criteria) applies. This requirement does not impact when the RNP system and SBAS sensor conduct their final checks before beginning the procedure-defined FAS. Most SBAS sensor integrations will conduct these checks 2 NM prior to the FAF or "precision FAF" (PFAF) prior to making the flight guidance mode change to LPV or LP guidance. The VTF function in the RNP system does not impact where the aircraft's SBAS installation conducts these checks.

5.3.4 Operating procedures

5.3.4.1 Airworthiness approval for conduct of an RNP APCH to LP or LPV minima alone does not authorize an operator to conduct RNP APCH operations down to LP or LPV minima. Operational authorization is also required to confirm the adequacy of the operator's normal and contingency procedures for the SBAS equipment installation.

5.3.4.2 Pre-flight planning

5.3.4.2.1 Operators and pilots intending to conduct RNP APCH operations down to LP or LPV minima must file the appropriate ATC flight plan suffixes when applicable. The on-board navigation data must be current and must include the appropriate procedures.

Note.— The aircraft's on-board navigation database(s) are expected to be current for the duration of the flight. If the AIRAC cycle is due to change during flight, operators and pilots should establish procedures to ensure the accuracy of navigation data, including suitability of navigation facilities used to define the routes and procedures for flight.

5.3.4.2.2 In addition to the normal pre-flight planning, the following checks must be carried out:

a) the pilot must ensure that approach procedures that may be used for the intended flight (including alternates aerodromes) are selectable from a valid navigation database (current AIRAC cycle), have been verified by the appropriate process and are not prohibited by a company instruction or NOTAM;

b) subject to State's regulations, during the preflight phase, the pilot should ensure sufficient means are available to navigate and land at the destination or at an alternate aerodrome in the case of loss of GNSS and SBAS resulting in loss of LP or LPV approach capability;

c) operators and flight crews must take account of any NOTAMs (including SBAS NOTAMs) or operator briefing material that could adversely affect the aircraft system operation, or the availability or suitability of the procedures at the airport of landing, or any alternate airport; and

d) if the missed approach procedure is based on conventional means (such as VOR, DME), the appropriate airborne equipment required to fly this procedure must be installed in the aircraft and must be operational. The associated ground-based NAVAIDs must also be operational. If the missed approach procedure is based on RNAV or RNP (no conventional or dead reckoning missed approach available) the appropriate airborne equipment required to fly this procedure must be installed in the aircraft and must be operational.

5.3.4.2.3 The operator must confirm the availability of the NAVAID infrastructure required for the intended routes, including any non-RNAV contingencies, for the period of intended operations using all available information. Since GNSS integrity is required by Annex 10, the availability of this the operator should confirm the availability of GNSS and SBAS as appropriate.

5.3.4.3 SBAS availability

5.3.4.3.1 Service levels required for RNP APCH operations down to LP or LPV minima can be verified either through SBAS NOTAMs (where available) or may be available through prediction services. The State operating authority may provide specific guidance on how to comply with this SBAS availability confirmation requirements. Operators should be familiar with the prediction information available for the intended route and approach operations.

5.3.4.3.2 LP or LPV service availability prediction should take into account the latest GNSS constellation and SBAS system status NOTAMs and avionics model (when available). The service may be provided by the ANSP, avionics manufacturer, other entities or through an airborne receiver LP or LPV service prediction capability.

Note.— In some instances, predicting the availability of an RNP APCH flown to LP or LPV minima may be as simple as checking SBAS NOTAMs for availability of the SBAS service for the time of the intended operation in the SBAS coverage. Operators should reference the State's AIP for any specific SBAS prediction requirements required by the State or by the ANSP acting on behalf of the State.

5.3.4.3.3 In the event of a predicted, continuous loss of appropriate level of GNSS fault detection of more than five minutes for any part of the RNP APCH operation, the operator should revise their filed flight plan appropriately (such as delay the departure time or plan to conduct a different instrument procedure that does not depend on GNSS and SBAS).

5.3.4.3.4 Service availability prediction software does not guarantee the GNSS or SBAS service; they are simply tools to assess the expected aircraft capability to meet the route and procedural RNP requirements. Because of unplanned failure of some GNSS or SBAS elements, pilots or ANSPs should realize that the GNSS or SBAS service or signal in space may be lost over a wide geographic area with many aircraft airborne. This may require reversion at the aircraft level to an alternative means of navigation, and at the ANSP service level to pre-planned contingency procedures for loss of GNSS. Therefore, both the operator and the ANSP should assess the contingency situation created by the loss of GNSS or SBAS service for any reason (such as GNSS jamming or SBAS system failures).

5.3.4.3.5 These specifications assume future GNSS systems will require availability prediction services equivalent to the services required for operational use of an SBAS service.

5.3.4.4 Prior to commencing the procedure

5.3.4.4.1 In addition to normal procedure prior to commencing the approach (before the IAF and in compatibility with crew workload), the pilot must verify the correctness of the loaded procedure by comparison with the appropriate approach charts. This check must include:

a) the waypoint sequence;

b) reasonableness of the tracks and distances of the approach legs, and the accuracy of the inbound course and mileage of the FAS; and

Note 1.— As a minimum, this check could be a simple inspection of a suitable map display.

Note 2.— Pilots may notice a slight difference between the navigation information portrayed on the chart and their map display. Differences of three degrees or less may result from the equipment manufacturer's application of magnetic variation and are operationally acceptable.

c) the vertical path angle.

5.3.4.4.2 Air traffic control (ATC) tactical interventions in the terminal area may include vectoring, "direct to" clearances that by-pass the initial legs of an approach, interception of an initial or intermediate segment of an approach or the insertion of waypoints loaded from the database. In complying with ATC instructions, the pilot should be aware of the following implications for the navigation system:

a) the manual entry of coordinates into the navigation system by the pilot for operation within the terminal area is not permitted; and

b) "direct to" clearances may be accepted to the IF provided that the resulting track change at the IF does not exceed 45 degrees.

Note.— "Direct to" clearance to FAP or FAF or vector to intercept final course inside FAF is not acceptable.

5.3.4.4.3 The approach system provides the capability for the pilot to intercept the final approach track well before the FAP (VTF function or equivalent). This function should be used to respect a given ATC clearance.

5.3.4.5 During the procedure

5.3.4.5.1 The RNP system and SBAS installation will automatically activate the approach mode, including the transition to LP or LPV guidance. When a direct transition to the approach procedure is conducted (such as when the aircraft is vectored by the ATC to the extended FAS and the crew selects the VTF function or an equivalent function), the SBAS LP or LPV approach mode may be immediately activated.

5.3.4.5.2 The crew must check that the SBAS and approach mode indicates LP or LPV (or an equivalent annunciation) 2 NM before the FAP.

5.3.4.5.3 The aircraft should intercept the FAS prior to the FAP (that is, the FAF) in order for the aircraft to correctly make the transition to LP or LPV angular guidance and for the flight crew to stabilize the aircraft on the lateral and vertical guidance as they begin the descent in the FAS (in accordance with flight operating manual procedures and to ensure terrain and obstacle clearance).

5.3.4.5.4 The appropriate displays should be selected so that the following information can be monitored:

a) aircraft position relative to the lateral path;

b) aircraft position relative to the vertical path; and

c) presentation of LOI alerts and annunciations (such as loss of LPV vertical guidance).

5.3.4.5.5 The flight crew must respect all published altitude and speed constraints.

5.3.4.5.6 Prior to sequencing the FAP, the crew should abort the approach procedure if there is:

a) loss of navigation indicated by a warning flag (such as absence of power, equipment failure, etc.);

b) LOI alerting, annunciated locally, or equivalent (such as failure to progress into the LP or LPV approach mode); and

c) low altitude alert (if applicable).

5.3.4.5.7 After sequencing the FAP, unless the pilot has the visual references required to continue the approach in sight, the procedure must be discontinued if:

a) loss of navigation is indicated by a warning flag (such as lateral flag, vertical flag or both flags);

Note.— LOI alerting after sequencing the FAP leads to a loss of the desired and selected navigation function (warning flag).

b) loss of vertical guidance is indicated (even if lateral guidance remains displayed); and/or

c) FTE is excessive and cannot be corrected in a timely manner.

5.3.4.5.8 Pilots must execute a missed approach if excessive lateral and/or vertical deviations occur and cannot be corrected on time, unless the pilot has in sight the visual references required to continue the approach. The missed approach must be flown in accordance with the published procedure (such as conventional or RNAV).

5.3.4.6 General operating procedures

5.3.4.6.1 Operators and pilots must not request an RNP APCH requiring use of LP or LPV minima unless they satisfy all the criteria in the relevant State documents. If an aircraft without an airworthiness approval for LP or LPV receives a clearance from ATC to conduct such an RNP APCH procedure to LP or LPV minima, the pilot must refuse the clearance and advise ATC they are unable to accept the clearance and request alternate instructions.

5.3.4.6.2 The pilot must comply with any instructions or procedures identified by the manufacturer as necessary to comply with the performance requirements in this chapter.

5.3.4.6.3 If the missed approach procedure is based on conventional means (such as VOR, DME), related navigation equipment must be installed and be serviceable.

5.3.4.6.4 Pilots are encouraged to use flight director and/or autopilot in LNAV, if available.

5.3.4.7 Contingency procedures

5.3.4.7.1 The operator should develop contingency procedures in order to react safely following the loss of the approach capability during any RNP APCH.

5.3.4.7.2 The pilot must notify ATC of any loss of the RNP APCH capability, together with the proposed course of action. If unable to comply with the requirements of an RNP APCH procedure, pilots must advise ATS as soon as possible. The loss of RNP APCH capability includes any failure or event causing the aircraft to no longer satisfy the RNP APCH requirements of the procedure, including loss of LP or LPV functionality or loss of SBAS service.

5.3.4.7.3 In the event of a communications failure, the pilot should continue with the procedure in accordance with published lost communications procedures.

5.3.5 Pilot knowledge and training

The pilot training programme should be structured to provide sufficient theoretical and practical training, using a simulator, training device, or line training in an aircraft, on the use of the aircraft's approach system to ensure that pilots are not just task oriented. The following syllabus should be considered as a minimum amendment to the training programme to support these operations:

a) RNP APCH concept containing LP or LPV minima:

1) theory of approach operations;

2) approach charting;

3) use of the approach system including:

i) selection of the LP or LPV minima on an RNP APCH procedure; and

ii) instrument landing system (ILS) look alike principle;

4) use of lateral navigation mode(s) and associated lateral control techniques;

5) use of VNAV mode(s) and associated vertical control techniques;

6) the manner in which the RNP system provides temperature compensation (if applicable);

7) R/T phraseology for LP or LPV approach operations; and

8) the implication for LP or LPV approach operations of systems malfunctions that are not related to the approach system (such as hydraulic failure);

b) RNP APCH operation for procedures containing solely an LP or an LPV minima:

1) definition of LP or LPV approach operations during RNAV(GNSS) procedures;

2) regulatory requirements for LP or LPV approach operations;

3) required navigation equipment for LP or LPV approach operations:

i) GPS concepts and characteristics;

ii) SBAS characteristics; and

iii) MEL;

4) procedure characteristics:

i) chart depiction;

ii) aircraft display depiction; and

iii) minima;

5) retrieving an RNP APCH procedure from the database (such as using its name or the SBAS channel number);

6) change arrival airport and alternate airport;

7) flying the procedure:

   i) use of autopilot, autothrottle and flight director;

   ii) flight guidance mode behaviour;

   iii) lateral and vertical path management;

   iv) adherence to speed and/or altitude constraints;

   v) fly interception of an initial or intermediate segment of an approach following ATC instruction;

   vi) fly interception of the extended FAS (such as using the VTF function);

   vii) consideration of the SBAS approach mode indication (LP, LPV, LNAV/VNAV); and

   viii) the use of other aircraft equipment to support track monitoring, weather and obstacle avoidance;

8) ATC procedures;

9) abnormal procedures; and

10) contingency procedures.

5.3.6 Navigation database

5.3.6.1 The operator should not use a navigation database for these approach operations unless the navigation database supplier holds a Type 2 LOA or equivalent.

5.3.6.2 The navigation database should be obtained from a supplier that complies with RTCA DO 200()/EUROCAE document ED 76(), Standards for Processing Aeronautical Data. An LOA issued by the appropriate regulatory authority demonstrates compliance with this requirement (such as FAA LOA issued in accordance with FAA AC 20-153() or EASA certification of data services provider in accordance with Regulation (EU) 2017/373 (Part DAT)).

5.3.6.3 EUROCAE/RTCA document ED-76()/DO-200() Standards for Processing Aeronautical Data contains guidance relating to the processes that the supplier may follow. The LOA demonstrates compliance with this standard.

5.3.6.4 The operator should continue to monitor both the process and the products in accordance with the quality system required by the applicable operational regulations.

5.3.6.5 The operator should implement procedures that ensure timely distribution and insertion of current and unaltered electronic navigation data to all aircraft that require it.

5.3.7 Oversight of operators

5.3.7.1 A regulatory authority may consider any navigation error reports in determining remedial action. Repeated navigation error occurrences attributed to a specific piece of navigation equipment may result in cancellation of the authorization for use of that equipment.

5.3.7.2 Information that indicates the potential for repeated errors may require modification of an operator's training programme. Information that attributes multiple errors to a particular pilot crew may necessitate remedial training or licence review.

5.4 REFERENCES

The applicable versions of industry and regulatory references, standards and guidance included in this chapter, shown as open reference (), are listed in Attachment E to this volume. Some references contained in the chapter are part of background or historical information, and not included in Attachment E.

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Chapter 6

IMPLEMENTING RNP WITH AUTHORIZATION REQUIRED (RNP AR APCH AND RNP AR DP)

6.1 INTRODUCTION

6.1.1 Background

6.1.1.1 This RNP navigation specification for operations with authorization required (RNP AR operations) represents the global standard for developing instrument approach and departure procedures at airports with limiting terrain and obstacle environments, or other operational challenges. These specifications are not intended for application at every airport, nor are they intended for every operator. Instead, RNP AR operations implemented consistent with the specifications of this standard can offer efficiency and/or access in challenging environments where no other navigation specification in this manual or any other public instrument procedure can offer benefits.

6.1.1.2 The implementation of RNP AR operations offers unique instrument procedures requiring additional levels of scrutiny, control and authorization. RNP AR procedures increase risk and complexity, yet stringent performance and eligibility criteria mitigates this risk and achieves safe operations by taking advantage of advanced aircraft capabilities and additional training and procedures for the operator and the operator's flight crews.

6.1.1.3 Originally, the Federal Aviation Administration (FAA) published authorization guidance for RNP AR approach procedures through AC 90-101(). The European Union Aviation Safety Agency (EASA) also developed equivalent guidance in AMC 20-26. In line with the performance-based navigation (PBN) concept, this navigation specification seeks to harmonize these examples of standards and requirements as they apply to highly specialized instrument approach and instrument departure operations requiring formal operational authorization.

6.1.1.4 This chapter includes specifications for RNP AR operations enabling an operator to conduct RNP AR approach procedures (RNP AR APCH) and RNP AR departure procedures (RNP AR DP). These specifications take advantage of the unique capabilities of an operator's aircraft, their flight crews and their operations. These navigation specifications assume the aircraft and flight crew eligibility meets the specifications for all RNP AR operations, both RNP AR APCH and RNP AR DP.

6.1.1.5 Where applicable, these specifications also include any unique eligibility requirements as they independently apply to either an RNP AR APCH or an RNP AR DP. In this chapter, the term "RNP AR operations" refers to requirements and guidance applicable to both RNP AR APCH and RNP AR DP. When the requirements or the guidance refers to just the instrument approach operations these specifications cover, the term "RNP AR APCH" is used. In contrast, requirements and guidance applicable for just the instrument departure procedures use the term "RNP AR DP". The term "RNP AR procedures" simultaneously refers to both types of instrument procedures, RNP AR APCH and RNP AR DP.

6.1.1.6 To further clarify the specifications, this chapter also uses the latest airworthiness terminology from the recent industry airworthiness standards for RNP and the existing airworthiness terminology in State regulations and guidance materials. For example, instead of "aircraft navigation system", the term "RNP system" is used. Also, in lieu of "navigation accuracy", the term "RNP value" is used. These new terms should help both operators and regulators better embrace these specs as they endeavour to determine aircraft and operations eligibility for RNP AR operations.

6.1.2 Purpose

This chapter provides a recommendation for the operational implementation and conduct of RNP AR procedures. These recommendations cover the operational and airworthiness requirements that a State may choose to employ when they publish RNP AR procedures. However, these specifications do not address all the requirements for conducting an individual State's RNP AR procedures. States may specify additional requirements beyond these specifications in other documents such as their State operating rules or their State AIP. Likewise, States may agree to, and standardize, regional implementations of RNP AR procedures.

Note.— See the Regional Supplementary Procedures *(Doc 7030) for details of regional implementations.*

6.2 IMPLEMENTATION CONSIDERATIONS

6.2.1 NAVAID infrastructure considerations

6.2.1.1 The primary NAVAID infrastructure supporting RNP AR operations is the global navigation satellite system (GNSS).

6.2.1.2 Operators should not use RNP AR procedures in areas of known navigation signal interference when the interference targets the infrastructure their aircraft depends on. For example, if GNSS interference and/or jamming are present at the destination, and the operator requires GNSS to conduct RNP AR procedures, the operator should consider the RNP AR procedures unavailable and seek an alternative means of navigation or another destination.

Note 1.— Most multi-sensor RNP systems prioritize the system's navigation sensor inputs in a hierarchy of use. Typically, the RNP system prioritizes inputs from GNSS sensors above other navigation sensors and, when GNSS is not available, many RNP systems revert to DME/DME positioning. Regardless of the sensor the RNP system uses, the RNP AR operations in this specification rely on the availability of the NAVAID infrastructure and a prediction of the availability of the infrastructure.

Note 2.— While an RNP system may also revert to VHF omnidirectional radio range (VOR)/DME positioning when DME/DME positioning is not available, the variability of a VOR station's very high frequency (VHF) signal-in-space (SIS) pose serious challenges for the State, the aircraft's RNP system and the operator. Due to the unpredictability of the VOR VHF SIS behaviour, it is virtually impossible to rely on VOR/DME positioning to achieve the required performance and path compliance for any RNP AR operations. This specification does not rely on, or advocate, operational use of VOR/DME positioning during RNP AR operations. Operators may require procedures to prevent the RNP system from conducting navigation through VOR/DME positioning.

6.2.2 Communications and air traffic services surveillance considerations

The implementation of RNP AR operations does not inherently require or impose any specific communications or ATS surveillance requirements or considerations, over and above that required for an RNP APCH implementation (see Part C, Chapter 5, 5.2.2).

6.2.3 Obstacle clearance and route spacing

6.2.3.1 The *Required Navigation Performance Authorization Required (RNP AR) Procedure Design Manual* (Doc 9905) contains guidance for the design of RNP AR operations procedures and assumes normal operations.

6.2.3.2 States should publish terrain and obstacle data in the vicinity of the RNP AR APCH and RNP AR DP procedures in accordance with Annex 15 – *Aeronautical Information Services*.

6.2.3.3 Doc 9905 ensures obstacle clearance for normal operations through the application of standardized procedure design criteria for RNP AR procedures. Despite this, a State or regional ATM must conduct a safety assessment to determine the surveillance services and the appropriate route spacing applicable to their specific RNP AR procedures.

6.2.3.4 While applying the criteria in Doc 9905 ensures separation from terrain and obstacles, and the ATM system's route spacing and ATC ensures separation from other traffic, RNP AR DPs introduce new aircraft performance requirements. These performance requirements rely on the operator applying detailed take-off and climb performance data, and they demand robust flight crew procedures and training. Given these unique operational characteristics, the State of the Operator must ensure a flight operational safety assessment (FOSA) confirms an operator's preparation for all aspects of an RNP AR DP before granting an operational authorization. Failure to conduct a FOSA can result in the operator's failure to ensure proper conduct of RNP AR DPs and a loss of clearance from obstacles and terrain.

6.2.4 Additional considerations

6.2.4.1 Overview

6.2.4.1.1 The guidance in this chapter does not supersede a State's requirements for equipage or the manner in which an operator gains authorization to conduct the State's RNP AR procedures.

6.2.4.1.2 RNP AR APCH requires the availability of a current, local barometric altimeter setting for flight crew use. Consequently, States should ensure the availability of a current, local barometric altimeter setting at any airport where they offer RNP AR procedures.

6.2.4.1.3 As part of the safety assessment process supporting each RNP AR procedure, the State of the Operator and the operator must address the procedures' specific operational risks in accordance with criteria listed in 6.5.

6.2.4.1.4 These specifications also rely on demanding flight crew and aircraft performance requirements above and beyond the performance requirements of the other specifications in this manual. These specifications assume the operator maintains a complete set aircraft performance data covering all aspects of RNP AR operations, including the additional climb performance requirements of RNP AR DPs, and that the operator's training and procedures include the safe application of their aircraft performance.

6.2.4.2 State validation

6.2.4.2.1 As RNP AR operations do not rely on specific underlying navigation facilities, there is no requirement for flight inspection of navigation SIS. However, due to the importance of publishing correct procedural data in the State's AIP, the State must validate each RNP AR procedure in accordance with the *Procedures for Air Navigation Services – Aircraft Operations*, Volume II – *Construction of Visual and Instrument Flight Procedures* (PANS-OPS, Doc 8168) Part I, Section 2, Chapter 4, 4.6. Prior to publication, the validation process should confirm obstacle data, basic flyability, track lengths, bank angles, climb gradients, descent gradients and compatibility with aircraft predictive terrain awareness and warning systems (TAWS), as well as the other factors listed in PANS-OPS.

Note 1.— When the State can verify, by ground validation, the accuracy and completeness of all obstacle data the procedure design considers, and any other factors the flight validation normally considers, then the State may dispense of the flight validation requirement.

Note 2.— When the State dispenses of the flight validation of an RNP AR procedure, the State of the Operator may still require the operator to conduct their own flight validation of any RNP AR procedures the operator desires to conduct. This validation by the individual operator may be part of FOSA supporting the operator's authorization to conduct RNP AR procedures.

6.2.4.2.2 Because of the unique nature of RNP AR procedures, operators should conduct simulator assessments of each RNP AR procedure they intend to conduct to evaluate all factors, including their aircraft's performance during the procedure and the basic flyability of the procedure. To the maximum extent possible, the operator should also complete the entirety of their State's assessment and authorization requirements prior to conducting any flight validation of an RNP AR procedure.

Note.— The evaluation of procedure flyability (such as take-off performance, climb capability, airspeeds, aircraft operating weights, etc.) and the performance of navigation and flight control systems is the responsibility of the operator.

6.2.5 Publication

6.2.5.1 The State AIP should clearly indicate when a published RNP AR operation is an RNP AR APCH procedure or an RNP AR DP procedure. The AIP should also clearly indicate the procedures require specific authorization (such as "AUTHORIZATION REQUIRED"). Also, when the State requires distinct authorization for specific RNP AR operations or at specific aerodromes where they publish RNP AR procedures, the State should clearly document this requirement(s) in their AIP (see 6.3.2.2).

6.2.5.2 The State should clearly publish the minimum RNP value any RNP AR procedure requires during any segment or part of the procedure.

Note.— When not otherwise readily identified (such as the lines of minima on an RNP AR APCH), publishing the procedure's minimum RNP value can help operators and flight crews identify the operational suitability of each individual RNP AR procedure. In some cases, where the operational authorization permits it, the flight crew may also need to set the minimum RNP value before beginning an RNP AR procedure.

6.2.5.3 The navigation data the State publishes in their AIP for the RNP AR procedures, including data for supporting NAVAIDs (if used), must meet the requirements of Annex 15 – *Aeronautical Information* Services and Annex 4 – *Aeronautical Charts* (as appropriate). In particular, the State must make this AIP procedural data available in a manner suitable for verification of the packed procedure in an aircraft's on-board navigation database.

6.2.5.4 When the State publishes "special" or proprietary "non-public" RNP procedures in their AIP, they should make every effort to distinguish the non-public RNP procedures from the public RNP AR procedures this navigation specification covers. Operator and flight crew confusion about these non-public RNP procedures could result in attempts by a flight crew to fly a procedure inadvertently included in their aircraft's on-board navigation database. These attempts may compromise safety.

Note.— Worldwide, many States publish instrument flight procedures (IFPs) similar to RNP AR APCH procedures, and some are charted in a manner similar to the public RNP AR APCH procedures other States publish in their AIP. However, many of these procedures are proprietary and designed for specific aircraft types and operators. Compliance with this chapter may not ensure aircraft eligibility and operational qualification for these procedures as they may not be designed in accordance with Doc 9905. These applications may apply different aircraft qualification, operational authorization and procedure design criteria. When possible, States should not publish these proprietary procedures in their public AIP.

6.2.6 Controller training

6.2.6.1 Air traffic controllers, who provide control services at airports where the State publishes RNP AR procedures, should complete a course of training covering the following minimum items.

6.2.6.2 Core training

a) How RNP systems work (in the context of this navigation specification):

   1) include functional capabilities and limitations of this navigation specification;

   2) accuracy, integrity, availability and on-board performance monitoring and alerting;

   3) Global Positioning System (GPS) receiver, receive autonomous integrity monitoring (RAIM), FDE, and integrity alerts;

   4) fly-by waypoints versus fly-over waypoints and their application to RNP AR operations (and different turn performances); and

   5) radius to fix (RF) leg applications in RNP AR APCH and RNP AR DP designs;

b) flight plan requirements;

c) ATC procedures:

   1) ATC contingency procedures;

   2) separation minima;

   3) mixed equipage environment; and

   4) transition between different operating environments; and

   5) phraseology.

6.2.6.3 Training specific to this navigation specification

a) Related air traffic control procedures:

   1) vectoring techniques (where appropriate):

      i) limitations and prohibitions for vectoring to RF legs; and

      ii) airspeed constraints;

b) RNP AR APCH procedures:

   1) approach minima; and

   2) additional requests for current barometric altimeter settings;

c) impacts of requesting an aircraft change routing during an RNP AR procedure:

1) when possible, once a flight begins an RNP AR procedure, allow the flight crew to complete the procedure in its entirety without interruption; and

2) when necessary to vector a flight off an RNP AR DP, do not request the flight crew to resume the departure at a later point since the flight crew may not be able to determine safe climb performance along the procedure's path.

6.2.7 Navigation service monitoring

Navigation service monitoring should be consistent with Volume II, Part A, Chapter 4.

6.2.8 Air traffic services system monitoring

If the controller observes a deviation during an RNP AR operation through ATS surveillance observation/analysis, and a loss of separation between aircraft or from terrain or obstacles occurs requiring intervention, the ATS provider, the State's operational regulator and the operator(s) should identify the cause of the deviation and take steps to prevent a recurrence. Monitoring of overall system safety should continuously confirm the ATS system contributes to meeting the acceptable level of safety performance for the RNP AR operation.

6.3 NAVIGATION SPECIFICATION FOR IMPLEMENTING RNP AR OPERATIONS

6.3.1 Background

This section identifies the operational requirements for RNP AR operations. Each State publishing RNP AR operations procedures should address operational compliance with these requirements in their national operational regulations.

6.3.2 Authorization process

6.3.2.1 The navigation specification for implementing RNP AR is not a State regulation or guidance material against which a State will assess and approve either an aircraft or an operator. The State of Manufacture of an aircraft certifies and approves its eligibility for RNP AR operations, while defining limitations that impact RNP operations. The State of the Operator authorizes each operator in accordance with their national operating rules. This navigation specification provides the technical and operational criteria and does not necessarily imply a need for recertification.

Note 1.— The Performance-based Navigation (PBN) Operational Authorization Manual *(Doc 9997)*[1] *provides detailed information on operational authorizations.*

Note 2.— Where appropriate, States may refer to previous operational authorizations for RNP operations in order to expedite this process for individual operators where the aircraft performance and functionality are applicable to the current request for authorizations to conduct RNP AR operations.

1. Formerly the *Performance-based Navigation Operational Approval Manual*, renamed in its third (forthcoming) edition.

6.3.2.2 Any operator with an appropriate operational authorization may conduct RNP AR operations in a manner similar to authorization to conduct CAT II and CAT III ILS operations. While this authorization may be valid for all RNP AR procedures within a State, separate authorizations can be given for RNP AR APCH, RNP AR DP, or a combination of these methods (for example, State-wide authorization for all procedures except those in highly challenging operational environments).

6.3.2.3 Due to the unique requirements of RNP AR operations and the demand for crew procedures specific to each particular aircraft and navigation system, RNP AR operations require operational support documentation from the manufacturer of the aircraft and avionics. The documentation should describe the navigation capabilities of the applicant's aircraft in the context of the RNP AR operations for which authorization is being sought, and provide all the assumptions, limitations and supporting information necessary for the safe conduct of RNP AR operations. Such documentation will support the operational authorization requirements of the appropriate State regulatory authorities.

6.3.2.4 To prepare for an RNP AR operational authorization, operators should refer to aircraft and avionics manufacturers' recommendations and guidance on how to operate the aircraft during these unique operations. Installation of equipment or recognition of aircraft eligibility is not sufficient to obtain operational authorization for RNP AR operations from the State's regulatory authority.

6.3.2.5 Aircraft eligibility

The State of the Manufacturer (or another airworthiness regulator) determines aircraft eligibility by demonstrating compliance against the relevant airworthiness criteria and the requirements of 6.3.3. The original equipment manufacturer (OEM) or the holder of an installation approval for the aircraft (such as the STC holder) will demonstrate compliance and the resulting documentation can identify airworthiness approval. This may be documented by AFM supplements (AFMS) or other recognitions of eligibility for RNP AR operations, such as service letters or detailed OEM documents on RNP capability and eligibility. When the State accepts other OEM documentation, there is no need for additional AFM entries or AFMS.

Note.— This specification does not require additional AFM entries or an AFMS. New AFM entries are usually a result of formal airworthiness projects and applications for approval from an airworthiness authority. For efficiency purposes, the eligibility requirements for this specification are defined for RNP AR operations without requiring AFM entries defining eligibility. Each State should determine their own means of confirming compliance to the airworthiness and operational requirements and guidance in this specification.

6.3.2.6 Operational authorization

6.3.2.6.1 ***Description of aircraft equipment***

The operator must have a configuration list and, if necessary, an MEL, detailing the required aircraft equipment for RNP AR operations.

6.3.2.6.2 ***Training documentation***

6.3.2.6.2.1 Commercial operators must have a training program addressing the operational practices, procedures and training items related to RNP AR operations (such as initial, upgrade or recurrent training for pilots, dispatchers or maintenance personnel).

Note.— Operators need not establish a separate training program if they already integrate RNAV and RNP training as elements of their training program. However, the operator should conduct an FOSA for their RNP AR operations to enable them to better identify specific aspects of their RNP AR operations their training program should cover.

6.3.2.6.2.2 Private operators conducting RNP AR operations must be familiar with the practices and procedures identified in 6.3.5.

6.3.2.6.3 ***Operations manuals and checklists***

6.3.2.6.3.1 Operations manuals (OMs) and checklists for commercial operators must address information/guidance on the SOP detailed in 6.3.4. The appropriate manuals should contain operating instructions and contingency procedures, when specified. When required by the State of the Operator/Registry, the operator must submit their OMs and checklists for review as part of the application process.

6.3.2.6.3.2 Private operators should operate using the practices and procedures identified in 6.3.5.

Note.— To accelerate the acceptance of their application to conduct RNP AR operations, private operators should accept and follow the aircraft and avionics OEMs recommendations and operating instructions for their aircraft and its RNP system. If practical, and when the OEMs provide it, the private operator should accept and implement flight crew procedures and checklists the OEMs develop in support of RNP AR operations.

6.3.2.6.4 ***MEL considerations***

The State of the Operator or State of Registry must approve any MEL revisions necessary to address aircraft eligibility for RNP AR operations. Operators must adjust the MEL, or equivalent documentation, and specify the required dispatch conditions.

6.3.2.6.5 ***Continuing airworthiness***

The operator must submit the continuing airworthiness instructions applicable to the aircraft's configuration and the aircraft's eligibility for this navigation specification. Also, the operator must submit their maintenance program to the State regulatory authority, including their reliability program for monitoring and updating the aircraft equipment essential to conduct of RNP AR operations.

Note 1.— The operator should confirm any changes in the aircraft configuration documented in service bulletins or other OEM documents, either directly with the OEM or with the holder of installation approval for the aircraft, to ensure their current operational authorizations are not altered or invalidated. The OEM documentation should contain a statement of no impact, or direct statement(s) of impact, on RNP AR aircraft eligibility.

Note 2.— RNP AR operations require an operable TAWS. However, the TAWS can only support RNP AR operations when its operating software and database of terrain and obstacles are the most current available from the TAWS OEM. Thus, the operator's application for RNP AR operations should contain continuing airworthiness instructions documenting how the operator keeps the TAWS software and database current. The intent behind the recommendation to install the most current operating software version is to install those updates correcting software defects affecting TAWS airworthiness. There is no intent to require installation of new TAWS functions or features.

6.3.2.7 Authorization submittal

6.3.2.7.1 Following the successful completion of the above steps, the operator may submit an application to the State regulatory authority. Any operational authorization (subject to any conditions or limitations) should follow national regulations.

6.3.2.7.2 The operator and the State regulatory authority should consider all applicable safety assessment items in 6.4 prior to granting an operational authorization to conduct RNP AR operations.

6.3.2.7.3 When the operator has met all requirements, the State regulatory authority may issue an RNP AR operational authorization (LOA, appropriate operations specifications, or amendment to the operations manual (OM)) annotating the specific RNP AR operation(s) the operator may conduct (such as solely RNP AR APCH or both RNP AR APCH and RNP AR DP), as appropriate.

6.3.2.7.4 Once an operator receives authorization from their State of Registry, they may also perform RNP AR operations in other States.

Note.— Some States may require the operator to apply for permission to conduct the RNP AR operations in the State's AIP. The host State may also choose to limit the RNP AR operations conducted in their airspace and grant an authorization for a subset of all of the RNP AR procedures in their AIP.

6.3.2.7.5 The operational authorization should identify the type of RNP AR procedures it covers (that is, the most demanding level of performance the operational authorization permits, RNP 0.30, RNP 0.15, etc.). The operational authorization should also document equipment configurations, accepted operating modes for the aircraft and avionics (that is, requirement for use of the autopilot or flight director, if applicable) and any unique procedures the operator must follow.

6.3.3 Aircraft requirements

This section describes the aircraft performance and functional criteria for aircraft to qualify for RNP AR operations. In addition to the specific guidance in this chapter, the aircraft must comply with the requirements in FAA AC 90-101(), AC 20-138(), EASA CS-ACNS or equivalent.

6.3.3.1 System performance, monitoring and alerting

This section defines the general performance requirements for aircraft qualification. The requirements for RNP AR operations are unique due to the reduced obstacle clearance and advanced aircraft and avionics functionality these operations rely on. Therefore, the requirements in this section do not use the same structure as other navigation specifications, such as the specifications for RNP 4, RNP 1 and RNP APCH.

6.3.3.1.1 ***RNP system performance***

6.3.3.1.1.1 *Lateral accuracy.* All aircraft operating on RNP AR operations must have a cross-track navigation error no greater than the applicable RNP value (0.1 NM to 0.3 NM) for 95 per cent of the flight time. This includes positioning error, FTE, PDE and display error. Also, the aircraft along-track positioning error must be no greater than the applicable accuracy value for 95 per cent of the flight time.

6.3.3.1.1.2 *Vertical accuracy.* For all aircraft conducting RNP AR APCH procedures, the vertical error budget (VEB) includes barometric altimetry system error (assuming the temperature and lapse rates of the ISA), the effect of along-track error, system computation error, data resolution error, and FTE. The 99.7 per cent of system error in the vertical direction must be less than the following (in feet):

$$\sqrt{((6076.115)(1.225)RNP \cdot tan\,\theta)^2 + (60\,tan\,\theta)^2 + 75^2 + \left((-8.8 \cdot 10^{-8})(h + \Delta h)^2 + (6.5 \cdot 10^{-3})(h + \Delta h) + 50\right)^2}$$

Where: θ is the VNAV path angle
h is the height of the local altimetry reporting station
Δh is the height of the aircraft above the reporting station

Note.— VNAV systems compliant with the performance specification for RNP APCH operations with SBAS flown down to LPV minima (see Chapter 5, Section B) meet or exceed the VEB vertical accuracy criteria.

