Doc 9613
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Performance-based Navigation (PBN) Manual

Approved by the Secretary General
and published under his authority

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AMENDMENTS

Amendments are announced in the supplements to the *Catalogue of ICAO Publications;* 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

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VOLUME I

CONCEPT AND IMPLEMENTATION GUIDANCE

EXECUTIVE SUMMARY

Background

The continuing growth of aviation increases demands on airspace capacity therefore emphasizing the need for optimum utilization of available airspace. Improved operational efficiency derived from the application of area navigation (RNAV) techniques has resulted in the development of navigation applications in various regions worldwide and for all phases of flight. These applications could potentially be expanded to provide guidance for ground movement operations.

Requirements for navigation applications on specific routes or within a specific airspace must be defined in a clear and concise manner. This is to ensure that the flight crew and the air traffic controllers (ATCs) are aware of the on-board RNAV system capabilities in order to determine if the performance of the RNAV system is appropriate for the specific airspace requirements.

RNAV systems evolved in a manner similar to conventional ground-based routes and procedures. A specific RNAV system was identified and its performance was evaluated through a combination of analysis and flight testing. For domestic operations, the initial systems used very high frequency omnidirectional radio range (VOR) and distance measuring equipment (DME) for estimating their position; for oceanic operations, inertial navigation systems (INS) were employed. These “new” systems were developed, evaluated and certified. Airspace and obstacle clearance criteria were developed based on the performance of available equipment; and specifications for requirements were based on available capabilities. In some cases, it was necessary to identify the individual models of equipment that could be operated within the airspace concerned. Such prescriptive requirements resulted in delays to the introduction of new RNAV system capabilities and higher costs for maintaining appropriate certification. To avoid such prescriptive specifications of requirements, this manual introduces an alternative method for defining equipage requirements by specifying the performance requirements. This is termed performance-based navigation (PBN).

Performance-based navigation (PBN)

The PBN concept specifies that aircraft RNAV system performance requirements be defined in terms of the accuracy, integrity, availability, continuity and functionality, which are needed for the proposed operations in the context of a particular airspace concept. The PBN concept represents a shift from sensor-based to performance-based navigation. 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 at a sufficient level of detail to facilitate global harmonization by providing specific implementation guidance for States and operators.

Under PBN, generic navigation requirements are defined based on operational requirements. Operators then evaluate options in respect of available technology and navigation services, which could allow the requirements to be met. An operator thereby has the opportunity to select a more cost-effective option, rather than a solution being imposed as part of the operational requirements. Technology can evolve over time without requiring the operation itself to be reviewed, as long as the expected performance is provided by the RNAV system. As part of the future work of ICAO, it is anticipated that other means for meeting the requirements of the navigation specifications will be evaluated and may be included in the applicable navigation specifications, as appropriate.

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

a) reduces the need to maintain sensor-specific routes and procedures, and their associated costs;

b) avoids the need for developing sensor-specific operations with each new evolution of navigation systems, which would be cost-prohibitive;

c) allows for more efficient use of airspace (route placement, fuel efficiency and noise abatement);

d) clarifies how RNAV systems are used; and

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

Within an airspace concept, PBN requirements will be affected by the communication, surveillance and ATM environments, the navaid infrastructure, and the functional and operational capabilities needed to meet the ATM application. PBN performance requirements also depend on what reversionary, non-RNAV means of navigation are available and what degree of redundancy is required to ensure adequate continuity of functions.

During development of the performance-based navigation concept, it was recognized that advanced aircraft RNAV systems are achieving a predictable level of navigation performance accuracy which, together with an appropriate level of functionality, allows for more efficient use of available airspace. It also takes account of the fact that RNAV systems have developed over a 40-year period and as a result there are a large variety of systems already implemented. PBN primarily identifies navigation requirements irrespective of the means by which these are met.

Purpose and scope

This manual identifies the relationship between RNAV and RNP applications and the advantages and limitations of choosing one or the other as the navigation requirement for an airspace concept. It also aims at providing practical guidance to States, air navigation service providers and airspace users on how to implement RNAV and RNP applications, and how to ensure that the performance requirements are appropriate for the planned application.

Recognizing that there are many airspace structures based on existing RNAV applications, and conscious of the high cost to operators in meeting different certification and operational approval requirements for each application, this manual supports those responsible for assessing whether an application can use an existing navigation specification for implementation. The primary aim is to provide guidance in the identification of whether, by a suitable adjustment of the airspace concept, navigation application and/or infrastructure, it is possible to make use of an existing navigation specification, thereby obviating the need for a specific and potentially costly imposition of a new certification requirement for operation in an individual airspace.

Where analysis identifies that a new standard is needed, the manual identifies the steps required for the establishment of such a new standard. It identifies a means by which, through the auspices of ICAO, unnecessary proliferation of standards can be avoided.