6.3.3.1.1.3 *Path definition.* The OEM and airworthiness authorities evaluate aircraft performance around the lateral and vertical paths defined by the published RNP AR procedure and RTCA/DO-236() section 3.2, EUROCAE ED-75() or equivalent. Each RNP AR APCH also uses a flight path angle (FPA) to define the vertical paths the aircraft follows in the FAS (RTCA/DO 236(), section 3.2.8.4.3). The RNP system derives the vertical path as a straight line emanating from a select height above the runway threshold or the displaced threshold (usually 50 feet above the threshold or the published threshold crossing height for the RNP procedure). The vertical path then extends up from this point along the FAS lateral path to a fix and altitude (usually the FAF and the procedural altitude published at the FAF).

6.3.3.1.1.4 *Airspace containment*

— *RNP and Baro-VNAV aircraft.* This chapter provides an acceptable means of compliance for aircraft with an RNP system relying on GNSS updating and a barometric VNAV airworthiness approval for approach operations relying on the aircraft's barometric altimetry system(s). Aircraft and operations complying with this navigation specification provide the requisite airspace protection through the monitoring and alerting capability of the RNP system, along with flight crew training and procedures. As a result, aircraft and operations complying with this navigation specification either meet or exceed the requisite performance and assurance to satisfy the airspace requirements. They also offer safety margins through monitoring and alerting (such as "Unable RNP", implementation of GNSS alert limits, and FTE monitoring).

— *Other aircraft systems or alternate means of compliance.* The probability of an aircraft exiting the lateral obstacle clearance surface (OCS) of the procedure (two times the RNP value in NM) must not exceed 1×10^{-7} per approach (including the missed approach), rendering it improbable. The OEM or the operator may satisfy this requirement by an operational safety assessment applying:

a) appropriate quantitative numerical methods;

b) qualitative operational and procedural mitigations; or

c) an appropriate combination of both quantitative and qualitative methods.

Note 1.— This requirement applies to the total probability of an aircraft excursion outside the obstruction clearance volume, including events caused by latent conditions (integrity) and by detected conditions (continuity) when the aircraft does not remain within the obstruction clearance volume after the RNP system annunciates the failure. The requirement assumes the aircraft does not exit the obstruction clearance volume when considering: the monitor limits of the RNP system alerts, the latency of the alerts, the flight crew reaction time to alerts and the aircraft response to alerts (such as the resulting aircraft performance). This requirement applies to a single approach, considering the exposure time of the approach operation through the missed approach procedure, and assumes the requisite navigation performance is available when beginning the RNP AR APCH.

Note 2.— This containment requirement derives from the operational requirement, which is notably different than the containment requirement specified in RTCA/DO 236() (EUROCAE ED-75()). The requirement in RTCA/DO-236() (EUROCAE ED-75()) facilitates airspace design and does not directly ensure obstacle clearance.

6.3.3.1.2 ***On-board performance monitoring and alerting***

6.3.3.1.2.1 The RNP system is required to provide an alert if the accuracy requirement is not met, or if the probability that the lateral TSE exceeds 2xRNP NM is greater than 1×10^{-5} per approach. The alert is required to be consistent with RTCA DO-236(), DO-283(), DO-229() and EUROCAE ED-75().

6.3.3.1.2.2 A critical component of RNP operations is the ability of the RNP system to monitor its achieved navigation performance. Thus, the RNP system is required to provide an alert to the flight crew when the operational requirement is no longer met during an RNP operation (“Unable RNP” and “Nav Accur Downgrade” are two example alerts).

Note.— While there is no companion requirement for the RNP system to alert when the aircraft exceeds lateral or vertical FTE limits, some RNP systems alert for FTE independently or as part of an alerting system based on TSE (NSE plus FTE). When the RNP system does not include any manner of FTE alerting, flight crew training, procedures and operational limits must bound FTE.

6.3.3.1.2.3 *GNSS updating.* Since GNSS is the primary sensor for all RNP operations, the RNP system should provide a means for the flight crew to confirm GNSS is available to the aircraft’s RNP system before beginning an RNP AR operation. The aircraft must also issue a flight crew alert when the system loses GNSS for any reason (jamming, interference, sensor failure or any other reason).

Note.— An operational requirement for the flight crew to confirm the availability of GNSS prior to commencing all RNP AR operations, approaches or departures supports this aircraft requirement (see 6.3.4.2.4).

6.3.3.2 Criteria for specific navigation services

6.3.3.2.1 This section identifies unique issues for the navigation sensors within the context of RNP AR APCH operations.

6.3.3.2.2 *ABAS and other GNSS augmentations based on GPS*

a) The GPS sensor must comply with the guidelines in AC 20-138().

Note.— RNP systems complying with AC 20-138()may assume the following GPS receiver sensor accuracies without additional substantiation: GPS (ABAS) sensor lateral accuracy is better than 36 m (119 ft) 95 per cent; and augmented GPS (GBAS or SBAS) sensor lateral accuracy is better than 2 m (7 ft), 95 per cent.

b) In the event of a latent GPS satellite failure and marginal GPS satellite geometry (such as the horizontal integral limit (HIL) equal to the horizontal alert limit (HAL)), the probability of the aircraft remaining within the RNP AR procedure's obstacle clearance volume must be greater than 95 percent, both laterally and vertically (as applicable).

Note 1.— RNP systems using other GNSS systems meeting or exceeding the accuracy of GPS can use the criteria in a) and b) above.

Note 2.— GNSS-based sensors output an HIL, also known as a horizontal protection level (HPL) (see AC 20-138(), Appendix 1, and RTCA/DO-229() for an explanation of these terms). The HIL measures the position estimation error assuming a latent failure is present. In lieu of a detailed analysis of the effects of latent failures on the TSE, an acceptable means of compliance for GNSS-based systems is to ensure the HIL remains less than twice the RNP value, minus the 95 per cent of FTE, during the RNP AR APCH operation.

6.3.3.2.3 ***Inertial navigation system requirements***

6.3.3.2.3.1 RNP AR procedures require the aircraft to include an approved inertial navigation system integrated with the aircraft's RNP system to serve as a contingency backup to GNSS. These specifications expect the RNP system to revert to inertial coasting when GNSS is lost for any reason. Approved inertial navigation systems meeting FAA 14 Code of Federal Regulations (CFR), Part 121, Appendix G, or an equivalent standard, may assume an initial drift rate of 4 NM/hour for the first 30 minutes (95 per cent).

6.3.3.2.3.2 Alternatively, the aircraft's RNP system may integrate an approved inertial navigation system demonstrating coasting performance through a means of compliance other than FAA 14 CFR, Part 121, Appendix G (such as RTCA/DO-384, Minimum Operating Performance Standards (MOPS) for GNSS-aided Inertial Systems). When this occurs, the aircraft OEM or Type Certificate holder is required to ensure the aircraft's RNP system integrates the inertial navigation system's demonstrated coasting performance, consistent with the inertial system's airworthiness approval.

Note 1.— Some RNP systems' GNSS-inertial integrations offer better short-term inertial coasting performance than required to meet FAA 14 CFR, Part 121, Appendix G. However, before an operator may rely on the improved performance during an RNP AR procedure, they must obtain formal documentation from the aircraft OEM or Type Certificate holder highlighting the improved inertial coasting performance and any limitations associated with the improved performance.

Note 2.— The RNP system's integration of the aircraft's GNSS sensor with the aircraft's approved inertial navigation systems can enhance the availability of RNP after loss of GNSS. For "tightly coupled" GNSS/inertial integrations, see RTCA/DO-229(), Appendix R, or RTCA/DO-384. For other categories of GNSS/inertial navigation system integration see RTCA/DO-384.

6.3.3.2.4 ***Loss of GNSS***

Upon loss of GNSS for any reason, the aircraft must automatically revert to another means of navigation that complies with the RNP value.

Note.— These specifications assume the RNP system reverts to inertial coasting when GNSS is lost, but the aircraft may revert to another means of navigation as long as that means of navigation complies with the RNP value and provides a means for the aircraft to abandon the RNP AR APCH. Before an operator may rely on another means of navigation during an RNP AR procedure, they must obtain formal documentation from the aircraft OEM or Type Certificate holder highlighting the available performance and any limitations associated with the other means of navigation. This documentation must confirm the means by which the operator can predict the availability of the other means of navigation.

6.3.3.2.5 ***DME***

GNSS-updating is the basis for initiating all RNP AR operations. When authorized by the State, the aircraft may use DME/DME-updating as a reversionary navigation mode when the RNP system continues to comply with the required RNP value. The aircraft manufacturer or Type Certificate holder must identify any requirements for the DME infrastructure, and any necessary operational procedures and limitations for conduct of an RNP AR procedure through use of DME/DME-updating of the RNP system.

Note.— These specifications assume an aircraft eligible for RNP AR procedures includes an approved inertial navigation system integrated with the on-board RNP system and expect the RNP system to revert to inertial coasting when GNSS is lost for any reason. Operator reliance on the aircraft's DME/DME-updating capability may serve as an alternate means of compliance to abandon an RNP AR procedure when GNSS is lost. However, meeting the requirements above may severely limit available RNP AR procedures due to DME infrastructure constraints (such as lack of sufficient DME facilities to conduct the procedure through DME/DME-updating).

6.3.3.2.6 ***VOR***

6.3.3.2.6.1 The aircraft's RNP system should not use VOR-updating (or VOR/DME-updating) when conducting RNP AR procedures. The aircraft manufacturer should identify any pilot procedures or techniques to ensure the aircraft complies with this requirement.

Note.— This requirement does not imply a need for a direct means of inhibiting VOR-updating of the RNP system. An operational procedure requiring the flight crew to inhibit VOR-updating or a procedure requiring the flight crew to execute a missed approach when the RNP system reverts to VOR-updating may satisfy this requirement.

6.3.3.2.7 For multi-sensor systems, there must be automatic reversion to an alternate navigation sensor when the primary navigation sensor fails. Automatic reversion from one multi-sensor system to another multi-sensor system is not required.

6.3.3.2.8 The 99.7 percent aircraft altimetry system error (ASE) for each aircraft (assuming the temperature and lapse rates of the ISA) must be less than or equal to the following with the aircraft in the approach configuration:

$$\mathrm{ASE} = -8.8 \cdot 10^{-8} \cdot \mathrm{H}^2 + 6.5 \cdot 10^{-3} \cdot \mathrm{H} + 50(\mathrm{ft})$$

Where *H* is the true altitude of the aircraft.

6.3.3.2.9 *Automated temperature compensation systems*

RNP systems providing automated temperature-based compensation to RNP AR APCH procedural barometric altitudes must comply with RTCA/DO-236(), Appendix H.2 or an equivalent airworthiness approval basis. Manufacturers should document compliance to this standard for an operator to conduct RNP AR APCH operations when the actual temperature is either below or above the published procedure design limit. RTCA/DO-236(), Appendix H.2 also provides guidance on operational issues associated with RNP systems with automated temperature compensation, such as intercepting the compensated vertical path from a vertical path defined through uncompensated procedural barometric altitudes.

Note 1.— Some RNP systems providing automated temperature compensation provide compensation only for deviation below ISA (that is, only for cold temperatures). A systems limitation should highlight this in the OEM's documentation of the aircraft's automated temperature compensation system.

Note 2.— See 6.3.4.2.12 and Attachment B for operational guidance on application of temperature compensation.

6.3.3.3 Functional requirements

Note.— Additional guidance and information concerning many of the required functions are provided in EUROCAE ED-75()/ RTCA DO-236().

6.3.3.3.1 ***General requirements***

6.3.3.3.1.1 Path definition and flight planning*:*

a) *Maintaining track and leg transitions.* The aircraft must have the capability to execute leg transitions and maintain tracks consistent with the following paths:

1) a track between two fixes (TF leg);

2) a direct path to a fix (DF leg);

3) a specified course to a fix (CF leg);

4) a specified course to an altitude (CA leg); and

5) a radius to fix leg (RF leg).

Note 1.— Industry standards for these paths can be found in EUROCAE ED-75()/ RTCA DO-236() and ARINC 424, which refer to them as TF, DF, CF, CA and RF path terminators. EUROCAE ED-75()/ RTCA DO-236() and ED 77()/ DO-201() describe the application of these paths in more detail. Also, the RNP system must include RF leg functionality (Part C, Appendix 1 refers).

Note 2.— The RNP system may accommodate other ARINC 424 path terminators (such as heading to manual terminator (VM)), and RNP AR procedures may use these types of path terminators when there is no requirement for RNP containment.

b) *Fly-by and fly-over fixes*. The aircraft must have the capability to execute fly-by and fly-over fixes. For fly-by turns, the RNP system must limit the path definition within the theoretical transition area defined in EUROCAE ED-75()/ RTCA DO-236() under the wind conditions identified in the *Required Navigation Performance Authorization Required (RNP AR) Procedure Design Manual* (Doc 9905). The fly-over turn is not compatible with RNP containment and will only be used when there is no requirement for repeatable paths beyond a fly-over fix.

c) *Waypoint resolution error.* The navigation database must provide sufficient data resolution to ensure the RNP system achieves the required accuracy. The waypoint resolution error must be less than or equal to 60 ft, including both the data storage resolution and the RNP system computational resolution used in construction of flight plan waypoints. The navigation database must contain vertical angles (that is, FPA) stored to a resolution of hundredths of a degree (that is, X.XX°) to ensure the RNP system-defined path is within 1.5 m (5 ft) of the defined, procedural path.

d) *"Direct-to" function.* The RNP system must have a "direct-to" function the flight crew can activate at any time. This function must be available to any fix and provide a geodesic path to the desired fix without "S-turning" and without undue delay.

e) *Defining a vertical path.* The RNP system must be capable of defining a vertical path by FPA to a fix. The system must also be capable of specifying a vertical path between procedural altitude constraints, or ATC-assigned altitude constraints, at two fixes in the flight plan. An RNP AR procedure may define fix altitude constraints as one of the following:

1) an “AT” or “ABOVE” altitude constraint (such as 2400A may be appropriate for situations where bounding the vertical path is not required);

2) an “AT” or “BELOW” altitude constraint (such as 4800B may be appropriate for situations where bounding the vertical path is not required);

3) an “AT” altitude constraint (such as 5200); or

4) a “WINDOW” constraint (such as 2400A, 3400B).

Note.— For RNP AR APCH procedures, the FAS is usually the only segment with a published vertical path. The approach procedure defines that vertical path with a procedure-defined FPA for the FAS.

f) Altitudes and/or speeds associated with published terminal procedures must be extracted from the navigation database.

g) The system must be able to construct a path to provide guidance from the current position to a vertically constrained fix.

h) Capability to load RNP AR procedures from the navigation database. The RNP system must have the capability to load the entire selected RNP AR procedure(s) into the RNP system from the on-board navigation database.

i) *Retrieving and displaying navigation data.* The RNP system must allow the pilot to verify navigation data and any selected RNP AR procedure by retrieving and displaying the data stored in the on-board navigation database. This includes reviewing the detailed data for individual waypoints, fixes and NAVAIDs.

j) *Magnetic variation*. For paths defined by a course (such as CF and FA path terminators), the RNP system must use the magnetic variation value for the procedure retrieved from the on-board navigation database.

Note.— RTCA DO-236C and DO-283B contain industry standards for the manner in which an RNP system uses magnetic variation.

k) *Changes in RNP value*. RNP value changes to a lower RNP value (lower navigation accuracy) must be completed by the fix beginning the leg with the lower RNP value. The RNP system’s change to the new, lower RNP value may consider the RNP system’s alerting latency. The aircraft and avionics OEMs must identify any operational procedures the operator must employ related to this requirement.

l) *Automatic leg sequencing*. The RNP system must provide the capability to automatically sequence guidance to the next leg and display the sequencing to the flight crew in a readily visible manner.

m) The RNP system must display the procedural altitude constraints assigned to flight plan waypoints for flight crew reference. If there is a specified navigation database procedure with a FPA associated with a flight plan leg, the installation must display the FPA for the leg.

6.3.3.3.1.2 *Demonstration of flight technical error .* FTE reflects the path steering performance of the aircraft. This can vary depending on the flight guidance type used by the flight crew. When desired to gain credit for FTE, the aircraft OEM or the applicant for the STC must demonstrate FTE in a variety of operational conditions (that is, rare-normal conditions and non-normal conditions – see FAA AC 20-138() for more information). The FTE demonstration should use realistic and representative RNP procedures (number of waypoints, placement of waypoints, segment geometry, leg types, etc.), and the FTE demonstration should take place in the laboratory using simulation tools, an engineering flight simulator (when available) and the aircraft. The non-normal assessment should consider:

a) Probable failures during the FTE demonstration showing the aircraft trajectory remains within a 1×RNP lateral corridor, and within 22 m (75 ft) of the vertical guidance during the FAS of an RNP AR APCH. The aircraft OEM or the STC holder is required to provide proper documentation of an approved airworthiness demonstration in the AFM, AFM supplement (AFMS), or another document accepted by a State airworthiness regulator. The documentation will include the results of the FTE demonstration and record in new operational limits for the flight crew (that is, lateral and vertical deviation limits by flight guidance mode of flight) and will state any new minimum RNP value(s) the flight crew may use (if applicable).

b) *RNP-significant improbable failures.* The FTE demonstration should show the flight crew can safely extract the aircraft from the RNP procedure when an improbable failure occurs. Failure cases might include dual system resets, flight control surface runaway and complete loss of flight guidance function.

c) A mix of analyses and flight technical evaluations from a variety of operational scenarios using expert engineering and operational judgement.

6.3.3.3.1.3 The aircraft OEM or STC holder should also document any recommended flight crew operating procedures (relevant to sections 6.3.4 and 6.3.5) resulting from the FTE demonstration (such as one-engine-inoperative (OEI) FTE performance) in a supplement to the aircraft's operating manual or, when provided, a PBN operating manual.

Note.— Normally, the AFM, AFMS, or another document accepted by a State airworthiness regulator recording the results of the FTE demonstration, do not contain recommended flight crew operating procedures.

6.3.3.3.1.4 *Displays*

– *Continuous display of deviation*. The RNP system must provide the capability to continuously display to the pilot flying, on the primary flight instruments for navigation of the aircraft, the aircraft position relative to the RNP defined path (both lateral and vertical deviation). The display must allow the flight crew to readily distinguish if the cross-track deviation exceeds the RNP value (such as 1×RNP) or a smaller value during all RNP AR operations and distinguish if the vertical deviation exceeds 22 m (75 ft), or a smaller value, during the FAS of an RNP AR APCH operations.

Note.— The aircraft OEM or the STC holder may allocate a lateral deviation limit smaller than 1 × RNP to ensure lateral containment during RNP AR operations. Likewise, they may also require a vertical deviation limit smaller than 22 m (75 ft) to ensure compliance with the RNP AR APCH vertical error budget.

The aircraft should have an appropriately scaled non-numeric deviation display (that is, a lateral deviation indicator (such as a CDI) and a vertical deviation indicator) located in the pilot's primary field of view. A fixed-scale CDI is acceptable as long as the CDI demonstrates appropriate scaling and sensitivity for the intended RNP value and operation. With a scalable CDI, the scale should derive from the selection of the RNP value and must not require the flight crew to manually make a separate selection of a CDI scale. Alerting and annunciation limits must also match the scaling values. If the equipment uses default RNP values to define the operational mode (such as en-route, terminal area and approach default RNP values), then a display of the operational mode in the pilot's primary field of view may be an acceptable means for the flight crew to derive the CDI scale sensitivity.

Numeric display of lateral deviation, or graphic depiction of lateral deviation on a map display without an appropriately scaled CDI, is generally not an acceptable means to monitor deviation. However, the use of a numeric display or a map display may be feasible depending on the flight crew workload, the display characteristics, and associated flight crew procedures and training.

– *Identification of the active (To) waypoint*. The RNP system must provide a display identifying the active waypoint either in the pilot's primary field of view, or on a readily accessible and visible display.

– *Display of distance and bearing*. The RNP system must provide a display of distance and bearing to the active (TO) waypoint in the pilot's primary field of view. Where not viable, a readily accessible page on a CDU, readily visible to the pilot, may display the distance and bearing to the waypoint.

– *Display of ground speed (GS) and time to the active (To) waypoint.* The RNP system must provide the display of ground speed and time to the active (To) waypoint in the pilot's primary field of view. Where not viable, a readily accessible page on a CDU, readily visible to the pilot, may display the GS and time.

– *Display of the active fix*. The RNP system must display the active fix in the pilot's primary field of view.

– *Desired track display*. The RNP system must have the capability to continuously display to the pilot flying the desired aircraft track. This display must be on the primary flight display (PFD) the pilot flying uses to navigate the aircraft.

– *Display of aircraft track.* The RNP system must provide a display of the actual aircraft track (or track angle error) either in the pilot's primary field of view, or on another readily accessible and visible display.

– *Failure annunciation*. The aircraft must provide a means to annunciate failures of any aircraft component of the RNP system, including the navigation sensors. The annunciation must be visible to the flight crew and located in each pilot's primary field of view.

– *Slaved course selector*. The navigation system must provide a course selector automatically slaved to the RNP system's computed path.

– *RNP path display*. The RNP system must provide a readily visible means for the pilot monitoring to verify the aircraft's RNP-defined path and the aircraft's position relative to the defined path.

– *Display of distance to go*. The RNP system must provide the ability to display distance to go to any waypoint the flight crew selects.

– *Display of distance between flight plan waypoints*. The RNP system must provide the ability to display the distance between consecutive flight plan waypoints.

– *Display of deviation*. The RNP system must provide a numeric display of the vertical and lateral deviation. The numeric display of vertical deviation must use a resolution of 3 m (10 ft) or less for RNP AR APCH operations. The resolution of numeric display of lateral deviation must be:

a) 0.1 NM or less for RNP operations using RNP 0.3 or higher RNP values; or

b) 0.01 NM or less for RNP operations requiring RNP less than 0.3 (RNP<0.3).

– *Display of barometric altitude*. The aircraft must display barometric altitude from two independent altimetry sources, one independent display in each pilot's primary field of view.

Note 1.— This display requirement supports an operational cross-check of barometric altitude sources when necessary.

Example 1. If the aircraft does not include a function automatically monitoring the output of the barometric altimetry sources against one another, and the RNP system derives both pilot's displays of Baro-VNAV vertical guidance from a single barometric altimetry source.

Example 2. If the aircraft includes two RNP systems (that is, two FMS suites) and both RNP systems use just one common barometric altimetry source to derive Baro-VNAV vertical guidance, then the Baro-VNAV vertical guidance can be misleading if the single source of barometric altimetry that the RNP systems use is malfunctioning and inaccurate. When this is the aircraft design choice, to ensure the Baro-VNAV vertical guidance is not misleading, the flight crew must crosscheck the output of each pilot's primary barometric altimeter within 100 FT (30 M) of one another. This crosscheck should occur at a known flight plan waypoint while the aircraft is on the vertical path. Also, to protect the RNP AR APCH final approach operation, this crosscheck must occur prior to the flight crew beginning the FAS where the RNP AR APCH procedure design applies the VEB and relies on accurate Baro-VNAV guidance and assumes no misleading vertical guidance is present.

Note 2.— During the approach mode or approach phase of flight, if the barometric altitude sources the aircraft's RNP system uses to provide Baro-VNAV vertical guidance include an automatic comparison function (that is, a comparator monitor function), the function should provide an alert in the pilot's primary optimum field of view when the deviation between the barometric altimetry sources exceeds 100 ft (30 m). Aircraft documentation should define the comparator monitor function. When this comparator monitor function supports instrument approach operations, the function may eliminate the need for an operational mitigation requiring flight crew procedures to crosscheck the barometric altimeters against one another (see Note 1. above).

Note 3.— To prevent flight crew error and potential misleading vertical guidance when the RNP system provides Baro-VNAV vertical guidance, the aircraft's barometric altimetry system and the RNP system should both simultaneously use the local barometric altimeter setting the flight crew selects.

– *Display of active sensors.* The aircraft must display the current navigation sensor(s) in use in the primary field of view. If the aircraft does not display the current navigation sensor(s) in use, the RNP system must then either:

a) provide an alert and annunciation of the loss of the current navigation sensor; or

b) demonstrate the ability to safely continue the procedure and sustain RNP using an alternate navigation sensor (such as inertial-only navigation) until the RNP AR procedure is complete, and the flight crew transitions to landing or executes the published missed approach procedure to the MAP holding point.

Note.— The display of the active sensor supports the flight crew's operational contingency procedures. However, when the display of the active sensor is not in the primary field of view, flight crew procedures may mitigate the requirement when workload is acceptable. For example, during an RNP AR operation, a flight crew procedure requiring confirmation GNSS is the active sensor prior to beginning the RNP AR procedure may be an acceptable mitigation (such as prior to the aircraft sequencing the RNP AR APCH initial approach fix, the flight crew checks the RNP system's CDU for the active navigation sensor, usually GNSS).

6.3.3.3.1.4 *Design assurance*. The RNP system design assurance must be consistent with at least a major failure condition for the display of misleading lateral or vertical guidance during an RNP AR APCH procedure.

Note.— The display of misleading lateral or vertical RNP guidance is a hazardous (severe-major) failure condition for an RNP AR APCH requiring an RNP value less than RNP 0.3. The aircraft OEM should directly document when the RNP system meets this design assurance requirement and may recommend operational mitigations when there is a shortfall in design assurance.

6.3.3.3.1.4.1 The RNP system design assurance must be consistent with at least a major failure condition for the loss of lateral guidance and a minor failure condition for loss of vertical guidance on an RNP AR APCH procedure.

Note.— Loss of vertical guidance is considered a minor failure condition because the flight crew can take action to stop descending or climb when vertical guidance is lost.

6.3.3.3.1.5 *Navigation database.* The aircraft RNP system must use an on-board navigation database, which can receive updates in accordance with the AIRAC cycle and allow the flight crew to select and load RNP AR procedures into the RNP system. The RNP system must not allow the pilot to modify the navigation data stored in the on-board navigation database.

Note.— When the RNP system loads an RNP AR procedure from the on-board navigation database, the RNP system should execute the procedure as published. This does not preclude the flight crew from modifying a procedure loaded in the RNP system's flight plan in compliance with a revised, accepted ATC clearance.

6.3.3.3.1.6 The aircraft must provide a means to display the validity period of the on-board navigation database to the flight crew.

Note.— Some RNP system installations can store two on-board navigation databases on the aircraft. When this is the case, the flight crew must be able to ensure the currency of each on-board navigation database during pre-flight. If the flight crew confirmed the currency of the new database during pre-flight, there is no need to recheck the currency of the new database. RNP system documentation from the OEM should confirm the RNP system's selection of the new on-board navigation database and any necessary flight crew procedures.

6.3.3.3.2 ***Requirements for eligibility to conduct RNP AR procedures with RF legs***

6.3.3.3.2.1 The navigation system must have the capability to execute leg transitions and maintain a track defined by an RF leg.

6.3.3.3.2.2 The aircraft must have an electronic map display of the selected RNP AR procedure, including the RF leg.

6.3.3.3.2.3 The RNP system, the flight director system and autopilot must be capable of commanding a bank angle up to 30 degrees above 121 m (400 ft) above ground level (AGL) and up to 8 degrees below 121 m (400 ft) AGL.

6.3.3.3.2.4 When the flight crew initiates a go-around (through activation of take-off/go around (TOGA) or other means), the RNP system must provide continuous LNAV guidance to complete an RF leg during the go-around. When continuous LNAV is not available, and the activation of go-around (that is, TOGA) results in disconnecting LNAV guidance (reverting to heading or track-hold flight guidance), the aircraft OEM must define the mitigation necessary to overcome absence of the continuous LNAV function.

Note 1.– In some aircraft, the RNP system's continuous LNAV function is referred to as "TOGA-to-LNAV".

Note 2.– When continuous LNAV is not available from the RNP system, flight crew procedures and training may mitigate the absence of this function and ensure eligibility for RNP AR procedures with RF legs. The State regulator will ultimately decide on the suitability of any proposed operational mitigation.

6.3.3.3.2.5 When evaluating an aircraft's FTE during RF legs, the RNP system's turn anticipation and the effect of rolling into and out of the RF turn must be considered. The RNP AR procedure design provides a 5° manoeuvrability margin to enable the RNP system to provide flight guidance to correct minor deviations from the RF turn's defined track. The FTE evaluation must ensure the ability to contain FTE while correcting minor deviations in a timely manner.

6.3.3.3.3 ***Additional requirements for RNP AR approaches requiring less than RNP 0.3 (RNP<0.3)***

6.3.3.3.3.1 *No single point of failure.* No single point of failure can cause the loss of navigation guidance compliant with the RNP value required by the RNP procedure. Typically, the aircraft must have at least the following equipment: dual GNSS sensors, dual FMS, dual air data systems, dual autopilots, and a single inertial navigation system.

Note.— For RNP AR APCH operations requiring less than RNP 0.3 (RNP<0.3) to avoid obstacles or terrain, the loss of the display of lateral guidance is a hazardous (severe-major) failure condition. The AFM should document systems designed consistent with this hazard effect. This documentation should describe the specific aircraft configuration or mode of operation achieving RNP less than 0.3 (RNP<0.3). Directly meeting this airworthiness requirement may substitute for the general requirement for dual equipment described above.

6.3.3.3.3.2 *Design assurance*. The system design assurance must be consistent with at least a major failure condition for the loss of lateral or vertical guidance on an RNP AR APCH requiring RNP less than 0.3 (RNP<0.3) to avoid obstacles or terrain while executing the procedure.

6.3.3.3.4 ***Additional requirements for approaches with missed approach less than RNP 1.0 (RNP<1.0)***

6.3.3.3.4.1 *Single point of failure*. No single point of failure can cause the loss of lateral guidance compliant with the RNP value associated with a missed approach procedure. Typically, the aircraft must have at least the following equipment: dual GNSS sensors, dual FMS, dual air data systems, dual autopilots and a single inertial navigation system.

6.3.3.3.4.2 *Design assurance*. The aircraft design assurance must be consistent with at least a major failure condition for the loss of lateral guidance during an RNP AR APCH missed approach procedure where the missed approach procedure requires an RNP value less than 1.0 (RNP<1.0) to avoid obstacles or terrain.

Note.— For RNP AR APCH missed approach operations requiring less than 1.0 (RNP<1.0) to avoid obstacles or terrain, the loss of the display of lateral guidance is a hazardous (severe-major) failure condition. The AFM should document systems meeting this requirement. The documentation should describe the specific aircraft configuration or mode of operation achieving RNP less than 1.0 (RNP<1.0). Meeting this requirement may substitute for the general requirement for dual equipment described above.

6.3.3.3.4.3 *Loss of GNSS*. RNP AR operations rely on the aircraft's inertial navigation system as a contingency backup and alternative means to safely complete or extract from an RNP AR procedure when the aircraft's GNSS fails or the GNSS signal-in-space (SIS) becomes unavailable due to interference or jamming (see 6.3.3.2.3 and 6.3.3.2.4). Following loss of GNSS, the aircraft's RNP system must automatically revert to another means of navigation complying with the RNP value.

6.3.3.4 Terrain Awareness and Warning System (TAWS) requirements

All RNP AR operations require an operable Class A TAWS. The TAWS should:

a) use an altitude input compensating for local pressure and temperature effects (such as corrected barometric and GNSS altitude);

b) contain the latest operating software from the TAWS OEM; and

c) include a current terrain and obstacle database.

6.3.4 Operating procedures

6.3.4.1 Pre-flight considerations

6.3.4.1.1 *MEL.* The operator's MEL should be developed or revised to address the equipment required for aircraft eligibility for RNP AR operations. Guidance for the equipment requirements is available from the aircraft manufacturer. The required equipment may depend on the RNP value, the RNP procedure required or whether an RNP AR missed approach procedure requires an RNP less than 1.0 (RNP<1.0). For example, an autopilot is typically required equipment for RNP<0.30. Dual equipment is also typically required for RNP AR approaches when using RNP<0.30 and/or where the RNP AR missed approach procedure uses RNP<1.0. The flight crew must be knowledgeable of the required equipment, and inflight guides or RNP AR approach checklists containing quick-reference lists of the required equipment may aid the flight crew.

6.3.4.1.2 *Autopilot and flight director.* RNP AR APCH procedures using RNP<0.3 may require the use of an autopilot or flight director driven by the RNP system. Thus, the flight crew may need the autopilot/flight director to be operable to track the lateral and vertical path guidance. When it is determined that flying an RNP AR APCH procedure requires the autopilot at the destination airport and/or alternate airport, the dispatcher or flight crew must determine whether the autopilot is operational.

6.3.4.1.3 *Dispatch RNP availability prediction.* The operator must have an RNP availability prediction capability that can forecast whether or not the required RNP value will be available for a desired RNP AR operation. This RNP prediction capability can be a ground service and need not be resident in the aircraft's RNP system. The operator must establish procedures requiring use of the RNP prediction capability as both a pre-flight dispatch tool and as a flight-following tool in the event of reported failures. The RNP availability prediction must consider the specific aircraft capability (sensors and integration).

– *RNP prediction when GNSS updating*. The RNP prediction capability must account for known and predicted outages of GNSS satellites or other impacts on the RNP system's sensors. The RNP prediction program should not use a mask angle below 5 degrees since the satellite signal in space at low elevations may not be reliable. The RNP prediction must also use the actual GNSS constellation with the integrity-monitoring algorithm (RAIM, AAIM, etc.) identical to, or more conservative than, the algorithm used in the actual RNP system.

– RNP AR operations must have GNSS updating available prior to the flight crew beginning any RNP AR procedure. However, if the operator's aircraft relies on other sensors to continue the RNP AR operation upon loss of GNSS, then the operator's RNP availability prediction should also evaluate the other sensors essential to the desired RNP AR operation.

Note.— If the operator's aircraft relies on DME/DME navigation for an RNP AR missed approach procedure, the RNP availability prediction should confirm the availability of DME stations sufficient to support the RNP value the missed approach procedure requires.

6.3.4.1.4 *NAVAID exclusion.* The operator must establish procedures to exclude NAVAID facilities in accordance with NOTAMs (such as DMEs, VORs, localizers). However, if the operator's aircraft disables radio-updating during all RNP AR operations (either through flight crew procedures or by RNP system software defaults), this need not occur to support the RNP AR operations.

6.3.4.1.5 *On-board navigation database currency.* During RNP system initialization, the flight crew must confirm the on-board navigation database is current and will remain so for the duration of the flight. If the AIRAC cycle changes during flight, operators and pilots must establish procedures to ensure the accuracy of the navigation data. The flight crew must not use an outdated database to conduct RNP AR operations unless flight crew procedures ensure any amendments to the on-board navigation database have no material impact on the desired procedure. If there is a published, amended chart for the RNP AR procedure, the flight crew must not use the database to conduct the operation and must consider the procedure unavailable.

Note.— When RNP systems can store two on-board navigation databases on the aircraft, the flight crew must ensure the currency of each database during pre-flight. There is no need to recheck the currency of the new database once it is done during pre-flight. RNP system documentation from the OEM should confirm the RNP system's selection of the new on-board navigation database and any necessary flight crew procedures.

6.3.4.2 In-flight considerations

6.3.4.2.1 *Modification of the RNP system flight plan.* Flight crews may fly any published RNP AR operation they can retrieve by procedure name from the aircraft's on-board navigation database. Before using a selected RNP AR procedure, the flight crew must ensure the extracted procedure conforms to the charted procedure. When completing the RNP AR operation, the flight crew may not modify the RNP AR procedure extracted from the on-board navigation database, unless:

a) accepting a clearance to go direct to a fix in the RNP AR APCH procedure preceding the FAF that is not the beginning of an RF leg;

   Note.— The aircraft's RNP system cannot assure the ability to fly an RF leg when the aircraft's track is not aligned with the RF leg's defined path. Thus, the flight crew should not accept an ATC request to proceed direct to the initial fix of an RF leg or any point along the RF leg beyond the initial fix.

b) complying with an ATC vector to intercept an intermediate segment of the RNP AR APCH preceding the FAF as long as that segment is not an RF leg; and

c) changing a waypoint's altitude and/or airspeed constraints on the initial, intermediate, or missed approach segments of an approach (such as to apply temperature compensation or comply with a new ATC clearance/instruction).

6.3.4.2.2 *Required list of equipment.* The flight crew must have a required list of equipment for conducting RNP AR operations or an alternate method to address in-flight equipment failures prohibiting RNP AR procedures (such as a quick reference handbook).

6.3.4.2.3 *RNP value management.* The flight crew's operating procedures must ensure the RNP system uses the appropriate RNP value throughout the RNP AR procedure. If multiple lines of minima associated with a different RNP value are on an RNP AR APCH chart, the flight crew must confirm they select the correct RNP value that the RNP system will use during the procedure. If the RNP system does not extract and set the RNP value from the on-board navigation database for each leg of the procedure, then the flight crew's operating procedures must ensure they manually set the smallest RNP value required to complete the RNP AR APCH (to include the RNP values the missed approach procedure requires) or RNP AR DP before beginning the RNP AR procedure (such as before the IAF or before take-off).

Note.— Different leg segments of an RNP AR procedure may use different RNP values. Usually, the RNP AR procedure's chart does not annotate the RNP value for each leg segment to avoid chart clutter. However, during an RNP AR APCH, the line of minima the flight crew selects defines the minimum RNP value the procedure requires. In contrast, when an RNP AR DP uses varying RNP values, the State publishing the RNP AR DP should consider charting the minimum RNP value the DP uses (no lower than RNP 0.3). One technique would be to publish the minimum RNP value in the chart's "PBN box". The PBN box communicates the navigation specification the procedure employs and any unique PBN characteristics the procedure relies on.

6.3.4.2.4 *GNSS updating.* All RNP AR operations require GNSS updating of the RNP system. The flight crew must verify that GNSS updating is available prior to commencing any RNP AR operation, be it approach or departure. If GNSS updating is lost during any RNP AR APCH and the RNP system does not have the performance to continue the approach, the pilot must abandon the RNP AR APCH, unless the pilot has in sight the visual references required to safely continue the approach.

6.3.4.2.5 *Radio updating.* Initiating all RNP AR operations requires the availability of GNSS updating to the RNP system. These specifications assume the RNP system will revert to inertial coasting when GNSS is lost for any reason. However, except where an RNP AR procedure specifically designates "DME/DME not authorized", the RNP system may also use DME/DME updating as an additional reversionary mode during an RNP AR APCH or an RNP AR DP when the RNP system's performance complies with the RNP value. These specifications also prohibit VOR updating as a reversionary mode. Thus, the flight crew must comply with the aircraft and/or avionics OEM(s) recommendations and procedures for inhibiting VOR updating and, when necessary, specific radio facilities (that is, VOR and DME stations).

6.3.4.2.6 *Procedure confirmation.* The flight crew must confirm they selected the correct RNP AR procedure from the on-board navigation database. This confirmation ensures the RNP system's flight plan includes the proper waypoint sequence, shows reasonableness of track angles and distances, and reflects any other parameters the flight crew can enter, such as altitude or speed constraints. The flight crew must not use any RNP AR procedure when the validity of the on-board navigation database is in doubt. The flight crew must use a textual display of the selected procedure or a detailed navigation map display to conduct the confirmation.

6.3.4.2.7 *Track deviation monitoring.* Flight crews must use a lateral deviation indicator and/or flight director in a lateral navigation mode during RNP AR procedures. Flight crews of aircraft with a lateral deviation indicator must ensure that lateral deviation indicator scaling (full-scale deflection) is known and suitable for the RNP values an RNP AR procedure may use on various leg segments. All flight crews must maintain procedure centre lines by using the lateral deviation indicators and/or flight director guidance during all RNP operations described in this manual. The flight crew may deviate from the procedural path only when authorized by ATC or under emergency conditions. For normal operations, cross-track error/deviation (the difference between the RNP system's computed path and the aircraft's position relative to the path) should be limited to ±½ the RNP value the current leg segment uses. Brief lateral deviations from this standard (such as slight overshoots or undershoots) during and immediately after turns, up to a maximum of 1×RNP are permissible.

6.3.4.2.8 Vertical deviation from the RNP system's vertical flight guidance must remain within 22 m (75 ft) during an RNP AR APCH FAS. Brief transients in excess of 75 ft above the vertical path are acceptable (such as those resulting from configuration changes or energy management actions), but the flight crew should avoid any deviation below the vertical path. While being above the vertical path provides a margin against obstacles and terrain on the final approach, continued intentional flight above the vertical path may result in a go-around decision closer to the runway due to the inability to successfully transition to landing.

6.3.4.2.9 Flight crews must execute a go-around when the lateral deviation exceeds 1×RNP or the vertical deviation exceeds 22 m (75 ft) below path, unless the pilot flying is in visual conditions and has visual references in sight sufficient to safely continue visually to a landing.

– Some aircraft navigation displays do not include lateral and vertical deviation indicators scaled for each RNP procedure in the primary field of view. Where the flight crew uses a moving map, low-resolution VDI, or numeric display of deviation, flight crew training and procedures must ensure the effectiveness of these alternate displays. Typically, the operator must demonstrate the sufficiency of their proposed flight crew procedure and training to their State operations regulator and/or their operations inspector. The operator should be prepared to demonstrate their flight crews' procedures for monitoring deviation in a variety of scenarios in flight simulators with a number of trained flight crews. Once the operator's regulator accepts the training and flight crew procedures, the operator must include their procedures for monitoring deviation during RNP AR procedures in their initial and recurrent RNP AR operations training program.

– For RNP system installations using a CDI for monitoring lateral path tracking, the AFM or the OEM's aircraft qualification guidance should directly state which RNP values and RNP operations (that is, this manual's navigation specifications) the aircraft supports. The OEM documentation should also include any operational effects on the CDI scale. The flight crew must know the CDI full-scale value used by the RNP system during all RNP operations, including any flight crew procedures necessary to ensure the RNP system, or they should correctly set the deviation scaling.

– The RNP system may automatically set the CDI scale by phase of flight or by reference to the RNP values stored in the on-board navigation database. When the RNP system sets the deviation scaling solely by phase of flight, the operator should ensure the RNP values meet the requirements of the desired RNP procedures. Usually, RNP systems setting deviation scaling by phase of flight do not meet the deviation scaling setting requirements for RNP AR operations. When this occurs, the operator must ensure an alternate method for setting the deviation exists.

– When the RNP system does not automatically select the correct CDI scaling (by phase of flight or through reference to the on-board navigation database), the flight crew must manually set an appropriate scale. In this situation, the operator must have flight crew procedures and training in place to assure they select the appropriate CDI scale for the intended RNP operation(s). The deviation limit for the RNP procedure must be readily apparent given the deviation scaling (such as full-scale deflection).

6.3.4.2.10 *System cross-check.* For approaches with an RNP value less than 0.3, the flight crew must monitor the lateral and vertical guidance provided by the RNP system and ensure consistency with other available data and displays provided by an independent means.

Note.— This cross-check may not be necessary if the RNP system installation achieved an airworthiness approval recognizing design assurance that is consistent with a hazardous (severe-major) failure conditions for misleading information, and the RNP system performance supports containment during normal operations. This level of assurance ensures deviation outside the obstacle clearance volume provided for an RNP AR procedure due to hazardously misleading information is improbable and confirms the RNP system installation meets the required acceptable level of safety risk for RNP AR operations.

6.3.4.2.11 *Procedures with RF legs.* When flying an RF leg, flight crews must not exceed the maximum airspeeds shown in Table II-C-6-1 throughout the RF leg segment.

Note.— For example, a Category C A320 must slow to 160 KIAS at the FAF or may fly as fast as 185 KIAS if using Category D minima. A go-around prior to reaching decision altitude also requires compliance with the aircraft category maximum airspeeds in Table II-C-6-1.

Table II-C-6-1. Maximum airspeed by segment and category

Indicated airspeed (knots)						
Segment	*Indicated airspeed by aircraft category*					
	Cat H	*Cat A*	*Cat B*	*Cat C*	*Cat D*	*Cat E*
Initial and intermediate (IAF to FAF)	120	150	180	240	250	250
Final (FAF to decision altitude (DA))	90	100	130	160	185	As specified
Missed approach (DA to MAHF)	90	110	150	240	265	As specified
Airspeed restriction*	As specified					

* *RNP AR procedure designs may impose procedural airspeed restrictions to reduce the RF turn radius or for air traffic control purposes. These procedural airspeed constraints apply to all categories of aircraft. Operators must comply with all procedural limiting airspeeds on any RNP AR procedure under all operating configurations and conditions.*

6.3.4.2.12 *Temperature compensation.* Flight crew procedures may allow the crew to disregard the temperature limits published on RNP AR APCH procedures by applying temperature compensation. Refer to Attachment B for more information on temperature compensation.

6.3.4.2.13 *Barometric altimeter setting.* Most RNP systems use data from the aircraft's barometric altimeter(s) to provide vertical guidance during an RNP AR APCH. To ensure compliance with the RNP AR APCH VEB, the flight crew must obtain a current, local barometric altimeter setting (that is, a QNH setting). Flight crew procedures must also ensure a current, local barometric altimeter setting is available before beginning the RNP AR APCH, and the flight crew must set their altimeter(s) with this setting prior to crossing the FAF. If no current, local barometric altimeter setting is available, the flight crew must consider the RNP AR APCH unavailable. The inability to ensure compliance with the RNP AR APCH VEB prohibits use of a remote barometric altimeter setting. The flight crew must not use a remote barometric altimeter setting to conduct an RNP AR APCH.

6.3.4.2.14 *Crosscheck of the primary barometric altimeters.* Since most RNP systems derive their vertical guidance from the output of the aircraft's altimeter(s), the flight crew must complete a crosscheck of the primary barometric altimeters cross-cockpit to ensure both altimeters agree within 30 m (±100 ft). The flight crew must complete this crosscheck prior to the aircraft crossing the FAF, but no earlier than the IAF. The crosscheck should also occur at a known waypoint with the aircraft on the RNP system's vertical path, and the procedural altitude at the waypoint should serve as a reference altitude for the crosscheck. If the altimetry cross-check fails (that is, the barometric altimeters disagree with one another), then flight crew must abandon the RNP AR APCH and go-around.

Note.— Most RNP systems rely on a single source of barometric altimetry to feed multiple navigation computers (such as to feed multiple FMSs). This is done to ensure the RNP system provides identical vertical guidance to both pilots' PFDs. However, when this architecture exists, the single source of barometric altimetry can be inaccurate and provide misleading vertical guidance. Thus, the flight crew needs to crosscheck the primary barometric altimeters. This crosscheck of the independent primary barometric altimeters can confirm there is no misleading guidance from the RNP system.

6.3.4.2.15 If the aircraft's barometric altimetry sources (such as the air data computers) include a comparator warning system for the outputs to the flight crew's primary barometric altimeters, this crosscheck is unnecessary when the comparator warning system includes a function tailored for RNP AR APCH operations. If the aircraft includes a tailored system, then flight crew training and procedures must direct the flight crew to abandon the RNP AR APCH when a comparator monitor warning occurs.

Note.— The flight crew's operational crosscheck of their primary barometric altimeters need not occur when the aircraft includes a comparator monitoring system comparing the outputs of the barometric altimetry sources within 30 m (100 ft), or a tighter tolerance, during RNP approach operations (see also 6.3.3.3.1.4, Display of barometric altitude).

6.3.4.2.16 *VNAV altitude transitions.* When providing vertical guidance, RNP systems provide fly-by vertical guidance when sequencing flight plan waypoints. The "fly-by" vertical guidance may result in a descent slightly below the procedural altitude constraint at the waypoint; and this is necessary to smoothly intercept the vertical path of the next leg segment. This "fly-by" performance is particularly evident when the aircraft is in level flight and approaches the FAF. This small vertical displacement is operationally acceptable and the RNP AR APCH procedure design protects this characteristic of the VNAV guidance.

Note.— The momentary deviation below a published minimum procedure altitude when sequencing a flight plan waypoint is acceptable when the deviation is no more than 30 m (100 ft). However, there is no need for the flight crew to attempt to monitor waypoints to ensure compliance with this performance standard. VNAV airworthiness approval ensures this level of performance when State airworthiness regulators approve the RNP system's VNAV guidance for approach operations. This performance characteristic applies to:

a) "level off" or "altitude acquire" procedural leg segments following a climb or descent;

b) when the RNP system initiates vertical climbs or descent segments; and

c) when the RNP system sequences climbing or descending segments with different gradients (such as sequencing a waypoint where the descent gradient gets steeper).

6.3.4.2.17 *Non-standard climb gradient.* When an RNP AR APCH specifies a non-standard climb gradient in the missed approach procedure, the operator must ensure the aircraft is capable of complying with the published climb gradient(s) at the aircraft landing weight under the ambient atmospheric conditions.

6.3.4.2.18 *Go-around or missed approach.* The missed approach procedure for an RNP AR APCH is similar to the missed approach procedure of an RNP APCH. Where possible, an RNP AR APCH missed approach procedure will require an RNP value of RNP 1.0. However, where necessary, an RNP AR APCH missed approach procedure may use an RNP value less than RNP 1.0 (RNP<1.0). Eligibility to conduct RNP AR missed approach procedures requiring RNP<1.0 is defined in 6.3.3.3.4.

6.3.4.2.19 In some aircraft without a continuous LNAV function, activating the RNP system's go-around function (such as selecting TOGA) during the initiation of a go-around or when beginning a missed approach may cause a change in the aircraft's flight guidance mode (that is, TOGA disengages the autopilot and flight director from LNAV in some aircraft). The flight guidance may revert to heading-hold guidance based on an "average heading", or track-hold guidance derived from the aircraft's inertial system. In such cases, the operator must have flight crew training and procedures requiring the pilot flying to continue to comply with the RNP AR procedure's path and to reengage LNAV guidance to the flight director and autopilot as soon as possible.

Note.— In aircraft without continuous LNAV, the pilot flying needs to be prepared to ignore the aircraft's flight director guidance immediately after selecting "go-around" through TOGA or other similar means. When the aircraft's flight director guidance reverts to either heading-hold or track-hold and the aircraft is in a turn, or has just recently completed a turn, the aircraft's flight director guidance may command a turn away from the published RNP AR procedure path. If the *pilot even briefly follows this flight director guidance the aircraft may rapidly depart the lateral obstacle clearance area the RNP AR procedure provides and could cause a collision with terrain or obstacles. The pilot flying should either maintain the bank angle existing when they selected "go-around" or maintain wings-level flight until they can reengage LNAV and restore the RNP system's procedural path guidance.*

6.3.4.2.20 *Go-around during an RF leg.* The flight crew procedures and training must address the operational scenario a go-around creates when the pilot flying initiates the go-around prior to arriving at the RNP AR APCH decision altitude (DA) (that is, the missed approach point). When the pilot flying initiates a go-around prior to the DA, the pilot must adhere to the published procedural path unless ATC issues a new clearance. The operator's flight crew training and procedures must also ensure the flight crew is aware RNP AR procedure designs establish a maximum groundspeed for all RF legs. The flight crew must be aware if they initiate an early go-around with the aircraft in an RF leg, and they allow the aircraft's groundspeed to exceed the maximum groundspeed the procedure design protects, the aircraft may begin to overshoot the RF turn and a correction to the RF turn's procedural path will require manual intervention by the pilot flying to increase the aircraft's bank angle to correct and maintain the procedural path.

6.3.4.2.21 *Contingency procedures – loss of RNP system capability while en-route.* The aircraft's RNP system capability depends on the availability of all required aircraft equipment and the availability of the GNSS SIS. The flight crew must be able to assess the impact(s) of aircraft equipment failures on the planned RNP AR APCH procedure and take appropriate action such as requesting an alternate clearance. As described in 6.3.4.1.3 the flight crew also must be able to assess the impact of changes in the GNSS constellation, including a widespread loss of the GNSS SIS, and take appropriate action.

6.3.4.2.22 *Contingency procedures – failure on approach.* The operator's flight crew contingency procedures must address aircraft and RNP system component failures affecting the aircraft's lateral and vertical performance (such as loss of the GNSS SIS, the flight director or autopilot). The flight crew must understand the impacts of significant failures on the aircraft performance and how the failures affect their ability to safely comply with the procedural path.

6.3.5 Pilot, dispatch, operator knowledge and training

6.3.5.1 The operator must provide training for their key operations personnel, specifically their pilots and their dispatchers, in the planning for, and execution of, RNP AR procedures. An in-depth knowledge of their aircraft eligibility and performance, their required operational procedures, and best practices are critical to the safe operation of aircraft during an RNP AR operation, including RNP AR DPs. The operator's training programs must provide sufficient detail on the aircraft's navigation and flight control systems for the flight crews to identify failure conditions affecting the aircraft's RNP capability and how to apply appropriate abnormal or emergency procedures during RNP AR operations. The training programs should include a knowledge and skill assessment of the flight crews and dispatchers.

6.3.5.2 Operator responsibilities

6.3.5.2.1 Each operator must ensure their flight crew training and procedures addresses the specific characteristics of their planned RNP AR operations. The operator must include training on the different types of RNP AR APCH procedures and the aircraft's required equipment. Training must also discuss RNP AR operations regulatory requirements, including requirements regarding the use of RNP AR procedures in other States. The operator must include such requirements and procedures in their flight operations and training manuals, as applicable. The operator must also ensure all aspects of their operational authorization are understood by key personnel, including any operational limitations imposed by their State regulator or the RNP AR procedure host State's AIP. Every individual essential to the operator's conduct of RNP AR operations must complete all required ground and/or flight training before engaging in RNP AR operations.

6.3.5.2.2 Flight crew training segments must include training and checking modules representative of the type of RNP AR operations procedures the operator conducts. Operators may conduct line-oriented flight training (LOFT) activities for RNP AR operations under their established training standards and their provisions for advanced qualification programs. They may conduct evaluations in LOFT scenarios, event training scenarios or in a combination of both. The operator may conduct the required flight training modules in flight training devices, aircraft simulators and through other enhanced training devices and techniques, as long as the overall training accurately replicates the operator's equipment and the full range of their desired RNP AR operations.

6.3.5.2.3 Operators must address initial RNP AR operations training and qualification during initial, transition, upgrade, recurrent, differences or stand-alone programs in the respective qualification category. The qualification standards assess each individual pilot's ability to properly understand and conduct RNP AR procedures. The operator must also develop recurrent qualification standards to ensure each pilot maintains appropriate RNP AR operations knowledge and skills.

6.3.5.2.4 Operators may address RNP AR operation topics separately or integrate them with other curriculum elements. For example, an RNP AR APCH pilot qualification program may focus on a specific aircraft during transition, upgrade or differences courses. General training may also address RNP AR APCH qualification, for example, in recurrent training or checking events such as recurrent proficiency check/proficiency training, line-oriented evaluation or special purpose operational training. A separate, independent RNP AR APCH operations qualification program may also address RNP AR APCH training, for example by completion of an applicable RNP AR APCH curriculum at an operator's training centre or at designated crew bases.

6.3.5.2.5 Operators intending to receive credit for existing RNP operations training, when their proposed program relies on their previous training foundation, must receive specific authorization from the State regulator. In addition to their previously approved RNP training program(s), the operator will need to provide differences training between their existing training program(s) and their new RNP AR operations training requirements.

6.3.5.2.5.1 Training for flight dispatchers must cover:

a) the different types of RNP AR procedures (RNP AR APCH procedures and RNP AR DPs);

b) specific aircraft equipment impacting aircraft eligibility for RNP AR operations (the required equipment list the aircraft must have operable for the flight crew to complete an RNP AR procedure); and

c) the RNP AR operations regulatory requirements and dispatch procedures.

6.3.5.2.5.2 Dispatcher procedure and training manuals must reference these requirements, as applicable. Dispatcher training and procedures must cover all aspects of the operator's RNP AR operations including their specific operational authorizations. Each individual dispatcher must complete the dispatcher training course the operator's State regulator approves before they participate in the operator's day-to-day RNP AR operations.

6.3.5.2.5.3 The operator's dispatcher training must also address how to determine:

a) RNP AR procedure availability (considering aircraft, the aircraft equipment and performance capability);

b) MEL requirements;

c) the available aircraft performance (compliance with procedural airspeed limitations, aircraft climb performance versus any procedural climb gradients, etc.); and

d) the availability of RNP procedures through application of RNP predictions tools (GNSS SIS availability and impacts on the operator's RNP prediction tools).

6.3.5.2.5.4 The training must address all aspects of the operator's RNP AR operations, including operations at the departure, destination and alternate airports.

6.3.5.3 Ground training content

6.3.5.3.1 To gain an operational authorization from their State regulator for the initial pilot training for RNP AR operations, the operator's ground training must address the following subjects, preferably as training modules, in their RNP AR operations training program. For recurrent programs, the training curriculum need only review the initial training curriculum's requirements and address any new, revised or operational issues requiring additional emphasis, such as issues the operator identifies through their operational experience with RNP AR procedures.

6.3.5.3.2 *General concepts of RNP AR operations.* RNP AR operations training must cover systems theory for RNP AR operations sufficient to ensure pilots properly execute RNP AR procedures. A pilot must understand basic concepts of the RNP system's operation, operational classifications (differences between different types of RNP AR APCH and RNP AR DPs) and any operational limitations associated with their aircraft or imposed by their State regulator (for example, an operational limitation to conduct RNP AR APCH ops using RNP values no lower than RNP 0.3). The training must include general knowledge and an operational application of both RNP AR APCH and RNP AR DP, as required. This training module must address the following specific elements:

a) definition of RNP AR APCH and RNP AR DP;

b) differences between RNAV and RNP;

c) different types of RNP AR procedure charting the flight crew will use;

d) programming the aircraft's RNP system for specific types of RNP AR procedures;

e) aircraft-specific display characteristics supporting RNP AR operations (deviation display characteristics, presentation of alerts applicable to RNP AR operations, etc.);

f) how to enable and disable the various flight guidance modes and the navigation sensors the aircraft's RNP system requires during RNP AR operations;

g) how the aircraft's RNP system relies on setting RNP values for different phases of flight and RNP AR procedures, including any flight crew procedures for setting and confirming the proper RNP value for an RNP AR procedure, if required;

h) use of RNP prediction tool forecasts and the operational impacts of RNP availability on RNP AR procedures (pilot and dispatchers);

i) when and how to discontinue an RNP AR operation and transition to an alternate clearance relying on conventional navigation due to loss of RNP capability and/or aircraft equipment an RNP AR procedure requires;

j) how to determine the currency of the aircraft's on-board navigation database and whether it contains the navigational data RNP AR operations require (that is, GNSS waypoints based on the WGS-84 Earth reference, as required);

k) explaining the different components of a TSE and their characteristics, including the effect deviation from ISA (hot or cold temperatures) on the aircraft's vertical guidance and the aircraft's inertial navigation system drift characteristics when the RNP system relies on only inertial navigation system performance due to loss of the GNSS SIS; and

l) temperature compensation. When the operator includes approved flight crew training and procedures to use the RNP system's automated temperature compensation function, an explanation is given to flight crews operating the RNP system on:

1) how the function corrects errors in the procedural barometric altitudes introduced by deviations from ISA;

2) how and when the flight crew may disregard the temperature limits on an RNP AR APCH procedure; and

3) any unique implementation characteristics the temperature compensation function introduces (this may include, for example, how to distinguish between compensated barometric altitudes the RNP system depicts and the unaltered procedural barometric altitudes).

Refer to Attachment B for more information on temperature compensation.

Note 1.— The flight crew's training should include any recommended operating procedures and checklists the RNP system OEM offers for the system's automated temperature compensation function. The training should include areas such as how deviations from ISA bias the aircraft's barometric altimeter indications resulting in biased vertical path guidance, how to distinguish between the RNP system's display of compensated and uncompensated barometric altitudes, and any temperature compensation system limitations (for example some automated temperature compensation functions correct only cold temperatures). The flight crew should also know when they need to manually compensate the decision altitude DA since it is an operationally imposed altitude constraint and not a procedure-defined barometric altitude applicable to all operators.

Note 2.— A flight crew may employ manual temperature compensation when the State regulatory authority approves the operator's flight crew training and procedures for applying manual temperature compensation through use of a temperature compensation table or some other means (such as an electronic flight bag's (EFB) temperature compensation function). Before conducting a host State's RNP AR APCH procedures using manual temperature compensation, the operator should ensure the State's AIP permits flight crew use of manual temperature compensation techniques.

Note 3.— Training should address how State authorities may not permit temperature-compensated barometric altitudes for a variety of operational reasons (such as high traffic volume). Flight crew must therefore know if clearance should be requested to apply temperature compensation before applying compensated barometric altitudes to an RNP AR procedure. Likewise, training should prepare the flight crew to report all compensated barometric altitudes to the controller upon request and without delay.

6.3.5.3.3 *ATC communications and coordination for RNP AR operations.* The operator's ground training must instruct their pilots on proper flight plan classifications and any ATC procedures applicable to RNP AR operations. Each pilot must receive instruction to advise ATC as soon as practical when the aircraft's RNP system no longer supports the continuation of an RNP AR procedure. Each pilot must also know what essential aircraft equipment forms the basis for their aircraft's RNP AR eligibility and assess the impact of a failure of any aircraft system or loss of external systems (such as GNSS SIS), on the remainder of their flight plan.

6.3.5.3.4 *RNP AR operations equipment, components, controls, displays and alerts.* The operator's academic training must discuss RNP terminology, display symbology, optional controls and cockpit display features, including any items unique to the operator's implementation or aircraft. The training must address failure annunciations, audio and visual alerts and any equipment limitations impacting RNP AR operations. The operator's pilots and dispatchers should achieve a thorough understanding of the equipment essential to RNP AR operations and any equipment limitations impacting those operations.

6.3.5.3.5. *Aircraft Flight Manual information and operating procedures.* The AFM or other aircraft OEM documentation should document aircraft eligibility. Consistent with the aircraft's eligibility, the operator's flight crew procedures must address:

a) normal and abnormal checklists and procedures;

b) response to aircraft equipment failures;

c) response to annunciations and alerts;

d) application of any equipment limitations, including any essential information on the aircraft's RNP system's modes of operation; and

e) contingency procedures when facing loss or degradation of the aircraft's RNP system.

6.3.5.3.5.1 The operator's State regulatory authority should approve the flight operations manuals the flight crews use, such as operations manual or pilots operating handbook, and these documents should contain this information.

6.3.5.3.6 *MEL operating provisions.* Pilots must have a thorough understanding of the MEL requirements supporting eligibility for RNP AR operations.

6.3.5.4 Flight training segments – content

6.3.5.4.1 The operator's flight crew training programs must cover the proper execution of RNP AR procedures and ensure the programs are aligned with the aircraft OEM's documentation. The operational training must include:

a) RNP AR APCH procedures and limitations;

b) standardization of the cockpit's electronic displays during an RNP AR APCH procedure;

c) recognition of the aural and visual advisories, alerts and other annunciations impacting compliance with an RNP AR APCH procedure; and

d) the timely and correct responses to loss of RNP AR APCH capability in a variety of operational scenarios.

6.3.5.4.2 The scenarios must embrace the scope of the RNP AR APCH procedures the operator plans to complete, and the training may rely on a variety of training media the operator's State regulatory authority approves, such as computer-based training (CBT) or flight simulation training devices (FSTDs). The operator's training must address the following specific elements:

a) procedures for verifying each pilot sets their primary barometric altimeter to the current, local altimeter setting before beginning the final approach segment of an RNP AR APCH procedure and prohibiting use of remote barometric altimeter settings during any RNP AR APCH procedure;

b) the flight crew's use of aircraft radar, TAWS or other aircraft systems to support monitoring procedural track compliance, weather monitoring and terrain/obstacle avoidance;

c) the effect of wind on the aircraft's compliance with an RNP AR procedure and the need to remain within the 2×RNP procedural containment area, including operational wind limitations, procedural airspeed limitations and aircraft configurations essential to safely complete an RNP AR procedure;

d) the effect of groundspeed on compliance with RNP AR procedures and bank angle limitations impacting the aircraft's ability to remain on the course centreline including the requirement to maintain the aircraft's standard airspeed limits associated with the aircraft category;

e) the relationship between the aircraft's RNP eligibility and the appropriate line of minima and any operational limitations noted on the RNP AR approach chart such as temperature limits or RF leg airspeed limitations;

f) requirements for concise and complete flight crew briefings before all RNP AR procedures, including emphasis on crew resource management (CRM) and any contingency procedures required to successfully complete an RNP AR procedure;

g) alerts the RNP system may provide when incorrect RNP values are set for any segment of an RNP AR procedure and the flight crew's actions upon acknowledging the alerts;

h) any requirements to engage and couple the autopilot and/or flight director guidance to the RNP system's lateral and vertical guidance on RNP AR APCH procedures requiring an RNP value less than RNP 0.3 (RNP<0.3);

i) the importance of proper aircraft configuration such as flap settings to ensure the aircraft maintains required procedural airspeeds during RNP AR procedures;

j) the events requiring the flight crew to abandon an RNP AR procedure and, if necessary, complete the published missed approach procedure when using the aircraft's RNP system;

k) any aircraft bank angle restrictions or limitations impacting potential compliance with an RNP AR procedure;

l) the potential for detrimental effects on compliance with an RNP AR procedure caused by a change in the aircraft's configuration such as reducing the flap setting, reducing the bank angle from the bank angle the RNP system's flight guidance commands, or changing airspeed (exceeding a procedural airspeed limitation);

m) pilot knowledge and individual skills necessary to properly conduct RNP AR operations;

n) programming and operating the aircraft's RNP system, autopilot, auto-throttles, radar, inertial navigation system, electronic flight information system (including the moving map) and TAWS in support of RNP AR procedures;

o) the effect of activating the aircraft's go-around function (TOGA function) on the flight guidance during a straight leg segment and, when in a turn, including whether or not the aircraft's RNP system includes a continuous LNAV function;

p) flight crew procedures and techniques for monitoring FTE and the impacts on go-around decision when the FTE exceeds the FTE limit during an RNP AR procedure;

q) loss of the GNSS SIS during an RNP AR procedure and flight crew response;

r) impacts on the aircraft's performance when the RNP system reverts to an alternate means of navigation (including consideration of reversion that does and does not comply with the RNP performance requirements of an RNP AR procedure), such as reversion to only inertial navigation system guidance and prohibitions or limitations on the use of radio updating;

s) flight crew contingency procedures when a loss of RNP capability occurs during a missed approach procedure, including any tailored contingency procedures helping ensure separation from terrain and obstacles; and

t) familiarity with how the aircraft's RNP system provides VNAV guidance, including how it applies temperature compensation (if applicable) and how it manages the vertical path with respect to procedural barometric altitudes.

6.3.5.5 Evaluation module

6.3.5.5.1 *Initial evaluation of RNP AR operations knowledge and procedures.* The operator must evaluate each individual pilot's knowledge of RNP AR operations prior to the pilot participating in the operator's day-to-day RNP AR operations. As a minimum, the evaluation must review the pilot's knowledge of flight crew procedures and aircraft-specific eligibility requirements for RNP AR operations. An acceptable means for this initial evaluation includes one of the following:

a) an evaluation by an authorized instructor/evaluator or check-airman using a regulator-approved flight simulation training device (FSTD);

b) an evaluation by an authorized instructor/evaluator or check-airman during line operations, training flights, proficiency checks, practical tests events, operating experience, route checks and/or line checks; or

c) LOFT/line-oriented evaluation programs using a regulator-approved flight simulator profile incorporating the operator's unique RNP AR operations and the specific characteristics of the RNP AR procedures in the operator's operational authorization (including minimum RNP value(s), RF leg limitations, RNP AR missed approach procedure limitations, etc.).

6.3.5.5.2 *Evaluation content.* The evaluation module must address these specific elements:

a) application of any RNP limitations impacting the variety of RNP AR procedures the operator conducts;

b) application of the limitations of the RNP system's radio-updating capability, including flight crew procedures for disabling ground-based radio updating of the RNP system during an RNP AR procedure, and when to re-enable radio-updating. If the aircraft's RNP system does not include the means to disable radio updating, then the training must ensure the flight crew has an operational mitigation approved by the State regulatory authority that compensates for the absence of this function. For example, the monitoring of the GNSS SIS input to the RNP system by the pilot not flying, and a flight crew procedure to abandon the RNP AR procedure when GNSS updating of the RNP system's position solution is lost;

c) demonstration of the ability to monitor compliance with the RNP system's lateral and vertical flight guidance within the operational FTE limits and complete flight crew procedures when FTE exceeds a lateral or vertical limit;

d) demonstration of the ability to read and adapt to an RNP prediction, including a prediction indicating the RNP performance required by an RNP AR procedure is not available at the time of arrival at the desired destination airport where the flight crew must accomplish an RNP AR procedure;

e) demonstration of the proper set-up of the aircraft's RNP system, the weather radar, the TAWS and the moving map for the variety of RNP AR operations and likely scenarios the operator may implement;

f) demonstration of the use of flight crew briefings and checklists for RNP AR operations, as appropriate, with emphasis on CRM;

g) knowledge of, and ability to, perform an RNP AR APCH missed approach procedure in a variety of operational scenarios such as the loss of the GNSS SIS or failure to acquire visual conditions sufficient to transition to landing from the DA;

h) demonstration of airspeed control during segments of an RNP AR procedure with leg segments with speed constraints to ensure path compliance during RNP AR procedures;

i) demonstration of competent use of approach plates for RNP AR procedures, flight crew briefing cards and checklists;

j) demonstration of the ability to complete a stable RNP AR APCH, including bank angle requirements, airspeed control and the ability to remain on the procedure's centreline; and

k) knowledge of the operational limit for vertical deviation below the desired flight path (vertical FTE) during an RNP AR APCH and how to accurately monitor the aircraft's position relative to the vertical flight path when the vertical deviation indicator is not ideally scaled for RNP AR APCH operations, such as monitoring numerical vertical FTE readings on the RNP system's CDU.

6.3.5.6 Recurrent training

6.3.5.6.1 The operator should incorporate recurrent training embracing the unique RNP AR operations characteristics the operator employs as part of their overall training program.

6.3.5.6.2 Each pilot must complete a minimum of two RNP AR APCHs: one as pilot flying and one as pilot monitoring. These two RNP AR APCHs should employ the unique AR characteristics of the operator's approved procedures (RF legs, minimum RNP values, missed approach, etc.). One approach must culminate in a transition to landing after reaching the DA, and the other approach must result in a transition to the procedure's RNP AR missed approach procedure.

6.3.5.6.3 When adding these RNP AR APCHs to their recurrent training curriculum, the operator may substitute the RNP AR APCHs for any other events in the curriculum, requiring the pilot complete a "precision-like" instrument approach.

Note.— The operator may credit equivalent RNP APCHs employing Advanced RNP characteristics toward this requirement.

6.3.6 Navigation database

6.3.6.1 Navigation database validation

6.3.6.1.1 An RNP AR procedure in an aircraft's on-board navigation database contains the data that the aircraft's RNP system uses to define the procedural lateral and vertical path. The integrity and accuracy of this navigation data is critical to the safe execution of every RNP AR procedure the operator's flight crews complete. However, most navigation database vendors do not create their database products with an "assurance level" supporting the acceptable level of safety risk for RNP AR operations. Thus, an operator must validate the packed navigation data in the aircraft's on-board navigation database for each RNP AR procedure they desire to complete before permitting their flight crews to use the procedures.

Note 1.— RTCA DO-200() and EUROCAE ED-76() define data assurance levels as providing a means for a data supplier, such as a vendor of an on-board navigation database, to ensure that the data offered by the vendor matches the quality and integrity requirements of its intended use. Most on-board navigation database vendors do not offer database products containing RNP AR procedures with a data assurance level meeting the acceptable level of safety risk for RNP AR operations (that is, 1×10^{-7}). A robust database management program meeting the requirements of this section can help ensure that no data corruption occurs when a navigation database vendor packs a database containing RNP AR procedures in support of the operator's aircraft and their RNP systems.

Note 2.— When a State regulatory authority validates the data assurance level of a navigation database vendor's products (that is, meeting or exceeding the acceptable level of safety risk for RNP AR operations), it is not necessary for the operator to meet all the navigation database management requirements in this section.

6.3.6.1.2 This section defines the operator's requirement to establish and maintain a database management program supporting validation of the packed RNP AR procedures in the on-board navigation database of their aircraft, when the supplier of their aircraft's on-board navigation database does not offer a product meeting the acceptable level of safety risk for RNP AR operations. When the operator's database management program meets the requirements in this section, the operator ensures that the RNP AR procedural data in their aircraft's on-board navigation database safely supports RNP AR operations.

6.3.6.2 Navigation database management process

6.3.6.2.1 The operator must identify, in writing, the individual responsible for managing the process for maintaining the on-board navigation database(s) products for their aircraft conducting RNP AR operations.

Note.— The operator should provide the contact information of the responsible manager and any administrative support personnel (such as phone numbers and email addresses). This is essential in case of any emergency change notices to RNP AR procedures the operator may rely on and use on a regular basis.

6.3.6.2.2 The operator must document the processes and procedures for accepting, verifying and loading navigation data into their aircraft.

6.3.6.2.3 The operator must document and maintain the processes and procedures under configuration control.

Note.— The term configuration control *implies that the operator maintains formal control of the documented database management procedures and processes. As part of that formal control, the operator should not revise or update their database management program prior to receiving acceptance from the State of the Operator (the regulator responsible for overseeing their RNP AR operations and issuing their operational authorization).*

6.3.6.2.4 The operator must not delegate responsibility for their database management procedures and processes to a third party.

Note 1.— A third-party service provider may offer a full range of services and tools aiding the operator's efforts, but the operator retains the ultimate responsibility for their database management program.

Note 2.— Some States may formally recognize, in writing, the services and products of third-party database management service providers. Generally, this recognition acknowledges the third-party service provider's role in helping an operator achieve a database management process consistent with the requirements of this RNP AR navigation specification.

Note 3.— When the operator considers acquiring and applying third-party tools as part of their database management processes (such as an automated software tool for analysing a packed navigation database for changes and updates in RNP AR procedures), the operator should confirm that the design of the tool(s) is consistent with the *acceptable level of safety risk for RNP AR operations. The operator should also confirm their State regulatory authority accepts the third-party tools.*

6.3.6.2.5 *Initial data validation.* The operator must validate every RNP AR procedure they intend to complete before flying the procedure in instrument meteorological conditions. The validation can ensure both the compatibility with their aircraft and its avionics, and that the resulting path matches a State's published RNP AR procedure. To conduct a proper data validation effort, as a minimum, the operator's data validation process must:

a) compare the navigation data for the RNP AR procedure(s) in the RNP system's packed, on-board navigation database(s) with the State source data (the AIP) defining the published procedure for accuracy;

Note 1.— The FAA maintains a website providing an RNP AR Approach Parameter Chart listing specific procedure data elements an operator can use to check the accuracy of the data in the packed, on-board navigation database. The chart also lists suggested tolerances for confirming the accuracy between the State source data and the packed data. Database providers and OEMs developed these parameters and tolerances; and, before applying them as part of their database management program, the operator should confirm they apply to their aircraft and the specific navigation database products the aircraft employs. The parameter chart is available at the following website: https://www.faa.gov/about/office_org/headquarters_offices/avs/offices/afx/afs/afs400/afs410/pbn/media/AC_90_101A_Approach_Parameters_Chart.pdf.

Note 2.— When the operator's accuracy checks find an RNP AR procedure that fails (such as a data element in the packed, on-board navigation database exceeding the tolerance for the comparison of the data element against the State's AIP), the operator should consider the specific RNP AR procedure unavailable and report the failed procedure to their database supplier. Inaccurate data can corrupt the RNP system's path definition.

b) validate the packed, on-board navigation database procedure definition's flyability and completeness by flying the procedures either in an FSTD the State approves for RNP AR training, a desktop/laptop computer, or in the actual aircraft in visual meteorological conditions (VMC). If the operator uses an FSTD or a desktop/laptop computer to perform this evaluation, the device used by the operator must contain software identical to the software the aircraft's RNP system uses (such as the FMS software). The device must also contain an aerodynamic model of the aircraft's flight characteristics. During this procedure validation, the operator must compare the map display of the procedure against the charted, published RNP AR procedure. The operator must also execute the entire procedure to ensure the path is flyable by their specific aircraft type(s) and does not encounter any lateral or vertical path discontinuities while completing the procedure under normal operating conditions; and

c) retain and maintain a copy of the RNP AR procedure definition for comparison to subsequent data updates States may issue through the AIRAC cycle.

Note.— Once the operator validates the RNP AR procedures they plan to use, they need not revalidate the procedures with each AIRAC cycle when no changes occur to the procedures.

6.3.6.2.6 *AIRAC cycle data updates and changes.* The operator's documented database management processes must define the means the operator uses to check each 28-day AIRAC cycle update for changes and updates to the validated RNP AR procedures. These processes must include a means to re-confirm data accuracy to validate a State's new definition of any updated or altered procedure data elements against the procedure's corresponding packed navigation data in the aircraft's on-board navigation database. This validation must occur before any flight crew uses an updated or altered RNP AR procedure. The validation must also be robust enough to identify any discrepancies between the data elements in the packed on-board navigation database and the State's new source data in their AIP. The comparison of the data elements must use the same tolerances the operator uses for initial validation of an RNP AR procedure.

Note.— If the operator finds that a data element exceeds their prescribed tolerance, the operator should consult with their navigation database supplier and resolve the discrepancy prior to their flight crews using the RNP AR procedure. The operator may resolve discrepancies by correcting the error within the current cycle or by removing the procedure from the database. The State of the Operator may also approve other operational mitigations proposed by the operator, such as dispatch procedures prohibiting flight plans using the RNP AR procedure with a discrepancy.

6.3.6.2.7 The method the operator uses to conduct this recurring data comparison is optional and subject to authorization by the State of the Operator as part of their documented database management processes. One acceptable method is to establish a reference database containing known, validated RNP AR procedure data. The operator may use the database to compare data from subsequent AIRAC cycle updates against their own. Operators may also choose to compare the navigation data in the updated, revised database directly against the State's source data. Regardless of the method they use, the operator must document their process and assure the accuracy and completeness of the validated navigation data for their RNP AR procedures at each update cycle.

Note 1.— Some database suppliers, and/or the OEMs of the aircraft or RNP systems, offer automated tools to compare the accuracy and completeness of the data elements between database products. These automated products can alert the user of any changes in, or differences between, the packed, on-board navigation database content. If the operator chooses to use an automated tool to help maintain their on-board navigation database, then the use of the tools should be part of their documented database management processes.

Note 2.— Before adopting an automated tool as part of their database management processes, the operator should ensure the tool's quality and function supports RNP AR operations. Thus, if the operator acquires a tool from a third-party supplier or from their database supplier, the operator should ensure the tool's documentation includes recognition of the tool from a State airworthiness authority supporting its application for RNP AR procedures. The tool's development assurance should ensure it supports the RNP AR operations acceptable level of safety risk (ALSR) of $1{\times}10^{-7}$ per approach and the tool's provider should offer documentation of acceptance and recognition of its quality.

6.3.6.2.8 *Data suppliers.* As a minimum, the operator's data supplier must have an FAA Type 2 LOA for processing navigation data (FAA AC 20 153()), an accepted certified process (EASA Part DAT Type 2) or an equivalent process accepted by the State of the Operator. The authorization recognizes the data supplier as one whose data quality, integrity and quality management practices are consistent with the criteria of DO-200()/ED-76(). The operator's database supplier must have a Type 2 LOA. Those entities providing data to the aircraft operator's suppliers must likewise possess either a Type 1 or 2 LOA.

Note 1.— When the RNP system OEM is also the database supplier, the OEM may have a formal airworthiness approval recognizing how the quality and integrity of their navigation data directly support RNP AR operations. In this case, the airworthiness approval will recognize the OEM's database production processes and the approval basis should recognize the classification of the data consistent with that of critical data, as contained in Annex 15 – Aeronautical Information Services*. Specifically, the airworthiness approval should recognize the data supplier's processes consistent with the requirements RTCA DO-200()/EUROCAE ED-76() for protection against "hazardously misleading data". Typically, this type of process achieves what RTCA DO-201() refers to as "Assurance Level 1" data integrity for "critical data".*

Note 2 — When the operator's database supplier offers an approved database production process protecting against hazardously misleading RNP AR procedure data, the operator may not need to conduct initial and recurrent validation of the RNP AR procedure data. This can simplify the operator's documented database management processes, but this does not obviate the operator's requirement to establish and maintain a database management program consistent with the requirements of this navigation specification. When the quality and integrity of the operator's database supplier offer relief, the operator's database management process should directly reflect that relief in their simplified processes.

6.3.7 Aircraft modifications to RNP significant systems and functions

6.3.7.1 *Operator responsibility.* If the aircraft OEM, the avionics OEM(s) or another manufacturer offers a modification for a system the aircraft requires for RNP AR operations eligibility (such as a software or hardware change), or offers a modification impacting the controllability and flyability of the aircraft, the operator is responsible for validating the modification's impact(s) on the aircraft's RNP AR operations eligibility before accepting the modification and conducting RNP AR operations with a modified aircraft.

6.3.7.2 *Statement of impact.* The manufacturer offering the modification should formally document and offer a statement of impact when the modification alters the aircraft's RNP capabilities. This statement can help the operator expeditiously update their operational authorization basis to reflect their implementation of the aircraft modification.

Note.— The operator's operational authorization should document the configuration of the aircraft the State accepted as the foundation for the authorization. When the operator installs aircraft modifications, the State of the Operator should ensure that they update their operational authorization with the new configuration of the aircraft.

6.3.7.3 *Statement of no impact.* When the modification does not impact the aircraft's RNP capabilities, then the manufacturer should formally document a statement of no impact.

Note.— This statement enables the operator to make the modification and update their aircraft configuration (as part of their operational authorization for RNP AR operations) as expeditiously as practical.

6.3.7.4 *No available documentation.* If no documentation is available from the manufacturer directly stating the impacts of their modification on the aircraft's RNP capability, the operator must then validate the performance of the modified aircraft, noting any changes to flight control computers, the FGS, the RNP system's functions and any other operational software impacts on the aircraft performance.

Note.— For example, the operator may conduct an evaluation of a manufacturer's modification by confirming the aircraft's ability to fly RNP AR procedures with the modification installed in the aircraft. If the operator completes this evaluation in the actual aircraft, they should complete the evaluation during the day. The operator should also complete a representative number of RNP AR procedures available in the aircraft's on-board navigation database to ensure the modification retains the aircraft's flyability.

6.4 NAVIGATION SPECIFICATION FOR IMPLEMENTING RNP AR DEPARTURE PROCEDURES

6.4.1 Introduction and background

6.4.1.1 The navigation specifications in this section provide operators eligible for RNP AR APCH a means to depart from an airport when the departure path requires an RNP AR DP. Thus, the navigation specifications for an RNP AR DP build on the aircraft eligibility and functionality required for an RNP AR APCH and also rely on the foundation from the operational authorization specifications for RNP AR APCH. This section reflects only the additional aircraft and operator requirements for RNP AR DP operations.

6.4.1.2 In building upon the existing specifications, RNP AR DPs introduce additional aircraft performance considerations. In this case, the additional performance considerations include the need for synergy between the take-off and climb performance of the aircraft and the operator's ability to effectively employ the RNP system while complying with demanding, non-standard climb gradients and close-in departure turns. This synergy permits the safe application of RNP AR DPs with performance characteristics unavailable through the application of any other navigation specification in this manual.

6.4.1.3 Since an RNP AR DP may rely on non-standard climb performance, the operator and the regulator overseeing the operator must ensure they address both normal (all engines operating) and non-normal (OEI) performance requirements for RNP AR DPs. Ultimately, the operator must ensure their aircraft can safely clear all obstacles and terrain while completing an RNP AR DP. For example, proper application of these navigation specifications can enable the ability to design and implement an RF turn at the departure end of the runway (DER). This navigation specification applies a robust application of the aircraft's take-off and climb performance in concert with the aircraft's RNP system's performance.

6.4.1.4 While State regulatory materials generally address the climb performance requirements for the aircraft's take-off path, RNP AR DP operations can bring benefits through flexible application of the take-off performance, the performance of the aircraft from brake release through clean-up and the aircraft's climb performance once the take-off phase is complete. This new flexibility brings added complexity due to the application of the RNP AR DP procedure design criteria, which requires defining new aircraft eligibility (and any limitations), additional operational training, new flight crew procedures and a new basis for an RNP AR operations authorization by the State. The following RNP AR DP navigation specification reflects one means to achieve operational success when implementing RNP AR DPs.

6.4.2 Purpose

6.4.2.1 These navigation specifications provide a recommendation for the conduct of RNP AR DPs. The navigation specification addresses both airworthiness and operational issues for RNP AR DPs. Like the RNP AR APCH navigation specification, this specification does not address all the requirements that a State or region may impose in documents such as national operating rules, AIPs and *Regional Supplemental Procedures* (Doc 7030) for the conduct of RNP AR DPs.

6.4.2.2 The navigation specification also assumes that RNP AR DP designs will apply RNP values no lower than RNP 0.30. The application of RNP values below RNP 0.30 (RNP<0.30) during RNP departure procedures is not supported.

Note 1.— Prior to publishing the RNP AR DP navigation specification, numerous States offered individual and selected operational authorization to conduct proprietary RNP DPs tailored specifically for the individual operator and their specific aircraft type and its RNP system. The experience of these States and operators reveals how public RNP AR DPs, using not less than RNP 0.30, can meet the vast majority of those airports with departure procedure demands that other navigation specifications cannot meet. Unlike other navigation specifications, this public RNP AR DP navigation specification supports the combination of RNP values no lower than RNP 0.30, in concert with nonstandard take-off and climb performance requirements met in harmony with advanced aircraft and RNP system functionality. This unique combination offers the State the opportunity to publish safe, efficient public RNP AR DPs in their AIP.

Note 2.— When the State finds that applying the public RNP AR DP navigation specification and the public procedure design criteria do not provide a means to offer an RNP DP from a specific airport and runway, they should not publish a public procedure with deviations from the navigation specification and the procedure design criteria. When challenged with this situation, the State should consider offering a tailored, proprietary RNP DP applicable to an individual operator and the operator's individual, specific aircraft type, with its unique performance characteristics. There can be no assurance of safe compliance with RNP DPs that deviate from the standards the RNP AR DP navigation specification established in this manual.

6.4.3 Implementation considerations

6.4.3.1 NAVAID infrastructure considerations

6.4.3.1.1 Like an RNP AR APCH authorization, an operational authorization to conduct RNP AR DPs relies on the availability of GNSS as the primary NAVAID infrastructure. A State should not employ RNP AR DPs in an area where interference with the GNSS SIS is known to exist.

6.4.3.1.2 RNP AR DPs also rely uniquely on the aircraft's inertial navigation system as a contingency backup and alternative means to safely complete an RNP AR DP when the aircraft's GNSS fails or the GNSS SIS becomes unavailable for any reason. Thus, the unique operational requirements for aligning the aircraft's inertial navigation system are necessary to ensure optimal inertial system performance is available throughout an RNP AR DP.

6.4.3.2 Additional considerations

As part of the safety assessment process supporting RNP AR operations, the State and operator should address operational risks specific to RNP AR DP operations in accordance with the criteria in section 6.4.

6.4.3.3 Publication

The State's AIP should clearly identify if the State requires an operator to formally define their contingency procedures for OEI or other non-normal events that may occur during an RNP AR DP. States may impose requirements for the operator to develop individual, specific contingency procedures for each of the State's RNP AR DPs they intend to conduct.

Note.— See the operational requirements in 6.4.4.5.1.4.6.1 for guidance on how an operator may address contingency procedures during RNP AR DP operations.

6.4.3.4 Controller training

6.4.3.4.1 In addition to the requirements in 6.2.6, the additional training air traffic controllers receive prior to providing control services for an airport conducting RNP AR DP operations should include the following considerations.

6.4.3.4.2 RNP AR DP core training should define the RNP AR DP and how it may impose performance demands on the aircraft and the flight crew not found in any other PBN DP operation.

6.4.3.4.3 *RNP AR DP air traffic control procedures*

6.4.3.4.3.1 Once an aircraft receives take-off clearance and begins the take-off and climb-out on an RNP AR DP, the controller should allow the flight crew to complete the RNP AR DP in its entirety without interruption.

6.4.3.4.3.2 *ATC vectors off the RNP AR DP*. If safety dictates the controller vector an aircraft conducting an RNP AR DP off the procedure, the controller must not ask the flight crew to expect to continue the RNP AR DP. The controller cannot expect the flight crew to ensure the aircraft's ability to meet the RNP AR DP's climb performance requirements, should they attempt to rejoin the procedure.

6.4.4 Additional RNP AR DP navigation specifications

This section contains additional navigation specifications supplementing 6.3, which are necessary to support the operational implementation of RNP AR DPs. Each State's regulations should address these additional requirements before implementing RNP AR DPs and before granting any operational authorizations to conduct RNP AR DPs.

6.4.4.1 RNP AR DP authorization process

6.4.4.1.1 As with the guidance for RNP AR APCH, this section does not comprise the regulatory materials a State may use to assess and approve an operator to conduct RNP AR DPs, nor does this specification provide a means to determine eligibility of every aircraft, even those eligible for RNP AR APCH, as the performance requirements for an RNP AR DP differ. The specification also does not imply a need to recertify the aircraft and its RNP system. However, aircraft eligibility may require the operator to obtain additional aircraft performance data and confirmation of eligibility for RNP AR DPs from the aircraft OEM.

6.4.4.1.2 Before requesting an operational authorization and authorization to conduct RNP AR DPs, the operator should acquire and refer to the aircraft and RNP systems OEMs' recommendations and guidance for conduct of RNP AR DPs.

6.4.4.1.3 Compliance with the OEMs' recommendations and guidance, such as the flight crew procedures and information found in an aircraft OEM's RNP AR DP operating manual or similar document, can help the operator gain authorization more quickly.

6.4.4.2 RNP AR DP operational authorization

6.4.4.2.1 *Description of aircraft equipment.* The operator must have an RNP AR DP configuration list and, if necessary, a MEL detailing their aircraft equipment RNP AR DP operations require.

6.4.4.2.2 *Training documentation.* Before the State of the Operator offers authorization to conduct RNP AR DPs, the operator must specifically meet the following additional requirements:

Note.—These requirements supplement, and are in addition to, the requirements found in 6.3.2.6.2.

a) the operator must provide any training and procedures specific to RNP AR DPs necessary to ensure compliance with the configuration list;

b) the operator must provide any training and procedures required to ensure compliance with the take-off and climb performance requirements of an RNP AR DP. The training and procedures must ensure that the operator can simultaneously meet an RNP AR DP's RNP lateral path compliance requirements while meeting the normal and non-normal aircraft performance requirements for take-off and the subsequent climb; and

Note.—The training and procedures should support the ability to conduct RNP AR DPs compliant with public procedure design criteria and identify any performance limitations. Specifically, the training and procedures should address all issues associated with conducting RNP AR DPs where the procedure places an initial fix of an RF leg at the DER and the procedure also applies nonstandard climb performance requirements to multiple leg segments.

c) the training and procedures must also address the operator's application of any aircraft performance tools necessary to ensure compliance with the take-off and climb performance demands of an RNP AR DP.

Note 1.— If requested by a regulator, the operator should provide any documentation supporting their application of a "certified performance calculator" or evidence of aircraft performance "tool qualification" in support of RNP AR DP operations. The operator should also employ any procedures necessary to maintain tool qualification the tool provider's instructions require.

Note 2.— Computer-based applications, EFB performance calculators, RNP system performance calculators or third-party services may provide the performance tools to assess take-off and climb performance. Regardless of the source of the performance tool, the tool should demonstrate the ability to support RNP AR DPs.

6.4.4.2.3 ***OMs and checklists***

6.4.4.2.3.1 The operator must create any new additions to their operating manuals and checklists necessary to conduct RNP AR DPs. This new material should comply with the recommendations of the aircraft and avionics OEMs and include instructions for normal operations on an RNP AR DP and any requisite contingency procedures.

6.4.4.2.3.2 When the State of the Operator/Registry, or the State where the operator intends to conduct RNP AR DPs, requires the operator to submit the sections of their operating manuals and checklists supporting RNP AR DP operations for review per the State's application process for RNP AR DP authorization, the operator must submit their manuals and checklists for review and consideration.

6.4.4.2.3.3 To facilitate authorization without undue delay, operators should provide documentation to the State showing how they employ the aircraft OEM's recommended practices and procedures to conduct RNP AR DPs.

6.4.4.3 RNP AR DP Authorization submittal

6.4.4.3.1 The State of the Operator/Registry or host State of the RNP AR DP procedure must accept the operator's materials supporting RNP AR DP operations before the operator can expect the State to offer an operational authorization to conduct RNP AR DPs.

6.4.4.3.1.1 When the operator already has an operational authorization to conduct RNP AR APCH, the operator needs to apply for an amendment to expand their operations specifications to include authorization to conduct RNP AR DPs in accordance with the State of the Operator/Registry regulations. The operator's application should also identify any new conditions and limitations applicable to the RNP AR DPs they intend to conduct.

6.4.4.3.1.2 When the operator does not have an existing operational authorization to conduct RNP AR APCH from the State of the Operator/Registry, the operator may submit a single application for operational authorization to conduct both RNP AR APCH and RNP AR DPs. The operator should comply with the regulations the State of the Operator/Registry requires.

6.4.4.4 RNP AR DP aircraft requirements

6.4.4.4.1 This section defines the additional aircraft performance and functional specifications for an aircraft to be eligible for RNP AR DPs. These requirements supplement, and are additional to, the requirements of 6.3.3 and are unique to RNP AR DP aircraft eligibility.

6.4.4.4.2 ***Functional requirements for RNP AR DP***

6.4.4.4.2.1 *RNP AR DP path execution.* The aircraft's RNP system must be capable of loading and executing a flight plan where the RNP AR DP defined path begins at or just beyond the DER, including use of an RF leg.

Note 1.— Locating an initial fix of an RNP AR DP at or near the approach end of the take-off runway is one acceptable means to facilitate executing an RF leg at the DER. The straight segment from the initial fix leading to the fix defining the beginning of the RF leg at the DER helps ensure the aircraft's path is tangent to the RF leg to capture the RF leg guidance.

Note 2.— The aircraft's RNP system should not command a course reversal to return to the RNP AR DP's initial fix in the RNP system's flight plan. Some older, legacy RNAV systems demonstrated this undesirable characteristic during early implementations of RNAV DPs.

6.4.4.4.2.2 To support RNP AR DPs, the aircraft's installed RNP system must provide continuous lateral path guidance no later than 15 m (50 ft) above the departure runway during take-off.

Note 1.—This requirement is consistent with the lateral path steering requirement in RTCA DO-236C, paragraph 3.3.3.1, RNP MASPS and in DO-283B, paragraph 2.2.1.3.2, RNP MOPS.

Note 2.— This requirement supports executing RNP AR DPs where the first waypoint of the procedure is at or near the approach end of the take-off runway and ensures support for RNP AR DPs with close-in turns, including RF turns, at or just beyond the DER.

6.4.4.4.2.2.1 When the AFM or OM prohibits engaging LNAV on the ground, the aircraft's take-off performance must:

a) climb to the aircrafts LNAV minimum engage height; then

b) engage LNAV guidance through automatic or manual means; and then

c) provide the means to follow the RNP system's LNAV lateral guidance and maintain track prior to reaching the turn anticipation point for the RNP AR DP's first turn point.

Note.— An RNP AR DP's first turn point may be at or just beyond the DER. When the procedure requires a close-in turn at or just beyond the DER, the procedure will use an RF leg to define the turn. When the first turn point is an RF leg, the aircraft's take-off performance must support engaging LNAV early enough to ensure the RNP system's turn anticipation calculations are accurate and support smooth capture of the LNAV guidance necessary to fly the RF leg and avoid lateral path deviation.

6.4.4.4.2.3 *Close-in turn anticipation calculations.* When the RNP AR DP requires a close-in turn at or just beyond the DER, retraction of the landing gear and flaps during the take-off sequence and subsequent rapid acceleration to en-route climb airspeed may compromise the RNP system's ability to conduct accurate turn anticipation for the close-in turns. An inaccurate turn anticipation calculation may compromise the aircraft's ability to comply with the defined turn, resulting in an overshoot of a close-in RF turn. With this in mind, the RNP AR DP may include an airspeed constraint when the procedure includes a close-in turn.

Note.— The recommended climb airspeed should not be lower than the best climb airspeed with OEI.

6.4.4.4.2.4 *GNSS acquisition prior to take-off.* The aircraft's installed RNP system must provide a means for the flight crew to confirm use of GNSS for aircraft positioning immediately prior to take-off.

Note 1.— Meeting this requirement may require new flight crew procedures and training. The "before take-off" checklist should include this new procedure, when necessary.

Note 2.— The flight crew procedures and training should also ensure the flight crew does not take-off when GNSS is unavailable immediately prior to take-off.

6.4.4.4.2.5 *Inertial navigation system alignment and position updates.* To support the potential loss of GNSS and reversion to inertial-only navigation during an RNP AR DP operation, the installation of the aircraft's inertial navigation system and RNP system must include the ability to conduct a full inertial alignment and continuously update the inertial position during ground operations immediately prior to take-off.

Note 1.— This requirement helps ensure the best performance from the aircraft's inertial navigation system and RNP system should a loss of GNSS occur after take-off when the RNP system reverts to inertial-only navigation.

Note 2.— In many aircraft, an automatic inertial navigation system position update occurs during the actual take-off, and this meets the position updating requirement above.

6.4.4.5 RNP AR DP operating procedures

6.4.4.5.1 ***RNP AR DP pre-flight considerations***

6.4.4.5.1.1 The following inflight considerations supplement those in 6.3.4.1.

6.4.4.5.1.2 *MEL revisions.* The operator should revise their MEL as necessary to address the equipment requirements to conduct an RNP AR DP. The operator should seek guidance from their aircraft OEM to determine if any updates are necessary to ensure their aircraft are eligible to conduct RNP AR DPs.

6.4.4.5.1.2.1 The flight crew should review the MEL to confirm the aircraft configuration remains eligible for an RNP AR DP.

6.4.4.5.1.3 *Autopilot and flight director.* During pre-flight planning, the operator should confirm the availability of the aircraft's flight director(s) and/or autopilot(s) prior to flight planning their departure from the airport on an RNP AR DP.

6.4.4.5.1.4 RNP AR DP take-off and climb performance data

6.4.4.5.1.4.1 The operator must demonstrate competency in applying their aircraft's take-off and climb performance data in support of pre-flight planning of RNP AR DPs. The operator must also independently analyse the aircraft's performance during the take-off phase of an RNP AR DP and then analyse the climb phase of the DP from the point on the DP where the take-off phase ends, and the aircraft achieves the desired climb airspeed. Ultimately, this pre-flight performance analysis must confirm that the aircraft performance is available to safely complete the desired RNP AR DP.

Note 1.— Operators may need to acquire additional, more detailed take-off and climb performance data from the aircraft's OEM to conduct day-to-day RNP AR DP operations due to the unique performance demands these RNP operations require.

Note 2.— Operators conducting RNP AR DPs may seek and use the services of a third-party service provider for take-off and climb performance calculations. These service providers can also provide performance calculations for OEI take-off and climb. In some instances, the aircraft OEM provides these services for their customers. However, regardless of the source of the aircraft performance calculations, the operator is responsible to confirm the third-party provider supports all of the requirements of this section of the navigation specification.

6.4.4.5.1.4.2 *Non-standard climb gradients.* The operator's application of their aircraft take-off and climb performance computations must address the nonstandard climb performance requirements that an RNP AR DP may require. The operator's performance data must ensure compliance with the normal (all engines operating) climb gradient requirements of each leg of an RNP AR DP.

Note 1.— Simple climb performance computations, such as those using just the distance required to climb from the runway elevation to the highest procedural barometric altitude the RNP AR DP requires, may not be acceptable. Confirmation of aircraft performance is required for each leg, considering the unique performance characteristics that each aircraft types possesses for the take-off and climb phases of flight.

Note 2.— Typically, the procedure design criteria for public instrument departures procedures conducted under IFR assume the aircraft will cross the DER at or above 11 m (35 ft) AGL. The criterion then assumes the aircraft will *climb at a minimum of 200 ft/NM for the remainder of the departure procedure. In application, as a minimum, this means the aircraft's take-off phase performance must meet these criteria. In contrast, RNP AR DPs may demand the aircraft be at an altitude well above 11 m (35 ft) at the DER and also demand climb gradients well in excess of 200 ft/NM. These unique RNP AR procedures may also demand that the aircraft successfully complete close-in, guided turns, such as an RF leg, at or just beyond the DER.*

6.4.4.5.1.4.3 The operator must consider the forecast or actual weather conditions for the aircraft's take-off time when analysing the aircraft's climb performance against the RNP AR DP's climb gradient requirements. When using a forecast to conduct the climb performance analysis, the operator must obtain the forecast from an aviation weather source that their State regulator requires/accepts. When using actual weather conditions, the operator must obtain the reported weather conditions from an aviation weather office, an automated aviation weather observation station at the take-off aerodrome or another source the regulator requires/accepts. When the forecast or actual weather report identifies weather anomalies, such as a temperature inversion during the climb, the operator must ensure they apply the impacts of the anomaly when analysing the aircraft climb performance.

Note.— The aircraft can encounter a temperature inversion's effects quite rapidly when climbing through an inversion layer. Thus, when climbing through an inversion layer where the outside air temperature (OAT) increases, the higher temperatures at higher pressure altitudes may decrease the aircraft's climb capability to a point where the aircraft may not be able to comply with the non-standard climb gradients an RNP AR DP requires.

6.4.4.5.1.4.4 The operator must ensure that the flight crew's procedures and training require them to confirm the validity of the aircraft climb performance data prior to accepting a take-off clearance from ATC, as well as to recognize any performance limitations that may exist for the individual RNP AR DP to comply with the procedure defined lateral path and altitude constraints. The training and procedures must also identify when the flight crew must obtain new climb performance data.

Note.— For example, when the synergy between the aircraft's take-off performance and ability to anticipate and track an RF leg at the DER demand limiting the aircraft's airspeed at the end of the take-off phase (that is, limiting the initial climb airspeed), the operator's flight crew procedures and training should enforce the need for application of the limiting airspeed and identify any pre-flight planning and crew briefings the flight crew should complete before beginning the take-off.

6.4.4.5.1.4.5 *Flight crew take-off briefing*

6.4.4.5.1.4.5.1 The pilot-in-command (PIC) of the aircraft must conduct a take-off briefing covering all aspects of the flight crew's procedures necessary to successfully complete the planned RNP AR DP prior to take-off. The briefing must review any unique actions and procedures the flight crew must take during the aircraft's take-off phase and initial climb while complying with the RNP AR DP procedural path.

6.4.4.5.1.4.5.2 The PIC's take-off briefing must also include any pre-planned flight crew contingency procedures they can employ for non-normal conditions they may encounter after committing to the take-off (after reaching decision speed). The contingency procedures must address loss of an engine during take-off and climb-out as it relates to completing the RNP AR DP and any other events that may compromise the aircraft's ability to complete the RNP AR DP. The operator should rely on the guidance from the aircraft OEM when framing the recommended briefing the PIC must offer.

6.4.4.5.1.4.6 *RNP AR DP contingency procedures and planning*

6.4.4.5.1.4.6.1 In addition to the normal (all engines operating) requirements discussed above, the operator must define the non-normal contingency procedures their flight crews may employ to ensure the aircraft can safely extract from a departure airport, should a performance loss or system failure compromise the ability to complete an RNP AR DP after committing to the take-off. The State of the Operator should approve these contingency procedures.

Note.— Since RNP AR DPs are complex, the contingency procedures for each procedure may vary greatly and pilot rote knowledge of all the contingency procedures is impractical. With this in mind, it is recommended the operator create documentation containing the contingency procedures for each RNP AR DP. The flight crews can use this documentation to brief the contingency procedures and refer to them as needed once they begin the RNP AR DP.

6.4.4.5.1.4.6.2 When developing contingency procedures for OEI, the operator may consider three alternatives for each RNP AR DP (all three options assume that the loss of the engine occurs on the runway just beyond decision speed and that the aircraft will climb at its optimum OEI climb airspeed and configuration to reach a safe altitude clear of obstacles and terrain).

– *For loss of an engine, fly the published RNP AR DP with OEI*. This option requires the operator to ensure their aircraft's climb performance meets or exceeds all regulatory OEI take-off, climb and obstacle clearance requirements while following the RNP AR DP lateral track. It is acknowledged that an engine failure during take-off is a non-normal condition, and therefore takes precedence over normal operating considerations such as noise and air traffic.

  Note.— In this event, the operator must notify the flight crew that, in case of OEI, the published RNP AR DP should be flown, and the flight crew should not apply any other standard engine failure procedure after take-off. This can be accomplished through the take-off performance calculation tool pilots operate before each flight or a performance/operations manual documenting contingency procedures for OEI after take-off.

– *Build an alternate, tailored DP providing a safe lateral path, offering vertical constraints met by aircraft with OEI*. Publish the procedure in the aircraft's on-board navigation database.

  Note.— This option requires a means for the flight crew to manually select a tailored OEI DP by engaging a "secondary flight plan". Some RNP systems also automatically present the option for the flight crew to select an alternate DP upon the loss of an engine.

– *Obtain operational authorization for a specific OEI flight crew procedures for each RNP AR DP.* Each flight crew procedure should contain directions for a safe climb to an altitude clear of obstacles and terrain.

  Note.— These procedures are not in the on-board navigation database. Instead, the operator can publish these "pilot procedures" in a pilots' take-off performance calculation tool or performance/operations manual and the flight crew should pre-brief each specific, standardized contingency procedure for each RNP AR DP prior to take-off.

6.4.4.5.1.5 Vectors

6.4.4.5.1.5.1 If the controller provides the flight crew with a new clearance by issuing vectors taking the aircraft off the RNP AR DP, then the flight crew should not request permission to resume the RNP AR DP.

6.4.4.5.1.5.2 Likewise, controller procedures for RNP AR DPs should prohibit them from requesting the flight crew resume an RNP AR DP after issuing vectors taking the aircraft off the procedure. The flight crew should expect to receive an alternative ATC clearance.

6.4.5 Additional pilot knowledge and training for RNP AR DP

6.4.5.1 *RNP AR DP training credit.* The operator may receive credit for training, authorizations and operations already in place. However, when requesting credit, they should mention any differences in training that highlight and distinguish RNP AR DPs from their current RNP authorizations, especially differences between their current RNP DP authorization(s).

Note.— Some operator-specific RNP DPs (such as proprietary, special RNP DPs) may directly contribute to implementing RNP AR DPs with credit for similar operations experience.

6.4.5.2 Additional RNP AR DP flight crew training

6.4.5.2.1 *Initial training.* In addition to the requirements of 6.3.5.4, during initial RNP AR DP training each pilot should complete a minimum of two RNP AR DPs.

Note.— The operator may receive credit toward this requirement for any equivalent RNP DPs they complete.

6.4.5.2.1.1 Each pilot should complete one RNP AR DP through the last fix and altitude defined in the procedure.

6.4.5.2.1.2 Each pilot should also complete a second RNP AR DP under non-normal conditions, such as OEI or any other non-normal condition impacting the aircraft's ability to complete the RNP AR DP.

6.4.5.2.1.3 When completing an RNP AR DP with non-normal performance, the flight should demonstrate the ability to execute the operator's contingency procedures, including any specific contingency procedures for the RNP AR DP they are completing.

6.4.5.2.2 *Recurrent training.* In addition to the requirements of 6.3.5.6, during recurrent RNP AR DP training each pilot should complete a minimum of two RNP AR DPs.

6.4.5.2.2.1 Each pilot should fly these procedures in each role: one as the pilot-flying, and one as the pilot-monitoring.

Note.— This is not required if the operator requires the PIC to serve as the pilot-flying for all RNP AR DPs.

6.4.5.2.2.2 The recurrent training should embrace the unique RNP AR DP characteristics and limitations of the operator's authorization to conduct RNP AR DPs.

6.4.5.2.2.3 This recurrent training can substitute for any other DP training requirements when the operator's principal operations inspector/flight operations inspector formally authorizes the substitution in writing.

6.5 SAFETY ASSESSMENT

6.5.1 Flight operational safety assessment

6.5.1.1 As the name suggests, a FOSA is a safety assessment conducted by either the State or by the operator as part of the evaluation of an RNP AR procedure. In the latter case, this may form part of the existing destination authorization process for a given aerodrome and the procedures for conducting a FOSA may typically be embedded within the operator's safety management system (SMS). The degree of scope and rigour with which a FOSA is conducted will depend on the nature of the RNP AR procedure and whether the procedure is promulgated as a public procedure or is offered to an operator as a non-public procedure.

6.5.1.2 The safety objective associated with RNP AR procedures is to provide for safe flight operations in unique and challenging environments that no other PBN navigation specification covers. States normally define operational safety goals by establishing safety performance indicators and monitoring safety performance to meet their safety objective. A State's implementation of RNP AR procedures should achieve a safety performance target of 1×10^{-7} or less. Meeting this safety objective includes contributions from instrument flight procedure design, airworthiness approval of the aircraft and training and procedures covering aspects affecting the ANSP, ATC and the operator. The FOSA is the flight operations element of the overall safety assessment and the FOSA process (see Figure II-C-6-1) may be applied by either the State or the operator in demonstrating procedure design compliance for either RNP AR public or non-public procedures.

6.5.1.3 In general, RNP AR public procedures comply with the procedure design criteria of the *Required Navigation Performance Authorization Required (RNP AR) Procedure Design Manual* (Doc 9905) and are published in the State AIP and made available for public use. In these circumstances, the State will have likely conducted the evaluation of the RNP AR procedure and either conducted their own FOSA or published any specific procedures or requirements as part of an aerodrome briefing.

Note.— Whereas many States require all instrument flight procedures to be promulgated in their AIP, a State may still apply unique criteria to exclude some Doc 9905 compliant RNP AR procedures from being published and from being made available for public use.

6.5.1.4 The FOSA process may also be used for procedures not compliant with criteria of Doc 9905 or the RNP procedure design criteria of a sovereign State (such as FAA Order 8260.58()). These "non-compliant" procedures require unique operational authorization or authorization with additional oversight from the operator's national authority (State of the Operator/Registry). The FOSA methodology can help ensure that the operator complies with any unique requirements that a non-public procedure imposes on the operation. A State may choose not to promulgate non-public procedures in their AIP or else indicate that RNP AR special authorization is required.

6.5.1.5 RNP AR procedures that are non-compliant with the procedure design criteria contained in Doc 9905, and procedures that are not intended for public use (such as proprietary RNP procedures authorized for a single operator's specific aircraft) are generically called "special" procedures.

Note.— There is currently no ICAO guidance published for non-public or "special" procedures.

6.5.1.6 Figure II-C-6-1 illustrates a recommended process for identifying RNP AR public procedures from non-public procedures.

RNP AR public procedures

RNP AR procedures compliant to the design criteria of Doc 9905 are considered public procedures. This enables a global use of the procedures by approved RNP AR operators with the required RNP accuracy. RNP AR procedures designed according to Doc 9905 can range from low to high complexity (challenging terrain etc.). This evaluation is the responsibility of the State of the procedure, with support from the procedure designer and operators.

The State of the procedure may determine that an RNP AR procedure is not for public use, based on its complexity or other reasons.

All public procedures should state:

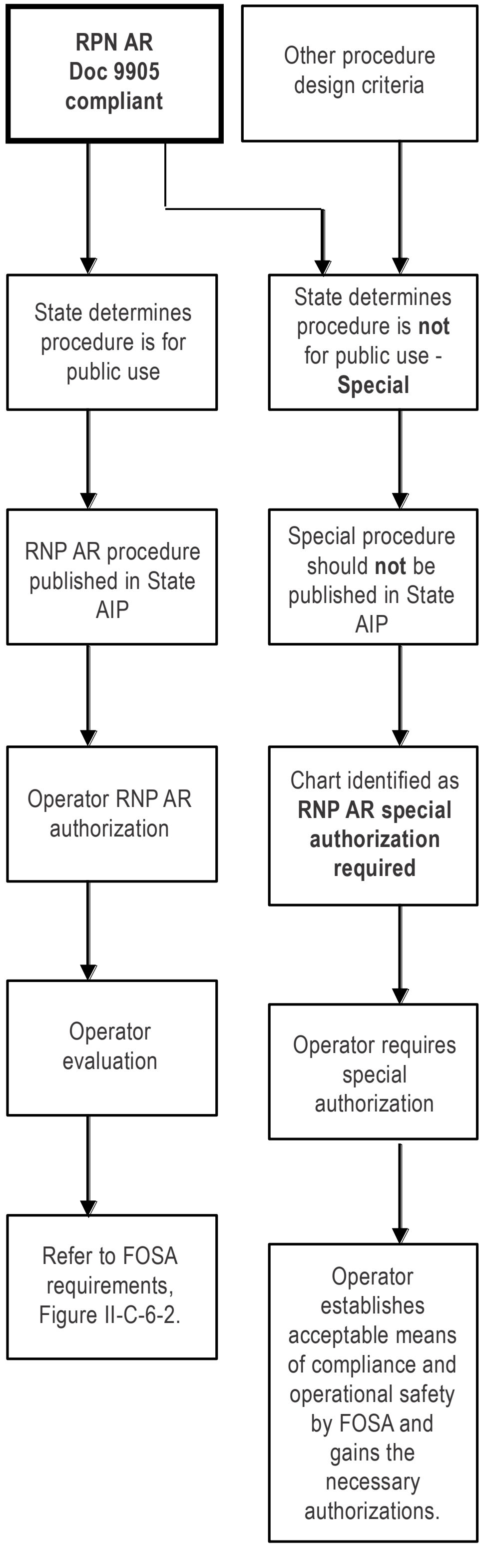
RNP AR authorization required

The State of the operator wishing to conduct RNP AR operations should evaluate the procedures intended to be operated to ensure they are covered by the operator's authorization.

Operators must conduct an operator evaluation of the RNP AR procedure. This provides an overall assessment of the proposed operation.

This evaluation should determine the depth of FOSA required based on aircraft capability under normal and abnormal procedures, crew training, procedure complexity and operating environment. The evaluation must take account of the FOSA considerations shown in Figure II-C-6-2.

Experienced RNP AR operators with agreement from the State of the Operator may not be required to conduct a FOSA, however the operator evaluation will provide a statement of consideration against FOSA requirements.



Non-public procedures

Procedures not compliant with Doc 9905, or those for which the State of the procedure has decided not to authorize for public use, should be considered "special" procedures.

Operators with an RNP AR authorization are not permitted to fly special procedures without additional oversight and authorization from the State of the procedure.

Special procedures should not be published in the State AIP.

States that decide to publish special procedures in their AIP need to safeguard against non-authorized operators having access to these special procedures in their navigation database.

Operators demonstrating their ability to safely operate a special procedure will be issued an **RNP AR special authorization**. This authorization is specific to the procedure. Only operators with the RNP AR special authorization for the specific special procedure are authorized to use the procedure.

Recognizing that the procedure design may be outside of the criteria of Doc 9905, it is recommended that the FOSA address these aspects when considering the guidance from this manual and Doc 9997. The chart should be annotated:

RNP AR special authorization required

Figure II-C-6-1. Procedure design compliance: RNP AR public procedures versus non-public procedures

6.5.1.7 The FOSA presents an assessment of the RNP AR operations hazards and potential mitigations as a means to aid in either the State's promulgation or operator evaluation of the RNP procedure. The overall safety of RNP AR operations ultimately rests with the operator and the ANSP conducting day-to-day RNP AR procedures through compliance with the specifications in this chapter.

6.5.1.8 Where a State conducts a FOSA prior to implementing RNP AR procedure, elements of the aircraft performance characteristics, the operational environment, the obstacle environment, etc., should be reviewed and assessed to ensure the implementation achieves the State safety objectives with respect to RNP AR. The assessment should give proper attention to the interdependence of the elements of RNP AR procedure design, aircraft capability, training requirements, flight crew procedures and the operating environment.

6.5.1.9 Following an operator evaluation of the RNP AR procedure, the State of the Operator/Registry should ensure that the results of the FOSA conducted by the operator are addressed in their RNP AR training program and operating procedures, as appropriate.

6.5.2 Conducting a flight operational safety assessment

6.5.2.1 While 6.5.2.5 contains examples of more significant potential hazards, this section provides operationally acceptable hazard mitigations. However, when an individual State's RNP AR operational experience results in changes or adjustments to the RNP AR procedure design criteria, aircraft eligibility requirements or flight crew training and procedures, the State should conduct a unique FOSA to determine the impact(s) of the changes or adjustments.

6.5.2.2 To understand the unique hazards faced by a State's RNP AR implementation, knowing the differences between normal, rare-normal and abnormal performance is essential. In this context, the following guidance applies:

6.5.2.2.1 *Normal performance.* The RNP AR navigation specifications address the aircraft's lateral and vertical performance requirements, and the specifications assume the aircraft and its systems function normally when the flight crew operates the aircraft in standardized configurations and standardized operating modes. In essence, the aircraft and systems designs, and their functional and implementation requirements, along with specific flight crew procedures for operating the aircraft and its systems during an RNP AR procedure, ensure there's a means to monitor and truncate potential individual error sources and failures, thus offering routine, normal performance. The RNP AR procedure design criteria are also based on "normal performance".

6.5.2.2.2 *Rare-normal and abnormal performance.* The impacts of rare-normal and abnormal failures on the aircraft's lateral and vertical performance are essential elements of the aircraft eligibility requirements for an RNP AR procedure. Additionally, the RNP AR navigation specifications also reflect the impacts of rare-normal and abnormal aircraft failures on ATC operations, flight crew procedures, NAVAID infrastructure requirements and limitations on the operating environment. Where a rare-normal or abnormal failure results in an unacceptable impact or condition that makes continuing the RNP AR operation, the RNP AR navigation specifications define operational mitigations and, when appropriate, limitations for the aircraft, flight crew and/or the State's conduct of RNP AR operations. Often, the aircraft OEM will identify these unacceptable impacts or conditions and they will publish recommended mitigation(s) or appropriate aircraft limitations as they relate to an RNP AR procedure.

6.5.2.3 Operator evaluation

6.5.2.3.1 Figure II-C-6-2 describes the operator evaluation process. The evaluation should determine the depth of FOSA required based upon aircraft capability under normal and abnormal procedures, flight crew training, procedure complexity and procedure environment. The evaluation must take account of the FOSA considerations shown.

6.5.2.3.2 In determining the level of FOSA detail, the operator may take credit for current approved RNP AR operations.

6.5.2.3.3 The State of the Operator will determine when credit can be taken.

6.5.2.3.4 Technical and operational expertise and experience are essential to the operational evaluation and FOSA determination and process.

6.5.2.3.5 For operators with significant RNP AR experience, and when the RNP AR procedure is comparable to existing RNP AR operations being conducted, an operational evaluation may be sufficient to determine if the operation is safe. The operator must document the operational evaluation and provide a statement of consideration of FOSA requirements.

6.5.2.3.6 The operator must conduct a detailed FOSA if:

a) the new procedure is considered complex;

b) the new procedure includes environmental challenges; or

c) the operator is applying for their first authorization.

6.5.2.3.7 In all cases, the operator is required to seek acceptance of the operator evaluation or detailed FOSA from their national authority (State of the Operator/Registry).

For each RNP AR operation based upon public procedures an Operator Evaluation is required, providing an overall assessment of the proposed operation.

This evaluation should determine the depth of FOSA required based upon aircraft capability under normal and abnormal procedures, crew training, procedure complexity and procedure environment. The evaluation must take account of the FOSA considerations shown.

In determining level of FOSA detail, the operator may be able to take credit for current approved RNP AR operations.

The State of the operator will determine when credit can be taken.

Technical and operational expertise and experience are essential to the Operational Evaluation and FOSA determination and process.

Note: The State of an RNP AR operator wishing to operate out of State, shall evaluate the RNP AR Public procedure to ensure it is within the operator's approval.

Experienced Operators – RNP AR Authorized:
For operators with significant RNP AR experience, and the RNP AR procedure is comparable to existing RNP AR operations being conducted, an operational evaluation may suffice to determine safe operation, without the requirement for a detailed FOSA. The Operational Evaluation shall provide a statement of consideration to FOSA requirements.

The operator evaluation must be acceptable to the State of the operator. An example follows:

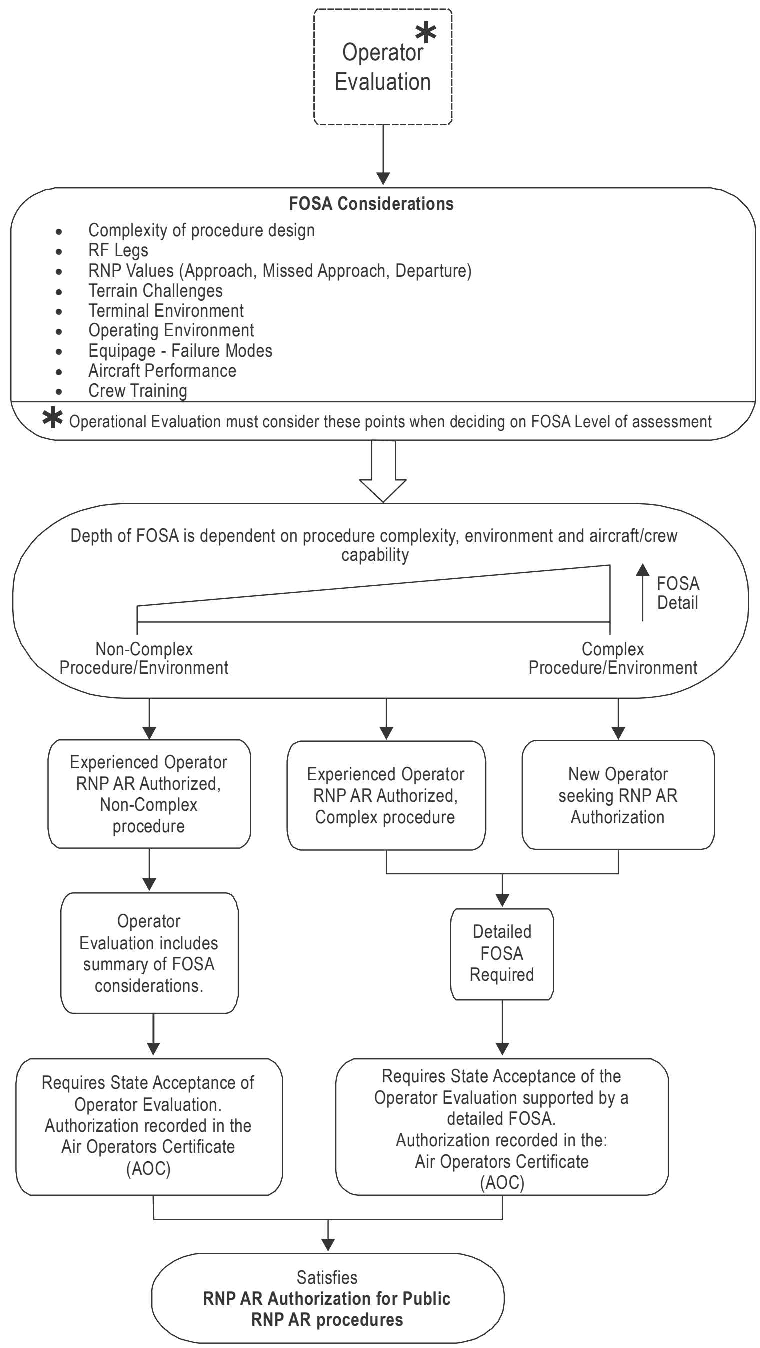
- An experienced operator is conducting RNP AR operations to RNP 0.3NM in a benign environment for the benefit of fuel efficiency. The new procedure to be evaluated has similar characteristics and profile. In this case the experienced operator may determine through an operator evaluation the risks are comparable and a detailed FOSA is not required.

Experienced Operators RNP AR Authorized - Complex Procedure.
In the new procedure is considered complex through procedure or environment challenges, a detailed FOSA is required to support the application.

New Operator seeking RNP AR Authorization
If the operator is applying for their first authorization, a detailed FOSA is required to support the application.

In all cases, the operator has to seek State of the operator acceptance of the Operator Evaluation or detailed FOSA to ensure safe operations are achieved.

Note: The Sovereign State of the procedures may choose to conduct FOSA evaluation of the RNP AR procedures, this can be used as credit for the Sovereign State operators to conduct these public RNP AR procedures.



The above process focuses on operator Flight Operations Safety Assessment with respect to Public RNP AR procedures.
It supports and confirms through safety evaluation the requirements of aircraft systems, functionality, performance, continued airworthiness, Pilot/Dispatch/Operator/ATC knowledge and training.

Figure II-C-6-2. Operator evaluation

6.5.2.4 RNP AR operations hazard conditions

6.5.2.4.1 ***Aircraft system failures***

6.5.2.4.1.1 The RNP AR navigation specifications consider the impacts of aircraft system failures on an RNP AR operation by defining explicit performance and functional requirements for:

a) the aircraft navigation system;

b) the aircraft's FGS (such as the flight director and autopilot);

c) the cockpit displays; and

d) annunciations and alerts, as they relate to the conduct of the RNP AR approach or missed approach (such as loss of GNSS updating, receiver failure, autopilot disconnect, FMS failure).

6.5.2.4.1.2 Likewise, the RNP AR navigation specifications specific flight crew training and operational procedure requirements strive to mitigate any potential shortfalls in aircraft and system design through unique flight crew training and operational procedures. Certain aircraft system requirements that the RNP AR navigation specifications address are:

a) requirements for system redundancy to avert the potential loss of RNP capability that the individual RNP AR APCH requires (such as carrying dual equipage and requirements to ensure no single point of failure causes loss of RNP);

b) specifications for consideration and response to loss of the GNSS signal in space during an RNP AR procedure (such as requirements for reversion to another navigation sensor);

c) specific cockpit alerting requirements for UNABLE RNP that are conservative enough to ensure containment while the flight responds to the alert; and

d) a myriad of other aircraft-level requirements as they relate to the flight crew's conduct of an RNP AR procedure (such as the requirement to confirm GNSS-updating immediately prior to beginning an RNP AR APCH, or the requirement to conduct a full alignment of the aircraft's inertial system before beginning an RNP AR DP).

6.5.2.4.1.3 Likewise, carrying additional equipment supporting an RNP AR operation may also help ensure the implementation achieves the desired ALSR (such as a requirement for carriage of an operable Class A TAWS with a current obstacle and terrain database and the most current software for the TAWS basic functions). Or, perhaps more classically, when the aircraft doesn't meet the specific aircraft performance or design assurance requirements, new flight crew training and procedures can mitigate the aircraft design shortfall (such as the flight crew requirement to complete a cross-cockpit crosscheck of the primary barometric altimeters within 100 feet of one another before beginning the RNP AR APCH FAS to ensure no misleading vertical guidance is present).

6.5.2.4.2 ***Aircraft performance***

Aircraft eligibility requirements and the aircraft OEM's recommended operational flight crew procedures ensure the aircraft performance is available for every RNP AR procedure. Aircraft performance requirements also embrace differences from older, in-service aircraft and newer aircraft meeting the latest RNP system performance and functional standards (such as extensive flight crew procedures and training for aircraft without continuous LNAV upon go-around and much simpler flight crew training and procedures for aircraft with continuous LNAV upon go-around or "TOGA-to-LNAV").

6.5.2.4.3 ***Navigation infrastructure and services***

6.5.2.4.3.1 Aircraft requirements and operational procedures for dispatch and for the flight crew help confirm that the required NAVAID infrastructure is available for a desired, flight planned RNP AR procedure and avert the risk of unavailable infrastructure (such as RNP AR operations unique requirements for pre-flight prediction of RNP availability).

6.5.2.4.3.2 Operators must also provide navigation database management processes under documented configuration control that endeavour to validate and protect the correctly defined, packed RNP AR procedures in the aircraft's on-board navigation database, while ensuring the database does not contain RNP AR procedures with errors. These processes must be specific to the operator's aircraft and the RNP AR procedures they desire to conduct.

6.5.2.4.4 ***Air traffic control operations***

6.5.2.4.4.1 Operators are responsible for declining clearances for procedures assigned to non-approved aircraft or for procedures their aircraft is not eligible to complete (such as an RNP AR APCH requiring use of RNP 0.1 when the aircraft limitations state the lowest RNP value the aircraft can support is RNP 0.30).

6.5.2.4.4.2 ATC should not vector aircraft to intercept on, or just prior to, an RF leg segment of a procedure.

6.5.2.4.5 ***Flight crew training and procedures for RNP AR operations***

6.5.2.4.5.1 Flight crew training and procedures for use of a current, local barometric altimeter setting.

6.5.2.4.5.2 Flight crew training and procedures verify the RNP system extracts the entirety of each RNP AR procedure the flight crew selects from the on-board navigation database and confirms that the RNP AR procedure and the RNP system loads match the published RNP AR procedure on the procedure chart (paper chart or electronic chart). Then, the flight crew ensures that the procedure on the aircraft's map display matches the charted RNP AR procedure. These requirements and flight crew procedures help avert the risk of selecting the incorrect RNP procedure, while confirming there's no corruption of the RNP AR procedure contained within the aircraft's on-board navigation database when the flight crew selects it and the RNP system extracts it.

6.5.2.4.5.3 Flight crew training and procedures emphasize the flight crew use of the proper FGS modes consistent with the aircraft requirements for conduct of RNP AR DP.

6.5.2.4.5.4 Flight crew training and procedures for manually setting the minimum RNP value that the RNP AR procedure requires when the integration of the RNP system in the aircraft does not include automated RNP scalability (that is, the automated setting of the RNP value that each procedural leg segment requires by extracting and setting the RNP values contained in the on-board navigation database). This ensures the flight crew conducts the RNP AR procedure with the necessary monitoring and alerting assumed by the RNP AR procedure design.

6.5.2.4.6 ***Operating conditions***

6.5.2.4.6.1 Excessive groundspeed, due to wind conditions during an RF leg can result in the aircraft's inability to maintain the RNP AR procedure's desired track. However, the RNP AR navigation specifications aircraft requirements ensure compliance with flight guidance command capability during RF turns to ensure a minimum of 5 degrees of bank angle authority margin exists for conduct of RF legs. This bank angle authority provides a means for the aircraft's RNP system's FGS to correct back to the desired path when there are momentary deviations during an RNP AR procedure. Likewise, RNP AR procedure design requirements to consider worst case historical winds or application of conservative (that is, strong) adverse winds, help ensure a procedure design offering characteristics consistent with the available aircraft RF turn performance, consideration of speed effect and crew procedure to maintain speeds below the maximum authorized.

6.5.2.4.6.2 Flight crew training and procedures also ensure that the crew may contain flight technical errors (such as deviations from the lateral or vertical path) consistent with the aircraft's system characteristics and an RNP AR procedure's demands. For example, most aircraft require that the flight crew maintain lateral deviation within 1×RNP and vertical deviation within 23 m (75 ft). However, some aircraft do not provide a means to set the lateral deviation and vertical scaling to these express limits. In this case, the flight crew training and procedures can mitigate the deviation display scaling shortfall by requiring the pilot-not-flying to monitor numeric deviation on a select page of the RNP system's CDU when seeing any lateral or vertical deviation on the deviation indicators or the moving map display. This unique mitigation considered in a State's FOSA again can support the RNP AR ALSR.

6.6 REFERENCES

The applicable, specific industry and regulatory references, standards and guidance included in this chapter, shown as open reference (), are listed in Attachment E to this volume.

Chapter 7

IMPLEMENTING RNP 0.3

7.1 INTRODUCTION

This specification is intended for the exclusive use of helicopters and rotorcraft.

7.1.1 Background

7.1.1.1 The helicopter community identified a need for a specification that has a single accuracy of 0.3 NM for all phases of flight, recognizing that such a specification would enable a significant part of the instrument flight rules (IFR) helicopter fleet to obtain benefits from PBN. Specifically, the operations they had in view included:

a) reduced protected areas, potentially enabling separation from fixed wing traffic to allow simultaneous non-interfering operations in dense terminal airspace;

b) low-level routes in obstacle-rich environments reducing exposure to icing environments;

c) seamless transition from en-route to terminal route;

d) more efficient terminal routing in an obstacle-rich or noise-sensitive terminal environment, specifically in consideration of helicopter emergency service IFR operations between hospitals;

e) transitions to helicopter point-in-space approaches and for helicopter departures; and

f) helicopter en-route operations.

7.1.1.2 The large majority of IFR helicopters are already equipped with TSO C145()/146() systems and moving map displays and require autopilot including stability augmentation for IFR certification.

7.1.1.3 Fulfilling the accuracy requirements of this specification may be achieved by applying operational limitations, which could include but are not necessarily limited to the maximum permitted airspeed and requirements for autopilot coupling. The latter requirement does not impact the helicopter eligibility since an autopilot is needed as part of the IFR helicopter certification.

7.1.1.4 A number of navigation systems using a global navigation satellite system (GNSS) for positioning will be capable of being approved for RNP 0.3 operations if suitably integrated into the FGS/flight display system. However, this specification takes advantage of known functionality and the on-board performance monitoring and alerting capability of many TSO-C145()/C146() GPS systems, which are installed in a wide range of IFR helicopters.

7.1.2 Purpose

7.1.2.1 This specification may be used for helicopter RNP 0.3 operations en-route and in the terminal airspace of airports as well as operations to and from heliports and for servicing offshore rigs. RNP 0.3 may also be needed en-route to support operations at low level in mountainous remote areas and, for airspace capacity reasons, in high density airspace.

7.1.2.2 This navigation specification provides guidance to States implementing RNP 0.3 and is applicable to departure, en-route, arrival (including the initial and intermediate approach segments), and to the final phase of the missed approach. This navigation specification addresses continental, remote continental and offshore operations. Route length restrictions may be applicable for en-route operations meeting RNP 0.3.

Note 1.— This specification may be applied in ATM environments both with and without ATS surveillance. This chapter does not address all requirements that may be specified for particular operations. These requirements are specified in other documents such as operating rules, AIPs and the Regional Supplementary Procedures *(Doc 7030).*

Note 2.— While operational authorization primarily relates to the navigation requirements of the airspace, operators and pilots are still required to take account of all operational documents relating to the airspace that are required by the appropriate State authority before conducting flights into that airspace.

7.2 IMPLEMENTATION CONSIDERATIONS

7.2.1 NAVAID infrastructure considerations

The RNP 0.3 specification is based upon GNSS; its implementation is not dependent on the availability of a satellite-based augmentation system (SBAS). Distance measuring equipment (DME)/DME based RNAV systems will not be capable of consistently providing RNP 0.3 performance, and States should not plan on implementing RNP 0.3 operations through application of DME/DME-based navigation. States must also not use RNP 0.3 in areas of known navigation signal (GNSS) interference. Operators relying on GNSS are required to have the means to predict the availability of GNSS fault detection (such as ABAS receiver autonomous integrity monitoring (RAIM)) to support operations along the RNP 0.3 ATS route. The on-board RNP system, GNSS avionics, the ANSP or other entities may provide a prediction capability. The AIP should clearly indicate when prediction capability is required and acceptable means to satisfy that requirement. This prediction will not be required where the navigation equipment can make use of SBAS augmentation, and the planned operation will be contained within the service volume of the SBAS signal.

Note.— Should the State permit the operator of an SBAS-equipped aircraft to disregard the requirement for a RAIM prediction when the RNP 0.3 operation occurs in an SBAS service area, then it is recommended the State consider establishing a requirement for that operator to check SBAS NOTAMs prior to the flight to ensure the availability of the SBAS signal in space (SIS).

7.2.2 Communications and air traffic services surveillance considerations

7.2.2.1 The need for direct pilot to ATC (voice) communications and surveillance will be determined by the airspace concept and the operating environment.

7.2.2.2 ATS surveillance may assist contingency procedures to mitigate the effect of blunder errors and to reduce route spacing. When ATS surveillance services are relied upon to these ends, the system's performance should be fit for purpose, ensuring that the routes lie within the ATS surveillance and communications service volumes and the ATS resources are sufficient for these tasks.

7.2.2.3 When GNSS is used as the sole basis for both ATS surveillance and aircraft navigation, the risks and requirement for mitigation techniques associated with the loss of GNSS potentially resulting in the loss of both navigation and surveillance capability, should be considered. This should typically be addressed through the regional or local State safety case prepared in support of the application.

7.2.3 Obstacle clearance and horizontal separation

7.2.3.1 Guidance on obstacle clearance is provided in the *Procedures for Air Navigation Services – Aircraft* Operations, Volume II – *Construction of Visual and Instrument Flight Procedures* (PANS-OPS, Doc 8168), where the general criteria in Parts I and III apply and assume normal operations.

7.2.3.2 The route spacing supported by this specification will be determined by a safety study for the intended operations, which will depend on the route configuration, air traffic density and intervention capability, etc. Horizontal separation standards are published in the *Procedures for Air Navigation Services – Air Traffic* Management (PANS-ATM, Doc 4444).

7.2.4 Procedure validation

7.2.4.1 Guidance on procedure validation is provided in the *Quality Assurance Manual for Flight Procedure Design* (Doc 9906), Volume 1 – *Flight Procedure Design Quality Assurance System*, and Volume 5 – *Flight Validation of Instrument Flight Procedures*.

Note.— Guidance on the flight inspection is provided in the Manual on Testing of Radio Navigation Aids *(Doc 8071), Volume II -* Testing of Satellite-based Radio Navigation Systems*.*

7.2.5 Additional considerations

7.2.5.1 Additional flight crew operational procedures and operational limitations may be required to ensure that FTE is bounded, and appropriate alerting is available to meet the requirements of the RNP 0.3 specification for all phases of flight. Therefore, this performance should only be demanded where it is operationally needed (such as RNP 0.3 ATS routes should not be implemented where RNP 2 routes would be sufficient to enable the operation).

7.2.5.2 Many aircraft have an RNAV holding capability. Aircraft can either hold manually over a waypoint when the aircraft holding functionality is not available and the pilot is expected to manually fly the RNAV holding pattern, or the RNAV system's holding functionality can be used to execute the published RNAV hold. See Volume I, Attachment A, 5.3.

7.2.5.3 Although this navigation specification does not include requirements for an RNAV holding function, ANSPs may include holding procedures in their airspace design using a waypoint as holding point.

7.2.6 Publication

7.2.6.1 The departure and arrival procedure design should comply with normal climb and descent profiles for the operation considered and identify minimum segment altitude requirements. The navigation data published in the State AIP for the procedures and supporting NAVAIDs must meet the requirements of Annex 15 – *Aeronautical Information* Services. All procedures must be based upon WGS 84 coordinates.

7.2.6.2 Where holding patterns are published, they are to comply with the criteria publication requirements in PANS-OPS, Volume II, Part 3, Section 3, Chapter 7. For the content of the performance-based navigation (PBN) requirement box published on the chart, see also PANS–OPS, Volume II, Part 3, Section 5, Chapter 1.

7.2.7 Controller training

7.2.7.1 Air traffic controllers who provide RNP terminal and approach control services where RNP 0.3 is implemented should have completed training that covers the items listed below.

7.2.7.2 Core training

a) How area navigation systems work (in the context of this navigation specification):

    1) functional capabilities and limitations of this navigation specification;

    2) accuracy, integrity, availability and continuity, including on-board performance monitoring and alerting;

    3) GPS receiver, RAIM, FDE, and integrity alerts;

    4) waypoint fly-by versus fly-over concept (and different turn performance);

    5) effect of interference on signal coverage; and

    6) SBAS augmentation;

b) GNSS RNP capable systems;

c) flight plan requirements;

d) ATC procedures;

    1) ATC contingency procedures;

    2) separation minima; and

    3) phraseology.

7.2.7.3 Training specific to this navigation specification

a) RNP 0.3 instrument flight procedures to specifically include the following rotorcraft operations:

    1) vectoring techniques (where appropriate);

    2) altitude constraints; and

    3) descend/climb clearances;

b) RNP approach and related procedures;

c) RNP 0.3 related phraseology; and

d) impact of requesting a change to routing during a procedure.

7.2.8 Navigation service monitoring

Navigation service monitoring should be consistent with Part A, Chapter 4.

7.2.9 Monitoring and investigation of navigation and system errors

7.2.9.1 The RNP value provides a basis for determining the lateral route spacing and horizontal separation minima necessary for traffic operating on a given route. When available, observations of each aircraft's proximity to track and altitude, based on ATS surveillance (such as radar, multilateration or automatic dependence surveillance), are typically noted by ATS facilities, and aircraft track-keeping capabilities are analysed.

7.2.9.2 If an observation/analysis indicates that a loss of separation or obstacle clearance has occurred, the reason for the apparent deviation from track or altitude should be determined and steps taken to prevent a recurrence.

7.3 NAVIGATION SPECIFICATION

7.3.1 Background

This section identifies the operational requirements for RNP 0.3 operations. Operational compliance with these requirements should be addressed through national operational regulations and may require an operational authorization from the State of the Operator/Registry.

7.3.2 Authorization process

7.3.2.1 This navigation specification does not in itself constitute regulatory guidance material against which either the aircraft or the operator will be assessed and approved. Aircraft are certified by their State of Manufacture. Operators are approved in accordance with their national operating rules. This navigation specification provides the technical and operational criteria and does not necessarily imply a need for recertification.

Note 1.— Detailed information on operational authorizations is provided in Doc 9997[1]*.*

Note 2.— Where appropriate, States may refer to previous operational authorizations in order to expedite this process for individual operators where performance and functionality are applicable to the current request for operational authorization.

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[1] Formerly the *Performance-based Navigation Operational Approval Manual*, renamed in its third (forthcoming) edition.

7.3.2.2 Aircraft eligibility

The aircraft eligibility must be determined through demonstration of compliance against the relevant airworthiness criteria and the requirements of 7.3.3. The OEM or the holder of installation approval for the aircraft, such as STC holder, will demonstrate compliance to their regulatory authority (such as the European Union Aviation Safety Agency (EASA), the Federal Aviation Administration (FAA)) and the approval can be documented in manufacturer documentation (such as service letters). Aircraft flight manual (AFM) entries are not required provided the State accepts manufacturer documentation.

Note.— Requests for approval to use optional functionality (such as radius to fix (RF) legs) should address the aircraft requirements as described in the appropriate functional attachment to Volume II.

7.3.2.3 Operational authorization

7.3.2.3.1 ***Description of aircraft equipment***

The operator must have a configuration list and, if necessary, an MEL detailing the required aircraft equipment for RNP 0.3 operations.

7.3.2.3.2 ***Training documentation***

7.3.2.3.2.1 Commercial operators must have a training programme addressing the operational practices, procedures and training items related to RNP 0.3 operations (such as initial, upgrade or recurrent training for pilots, dispatchers or maintenance personnel).

Note 1.— Operators need not establish a separate training programme if they already integrate RNAV training as an element of their training programme. However, the operator should be able to identify the aspects of RNP 0.3 operations covered within their training programme.

Note 2.— Operators should document specific training provided for the use of instrument flight procedures containing the RF path terminator. See Part C, Appendix 1, 5.2.

7.3.2.3.2.2 Private operators must be familiar with the practices and procedures identified in 7.3.5.

7.3.2.3.3 ***Operation Manuals and checklists***

7.3.2.3.3.1 Operations manuals (OMs) and checklists for commercial operators must address information/guidance on the SOP detailed in 7.3.4. The appropriate manuals should contain navigation operating instructions and contingency procedures, where specified. When required by the State of the Operator/Registry, the operator must submit their manuals and checklists for review as part of the application process.

7.3.2.3.3.2 Private operators should operate using the practices and procedures identified in 7.3.5.

7.3.2.3.4 ***Minimum equipment list considerations***

Any MEL revisions necessary to address provisions for RNP 0.3 operations must be approved. Operators must adjust the MEL, or equivalent, and specify the required dispatch conditions.

7.3.2.3.5 ***Continuing airworthiness***

The operator must submit the continuing airworthiness instructions applicable to the aircraft's configuration and the aircraft's qualification for this navigation specification. Additionally, there is a requirement for the operator to submit their maintenance programme, including a reliability programme for monitoring the equipment.

Note.— The operator should confirm with the OEM, or the holder of the installation approval for the aircraft, that acceptance of subsequent changes in the aircraft configuration, such as SBs, do not invalidate current operational authorizations.

7.3.3 Aircraft requirements

7.3.3.1 The following systems meet the accuracy, integrity and continuity requirements of these criteria:

a) aircraft with E/TSO-C145() and the requirements of E/TSO-C115() FMS installed for IFR use in accordance with FAA AC 20-138();

b) aircraft with E/TSO-C146() equipment installed for IFR use in accordance with FAA AC 20-138(); and

c) aircraft with RNP 0.3 capability certified or approved to equivalent standards (such as TSO-C196).

7.3.3.2 *General*

7.3.3.2.1 On-board performance monitoring and alerting is required. This section provides the criteria for a total system error (TSE) form of performance monitoring and alerting (as described in Part A, Chapter 2, 2.3.1.7) that will ensure a consistent evaluation and assessment of compliance for RNP 0.3 applications.

7.3.3.2.2 The aircraft navigation system, or a combination of the aircraft navigation system and the pilot, is required to monitor the TSE and to provide an alert if the accuracy requirement is not met or if the probability that the lateral TSE exceeds two times the accuracy value is larger than 10^{-5}. To the extent operational procedures are used to satisfy this requirement, the crew procedure, equipment characteristics and installation should be evaluated for their effectiveness and equivalence.

7.3.3.2.3 Examples of information provided to the pilot for awareness of navigation system performance include:

a) EPU;

b) ACTUAL;

c) ANP; and

d) EPE.

7.3.3.2.4 Examples of indications and alerts provided when the operational requirement is or can be determined as not being met include:

a) UNABLE RNP;

b) Nav Accur Downgrad;

c) GNSS alert limit;

d) loss of GNSS integrity; or

e) TSE monitoring (real time monitoring of NSE and FTE combined), etc.

7.3.3.2.5 The navigation system is not required to provide both performance and sensor-based alerts, such as if a TSE based alert is provided, a GNSS alert may not be necessary.

7.3.3.3 System performance monitoring and alerting

7.3.3.3.1 ***RNP system performance***

7.3.3.3.1.1 *Accuracy.* During operations in airspace or on ATS routes designated as RNP 0.3, the lateral TSE must be within ±0.3 NM for at least 95 per cent of the total flight time. The along-track error must also be within ±0.3 NM for at least 95 per cent of the total flight time. To meet this performance requirement, an FTE of 0.25 NM (95 per cent) may be assumed.

Note.— For all RNP 0.3 operations, the use of a coupled FGS is an acceptable means of complying with this FTE assumption (see RTCA DO-208(), Appendix E, Table 1). Any alternative means of FTE bounding, other than coupled FGS, may require FTE substantiation through an airworthiness demonstration.

7.3.3.3.1.2 *Integrity.* Malfunction of the aircraft navigation equipment is classified as a major failure condition under airworthiness regulations (that is, 1×10^{-5} per flight hour).

7.3.3.3.1.3 *Continuity*. Loss of function is a major failure condition for remote continental and offshore operations. The carriage of dual independent long-range navigation systems may satisfy the continuity requirement. Loss of function is classified as a minor failure condition for other RNP 0.3 operations if the operator can revert to a different available navigation system and proceed to a suitable airport.

7.3.3.3.2 ***On-board performance monitoring and alerting***

7.3.3.3.2.1 The installed RNP system must provide an alert if the accuracy requirement is not met, or if the probability that the lateral TSE exceeds 0.6 NM is greater than $1\text{x}10^{-5}$ per flight hour. The alert is required to be consistent with RTCA DO-236(), DO-283(), DO-229() and EUROCAE ED-75(). This section contains one acceptable means to satisfy the requirement.

7.3.3.3.2.2 RNP 0.3 operations require coupled FGS to meet the allowable FTE bound unless the manufacturer demonstrates and obtains airworthiness approval for an alternate means of meeting the FTE bound. The following may be considered as one operational means to monitor the FGS FTE:

a) FTE should remain within half-scale deflection (unless there is other substantiated FTE data);

b) pilots must manually set systems without automatic CDI scaling to not greater than 0.3 NM full-scale prior to commencing RNP 0.3 operations; and

c) aircraft with electronic map display, or another alternate means of flight path deviation display, must select appropriate scaling for monitoring FTE.

7.3.3.3.2.3 Automatic monitoring of FTE is not required if the necessary monitoring can be achieved by the pilot using available displays without excessive workload in all phases of flight. To the extent that compliance with this specification is achieved through operational procedures to monitor FTE, an evaluation of the pilot procedures, equipment characteristics and installation must ensure their effectiveness and equivalence, as described in the functional requirements and operating procedures.

7.3.3.3.2.4 Path definition error (DE) is considered negligible when the helicopter's on-board navigation database meets the data quality and assurance process requirements of 7.3.6 and the helicopter flight crew complies with the operating procedures of 7.3.4.

7.3.3.4 Functional requirements

The following navigation displays and functions (installed per AC 20-130A and AC 20-138A or equivalent airworthiness installation advisory material) are required.

Paragraph	*Functional requirement*	*Explanation*
a)	Navigation data, including a failure indicator, must be displayed on a lateral deviation display (CDI, EHSI) and/or a navigation map display. These must be used as primary flight instruments for the navigation of the aircraft, for manoeuvre anticipation and for failure/status/integrity indication.	Non-numeric lateral deviation display (such as CDI, EHSI), with a to/from indication and a failure annunciation, for use as primary flight instruments for navigation of the aircraft, for manoeuvre anticipation, and for failure/status/integrity indication, with the following six attributes: 1) the capability to continuously display to the pilot flying, on the primary flight instruments for navigation of the aircraft (primary navigation display), the computed path and aircraft position relative to the path. For operations where the required minimum flight crew is two pilots, the means for the pilot not flying to verify the desired path and the aircraft position relative to the path must also be provided; 2) each display must be visible to the pilot and located in the primary field of view (±15° from the pilot's normal line of sight) when looking forward along the flight path; 3) the lateral deviation display scaling should agree with any implemented alerting and annunciation limits; 4) the lateral deviation display must also have a full-scale deflection suitable for the current phase of flight and must be based on the required track-keeping accuracy; 5) the display scaling may be set automatically by default logic: automatically to a value obtained from a navigation database, or manually by pilot procedures. The full-scale deflection value must be known or must be available for display to the pilot commensurate with the required track-keeping accuracy; and

Paragraph	*Functional requirement*	*Explanation*
		6) the lateral deviation display must be automatically slaved to the computed path. The course selector of the deviation display should be automatically slewed to the computed path. As an alternate means of compliance, a navigation map display can provide equivalent functionality to a lateral deviation display as described in 1 to 6 above, with appropriate map scales and equivalent functionality to a lateral deviation display. The map scale should be set manually to a value appropriate for the RNP 0.3 operation.
b)	The following system functions are required as a minimum within any RNP 0.3 equipment.	1) Continuous display to the pilot flying, on the primary flight instruments for navigation of the aircraft (primary navigation display), the computed path and aircraft position relative to the path. For operations where the required minimum flight crew is two pilots, the means for the pilot not flying to verify the desired path and the aircraft position relative to the path must also be provided; 2) a navigation database, containing current navigation data officially promulgated for civil aviation, which can be updated in accordance with the AIRAC cycle and from which IFR procedures and ATS routes or waypoint data corresponding to the coordinates of significant points on ATS routes, can be retrieved and loaded into the RNP system. The stored resolution of the data must be sufficient to achieve negligible PDE. The database must be protected against pilot modification of the stored data; 3) display the validity period of the navigation data to the pilot; 4) retrieve and display data stored in the navigation database relating to individual waypoints and NAVAIDs, to enable the pilot to verify the ATS route to be flown; and 5) load from the on-board navigation database into the RNP system the entire RNP 0.3 route or procedure, or the RNP 0.3 routes by extracting the waypoints by name from the on-board navigation database.
c)	Display the following items, either in the pilot's primary field of view, or on a readily accessible display page.	1) The active navigation sensor type; 2) the identification of the active (To) waypoint; 3) the ground speed or time to the active (To) waypoint; and 4) the distance and bearing to the active (To) waypoint.

Paragraph	*Functional requirement*	*Explanation*
d)	Execute a "direct to" function.	
e)	Automatic leg sequencing with the display of sequencing to the pilot.	
f)	Execute RNP 0.3 terminal procedures extracted from the on-board navigation database, including the capability to execute fly-over and fly-by turns.	
g)	Automatically execute leg transitions and maintain tracks consistent with the following ARINC 424 path terminators, or their equivalent: – IF; – CF; – CA; – DF; and – TF.	*Note 1.— Path terminators are defined in ARINC Specification 424, and their application is described in more detail in RTCA/EUROCAE documents DO-236()/ED-75() and DO-201()/ED-76().* *Note 2.— Numeric values for courses and tracks must be automatically loaded from the on-board navigation database.* *Note 3.— A leg transition will be performed consistent with the conduct of a fly-by turn manoeuvre and the fly-by transition described in Volume I, Attachment A, 5.2.*
h)	Automatically execute leg transitions consistent with VA, VM and VI ARINC 424 path terminators, or must be able to be manually flown on a heading to intercept a course or to go direct to another fix after reaching a procedure-specified altitude.	
i)	Automatically execute leg transitions consistent with CA and FM ARINC 424 path terminators, or the RNAV system must permit the pilot to readily designate a waypoint and select a desired course to or from a designated waypoint.	
j)	Display an indication of the RNP 0.3 system failure, in the pilot's primary field of view.	
k)	The system must be capable of loading numeric values for courses and tracks from the on-board navigation database.	

7.3.4 Operating procedures

Airworthiness certification and recognition of RNP 0.3 aircraft qualification alone does not authorize RNP 0.3 operations. Operational authorization is also required to confirm the adequacy of the operator's normal and contingency procedures for the particular equipment installation applied to an RNP 0.3 operation.

7.3.4.1 Preflight planning

Operators and pilots intending to conduct operations on RNP 0.3 ATS routes, including standard instrument departures (SIDs) and standard instrument arrivals (STARs), initial and intermediate approach, should file the appropriate flight plan suffixes. The on-board navigation data must be current and include appropriate procedures.

Note.— Navigation databases are expected to be current for the duration of the flight. If the AIRAC cycle is due to change during flight, operators and pilots should establish procedures to ensure the accuracy of navigation data, including suitability of navigation facilities used to define the ATS routes.

7.3.4.2 RNP 0.3 availability prediction

7.3.4.2.1 RAIM prediction is not required where the equipment uses SBAS augmentation, and the planned operations are within the service volume of the SBAS system. In areas and regions where SBAS is not usable or available, RAIM availability for the intended route should be checked prior to flight. Operators can verify the availability of RAIM to support RNP 0.3 operations via NOTAMs (where available) or through GNSS prediction services. The operating authority may provide specific guidance on how to comply with this requirement. Operators should be familiar with the prediction information available for the intended ATS route. RAIM availability prediction should take into account the latest GNSS constellation NOTAMs and avionics model (when available). The ANSP, avionics manufacturer, or the RNP system may provide this service. In the event of a predicted, continuous loss of RNP 0.3 of more than five minutes for any part of the RNP 0.3 operation, the filed flight plan should be revised (such as delaying the departure or planning a different ATS route). If the prediction service is temporarily unavailable, ANSPs may still allow RNP 0.3 operations to be conducted.

7.3.4.2.2 RAIM availability prediction software does not guarantee the availability of GNSS. Rather, prediction tools simply assess the expected capability to meet the RNP. Because of potential unplanned failures of some GNSS elements, pilots/ANSPs must consider the loss of RAIM (or GNSS navigation altogether) while airborne may require reversion to an alternative means of navigation. Therefore, pilots should assess their capability to navigate in case of failure of GNSS navigation and consider the actions necessary to successfully divert to an alternate destination.

7.3.4.3 General operating procedures

7.3.4.3.1 The pilot must comply with any instructions or procedures the manufacturer identifies necessary to comply with the performance requirements in this chapter.

Note.— Pilots are expected to adhere to all AFM/RFM limitations or operating procedures required to maintain RNP 0.3 performance for the ATS route. This includes any speed limitations needed to ensure maintenance of RNP 0.3 navigation accuracy.

7.3.4.3.2 Operators and pilots should not request or file RNP 0.3 procedures unless they satisfy all the criteria in the relevant State documents. If an aircraft not meeting these criteria receives a clearance from ATC to conduct an RNP 0.3 operation, the pilot must advise ATC that he/she is unable to accept the clearance and must request alternate instructions.

7.3.4.3.3 The operator must confirm the availability of GNSS for the period of intended operations along the intended ATS route using all available information and the availability of NAVAID infrastructure required for any (non-RNAV) contingencies.

7.3.4.3.4 At system initialization, the pilot must confirm the navigation database is current and verify that initial position of the aircraft is entered correctly. The pilot must also verify proper entry of their desired ATS route and any ATC changes to that ATS route upon initial clearance and any subsequent change of ATS route. The pilot must ensure the waypoints sequence depicted by their navigation system matches the ATS route depicted on the appropriate chart(s) and their assigned ATS route.

Note.— The pilot may notice a slight difference between the navigation information portrayed on the chart and their primary navigation display. Differences of three degrees or less may result from the equipment manufacturer's application of magnetic variation and are operationally acceptable.

7.3.4.3.5 The pilot must not attempt to fly an RNP 0.3 IFP unless it is retrievable by name from the on-board navigation database and conforms to the charted procedure. However, the pilot may subsequently modify a procedure by inserting or deleting specific waypoints in response to ATC clearances. The pilot may select the ATS route to be flown for the en-route section of the flight from the database or may construct the ATS route by means of selection of individual en-route waypoints from the database. The manual entry or creation of new waypoints, by manual entry of latitude and longitude or rho/theta values, is not permitted. Additionally, pilots must not change any SID or STAR database waypoint type from a fly-by to a fly-over or vice versa.

7.3.4.3.6 The pilot should cross-check the current flight plan by comparing charts or other applicable resources with the navigation system textual display and the aircraft/rotorcraft map display, if applicable. If required, the pilot should also confirm exclusion of specific NAVAIDs in compliance with NOTAMs or other pilot procedures.

7.3.4.3.7 There is no pilot requirement to cross-check the navigation system's performance with conventional NAVAIDs as the absence of an integrity alert is considered sufficient to meet the integrity requirements. However, the pilot should monitor the reasonableness of the navigation solution and report any loss of RNP 0.3 capability to ATC. In addition, the pilot must continuously monitor the lateral deviation indicator (or equivalent navigation map display) during all RNP 0.3 operations.

7.3.4.3.8 The pilot is expected to maintain centre line, as depicted by on-board lateral deviation indicators, during all RNP operations unless authorized to deviate by ATC or under emergency conditions. For normal operations on straight segments, cross-track error/deviation (the difference between the RNP system computed path and the aircraft position relative to the path) should be limited to ±½ the navigation accuracy associated with the procedure (0.15 NM). Brief deviations from this standard (such as overshoots or undershoots) during track changes (fly-by and fly-over turns), up to a maximum of one times the navigation accuracy (that is, 0.3 NM for RNP 0.3), are allowable.

Note.— Some systems do not display or compute a path during track changes (fly-by and fly-over turns). As such, the pilots of these aircraft may not be able to adhere to the RNP value requirement (such as 0.15 NM) during these turns. However, the pilot is expected to satisfy the operational requirement during intercepts following turns and on straight segments.

7.3.4.3.9 If ATC issues a heading assignment taking the aircraft/rotorcraft off an ATS route, the pilot should not modify the flight plan in the RNAV system until receiving a new ATC clearance to rejoin the ATS route or the controller confirms a new ATS route clearance. When the aircraft is following an ATC heading assignment, the specified accuracy requirement does not apply.

7.3.4.3.10 Manually selecting aircraft bank limiting functions may reduce the aircraft's ability to maintain its desired track and is not recommended. The pilot should recognize manually selectable aircraft bank-limiting functions might reduce their ability to satisfy path requirements of the procedure, especially when executing large angle turns. This should not be construed as a requirement to deviate from flight manual procedures; rather, pilots should be encouraged to avoid the selection of such functions except where needed for flight safety reasons.

7.3.4.4 Aircraft/rotorcraft with RNP selection capability

The pilot of an aircraft/rotorcraft with a manual RNP input selection capability should select RNP 0.3 for all RNP 0.3 ATS routes.

7.3.4.5 RNP 0.3 SID specific requirements

7.3.4.5.1 Prior to commencing take-off, the pilot must verify the aircraft RNP system is available, operating correctly, and the correct airport/heliport and departure data are loaded and properly depicted (including the aircraft's initial position). A pilot assigned an RNP 0.3 departure procedure and subsequently issued a change to the procedure or a transition from the procedure must verify that the appropriate changes are entered and available for navigation prior to take-off. A final check of proper departure entry and correct route depiction, shortly before take-off, is recommended.

7.3.4.5.2 The GNSS signal must be available and acquired by the aircraft's GNSS avionics before the take-off.

7.3.4.5.3 *Engagement of system after take-off.* When required, the pilot must be able to engage (that is, couple) the FGS prior to reaching the first waypoint defining a procedure requiring RNP 0.3 in accordance with this specification.

7.3.4.6 RNP 0.3 STAR specific requirements

7.3.4.6.1 Prior to the arrival phase, the pilot should verify loading of the correct terminal route. The current flight plan should be checked by comparing the charts (paper or electronic) with the map display (if applicable) and the MCDU. This includes confirmation of the waypoint sequence, reasonableness of track angles and distances, any altitude or speed constraints, and, where possible, identification of which waypoints are fly-by, and which are fly-over or which represent the beginning or end of a radius-to-fix leg segment. An ATS route must not be used if the pilot has any reason to doubt the validity of the ATS route in the navigation database.

Note.— As a minimum, the arrival checks can be a simple inspection of a suitable map display that achieves the objectives of this paragraph.

7.3.4.6.2 The creation of new waypoints by manual entry into the RNP 0.3 system by the pilot would not create a valid ATS route and is unacceptable at all times.

7.3.4.6.3 Where contingency procedures require reversion to a conventional IFP, the pilot must complete all necessary preparation for such reversion (such as manual selection of NAVAID) before commencing any portion of the IFP.

7.3.4.6.4 Procedure modifications in the terminal area may take the form of ATC-assigned vectors or "direct to" clearances, and the pilot must be capable of reacting in a timely fashion. This may include a requirement for the pilot to insert tactical waypoints loaded from the on-board navigation database. The pilot must not make manual entries or modify and create temporary waypoints or fixes that are not provided in the on-board navigation database.

7.3.4.6.5 The pilot must verify their aircraft navigation system is operating correctly, and the correct arrival procedure (including any applicable transition) is entered and properly depicted. Although a particular method is not mandated, the pilot must adhere to any published altitude and speed constraints associated with an RNP 0.3 operation.

7.3.4.7 Contingency procedures

The pilot must notify ATC of any loss of the RNP 0.3 capability (integrity alerts or loss of navigation) together with the proposed course of action. If unable to comply with the requirements of an RNP 0.3 ATS route for any reason, the pilot must advise ATC as soon as possible. The loss of RNP 0.3 capability includes any failure or event causing the aircraft to no longer satisfy the RNP 0.3 requirements of the desired ATS route. In the event of communications failure, the pilot should continue with the published lost communications procedure.

7.3.5 Pilot knowledge and training

The training programme should provide sufficient training (such as simulator, training device, or aircraft) on the aircraft RNP system to the extent that the pilot is familiar with the following:

a) the information in this chapter;

b) the meaning and proper use of aircraft/helicopter equipment/navigation suffixes;

c) procedure characteristics as determined from chart depiction and textual description;

d) depiction of waypoint types (fly-over and fly-by) and path terminators (provided in 7.3.3.4 g);

e) required navigation equipment and MEL for operation on RNP 0.3 ATS routes;

f) RNP system-specific information:

   1) levels of automation, mode annunciations, changes, alerts, interactions, reversions, and degradation;

   2) functional integration with other aircraft systems;

   3) the meaning and appropriateness of route discontinuities as well as related flight crew procedures;

   4) pilot procedures consistent with the operation (such as monitor PROG or LEGS page);

   5) types of navigation sensors utilized by the RNP system and associated system prioritization/weighting/logic/limitations;

   6) turn anticipation with consideration for airspeed and altitude effects;

   7) interpretation of electronic displays and symbols used to conduct an RNP 0.3 operation; and

   8) understanding of the aircraft configuration and operational conditions required to support RNP 0.3 operations (that is, appropriate selection of CDI scaling/lateral deviation display scaling);

g) RNP equipment operating procedures, as applicable, including how to perform the following actions:

1) verifying currency and integrity of aircraft navigation data;

2) verifying successful completion of RNP system self-tests;

3) entry of and update to the aircraft navigation system initial position;

4) retrieving and flying an IFP with appropriate transition;

5) adhering to speed and/or altitude constraints associated with an RNP 0.3 IFP;

6) impact of pilot selectable bank limitations on aircraft/rotorcraft ability to achieve the required accuracy on the planned route;

7) selecting the appropriate STAR or SID for the active runway in use and be familiar with flight crew procedures required to deal with a runway change;

8) verifying waypoint and flight plan programming;

9) flying direct to a waypoint;

10) flying a course or track to a waypoint;

11) intercepting a course or track;

12) following vectors and rejoining an RNP ATS route from “heading” mode;

13) determining cross-track error or deviation. More specifically, the maximum deviations allowed to support RNP 0.3 must be understood and respected;

14) inserting and deleting route discontinuities;

15) removing and reselecting navigation sensor inputs;

16) when required, confirming exclusion of a specific NAVAID or NAVAID type;

17) changing the arrival airport or heliport and the alternate airport;

18) performing a parallel offset function, if the capability exists. The pilot should know how to apply offsets within the functionality of their particular RNP system and the need to advise ATC if this functionality is not available;

19) performing an RNAV holding pattern; and

20) where applicable, execution of an RF leg;

h) operator-recommended levels of automation for phase of flight and workload, including methods to minimize cross-track error to maintain route centre line;

i) R/T phraseology for RNAV/RNP applications; and

j) contingency procedures for RNAV or RNP failures.

7.3.6 Navigation database

7.3.6.1 Navigation data management is addressed in Annex 6 – *Operation of* Aircraft, Part I – *International Commercial Air Transport – Aeroplanes*, Chapter 7. The navigation database should be obtained from a supplier that complies with RTCA DO 200()/EUROCAE document ED 76(), Standards for Processing Aeronautical Data. A letter of authorization (LOA) issued by the appropriate regulatory authority demonstrates compliance with this requirement (such as FAA LOA issued in accordance with FAA AC 20-153() or EASA certification of data services provider in accordance with Regulation (EU) 2017/373 (Part DAT)). The operator must report any navigation database discrepancies that invalidate a route, SID, STAR or initial/intermediate approach procedure to the navigation database supplier, and the operator must prohibit their pilots from attempting an affected SID or STAR.

7.3.6.2 Aircraft operators should consider the need to conduct ongoing checks of the operational navigation databases in order to meet existing quality system requirements.

7.3.7 Oversight of operators

7.3.7.1 A regulatory authority may consider any navigation error reports in determining remedial action for an operator. Repeated navigation error occurrences attributed to a specific piece of navigation equipment may result in cancellation of the authorization for use of that equipment.

7.3.7.2 Information that indicates the potential for repeated errors may require modification of an operator’s training programme. Information that attributes multiple errors to a particular pilot may necessitate remedial training or licence review.

7.4 REFERENCES

The applicable versions of industry and regulatory references, standards and guidance included in this chapter, shown as open reference (), are listed in Attachment E to this volume. Some references contained in the chapter are part of background or historical information, and not included in Attachment E.

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Appendix 1 to PART C

RADIUS TO FIX PATH TERMINATOR

1. INTRODUCTION

1.1 Background

This appendix addresses radius to fix (RF) path terminator functionality when used in association with RNP 1, RNP 0.3, RNP APCH, A-RNP and RNP AR navigation specifications.

1.2 Purpose

1.2.1 This appendix provides guidance to States implementing instrument flight procedures (IFPs) where radius to fix (RF) legs are incorporated into terminal procedures.

1.2.2 For the ANSP, it provides a consistent ICAO recommendation on how to implement RF legs. For the operator, it provides training requirements. This appendix is intended to facilitate operational eligibility for existing RNP systems that have a demonstrated RF leg capability. An operational authorization based upon this standard allows an operator to conduct operations on procedures containing RF legs globally.

1.2.3 This appendix also provides airworthiness and operational criteria for the approval of an RNP system incorporating an RF functionality. Although the RF functionality in this appendix is identical to that found in the RNP AR specification, the approval requirements when applied in association with RNP 1, RNP 0.3, RNP APCH and A-RNP are not as constraining as those applied to RNP AR. This is taken into account in the related obstacle protection and route spacing criteria.

Note.— Industry standards for RF defined paths can be found in RTCA DO-236()/EUROCAE ED-75() section 3.2.5.4.1 and 3.2.5.4.2.

2. IMPLEMENTATION CONSIDERATIONS

2.1 Application of radius to fix legs

2.1.1 The RF leg should be only used when there is a requirement for a specific fixed radius curved path in a terminal procedure. The RF leg begins at the fix for the preceding path terminator, and is defined by an arc centre point, the arc ending fix and the turn direction. The radius is calculated by the navigation computer as the distance from the arc centre point to the arc ending fix. RNP systems supporting this leg type provide the same ability to conform to the track-keeping accuracy during the turn as in the straight-line segments. RF legs are intended to be applied where accurate repeatable and predictable navigation performance is required in a constant radius turn.

2.1.2 The RF leg may be associated as an optional requirement for IFPs defined using the following RNP navigation specifications found in Volume II, Part C, of this manual:

– Chapter 3 – Implementing RNP 1

– Chapter 5 – Implementing RNP APCH

– Chapter 7 – Implementing RNP 0.3

2.1.3 In addition, the RF leg is a minimum requirement for the following RNP navigation specification:

– Chapter 4 – Implementing Advanced RNP

2.1.4 For RNP1, RNP APCH, RNP0.3 and A-RNP, RF legs may be used on any segment of a terminal procedure: in the initial and intermediate approach segments, the final phase of the missed approach segment, SIDs and STARs. The criteria for designing procedures with RF legs are detailed in the *Procedures for Air Navigation Services – Aircraft Operations* (Doc 8168).

Note.— For an RNP APCH procedure design, the navigation specification assumes that the aircraft's LNAV guidance will be available at the end of the initial phase of the missed approach phase. For missed approach procedure designs with an RF leg(s), this means that the flight crew must be able to engage and follow their aircraft's RNP system LNAV guidance no later than 152 m (500 ft) AGL.

2.1.5 The RF leg is a minimum requirement for the following RNP navigation specification:

– Chapter 6 – Implementing RNP with Authorization Required (RNP AR APCH and RNP AR DP)

2.1.6 The RF leg is commonly used in the design of terminal procedures using the RNP AR navigation specification. RF legs may be applied in any segment of RNP AR terminal procedure: in the initial, intermediate and final approach segments, in the final phase of the missed approach segment, standard instrument departures (SIDs) and standard instrument arrival (STARs). The criteria for designing procedures with RF legs are detailed in the *Required Navigation Performance Authorization Required (RNP AR) Procedure Design Manual* (Doc 9905).

2.1.7 Chapter 6 contains additional requirements for RF legs that are specific to RNP AR operations.

Note.— Although the RF leg is designed to be applied within the extent of terminal procedures, during higher flight level/altitude segments aircraft may become bank angle limited. When designing terminal procedures with curved path segments, consideration should be given to the interface between the terminal procedure (SID or STAR) and the ATS route structure and whether it is more appropriate to implement the curved path segment though use of the fixed radius transition (FRT). The FRT design feature within an ATS route structure is provided for any such curved path requirements as part of the A-RNP navigation specification.

2.2 Instrument flight procedure design considerations and assumptions

2.2.1 The radius of turn depends upon the ground speed of the aircraft and the applied bank angle. From an IFP design perspective, the maximum ground speed of the aircraft is determined by the maximum allowable indicated airspeed (IAS), the turn altitude and the maximum tail wind. IFP design criteria for maximum IAS, turn altitude, bank angle and maximum tailwind are described in detail in PANS-OPS (Doc 8168).

2.2.2 When speed restrictions are required for departures, they will be placed on the RF leg exit waypoint or a subsequent waypoint as required. For arrivals, the speed restriction should be applied to the waypoint associated with the beginning of the RF leg (path terminator of preceding leg).

2.2.3 The inbound and outbound legs will be tangential to the RF leg.

2.2.4 The requirements of an RF leg may be continued through to a sequential RF leg when implementing wrap-around instrument procedures, such as departures.

2.2.5 The procedure will be subjected to comprehensive validation checks prior to publication in order to assure flyability by the intended aircraft types.

3. CONSIDERATIONS FOR USE OF RF LEGS

3.1 General

3.1.1 RF legs provide a predictable and repeatable ground track during a turn and prevent the dispersion of tracks experienced in other types of turn construction due to varying aircraft speeds, turn anticipation, bank, roll rate, etc. Therefore, RF legs can be employed where a specified path must be flown during a turn. Additionally, because an RF leg traverses a specified distance, it can be used to maintain aircraft longitudinal spacing between aircraft having the same speed. This is not necessarily true with other turn constructions, such as fly-by transitions, because of the varying turn paths aircraft execute.

3.1.2 Not all aircraft are capable to fly these procedures. Before including RF legs in a given procedure, the mix of aircraft and their capabilities and any possible alternatives should carefully be considered. One alternative to the RF leg is a series of subsequent TF legs.

3.2 Publication considerations

Guidance for charting RF legs is provided in PANS-OPS (Doc 8168). The requirement for RF functionality must be clearly marked on the chart.

3.3 Air traffic control coordination

3.3.1 It is expected that ATC will be familiar with RF leg benefits and their limitations, such as speed. ATC shall not allocate a speed that exceeds a constraint associated with the (design) flyability of an RF leg.

3.3.2 Aircraft must be established on the inbound track to the RF leg prior to it being sequenced by the navigation system. ATC must therefore not issue a DIRECT TO clearance to a waypoint beginning an RF leg or a vector to intercept an RF leg.

4. AIRCRAFT REQUIREMENTS

4.1 RNP system-specific information

4.1.1 The navigation system should not permit the pilot to select a procedure with an RF leg that is not supported by the equipment.

4.1.2 The installed navigation system should also prohibit pilot access to procedures requiring RF leg capability if the system can select the procedure, but the aircraft is not otherwise equipped.

Note 1.— One acceptable means to meet these requirements is to screen the aircraft's on-board navigation database and remove any routes or procedures the aircraft is not eligible to execute. For example, if the aircraft is not eligible to complete RF leg segments, then the database screening could remove all procedures containing RF leg segments from the navigation database.

Note 2.— Another acceptable means of compliance may be pilot training to identify and prohibit the use of procedures containing RF legs.

4.2 On-board performance monitoring and alerting

The performance monitoring and alerting requirements from the navigation specification to which the RF appendix is referred are applicable.

4.3 System failure modes/annunciations

The RNP system is required to provide a visible alert within the pilot's primary field of view during loss of navigation capability. This includes any failure modes that affect the RF leg capability of the aircraft.

4.4 Functional requirements

4.4.1 An electronic moving map display unambiguously depicting the curved RF computed path and the aircraft own-ship position is required.

4.4.2 An autopilot or flight director with at least "roll-steering" capability that is driven by the RNP system is required. The autopilot/flight director must operate with suitable accuracy to track the lateral and, as appropriate, vertical paths required by a specific RNP procedure.

4.4.2.1 Subject to regulatory airworthiness approval, for RNP-1 and RNP-APCH operations, an autopilot or flight director may not be required for non-type rated Part/CS-23 Category I, II and III aircraft operating at speeds of 200 knots or less, provided that the aircraft is equipped with a CDI and a suitable electronic moving map display located in the maximum primary field of view. The maximum primary field of view is defined as +/- 35 degrees horizontally and +40/-20 degrees vertically.

Note.— Regulatory airworthiness approval implies a requirement for a TC, STC or approved model list STC specifically addressing RF capability and eligibility.

4.4.3 The RNP system must be capable of providing guidance to achieve a bank angle up to 30 degrees above 400 ft AGL and 15 degrees above FL195.

4.4.4 Where autopilot or flight director is required, the flight guidance mode should remain in lateral navigation while on an RF leg, when a procedure is abandoned, or a missed approach/go-around is initiated (through activation of TOGA or other means) to enable display of deviation and display of positive course guidance during the RF leg. As an alternative means, crew procedures may be used that ensure that the aircraft adheres to the specified flight path throughout the RF leg segment.

4.5 Compliance demonstration

4.5.1 In seeking an airworthiness approval for a navigation system implementing the RF path terminator, the compliance demonstration supporting such an approval should be scoped to the airspace operational concept, the limitations of the applicable navigation specification and the boundaries to which the RF leg is likely to be applied.

4.5.2 Consideration should be given to evaluation of the navigation system on a representative set of procedure designs under all foreseen operating conditions. At a minimum, the evaluation should address maximum assumed tailwind and maximum altitude with the aircraft operating in the range of expected airspeeds for the manoeuvre and operating gross weights. A more exhaustive list of considerations has been detailed in the appropriate regulatory guidance material, such as the Federal Aviation Administration (FAA) Advisory Circular, the European Union Aviation Safety Agency (EASA) CS/AMC, including sample test procedures, which may be used as part of unit level bench testing, integration simulator or flight testing to “stress” the RF function. Procedure design constraints should include sequencing multiple, consecutive RF leg segments of varying turn radii, including consecutive RF leg segments reversing the direction of turn (that is, reversing from a left-hand RF turn to a right-hand RF turn).

4.5.3 Within the demonstration, the applicant should be seeking to confirm the FTE commensurate with the identified RNP navigation accuracy and that the RF turn entry and exit criteria are satisfied. When evaluating an aircraft’s FTE during RF legs, the FTE evaluation should consider the RNP system’s turn anticipation and the effect of rolling into and out of the RF turn. The RNP AR procedure design provides a 5 degree manoeuvrability margin to enable the RNP system to provide flight guidance aircraft to correct minor deviations from the RF turn’s defined track, and the FTE evaluation should ensure the ability to contain FTE while correcting minor deviations in a timely manner. Likewise, the FTE evaluation should ensure the RNP system’s ability to properly compute turn anticipation to capture an RF turn immediately after the RF turn initiation point and properly sequence onto the next leg segment of the RNP AR procedure, which may be a straight leg segment or another RF turn.

4.5.4 Any limitations identified during the compliance demonstration should be documented. Flight crew procedures should be assessed, including identification of any limitations that surround the use of pilot selectable or automatic bank angle limiting functions and confirmation of those related to go-around or missed approach from an RF leg segment.

5. OPERATIONAL REQUIREMENTS

5.1 Background

This section identifies the operational requirements associated with the use of RF legs as scoped in 1.1 of this appendix. It assumes that the airworthiness approval of the aircraft and systems has been completed. This means that the basis for the RF leg function and the system performance has already been established and approved based upon appropriate levels of analysis, testing and demonstration. As part of this activity, the normal procedures, as well as any limitations for the function, will have been documented, as appropriate, in the aircraft flight and operations manuals. Compliance with the operational requirements herein should be addressed through national operating rules. For example, certain operating rules require operators to apply to their national authority (State of Registry) for operational authorization.

5.2 Authorization process

5.2.1 The following steps must be completed before the use of the RF leg function in the conduct of an RNP terminal operation:

a) aircraft equipment eligibility must be determined and documented;

b) operating procedures must be documented;

c) pilot training based upon the operating procedures must be documented;

d) the above material must be acceptable to the State regulatory authority; and

e) operational authorization should then be obtained in accordance with national operating rules.

Note.— The criteria applied in the authorization process should be dependent on the navigation specification to which the RF leg is associated, such as during the authorization process of the navigation specification with RF leg associated, and it should be verified that the requirements valid for this navigation specification are also met when applying an RF leg.

5.2.2 Following the successful completion of the above steps, an operational authorization for the use of RF legs with the navigation specification with which it is associated, an LOA or appropriate operations specifications, or an amendment to the OM, if required, should then be issued by the State.

5.3 Aircraft eligibility

5.3.1 Relevant documentation acceptable to the State of the Operator/Registry must be available to establish that the aircraft is equipped with an RNP system with a demonstrated RF leg capability. Eligibility may be established in two steps:

a) recognizing the qualities and qualifications of the aircraft and equipment; and

b) determining the acceptability for operations.

The determination of eligibility for existing systems should consider acceptance of manufacturer documentation of compliance, such as FAA ACs 90-105(), 90-101(), 20-138().

Note.— RNP systems demonstrated and qualified for RNP AR operations using RF leg functionality are considered qualified with recognition that the RNP operations are expected to be performed consistent with the operators RNP AR authorization. No further examination of aircraft capability, operator training, maintenance, operating procedures, databases, etc. is necessary.

5.3.2 *Eligibility airworthiness documents.* The flight manual or referenced document should contain the following information:

a) a statement indicating that the aircraft meets the requirements for RNP operations with RF legs and has demonstrated the established minimum capabilities for these operations. This documentation should include the phase of flight, mode of flight (such as FDE on or off, and/or autopilot on or off, and applicable lateral and vertical modes), minimum demonstrated lateral navigation accuracy, and sensor limitations, if any;

b) any conditions or constraints on path steering performance (such as autopilot engaged, FDE with map display, including lateral and vertical modes, and/or CDI/map scaling requirements) should be identified. Use of manual control with CDI only is not allowed on RF legs; and

c) the criteria used for the demonstration of the system, acceptable normal and non-normal configurations and procedures, the demonstrated configurations and any constraints or limitations necessary for safe operation should be identified.

5.4 Operating procedures

5.4.1 Where autopilot or flight director is required, the pilot must use either a flight director or autopilot when flying an RF leg. The pilot should comply with any instructions or procedures identified by the manufacturer as necessary to comply with the performance requirements in this appendix.

5.4.2 Procedures with RF legs will be identified on the appropriate chart.

5.4.3 Where the autopilot or flight director is required and the dispatch of a flight is predicated on flying an RNP procedure with an RF leg, the dispatcher or pilot must determine that the installed autopilot or flight director is operational.

5.4.4 The pilot is not authorized to fly a published RNP procedure unless it is retrievable by the procedure name from the aircraft navigation database and conforms to the charted procedure. The lateral path must not be modified, with the exception of complying with ATC clearances/instructions.

5.4.5 The aircraft must be established on the procedure prior to beginning the RF leg.

5.4.6 The pilot is expected to maintain the centre line of the desired path on RF legs. For normal operations, cross-track error/deviation (the difference between the displayed path and the displayed aircraft position relative to the displayed path (that is, FTE)) should be limited to half the navigation accuracy associated with the procedure (such as 0.5 NM for RNP 1).

5.4.7 Where published, the pilot must not exceed maximum airspeeds associated with the flyability (design) of the RF leg.

5.5 Pilot knowledge and training

Note.— If an operator is authorized to conduct RNP AR operations, which includes training for instrument procedures with RF legs, they may receive credit from the State of the operator for the training elements listed below.

The training programme should include:

a) the information in this appendix;

b) the meaning and proper use of RF functionality in RNP systems;

c) associated procedure characteristics as determined from the chart depiction and textual description;

d) associated levels of automation, mode annunciations, changes, alerts, interactions, reversions and degradation;

Note.— Manually selecting aircraft bank limiting functions may reduce the aircraft's ability to maintain its desired track and are not permitted. The pilots should recognize that manually selectable aircraft bank-limiting functions may reduce their ability to satisfy ATC path expectations, especially when executing large angle turns.

e) monitoring track-keeping performance;

f) the effect of wind on aircraft performance during execution of RF legs and the need to remain within the RNP. The training programme should address any operational wind limitations and aircraft configurations essential to safely complete the RF turn;

g) the effect of ground speed on compliance with RF paths and bank angle restrictions impacting the ability to remain on the course centre line;

h) interpretation of electronic displays and symbols; and

i) contingency procedures.

5.6 Navigation database

Aircraft operators will be required to manage their navigation data base load either through the packing or through flight crew procedure, where they have aircraft systems capable of supporting the RF functionality, but as an operator they do not have an authorization for its use.

6. REFERENCES

The applicable, specific industry and regulatory references, standards and guidance included in this chapter, shown as open reference (), are listed in Attachment E to this volume.

Appendix 2 to PART C

FIXED RADIUS TRANSITION

1. INTRODUCTION

1.1 Background

1.1.1 The fixed radius transition (FRT) is intended to define transitions along airways in the case where separation between parallel routes is also required in the transition, and the fly-by transition is not compatible with the separation criteria.

1.1.2 Increasing demand on intense airspace use and the need to progress horizontal airspace availability in areas with high traffic density requires the design of new airspace structures with closer spaced routes. In a lot of instances, turns will be required in the route network, for example, to circumnavigate reserved airspace, transit from one airway structure to another or to connect en-route airspace to terminal airspace. Therefore, reduced route spacing will only be possible if similar route spacing can be maintained in the turns. Initial applications are expected to be based on the route designator conventions stipulated in Annex 11 – *Air Traffic Services*.

1.2 Purpose

The purpose of this appendix is to define the FRT navigation functionality, which is an enabler for applying closer route spacing along turns in the en-route network. This appendix may be associated with the following en-route RNP navigation specifications: RNP 4, RNP 2 and A-RNP.

2. IMPLEMENTATION CONSIDERATIONS

2.1 Turn geometry

The geometry of the FRT is defined by the track change, θ (difference between outbound and inbound track in degrees), and the radius, R (see Figure II-C-App 2-1). Those two parameters define the turn centre, the lead distance, Y, which is the distance from turn initiation towards the transition waypoint, and the abeam distance, X, which is the distance between the transition waypoint and the point where the aircraft crosses the bisector of the turn. The latter two values are determined by the following expressions:

$$Y = R \tan(\theta/2)$$

$$X = R\left(\frac{1}{\cos(\theta/2)} - 1\right)$$

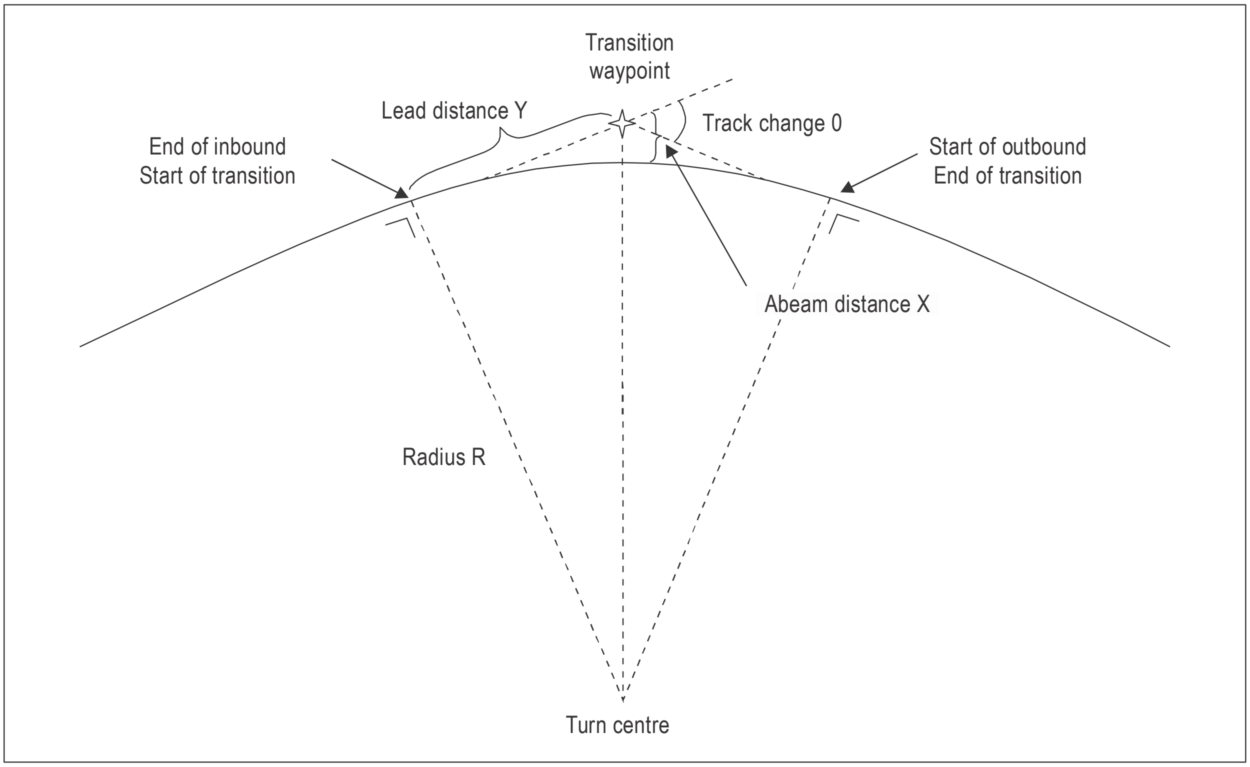

Figure II-C-App 2-1. Fixed radius transition

2.2 Aircraft bank angle

The FRT will result in a bank angle dependent upon ground speed. Therefore, during the turn, changes to airspeed and wind will result in varying bank angle. The turn radius must be selected to ensure that the bank angle remains within acceptable limits for cruise operations.

2.3 Application of FRT

2.3.1 The FRT should be used when there is a requirement for a specific fixed radius curved path en-route. The radius is calculated, and the curved path is seamlessly joined with the associated route segments by the RNP system. RNP systems supporting this path transition provide the same ability to conform to the track-keeping accuracy during the turn as in the straight-line segments. FRTs are expected to be applied where accurate repeatable and predictable navigation performance is required for what is, in effect, a constant radius fly-by turn.

2.3.2 The FRT may be associated as an optional requirement for routes defined using the following RNP navigation specification found in Volume II, Part C, of this manual:

– Chapter 1 – Implementing RNP 4

– Chapter 2 – Implementing RNP 2

– Chapter 4 – Implementing Advanced RNP

Note.— A data link route clearance may include airways in the database that contain FRTs. Existing datalink interfaces (such as, the Special Committee on Future Air Navigation Systems (FANS)) cannot specify an FRT for an individual waypoint in a route clearance. Future datalink specifications will allow for this capability.

2.3.3 Where there is a transition from one airway to another airway, both requiring an FRT at the common transition waypoint, the largest of the two radii applicable to the common transition waypoint should be assumed. For and entry or exit transition from one airway to another airway, where only one airway requires an FRT at the common transition waypoint, a fly-by transition will be used.

2.4 Route design considerations and assumptions

2.4.1 The system should use the navigation database specified radius associated with each waypoint along an airway, and if there is a blank entry in the database field for a particular waypoint no fixed-radius transition is required. The selected radius should be published for the appropriate waypoint(s) in the AIP for the route.

2.4.2 The inbound and outbound route segments will be tangential to the FRT as computed by the navigation system.

2.4.3 FRTs will not be constructed by the RNP system where the track change is greater than 90 degrees.

2.4.4 For FRTs where the next flight path segment requires a different navigation accuracy, the navigation accuracy applicable to the complete FRT must be the largest one. For example, when a transition occurs from a path segment requiring an accuracy of 1.0 NM to a path segment requiring an accuracy of 2.0 NM, the navigation accuracy of 2.0 NM must apply throughout the FRT.

2.4.5 Where there is a transition from one airway to another airway, both requiring an FRT at the common transition waypoint, the smaller of the two radii applicable to the common transition waypoint must be selected.

3. AIRCRAFT REQUIREMENTS

3.1 Functional requirements

The system must be able to define transitions between flight path segments using a fixed turn radius specified in the navigation database, associated with each waypoint along an airway, and if there is a blank entry in the database field for a particular waypoint no fixed-radius transition is required.

Note.— It is typically expected that a radius of 22.5 NM will be specified for use on upper routes (such as FL 200 and above) and a turn radius of 15 NM to be used on lower routes (such as FL 190 and below). Any other values will be determined by a State/service provider as appropriate to operational needs and as supported by operational safety assessments

3.2 On-board performance monitoring and alerting

3.2.1 The navigation system must have the capability to execute a flight path transition and maintain a track consistent with a fixed radius between two route segments. The lateral total system error (TSE) must be within ±1 × RNP of the path defined by the published procedure for at least 95 per cent of the total flight time for each phase of flight and any manual, autopilot and/or flight director mode. For path transitions where the next route segment requires a different

TSE and the path transition required is an FRT, the navigation system may retain the navigation accuracy value for the previous route segment throughout the entire FRT segment. For example, when a transition occurs from a route segment requiring an accuracy value of 2.0 to a route segment requiring an accuracy value of 1.0, the navigation system may use an accuracy value of 2.0 throughout the FRT.

Note.— Default values for FTE can be found in RTCA DO-283().

3.3 Display requirements

3.3.1 The aircraft system is required to provide means for the flight crew to monitor the FTE during the FRT.

3.3.2 FTE monitoring is required to be provided by means of displaying the curved path of the FRT on a moving map display (navigation display) with pilot selectable range and numerical indication of the cross-track value.

3.4 Navigation database

The navigation database will specify the radius associated with a particular fix, along an airway.

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Appendix 3 to PART C

TIME OF ARRIVAL CONTROL

Due to the importance of time of arrival control for trajectory based operations, this appendix is retained as a place holder. However, as research is incomplete and the level of maturity of the functionality is insufficient, no further information is provided at this time.

Attachments to Volume II

Attachment A

VERTICAL NAVIGATION IN THE FINAL APPROACH SEGMENT

1. INTRODUCTION

1.1 General

1.1.1 This attachment provides guidance on the operational application of vertical navigation (VNAV) in the FAS. VNAV is defined as the management of the flight along a specified vertical path using vertical guidance provided by an RNP system or as supported by other aircraft systems (such as autopilot flight path angle or vertical speed modes).

1.1.2 Vertical guidance is defined as guidance provided by the avionics to the flight crew to aid with the conduct of VNAV or compliance with a glide path. This includes data provided to the FGS.

1.1.3 The vertical path may be

a) published by the State in the AIP and coded in the navigation database;

b) defined by the provider of the navigation database using a standardised process;

c) defined by the pilot and executed through a flight path angle, vertical speed or an altitude controller; or

d) computer-generated navigation data from ground-based, space-based, self-contained navigation aids or any combination of these.

1.1.4 States protect vertical paths and publish these in the AIP for approach procedures whereby vertical guidance for VNAV or compliance with a glide path (or a glide slope) is required, including select PBN approach procedures. With other procedures, States may still publish data allowing the definition of a vertical path, for example by publishing a vertical path angle (VPA) and threshold crossing height (TCH). The provider of the navigation database may use the information to code the necessary elements to construct a vertical path in the database.

Note.— It should be noted that the latter procedures may not be protected to the same standards as those for which vertical guidance compliance with a glide path (or glide slope) is required.

1.1.5 The aircraft's systems may also provide vertical guidance as an aid to the pilot to fly a vertical path outside of the final approach segment such as during the descent, initial and intermediate approach phases of the flight. Using vertical guidance can enable a pilot to conduct a smooth continuous descent and transition to the final approach segment of an instrument approach, including a stabilized transition into a CDFA operation.

1.1.6 A continuous decent final approach (CDFA) is considered to be a safety enhancement, improving flight crew efficiency and reducing cockpit workload while enabling stabilised continuous descent operations. Using CDFA techniques also reduces fuel consumption and noise.

Note.— For more information on CDFA, see the Manual of All-Weather Operations *(Doc 9365).*

1.1.7 This attachment focusses on VNAV in the FAS, supported by an RNP system providing vertical guidance in the context of performance-based navigation (PBN). However, vertical guidance may also be provided by other avionics. Moreover, vertical guidance may not just be provided on PBN procedures, but on conventional instrument procedures (approaches and arrivals).

Note 1.— The term vertical guidance in this attachment refers to an approved, avionics functional capability a manufacturer integrates into an aircraft to provide a flight crew vertical situational information, displays and cues aiding in their conduct of vertical flight operations.

Note 2.— Vertical guidance provided on instrument procedures where VNAV is required is often referred to as vertical guidance for credit *or as* approved VNAV*.*

Note 3.— The application of VNAV on procedures where VNAV is not required is often referred to as advisory vertical navigation *and provision of vertical guidance on those procedures is referred to as* advisory vertical guidance*. Where advisory vertical guidance is provided by the aircraft's avionics, its use is left to the discretion of the flight crew.*

1.2 Purpose

This attachment provides additional information in the use of vertical guidance during the final approach segment of instrument approach operations. It is generic in nature and does not attempt to cover all the requirements for the operational use of VNAV. State publications may contain additional, specific requirements and guidance applying to a flight crew's application of VNAV.

1.3 Background

1.3.1 Many aircraft are equipped with avionics that provide vertical guidance. RNP systems can provide different types of vertical guidance, which can either be based on barometric altimetry, or based on a global navigation satellite system (GNSS) (that is, where the altitude is derived through GNSS satellite ranging and the altitude is referenced to a mathematical model of the earth, such as WGS-84), or both. Other systems on board are also used in support of vertical navigation, for example display and alerting systems and the FGS (autopilot).

1.3.2 Certain instrument approach operations require vertical guidance (such as RNP APCH to LNAV/VNAV minima) and a specific airworthiness approval for the aircraft to provide vertical guidance in the FAS. The aircraft's avionics may also provide vertical guidance on an advisory basis on instrument procedures that do not require vertical guidance as well as outside of the FAS. In this case, vertical guidance is provided to aid a flight crew's vertical situational awareness and supports the pilot by offering a means to conduct smooth continuous descents.

2. CONSIDERATIONS FOR APPLYING VERTICAL NAVIGATION IN INSTRUMENT APPROACH OPERATIONS

2.1 General

This section describes the use of vertical guidance in support of VNAV during instrument approach procedures, including the associated minima, as well as the use of vertical guidance outside of the final approach segment. The only instrument approach procedures where vertical guidance or compliance with a glide path or glide slope, to one or more lines of minima, is required are ILS, MLS, GLS, RNP APCH to LNAV/VNAV or LPV minima and RNP AR APCH procedures.

Note.— Precision approach procedures where vertical guidance requires a ground-based NAVAID, such as ILS with glideslope, MLS and GLS fall outside the scope of PBN and are not addressed in further detail in this attachment. For more information on these areas, see the Manual of All-Weather Operations *(Doc 9365).*

2.2 Performance-based navigation approach procedures where vertical guidance is required

2.2.1 Vertical guidance is required for operations in the FAS when operating one the following types of PBN approaches:

a) RNP APCH operated to LNAV/VNAV minima;

b) RNP AR APCH; and

c) RNP APCH operated to LPV minima.

2.2.2 The design of such procedures is based on the assumption that vertical guidance is available and used by the flight crew. The corresponding procedure design criteria are applied by procedure designers and used in the determination of the minima. These procedures are flown to a DA.

2.2.3 For certain procedures (such as RNP APCH to LPV minima), the vertical path must be published in the State's AIP and coded in the navigation database.

2.3 Performance-based navigation approach procedures where vertical guidance is not required

2.3.1 Vertical guidance is not required in the FAS when operating one of the following types of PBN approaches:

a) RNP APCH to LNAV minima; and

b) RNP APCH to LP minima.

2.3.2 The design of these procedures does not require that vertical guidance information is available or used by the flight crew. Other vertical reference and aircraft state information may be used. The corresponding procedure design criteria are similar to conventional non-precision approach procedures and the procedure is flown to a minimum descent altitude (MDA).

Note.— See the Manual of All-Weather Operations *(Doc 9365) for details regarding the application of CDFA and the use of MDA as a DA.*

2.4 Non-precision approach procedures where vertical guidance is not required

2.4.1 Vertical guidance is not required in the FAS when operating one of the following types of conventional approaches:

a) NDB-based non-precision approach procedures;

b) VOR/DME-based non-precision approach procedures; and

c) LOC-only-based non-precision approach procedures, etc.

Note.— See the Manual of All-Weather Operations *(Doc 9365) for details regarding the application of CDFA and the use of MDA as a DA.*

2.4.2 Similar to the PBN approach procedures addressed in 2.3, the design of these procedures does not require that vertical guidance information is available or used by the flight crew. Other vertical reference and aircraft state information may be used. The procedure is flown to an MDA.

2.5 Decision altitude/height versus minimum descent altitude

2.5.1 Instrument approach procedures requiring VNAV have published minima that are referred to as DAs or decision heights (DHs). These refer to the altitude (or height above ground) at which the pilot must have sufficient visual reference to the runway (for example approach or runway lights) to continue the landing. In the case whereby the approach is discontinued, it is permissible for the aircraft to momentarily descend below the DA/H to allow for the engines to spool up and the aircraft to transition to a climb.

2.5.2 Instrument approach procedures not requiring VNAV have published minima that are referred to as an MDA. The aircraft is not allowed to descend below the MDA, unless the pilot has sufficient visual reference to the runway.

Note.— See the Manual of All-Weather Operations *(Doc 9365) for details regarding the use of MDA as a DA.*

2.6 Step-down fixes and compliance with procedural altitude constraints

RNP APCH procedures to LNAV or LP minima may contain a step-down fix in the FAS, published with a barometric altitude constraint. Altitude constraints are also found outside of the FAS. If vertical guidance is provided by the RNP system on these procedures, the pilot must still comply with the standard operational requirements for instrument flight procedures, which includes complying with the barometric altitude constraints at waypoints and step-down fixes, published on instrument charts. It must be ensured that they do not inadvertently descend below the step-down fix altitude constraint as the vertical guidance for such procedures does not automatically provide such assurance

Note.— Pilots may desire to descend as soon as practical to a non-precision approach MDA to get below icing conditions, to enable a smooth transition to landing from the MDA when conducting a final approach path that's offset from the landing runway or for other operational reasons.

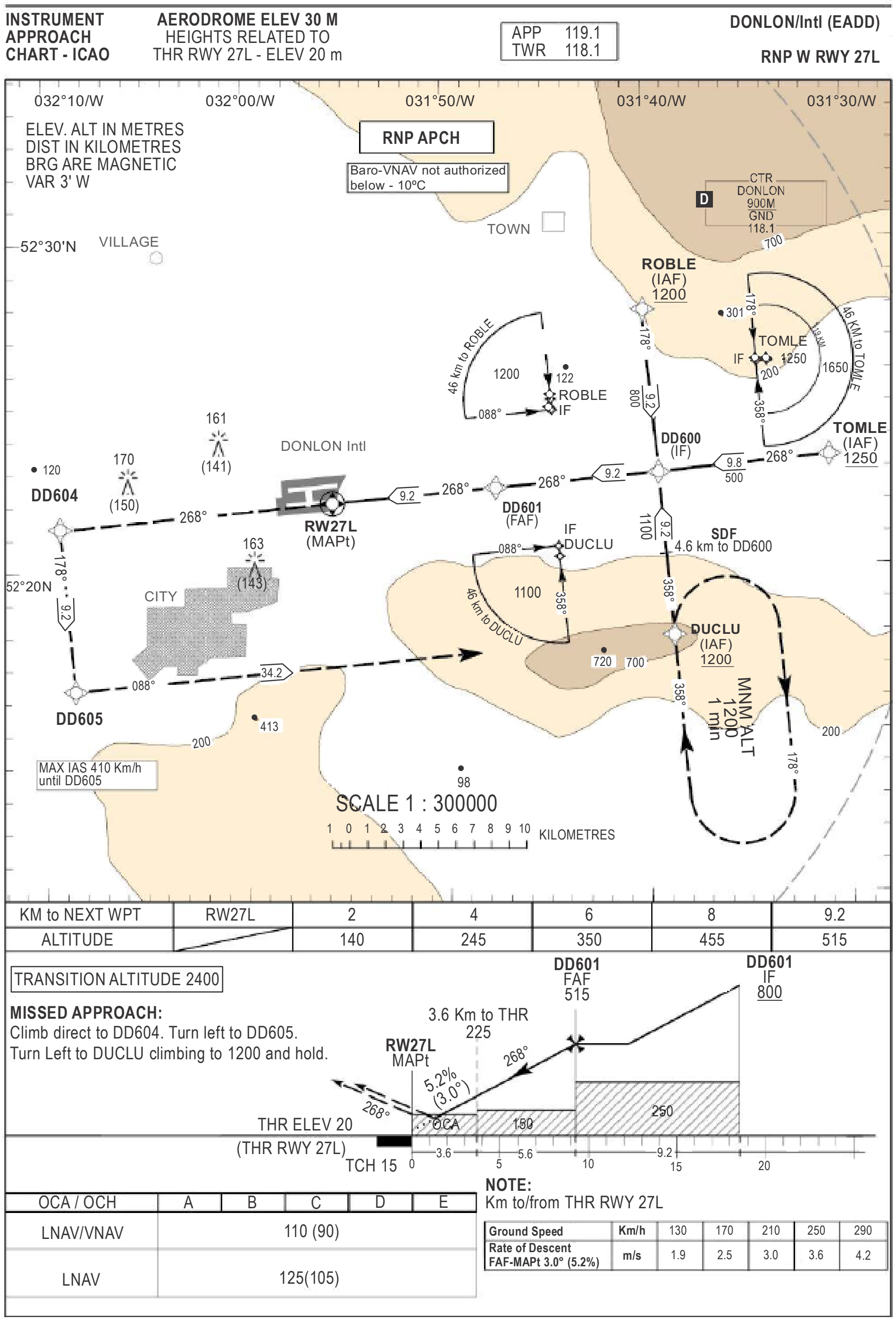
3. AIRCRAFT ELIGIBILITY

3.1 Aircraft operating on instrument approach procedures requiring VNAV or compliance with a glide path need to comply with airworthiness criteria that include specific performance requirements for the system providing vertical guidance.

3.2 Aircraft operating on instrument approach procedures where VNAV is not required historically have not had to comply with specific performance requirements. The applicant for airworthiness only had to demonstrate that the vertical guidance that was provided was not misleading. More recently, at least one regulator has started to impose performance criteria for future applications of RNP systems providing vertical guidance on procedures where VNAV is not required.

3.3 The European Union Aviation Safety Agency (EASA) and Federal Aviation Administration (FAA) have each published requirements and/or guidance material for compliance of aircraft equipment, functionality, performance, and operator use of aircraft and equipment intended to provide vertical guidance in the conduct of operations where VNAV is used or required. EUROCAE and RTCA have published RNP System MASPS and MOPS containing systems and equipment functionality, performance and qualification requirements with regard to VNAV operations where vertical guidance capability is utilized. References to EASA, FAA, EUROCAE and RTCA documents may be found in Attachment E.

Appendix to Attachment A: Example of a performance-based navigation approach procedure



Attachment B

RNP APCH AND RNP AR APCH OPERATIONS IN NON-STANDARD TEMPERATURE CONDITIONS

1. INTRODUCTION

1.1 General

1.1.1 This attachment contains general guidance regarding the correction of the effects of non-standard temperature conditions on an aircraft's barometric altimeter and its RNP system's vertical path guidance. These impacts can be present during RNP APCH and RNP AR APCH operations.

1.1.2 Reference to vertical navigation (VNAV) guidance in this attachment refer to VNAV guidance based on barometric information (Baro-VNAV) and do not include guidance based on a geometric path such as RNP APCH to localiser performance with vertical guidance (LPV) lines of minima, since these are unaffected by temperature effects.

Note.— Requirements for operations during nonstandard temperatures are contained in the Procedures for Air Navigation Services – Aircraft Operations, *Volume I –* Flight Procedures *and Volume III –* Aircraft Operating Procedures *(Doc 8168) which should be consulted in addition to this attachment.*

1.1.3 Non-standard temperatures affect the measurement of pressure altitude by the aircraft's barometric altimetry systems. The measured pressure altitude can then negatively impact the actual vertical flight path and the VNAV guidance an aircraft's RNP system provides during RNP APCH and RNP AR APCH operations. During cold temperatures, the aircraft's vertical path can be lower than indicated and reduced enough to potentially compromise the vertical protection procedural barometric altitudes provide during an instrument approach. In contrast, during hot temperatures, the aircraft's vertical path can be higher than indicated and result in aircraft VNAV guidance for a vertical path that is actually steeper than desired, potentially creating difficulties for energy management on the final approach segment.

1.1.4 This attachment provides guidance on how temperature compensation can correct for the temperature effects on the procedural altitudes. Using temperature compensation can result in the aircraft's RNP system offering VNAV guidance for a stabilized vertical path that matches the procedure's intended vertical path, in compliance with the vertical protection from obstacles and terrain an RNP APCH or RNP AR APCH instrument approach procedure design offers. Industry and States are strongly encouraged to consider this guidance in their performance-based navigation (PBN) implementations to enable flight crew use of temperature compensation during RNP APCH and RNP AR APCH operations when nonstandard temperatures exist.

Note.— Detailed guidance on obstacle clearance for the final approach segment with Baro-VNAV is provided in PANS-OPS (Doc 8168), Volume II.

1.2 Background

1.2.1 Manufacturers calibrate an aircraft's barometric altimeter to a "standard day" at sea level. The ISA defines the "standard day" and establishes a standard temperature at sea level of +15°C or +59°F. Under ISA conditions, temperature decreases as altitude increases above sea level, and the standard temperature gradient or "standard lapse rate" from sea level is a decrease of 2°C per 1 000 feet of altitude above sea level (-2°C/1000 ft) up to 10 km (36 000 ft). For example, at 1.5 km (5 000 ft) above sea level, the ambient temperature on a "standard day" would be +5°C. Thus, an aircraft's barometric altimeter follows the ISA model of a standard day and provides barometric altitude outputs consistent with the ISA temperature gradient.

Note.— The standard atmosphere is defined in the Manual of the ICAO Standard Atmosphere (extended to 80 kilometres (262 500 feet)) *(Doc 7488) procedure design and also assumes an ISA condition. However, when the aircraft encounters an OAT colder than the standard temperature for a given altitude, the aircraft's true altitude is lower than the altitude displayed on the aircraft's barometric altimeter. Similarly, when OAT is warmer than the standard temperature for a given altitude, the aircraft's true altitude is higher than the altitude displayed on the aircraft's barometric altimeter. Thus, since instrument procedure design assumes ISA conditions, when non-standard outside air temperatures are present, the aircraft's true altitude deviates from the procedure's charted barometric altitudes.*

1.2.2 During RNP APCH and RNP AR APCH operations, the aircraft's RNP system can provide both lateral and vertical guidance. The RNP system relies on the definition of the barometric altitudes in the RNP APCH and RNP AR APCH procedure design and the output of the aircraft's barometric altimeter to provide vertical guidance during the instrument approach. In an instrument approach procedure's final approach segment, aircraft providing vertical guidance base the vertical guidance on the procedure's defined vertical path angle (VPA).

1.2.3 To protect the instrument approach operation for non-standard temperatures, the RNP APCH and RNP AR APCH procedure designs publish a temperature range (or just a cold temperature limit) within which the primary barometric altimeter's biases will not compromise the procedure's provided vertical obstacle and terrain protection in the final approach segment (see Figure II-Att B-1). The effects of non-standard temperature biases in the barometric altimeter diminish as the aircraft approaches the runway threshold.

Note 1.— During an RNP APCH or RNP AR APCH operation, the RNP system provides vertical guidance for the final approach segment by using the procedure-defined VPA.

Note 2. — When the aircraft provides VNAV guidance in the final approach segment of an RNP APCH or an RNP AR APCH based on the SBAS sensor's LPV vertical guidance, the LPV vertical guidance is not affected by the effects of non-standard temperatures. The SBAS sensor does not incorporate the aircraft's barometric altimeter output into the SBAS LPV vertical guidance. Refer to Volume II, Part C, Chapter 5, Section B.

1.3 Purpose

This attachment provides guidance to States authorizing operators who are implementing temperature compensation during RNP APCH and RNP AR APCH flight operations, including considerations that a State may use to authorize temperature compensation through the RNP system's automated temperature compensation function. Ultimately, this attachment intends to aid operational authorization for existing aircraft with RNP systems offering this automated function that have an airworthiness approval. An operational authorization for use of the RNP system's automatic temperature compensation function can allow an operator to conduct temperature compensation during RNP APCH and RNP AR APCH operations mitigating the impact of nonstandard temperatures on these operations.

Note.— For additional technical information on the public standards for an RNP system's automated temperature compensation function see RTCA/DO-236C (or latest version) or EUROCAE ED-75 D (or latest version).

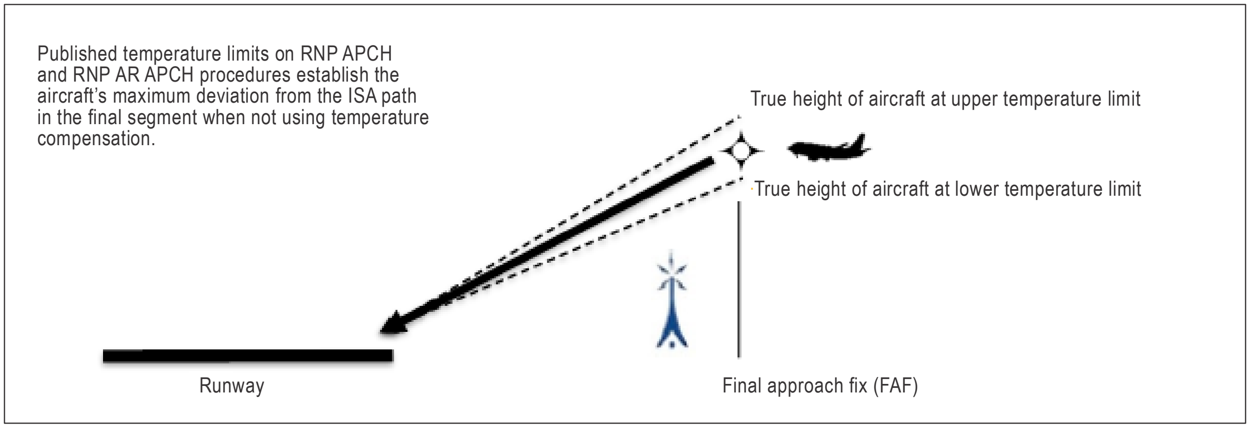


Figure II-Att B-1. Temperature Limits on RNP APCH and RNP AR APCH final approach segments

2. AIR NAVIGATION SERVICES PROVIDER CONSIDERATIONS

2.1 Application of temperature compensation

States are encouraged to publish guidance in the State AIP detailing the means, if any, for application of temperature compensation during RNP APCH and RNP AR APCH instrument procedures and operations.

2.2 Obstacle clearance

Detailed guidance on obstacle clearance for the final approach segment is provided in PANS-OPS (Doc 8168), Volume II: the general criteria in Parts I and III apply. The operational use of temperature compensation can mitigate hazards associated with operations outside any temperature limitations the State publishes on the RNP APCH and RNP AR APCH instrument approach procedures.

3. GENERAL CONSIDERATIONS

3.1 Infrastructure considerations

The procedure design application of temperature limitations and the operational use of temperature compensation does not impose any infrastructure requirements. The criteria in this attachment assume the use of the aircraft's barometric altimeter by an RNP system with an airworthiness approval for an automatic temperature compensation function supporting RNP APCH and RNP AR APCH operations. States offering RNP APCH and RNP AR APCH procedures should take into account the guidance this attachment offers.

3.2 Publication considerations

Charting should follow the Standards of Annex 4 — *Aeronautical Charts* when publishing RNP APCH and RNP AR APCH procedures where the procedure provides a vertical flight path defined by a VPA. The charting of these procedures should specify temperature limitations when applicable, per PANS-OPS.

3.3 State implementation of temperature compensation

3.3.1 States should establish guidance for operational implementation of temperature compensation during instrument approach operations including flight crew responsibility for coordination with ATC. When RNP APCH or RNP AR APCH operations using temperature compensation show coordination problems or flight profiles inconsistent with the ATC clearance or the procedure's intended vertical path, the State must determine the reason and take steps to prevent recurrence.

3.3.2 States should provide guidance in their AIP for the conduct of RNP APCH and RNP AR APCH with charted temperature limitations. This guidance should address the operational application of temperature compensation by flight crews in aircraft with and without an automated temperature compensation function

Note.— States may permit the operational use of manual temperature correction techniques in lieu of use an automated temperature compensation from an aircraft's RNP system. States allowing operators to apply manual temperature compensation techniques should ensure that each operator uses standardized flight crew training and procedures for application of these techniques to minimize the risk of flight crew error.

3.3.3 If the operational authorization to conduct RNP APCH and RNP AR APCH procedures permits the use of the aircraft's automated temperature compensation function, then the authorization should require verifying the airworthiness approval of the function and any associated limitations. Likewise, operational authorization should consider whether the aircraft operator applies the aircraft's original equipment manufacturer (OEM) recommended flight crew procedures for applying automated temperature compensation during instrument approach operation and ensure that the operator provides adequate training on use of automated temperature compensation.

Note.— Some installed RNP systems with an automated temperature compensation function do not offer compensation of temperatures above ISA (hot temperatures). States should consider this during operational authorization.

4. RATIONALE FOR TEMPERATURE COMPENSATION

4.1 General

4.1.1 Non-standard temperatures affect the indications and outputs of the aircraft's barometric altimeter. During cold temperature operations (below ISA), the aircraft's true altitude is lower than that indicated on the altimeter. Similarly, during hot temperature operations (above ISA), the aircraft's true altitude is higher than the altimeter's indicated altitude. This results in an aircraft flying a vertical path angle shallower (for cold temperature) or steeper (for hot temperature) than the procedure design's vertical path.

4.1.2 However, when non-standard temperatures are present, some RNP systems provide an automated temperature compensation function to correct the barometric altitudes the RNP system uses to generate vertical path guidance (that is, VNAV path guidance) and to mitigate the effects of nonstandard temperatures. This results in the aircraft's VNAV guidance better matching the designed vertical path of the RNP APCH or RNP AR APCH procedures.

4.2 Temperatures below ISA

During cold temperatures, the aircraft's actual altitude is lower than the barometric altimeter's indicated altitude. When cold temperatures are extreme (below an instrument procedure's charted low temperature limitation) failing to compensate for the cold temperature effects on the barometric altimeter may compromise the obstacle and/or terrain clearance provided by the procedure design criteria. That is, the aircraft's uncorrected, true altitude can place the aircraft below the procedure design's intended vertical protection. In the FAS, the effects of extreme cold temperatures may compromise the protection that the procedure design's vertical obstacle clearance surface provides.

Note.— The charted temperature limits on an RNP APCH and RNP AR APCH solely address the impacts of non-standard temperatures on the VNAV path in the final approach segment.

4.3 Temperatures above ISA

During hot temperatures, the aircraft's true altitude is higher than the barometric altimeter's indicated altitude. When temperatures are above ISA, the resulting descent may be steeper than normal. When temperatures are above any instrument procedure's charted high temperature limitation, a steeper descent may increase the risk of an unstable approach.

Note.— Operations at higher elevation airports during high temperatures can magnify the effects due to increases in the aircraft's true airspeed. This increases the aircraft's groundspeed and vertical velocity, which may cause difficulty with speed management.

4.4 Aircraft installation of automated temperature compensation

4.4.1 When the aircraft's installed RNP system includes an approved automated temperature compensation function consistent with the public standards in RTCA/DO-236C () or EUROCAE ED-75 D (or latest version), the function may compensate the procedural barometric altitudes of all RNP APCH or RNP AR APCH procedures in the aircraft's onboard navigation database. The flight crew may activate the automated temperature compensation function as the aircraft begins the approach procedure.

Note 1.— Some RNP systems compensate hot and cold temperatures (above and below ISA), while others compensate solely for cold temperatures.

Note 2.— Some RNP systems compensate only the final approach segment, while others provide temperature compensation for the initial, intermediate, final and missed approach segments.

4.4.2 *Aircraft displays during automated temperature compensation.* The installation of an RNP system's automated temperature compensation function requires clear differentiation in display of temperature-compensated barometric altitudes from display of uncompensated barometric altitudes. This enables the flight crew to easily distinguish when an altitude constraint in the RNP system flight plan is a temperature-compensated altitude or an uncompensated altitude.

Note 1.— Some aircraft automatically compensate the final approach segment vertical path without modifying the display of uncompensated barometric altitude constraints.

Note 2.— Some aircraft meet this requirement by simultaneously displaying both the uncompensated barometric altitudes and the temperature-compensated barometric altitudes to the flight crew where each is easily recognized.

Note 3.— Other aircraft meet this requirement by making the uncompensated procedural barometric altitude constraints readily and easily retrievable by the flight crew.

4.4.3 *Flight crew enabling/disabling automated temperature compensation*. An RNP system with an approved automated temperature compensation function should provide a means for the flight crew to easily activate and deactivate temperature compensation. As an example, entering the destination airport's temperature has been one acceptable means of enabling the aircraft's automated temperature compensation function in some aircraft. Should the flight crew desire to disable the function, they simply remove the temperature entry.

4.4.4 *ATC-assigned altitudes at a waypoint.* The aircraft's RNP system allows the flight crew to manually enter a new, ATC-assigned altitude clearance directly in the system's flight plan adjacent to the waypoint identification. When the RNP system's automated temperature compensation function is active, the function does not compensate the manual entry of the ATC-assigned altitude. After the RNP system sequences the waypoint with a manually entered, ATC-assigned, barometric altitude constraint, the RNP system continues temperature compensation of the remaining procedural barometric altitudes at all subsequent waypoints.

4.5 Operational considerations for application of temperature compensation.

Note.— See PANS-OPS, Volume I, Chapter 1 for operational requirements related to temperature corrections.

4.5.1 The flight crew's training and operating procedures should use the destination airport's current temperature when applying temperature compensation during an RNP APCH or an RNP AR APCH.

Note.— Activating the aircraft's automated temperature compensation function may require the flight crew to acquire and insert the airport's current temperature in the RNP system.

4.5.2 The flight crew should not apply temperature compensation to procedural barometric altitudes for standard terminal arrival procedures (STARs) or standard instrument departures (SIDs).

Note.— In most aircraft with an approved automated temperature compensation function, the flight crew can activate or deactivate temperature compensation at any time. The aircraft need not be established on an approach procedure to activate temperature compensation. Flight crews should ensure they do not erroneously apply automated temperature compensation to procedural barometric altitudes of STARs or SIDs.

4.5.3 The flight crew should not apply temperature compensation to an ATC-assigned barometric altitude constraint at waypoint during RNP APCH or RNP AR APCH operations.

Note 1.— Compensating ATC-assigned barometric altitudes may compromise the safe separation ATC provides from nearby aircraft.

Note 2.— An automated temperature compensation function in compliance with RTCA/DO-236C() or EUROCAE ED-75 D() will not apply temperature compensation to ATC-assigned barometric altitudes the flight crew manually enters into the RNP system's flight plan when automated temperature compensation is active.

4.5.4 *Temperature compensation of the procedural minimum descent altitude/descent altitude (MDA/DA).* The MDA/DA is not an ATC-assigned altitude, and this makes it eligible for temperature compensation. However, with the aircraft at a low altitude near the airport when it arrives at the MDA/DA, the impacts of nonstandard temperatures decrease to the point of being operationally negligible.

4.5.5 *Transition level monitoring and indications.* When a waypoint altitude in the RNP system flight plan for an RNP APCH or an RNP AR APCH is above the local transition level and the flight crew activates automated temperature compensation, the RNP system provides the flight crew an alert. However, the flight crew can resolve this situation through coordination with ATC or other means (such as delaying activating automated temperature compensation until the aircraft is below the transition level).

Note.— This operational situation may occur in States or regions where the transition level is below FL 180.

4.5.6 *The altimeter setting is never adjusted to correct for temperature error.* Flight crews should not change the altimeter setting of their barometric altimeter to compensate or correct a procedural barometric altitude. During RNP APCH and RNP AR APCH operations, flight crews should follow their training and procedures to set the aircraft's barometric altimeter to the current, local altimeter setting for the destination airport in accordance with the State's AIP.

4.5.7 *Temperature compensation during QFE operations*. The States and flight crews may apply the guidance in this attachment to the operational use of an RNP system's automated temperature compensation function where the system supports QFE operations.

Note 1 — During QFE operations, the flight crew sets the primary barometric altimeter's subscale pressure setting for the altimeter to indicate height above a specific reference elevation. Typically, the reference elevation is the aerodrome's elevation or the elevation of the landing runway's threshold.

Note 2.— During QFE operations, like QNH operations, RNP APCH or RNP AR APCH still base their minimum instrument flight rules (IFR) altitudes on required obstacle clearance and the flight crew's use of the aircraft's QFE barometric altimeter setting to ensure obstacle clearance. Thus, QFE operations encounter the same effects from nonstandard temperatures and the RNP system's use of barometric altitudes. Flight crews conducting RNP APCH and RNP AR APCH through QFE operations may benefit from the RNP system's application of automated temperature compensation.

Attachment C

SAMPLE AIRSPACE CONCEPTS BASED ON NAVIGATION SPECIFICATIONS

1. OVERVIEW

1.1 This attachment provides sample route spacings achieved under specific conditions and in particular regional or national environments. None of the route spacing values contained herein can be automatically applied in another airspace without a full understanding of the underlying assumptions and validation processes used in the specific route spacing study, which was undertaken to calculate each route spacing result.

1.2 Annex 11 – *Air Traffic Services*, Chapter 2 and the *Procedures for Air Navigation Services – Air Traffic Management* (PANS-ATM, Doc 4444), Chapter 2, have unambiguous requirements for specific safety assessments to be undertaken when implementing airspace changes.

1.3 Some route spacing values are published in ICAO documents such as the appendices of the *Manual on Airspace Planning Methodology for the Determination of Separation Minima* (Doc 9689) and PANS-ATM (Doc 4444).

1.4 More recently, regional studies have been undertaken to determine the minimum spacing value between strategically de-conflicted routeing configurations for terminal airspace concepts using independent surveillance. While the results of some of the studies in this attachment are examples*,* none may be summarily transferred or implemented in a different operating environment without the required implementation safety assessment being undertaken, as per the above introductory caveat.

2. BACKGROUND

2.1 The spacing between ATS routes may be determined, in part, by the navigation performance of the aircraft that is expected to use them, and by the communications and ATS surveillance services that are available to those aircraft. Prior to the widespread use of a global navigation satellite system (GNSS), an aircraft's navigation performance often depended on the NAVAID infrastructure along its route. Navigation performance in oceanic and remote continental areas therefore differed significantly from that in other continental areas and in terminal areas. Route spacing for oceanic and remote continental areas was largely based on the performance of aircraft using inertial navigation systems, whilst the spacing for other continental ATS routes was typically based on the performance of aircraft navigating by VHF omnidirectional radio range (VOR), and considerably influenced by the availability of ATS surveillance.

2.2 While the increased use of GNSS for position determination has significantly changed the previous differences between navigation performance in oceanic and continental en-route airspace, to date, ATS surveillance remains exclusively available in continental airspace where the maximum benefit of the navigation performance (where GNSS provides performance) and independent ATS surveillance availability can be obtained. This is likely to change with the advent of satellite-based surveillance for oceanic and remote continental areas.

Note.— As explained in Volume I, Chapter 3, 3.2.1.4, the availability of ATS surveillance mitigations blunder errors through the controller's ability to detect and correct deviations. As such, smaller spacing between ATS routes is *possible in a radar-controlled environment compared to one which is procedural. Critically, however, it is important when determining route spacing based upon C-N-S, that a GNSS outage (used, for example, for RNP operations and ADS-B) will not cause the loss of both navigation and surveillance services.*

2.3 Over the last few decades, ICAO and regional route spacing studies undertaken primarily for en-route airspace in oceanic, remote-continental, and continental areas, were sometimes published in ICAO documentation. In other instances, the information was not published for global use due to the limited regional applicability of the study.

3. ROUTE SPACING VALUES AND AIRSPACE DESCRIPTIONS

3.1 Route spacing values described in this attachment have mostly been determined using the collision risk model complemented by validations in most instances, the results of which were documented in comprehensive studies. These studies show that the route spacing values have been derived as function of communication, navigation and ATS surveillance as well as ATM system capability, ATC intervention capability, operating procedures, traffic density and route configurations. Notably, navigation performance (as expressed in the performance-based navigation (PBN) specification used for a particular study) is one of the factors determining the minimum route spacing value in a given environment. This explains why, if the same navigation specification is implemented in another operating environment in another part of the world (that is, where the communication, surveillance and, for example, ATM system capability is different) a different route spacing value will inevitably be calculated. Particularly for continental operations, the conditions and criteria can be quite distinct in different operating environments. This is in line with the emphatic introductory text to this attachment.

3.1.1 The most recent generic regional route spacing study was undertaken by EUROCONTROL (2015-2016) for the European Civil Aviation Conference (ECAC) region and is reflected in this attachment. This study is characterised by observed navigation performance, instead of required navigation performance, thereby emphasizing the analysis of empirical data from ATS surveillance systems for track compliance.

3.1.1.1 This study was conducted in an ATS surveillance environment using independent surveillance (radar, without ADS-B) and it investigated the spacing between different route configurations. As with previous studies, these recent studies demonstrated that the availability of independent surveillance enables the spacing between parallel routes to be reduced due to the ATC intervention capability (detection and correction of deviations). When determining route spacing for application in a dependent surveillance environment, the potential loss of both navigation and surveillance services should be considered, such as where ADS-B and a PBN specification requiring GNSS are used.

Note.— For other ATS surveillance means, additional studies would be required for the same operating environments as the hazards could change.

3.1.2 Multiple route spacing studies completed by other authorities in different regions continue to demonstrate that the availability of independent ATS surveillance (specifically radar) with observed navigation performance is what enables spacing between parallel routes or other routing configurations to be reduced due to ATC intervention capability (detection of correction of deviations) using direct VHF controller/pilot voice communications. The route spacing studies in a surveillance environment undertaken to date in the European and North American regions have been based on the availability of direct VHF controller/pilot voice communications and radar as the ATS surveillance system used, that is, cooperative independent surveillance as opposed to dependent surveillance. This is particularly evident in en-route and terminal airspace applications of different route configurations or spacings where the expression 'radar surveillance' is intentionally used so as to prevent the misconception that any surveillance system would yield equivalent results.

3.1.3 When route spacing values have been derived for use in a radar surveillance environment using observed performance, such spacing can never be equal to or less than the prescribed radar separation minima applied in the airspace.

3.2 Regarding airspace terminology, this attachment follows the convention of the previous chapters by using expressions such as en-route continental or remote airspace as well as terminal airspace. Despite widespread use, these terms are quite vague. What is a "remote" operation (as in oceanic and remote operations)? Is the remoteness determined by the absence of human habitation, a hostile natural environment, total reliance on GNSS for navigation or a low density of traffic? Similarly, where does terminal airspace end and en-route begin? There is no line in space where the switch over occurs, even though some FMS manufacturers have chosen a flight level to distinguish one flight phase from the other. Attempts to characterize en-route and terminal airspace using the type of routes in the airspace are not helpful, as both en-route and terminal airspaces can have ATS routes designated as per Annex 11, Appendix 1 or standard instrument departures (SIDs) and standard instrument arrivals (STARs) designated as per Annex 11, Appendix 3 or even permit free routeing. Some SIDs or STARs can extend up to 200 NM from an airport into "en-route" airspace. Characterizing the airspace in terms of the name of the ATC unit providing the service is no easier. In many airports, area controllers (responsible for en-route) often perform an extended approach function, normally considered to be terminal operations. Similarly, some major airports have hybrid area-approach controllers who provide an area or approach service at the undefined, but extremely busy, interface between en-route and terminal. Many major airports have this hybrid function: flow management would be impossible without it.

3.2.1 This dilemma is reflected in the route spacing examples contained in this attachment (some en-route examples actually required aircraft to be RNP 1 qualified with RF required) and RF is a departure/arrival functionality and not one associated with ATS routes. The study envisaged the previously referred to hybrid type airspace of extended terminal/en-route operations.

3.2.2 Both above dilemmas notwithstanding, what is unambiguous is that the ATS surveillance separation minima permitted for terminal operations is smaller than that in en-route operations (for example, 3 NM and 5 NM respectively when using radar surveillance). Given that many of the route spacing studies cited below were undertaken for operations in an ATS surveillance environment, which is highly beneficial to the resultant route spacing as suggested in 3.1.2, the relationship between radar separation minima and route spacing cannot be overlooked.

3.2.3 When route spacing values have been derived for use in a radar surveillance environment using observed navigation performance, such spacing values can never be equal to or less than the prescribed radar separation minima applied in the airspace, be that airspace en-route or terminal or remote continental. If 5 NM radar separation minima is used in an en-route environment, the applied route spacing cannot be equal to or less than 5 NM. Generic European validation studies have shown that, in such instances, the minimum spacing used tends to be between 6 and 8 NM. Similarly, for the terminal airspace where a 3 NM radar separation is used, studies have shown that, in such instances, the minimum spacing used is between 4 and 5 NM. In many cases, human factors, controller perception, screen resolution and sector size have influenced the spacing that controllers consider acceptable. At times, the acceptable spacing applied is significantly larger than the separation minima.

4. OCEANIC AND REMOTE CONTINENTAL AIRSPACE

4.1 Although route spacings for oceanic and remote continental have become performance-based communication and surveillance (PBCS) applications and have their minima published in PANS-ATM, Chapter 5, several lateral route spacings are used without PBCS requirement.

4.2 The following table is an extract of PANS-ATM, (Doc 4444) Chapter 5, Table 5-2, and shows examples of the CNS requirements for all oceanic or remote continental lateral spacing.

Minimum Spacing Between Tracks		*Performance Requirements*			*Additional Requirements*
Airspace where SLOP is not authorized, or is only authorized up to 0.5 NM	*Airspace where SLOP up to 2 NM is authorized*	*Navigation*	*Communication*	*Surveillance*	
93 km (50 NM)	93 km (50 NM)	RNAV 10 (RNP 10) RNP 4 RNP 2	Types of communication other than direct controller-pilot VHF voice		
37 km (20 NM)	42.6 km (23 NM)	RNP 4 RNP 2	RCP 240	RSP 180	Conformance monitoring shall be ensured by establishing an ADS-C event contract specifying a lateral deviation change event with a maximum of 5 NM threshold and a waypoint change event
37 km (20 NM)	42.6 km (23 NM)	RNP 2 or GNSS equipage	Types of communication other than direct controller-pilot VHF voice		While one aircraft climbs/descends through the level of another aircraft remaining in level flight
27.8 km (15 NM)	33.4 km (18 NM)	RNP 2 or GNSS equipage	Direct controller-pilot VHF voice communications		
16.7 km (9 NM)	22.3 km (12 NM)	RNP 4 RNP 2	RCP 240	RSP 180	While one aircraft climbs/descends through the level of another aircraft remaining in level flight
13 km (7 NM)	19 km (10 NM)	RNP 2 or GNSS equipage	Direct controller-pilot VHF voice communications		While one aircraft climbs/descends through the level of another aircraft remaining in level flight

Note.— Guidance material for the implementation of communication and surveillance capability supporting the lateral separation minima above is contained in the Performance-based Communication and Surveillance (PBCS) Manual *(Doc 9869) and the* Global Operational Data Link (GOLD) Manual *(Doc 10037).*

5. EN-ROUTE CONTINENTAL AIRSPACE

Various spacings are used in en-route continental airspace. They vary with the availability of ATS surveillance and with traffic characteristics as explained in 3.1.

5.1 Route spacing 16.5 NM or 18 NM without surveillance

Route spacing of 16.5 NM for straight unidirectional tracks and 18 NM route spacing for straight bidirectional tracks have been derived by comparison to a high-density continental reference system (VOR spacing) described in Annex 11, Attachment A.

Minimum air traffic services requirements

NAV – RNAV 5. The NAVAID infrastructure must be sufficient to support RNAV 5 operations.

COM – Direct VHF controller/pilot voice communications.

SUR – Procedural pilot position reports.

Note.— These route spacing values were determined using a comparative method. A comparison was made between the acceptable spacing between VOR prescribed routes and RNAV 5, which, when implemented, was enabled primarily by VOR/DME navigation.

5.2 Route spacing 16.5 NM or 18 NM with surveillance

Route spacing of 16.5 NM for straight unidirectional tracks operated with radar surveillance and 18 NM route spacing for straight bidirectional tracks operated with radar surveillance have been derived for European continental airspace by comparison to a reference system (VOR spacing) described in Annex 11, Attachment A.

Minimum air traffic services requirements

NAV – All aircraft need an RNAV 5 operational authorization valid for the routes or tracks to be flown, and the NAVAID infrastructure must be sufficient to support RNAV 5 operations.

COM – Direct VHF controller/pilot voice communications.

SUR – With radar surveillance.

Note 1.— This spacing is not applicable to remote or oceanic airspaces, which lack VOR infrastructure.

Note 2.— For general ECAC application, spacing of 16.5 NM for same-direction routes and 18 NM for opposite-direction routes was shown to produce an acceptable intervention rate. Moreover, route spacing could be safely reduced to as little as 10 NM, provided the resultant intervention rate was considered acceptable.

Note 3.— Here again, a comparative method was used as per the note in 5.1. The basis of the safety argument was that as 16.5/18 NM could be applied for RNAV 5 without ATS surveillance based on VOR/DME in medium density airspace, the same minima could be used in an area with extensive radar surveillance.

5.3 Route spacing 8 NM

Route spacing of 8 NM for straight tracks in a high-density continental en-route system using radar surveillance has been derived by independent collision risk analyses undertaken separately by the Federal Aviation Administration (FAA).

Minimum air traffic services requirements

NAV – All aircraft need an RNAV 2 operational authorization valid for the routes or tracks to be flown, and the NAVAID infrastructure must be sufficient to support RNAV 2 operations.

COM – Direct VHF controller/pilot voice communications.

SUR – Radar surveillance.

DATA – Observed navigation performance.

5.4 Route Spacing 7 NM

Route spacing of 7 NM for straight and turning tracks (with turns not exceeding 90 degrees) in a high-density continental en-route system, using radar surveillance, has been derived by independent collision risk analyses undertaken by EUROCONTROL.

Minimum air traffic services requirements

NAV – All aircraft need an RNP 1 operational authorization (that is, with a navigation accuracy of at least 1 NM either side of track 95 per cent of the flight time) valid for the routes or tracks to be flown, and the NAVAID infrastructure must be sufficient to support RNP 1 operations.

COM – Direct VHF controller/pilot voice communications.

SUR – Radar surveillance.

DATA – Specific observed navigation performance data set (1984) that is characterized by aircraft of the 1960 to 1970s generation.

5.5 Various route spacing values

Various route spacing for straight and turning tracks (with turns not exceeding 35 degrees), using radar surveillance, has been derived by NATS using a Loss of Separation Risk Model as validated using the collision risk analysis by the United Kingdom Civil Aviation Authority (CAA). Observed navigation performance was obtained from a dedicated High Level High Speed trial conducted in 2016.

5.5.1 *Minimum air traffic services requirements*

NAV – All aircraft need an RNAV 1 operational authorization (with a navigation accuracy of at least 1 NM either side of track 95 per cent of the flight time) valid for the routes or tracks to be flown, and the NAVAID infrastructure must be sufficient to support such operations.

COM – Direct VHF controller/pilot voice communications.

SUR – Integrated and multiple radar surveillance; 3 NM or 5 NM radar separation minima that is, minimum radar separation+.

DATA – Observed navigation performance, United Kingdom (2015 to 2016).

5.5.1.1 *Key point.* Various routeing scenarios were examined based on intended implementation in the United Kingdom. This study validated that the terminal airspace straight light performance and limited turns can be extended to the high level and high speed flight.

6. TERMINAL AIRSPACE

6.1 Overview

6.1.1 Several spacings can be used in terminal airspace. They vary with the availability of ATS surveillance and with traffic characteristics particularly when observed navigation performance is used based on a high performance fleet.

6.1.2 Route spacing studies repeatedly demonstrate that the availability of ATS Surveillance (specifically radar), enable spacing between parallel routes to be reduced due to ATC intervention capability (detection of correction of deviations).

6.1.2.1 Route spacing studies in a surveillance undertaken to date in the European and North American Regions have been exclusively focussed on radar as the surveillance system used, that is, cooperative independent surveillance as opposed to dependent surveillance. The studies repeatedly demonstrated that the availability of ATS surveillance (specifically radar) enabled spacing between parallel routes to be reduced due to ATC intervention capability (detection of correction of deviations). This was particularly evident in en-route and terminal airspace applications of route spacings determined in a radar environment. The expression “radar surveillance” is intentionally used to prevent the misconception that any surveillance system would yield equivalent results.

6.1.2.2 It is specifically noted that when route spacings have been derived for use in a radar surveillance environment, such spacing can never be equal to or less than the prescribed radar separation minima applied in the airspace. Thus, in an approach radar environment where 3 NM radar separation minima is used, the route spacing could not be equal to or less than 3 NM. European validation studies have shown that, in such instances, the minimum spacing used tends to be 5 NM.

6.2 Route spacing 8 NM

Route spacing of 8 NM for straight tracks in high-density terminal areas using radar surveillance has been derived by a collision risk analysis undertaken by EUROCONTROL.

Minimum air traffic services requirements

NAV – All aircraft need an RNAV 1 operational authorization valid for the routes or tracks to be flown, and the NAVAID infrastructure must be sufficient to support RNAV 1 operations.

COM – Direct VHF controller/pilot voice communications.

SUR – Radar surveillance.

DATA – Specific observed navigation performance data set (1984) that is characterized by aircraft of the 1960 to 1970s generation not GNSS equipped.

6.3 Route spacing 5 NM

Various route spacing for straight and turning tracks (with turns not exceeding 90 degrees) in a high-density continental en-route system, using radar surveillance, has been derived by independent collision risk analyses undertaken by EUROCONTROL in 2016. Observed navigation performance from 2015 to 2016 was used. The navigation performance data was derived from aircraft flying departure and arrival procedures in extended terminal operations. When applying this study in an operational environment including the required safety studies, the practical route spacing applied is in the order of 5 NM.

6.3.1 *Minimum air traffic services requirements*

NAV – All aircraft need an RNAV 1 operational authorization valid for the routes or tracks to be flown, and the NAVAID infrastructure must be sufficient to support such operations.

COM – Direct VHF controller/pilot voice communications.

SUR – Integrated and multiple radar surveillance; 3 NM radar separation minima.

DATA – Observed navigation performance, France, Netherlands and the United Kingdom (2015 to 2016), that is characterized by aircraft from the 1990 to 2010s generation 90 per cent of which were equipped with GNSS.

6.3.2 *Key point.* The EUROCONTROL study was generic in nature, made available to ECAC member States as a starting point to further implement safety analysis on a case-by-case basis.

6.3.3 *Key point.* The EUROCONTROL study concluded that a small minimum spacing between routes in various configurations could be used, given the precision of the observed navigation performance. However, as the findings were intended for potential application in terminal operations where a radar separation minima of 3 NM is used, the minimum usable spacing is likely to be in the order of 5 NM, which is more of a function of the display resolution, sector size and human factors.

6.4 Route spacing 4 to 5 NM

Various route spacing for straight and turning tracks (with turns not exceeding 90 degrees) in a high-density continental en-route system, using Radar surveillance, has been derived by independent collision risk analyses undertaken by EUROCONTROL in 2016. Observed navigation performance from 2015/2016 was used. A distinction was made in the analysis between high (above 350kts) and low (below 350 kts) groundspeeds, representing applications in the lower as well as the extended TMA. Spacing values were also presented for specific route configurations, such as converging routes with turns using both RF and fly-by turn performance.

6.4.1 *Minimum air traffic services requirements*

NAV – All aircraft need an RNAV 1 operational authorization valid for the routes or tracks to be flown, and the NAVAID infrastructure must be sufficient to support such operations.

Note.— For route configurations requiring RF, all aircraft need an RNP 1 operational authorization valid for the routes or tracks to be flown and the NAVAID infrastructure must be sufficient to support such operations.

COM – Direct VHF controller/pilot voice communications.

SUR – Integrated and multiple radar surveillance; 3 NM radar separation minima.

DATA – Observed navigation performance, France, Netherlands and the United Kingdom (2015 to 2016).

6.4.2 *Key point.* The EUROCONTROL study was generic in nature, made available to ECAC member States as a starting point to further implement safety analysis on a case-by-case basis.

6.4.3 *Key point.* The EUROCONTROL study concluded that a small minimum spacing between routes in various configurations could be used, given the precision of the observed navigation performance. However, as the findings were intended for potential application in en-route operations where a radar separation minima of 3 NM is used, the minimum usable spacing is likely to be between 4 to 5 NM, which is more of a function of the display resolution, sector size and human factors.

6.5 Various route spacing values

Various route spacing for straight and turning tracks in a high-density continental terminal system, using radar surveillance, has been derived by NATS (United Kingdom) using a Loss of Separation Model as validated using the collision risk analysis by the United Kingdom Civil Aviation Authority. Observed navigation performance from trials conducted in the London Terminal Area during 2015 to 2016 was used.

6.5.1 *Minimum air traffic services requirements*

NAV – All aircraft need an RNAV 1 operational authorization (with a navigation accuracy of at least 1 NM either side of track 95 per cent of the flight time) valid for the routes or tracks to be flown, and the NAVAID infrastructure must be sufficient to support such operations.

COM – Direct VHF controller/pilot voice communications.

SUR – Integrated and multiple radar surveillance; 3 NM radar separation minima.

DATA – Observed navigation performance, United Kingdom (2015 to 2016), which is characterized by aircraft of the 1990 to 2010s generation 90 per cent of which was equipped with GNSS.

6.5.2 *Key point.* Various routeing scenarios were examined based on intended implementation in the United Kingdom.

Attachment D

MAGNETIC VARIATION

1. INTRODUCTION

1.1 Background

1.1.1 Aircraft navigate using a blend of true and magnetic references. The area navigation systems on the aircraft perform their calculations based on true references but require the ability to navigate in both true and magnetic reference frames because, most charts, runways, facility references and ground-based NAVAIDS use magnetic references. In addition, instrument approach procedures, charts and airports use magnetic references. All of these elements (airborne, ground and flight procedures) may differ, creating issues for the flight crew and in operations.

1.1.2 Excessive differences in the MagVar used by aircraft systems, what is designated for or associated with ground NAVAIDS and what is specified in routes and procedures can result in unacceptable aircraft lateral guidance performance, misleading information to the crew and/or an unsafe condition. There is no simple means of reconciling all elements for magnetic variation since they reside in different media and systems subject to a wide variety of processes and means for specifying and changing the MagVar information; examples of the variety are as follows:

a) aircraft area navigation systems, FGSs, navigation sensors, navigation databases and manufacturer documentation; and

b) State/service provider specifications and processes for managing, checking and publishing MagVar information (such as airport diagrams, charts, etc.) and MagVar models.

1.2 Purpose

1.2.1 This attachment provides information to States implementing instrument flight procedures (IFPs) where magnetic variation is an element of the routes and procedures stored in onboard navigation databases used by the RNAV and RNP system. This specification is intended to facilitate the operational application of RNAV and RNP systems that have demonstrated their capabilities and obtained regulatory authorization for usage.

1.2.2 This specification provides information and requirements in support of airworthiness and operational criteria for the authorization of an RNAV and RNP system where magnetic variation is an element of its path definition.

2. IMPLEMENTATION CONSIDERATIONS

MagVar data should be kept current to minimize path definition errors in support of the navigation system and in recognition of how it will be used as described herein.

3. AIRCRAFT SYSTEM REQUIREMENTS

3.1 *MagVar effects on RNP and RNAV system path definition.* RNAV systems use MagVar data contained in onboard navigation databases. Some terminal area procedures are designed with magnetic course-based leg types, which require a magnetic variation to compute repeatable tracks over the ground. When MagVar data relative to a specific leg is provided in the navigation database, most RNP and RNAV systems will utilize it to compute the true ground track. Others use an internal model of magnetic variation. The navigation database containing magnetic variation information originates from the States.

3.2 The navigation database MagVar data elements are based on the route or procedure type. For RNP and RNAV, the data is used in one fashion; for ILS, it is something different; for VHF omnidirectional radio range (VOR) and non-directional beacons it is something different again (see *Procedures for Air Navigation Services – Aircraft Operations*, Volume II – *Construction of Visual and Instrument Flight Procedures* (PANS-OPS, Doc 8168), Part I, Section 2, Chapter 1, Section 1.13.1.1).

3.3 For RNP and RNAV terminal procedures, the navigation database MagVar data is the airport's MagVar (reflected in the State's AIP).

3.4 To ensure consistency with the MagVar for defining the path to be flown and for the information presented to the flight crew, the source of the magnetic variation used for path definition computations for magnetic referenced flight path legs (such as CF, FA, and HA/high frequency/holding to manual termination (HM) legs) must be in accordance with the following:

a) if the leg is part of a database terminal area procedure, then the magnetic variation to be used is the value specified for that procedure;

b) if the leg is part of a terminal area procedure from the database and the magnetic variation for the procedure is not specified, then the magnetic variation must be either the magnetic variation of record for the airport or the recommended VHF NAVAID magnetic declination of the leg if specified;

c) if the leg is not part of a procedure and the terminating fix is a VOR, then the magnetic variation to be used is the station declination for the VOR; and

d) if the leg is not part of a procedure and the terminating fix is not a VOR, then the magnetic variation to be used must be defined by the system using an internal model.

3.5 The navigation system should also have the capability of assigning a magnetic variation at any location within the region that flight operations may be conducted using a Magnetic North reference. For locations with a magnitude of the local magnetic main field inclination of less than 72 degrees, the assigned magnetic variation used for path definition should be within two degrees of the value determined at the same location and time by an internationally recognized magnetic model that is valid for the time of computation (such as USGS, IGRF). Harmonizing magnetic variation tables with other airborne equipment should be considered, such as inertial navigation systems, such that a consistent display of magnetic bearings is presented in the aircraft cockpit.

3.6 It is expected that aircraft continuing airworthiness data will include the conditions under which the magnetic variation data, and if applicable, conversion algorithms or hardware, must be updated, as well as other software configuration controllable schemes for managing and maintaining magnetic variation data. The aircraft flight manual or other manufacturer documentation are typical examples of where operational capabilities, procedures and/or limitations will be specified.

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Attachment E

DOCUMENT REFERENCES FOR NAVIGATION SPECIFICATIONS

The following table lists the applicable version for the airworthiness approval guidance material, system/equipment standards, equipment installation, etc. referenced in the navigation specifications (such as installed equipment references to ETSO-C146() = ETSO-C146e, or later version on the associated website). Organizations or agencies, as well as websites for the references are also included. Table Att E-1 is not a comprehensive list of all States or agencies who may have issued their own equivalent regulatory guidance for performance-based navigation (PBN).

Table Att E-1. Applicable version for standards, regulatory rules and documents referenced in navigation specifications

Organization	*Reference and version*	*Title*
	Regulation and Guidance Material	
FAA	14 CFR Part 121 Appendix G	Doppler Radar and Inertial Navigation System (INS): Request for Evaluation; Equipment and Equipment Installation; Training Program; Equipment Accuracy and Reliability; Evaluation Program
FAA	14 CFR Part 121, Subpart K, Section 121.351(c)	Communication and navigation equipment for extended over-water operations and for certain other operations
EU	EU 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
EU	EU 2017/373	Laying down common requirements for providers of air traffic management/air navigation services and other air traffic management network functions and their oversight
FAA	Order 8900.1	Flight Standards Information Management System
	Industry Standards	
ARINC	ARINC 424	Navigation System Data Base Standard
RTCA	DO-200B	Standards for Processing Aeronautical Data
RTCA	DO-201B	User Requirements for Navigation Data
RTCA	DO-229D	Minimum Operational Performance Standard for Global Positioning System/Wide Area Augmentation System Airborne Equipment
RTCA	DO-236C	Minimum Aviation System Performance Standards: Required Navigation Performance for Area Navigation

Organization	*Reference and version*	*Title*
RTCA	DO-283B	Minimum Operational Performance Standards for Required Navigation Performance for Area Navigation
EUROCAE	ED-75D	Minimum Aviation System Performance Specification Required Navigation Performance for Area Navigation
EUROCAE	ED-76A	Standards for Processing Aeronautical Data
EUROCAE	ED-77A	User Requirements for Navigation Data
	Airworthiness Approval	
FAA	AC20-138D	Airworthiness Approval of Positioning and Navigation Systems
FAA	AC20-153B	Acceptance of Aeronautical Data Date: 4/19/16 AC No: 20-153B Processes and Associated Databases
EASA	CS-ACNS	Certification Specifications and Acceptable Means of Compliance for Airborne Communications, Navigation and Surveillance
	Operational authorization	
FAA	AC 90-100A	U.S Terminal and En Route Area Navigation (RNAV) Operations
FAA	AC 90-101A	Approval Guidance for Required Navigation Performance (RNP) Procedures with Authorization Required (AR)
FAA	AC 90-105A	Approval Guidance for RNP Operations and Barometric Vertical Navigation in the U.S. National Airspace System and in Oceanic and Remote Continental Airspace
	Equipment approval	
EASA	ETSO-C115d	Required Navigation Performance (RNP) Equipment using Multi-Sensor Inputs
EASA	ETSO-C145e	Airborne Navigation Sensors Using the Global Positioning System Augmented by the Satellite Based Augmentation System
EASA	ETSO-C146e	Stand-Alone Airborne Navigation Equipment Using the Global Positioning System Augmented by the Satellite Based Augmentation System
FAA	TSO-C66c	Distance Measuring Equipment (DME) Operating Within the Radio Frequency Range of 960-1215 Megahertz
FAA	TSO-C115d	Required Navigation Performance (RNP) Equipment Using Multi-Sensor Inputs
FAA	TSO-C145e	Airborne Navigation Sensors Using the Global Positioning System (GPS) Augmented by the Satellite-Based Augmentation System (SBAS)

Organization	*Reference and version*	*Title*
FAA	TSO-C146e	Stand-Alone Airborne Navigation Sensors Using the Global Positioning System (GPS) Augmented by the Satellite-Based Augmentation System (SBAS)
FAA	TSO-C196b	Airborne Supplemental Navigation Sensors for Global Positioning System Equipment using Aircraft-Based Augmentation *Note.— TSO-C196() cancels TSO-C129a()*

DOCUMENT AVAILABILITY

ICAO documents may be purchased from the International Civil Aviation Organization, Customer Services Unit, 999 Robert-Bourassa Boulevard, Montréal, Quebec, Canada H3C 5H7, (Fax: +1 514 954 6769, or email: sales@icao.int) or through sales agents listed on the ICAO website: www.icao.int.

Copies of ARINC documents may be obtained from ARINC Industry Activities, A Program of SAE ITC. Website: https://www.aviation-ia.com/product-categories.

Copies of EASA documents may be obtained from EASA (European Union Aviation Safety Agency Website: .

Copies of EUROCAE documents may be purchased from EUROCAE through: www.eurocae.net.

Copies of EUROCONTROL documents may be requested directly from EUROCONTROL at www.eurocontrol.int.

Copies of FAA documents may be obtained from Superintendent of Documents, Government Printing Office, Washington, DC 20402-9325, USA, or through the FAA website: www.faa.gov (Regulatory and Guidance Library)

Copies of RTCA documents may be obtained through: www.rtca.org

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