Performance-based navigation (PBN) terminology

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

A navigation specification is a set of aircraft and aircrew requirements needed to support a navigation application within a defined airspace concept. The navigation specification defines the performance required by the RNAV 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 specification. One not having such requirements is referred to as an RNAV specification. An area navigation system capable of achieving the performance requirement of an RNP 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-related expressions could create some complexities. States and international organizations should take particular note of the Explanation of Terms and to Chapter 1, Part A, of Volume I of this manual.

Because specific performance requirements are defined for each navigation specification, an aircraft approved for a RNP specification is not automatically approved for all RNAV specifications. Similarly, an aircraft approved for an RNP or RNAV specification having stringent accuracy requirements (e.g. RNP 0.3 specification) is not automatically approved for a navigation specification having a less stringent accuracy requirement (e.g. RNP 4).

Transition strategies

Transition to PBN

It is expected that all future RNAV applications will identify the navigation requirements through the use of performance specifications rather than defining equipage of specific navigation sensors.

Where operations exist that were defined prior to the publication of this manual, a transition to PBN may not necessarily be undertaken. However, where revisions to the functional and operational requirements are made, the development and publication of the revised specifications should use the process and description established in this manual.

Transition to RNP specifications

As a result of decisions made in the industry in the 1990s, most modern RNAV systems provide on-board performance monitoring and alerting, therefore the navigation specifications developed for use by these systems can be designated as RNP.

Many RNAV systems, while offering very high accuracy and possessing many of the functions provided by RNP systems, are not able to provide assurance of their performance. Recognizing this, and to avoid operators incurring unnecessary expense, where the airspace requirement does not necessitate the use of an RNP system, many new as well as existing navigation requirements will continue to specify RNAV rather than RNP systems. It is therefore expected that RNAV and RNP operations will co-exist for many years.

However, RNP systems provide improvements on the integrity of operation permitting, inter alia, possibly closer route spacing, and can provide sufficient integrity to allow only the RNP systems to be used for navigating in a specific airspace. The use of RNP systems may therefore offer significant safety, operational and efficiency benefits. While RNAV and RNP applications will co-exist for a number of years, it is expected that there will be a gradual transition to RNP applications as the proportion of aircraft equipped with RNP systems increases and the cost of transition reduces.

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PART B — IMPLEMENTATION GUIDANCE

ATTACHMENTS TO VOLUME I

FOREWORD

This manual consists of two volumes:

Volume I — *Concept and Implementation Guidance*

Volume II — *Implementing RNAV and RNP*

Organization and contents of Volume I:

Part A — *The Performance-based Navigation (PBN) Concept,* contains three chapters:

Chapter 1 — *Description of Performance-based Navigation,* explains the PBN concept and specifically emphasizes the designation of navigation specifications as well as the distinction between RNAV and RNP specifications. This chapter provides the foundation for this manual.

Chapter 2 — *Concepts of Operation,* provides a context to PBN and explains that it does not exist in isolation but rather as an integral component of an airspace concept. This chapter also clarifies that PBN is one of the CNS/ATM enablers in an airspace concept.

Chapter 3 — *Stakeholders' Uses of Performance-based Navigation,* 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.

Part B — *Implementation Guidance,* contains five chapters based on three processes aimed at providing practical guidance for the implementation of PBN:

Chapter 1 — *Introduction to Implementation Processes,* provides an overview of the three implementation processes with a view to encouraging the use of existing navigation specifications when implementing PBN.

Chapter 2 — *Process 1: Determine Requirements,* outlines steps for a State or region to determine its strategic and operational requirements for performance-based navigation through development of an airspace concept.

Chapter 3 — *Process 2: Identifying an ICAO Navigation Specification for Implementation,* explains how, once the navigation requirements are identified, attempts should be made to use an existing navigation specification to satisfy the requirements identified.

Chapter 4 — *Process 3: Planning and Implementation,* provides guidance on activities and tasks to be undertaken in order to enable operational implementation.

Chapter 5 — *Guidelines for Development of a New Navigation Specification,* outlines how a State or region should progress if it becomes impossible to satisfy an airspace concept using an existing navigation specification.

Attachments to Volume I

Attachment A — Area Navigation (RNAV) Systems, provides an explanation of RNAV 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.

Specific remarks

This volume, to a large extent, is based on the experiences of States which have used RNAV operations. The PBN concept described in Volume I is a notable exception, as it is new and should be viewed as more than just a remodelling or an extension of the RNP concept — see Part A, 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.*

Attention is drawn to the fact that expressions such as RNP type and RNP value that were associated with the RNP concept (as referred to in Doc 9613, Second Edition, formerly titled *Manual on Required Navigation Performance (RNP)*) are not used under the PBN concept and are to be deleted in all ICAO material.

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. The RGCSP, in 1990, 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 accuracy 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 communication, surveillance and ATM environment. It was also due to practical considerations stemming from the gradual development of RNAV capability together with the need to derive early benefits from the installed equipment. This resulted in different specifications of navigation capability with common navigation accuracy. It was noted that such developments were unlikely to cease as vertical (3D) navigation and time (4D) navigation evolved and was subsequently applied by ATM to increase airspace capacity and efficiency.

The above considerations have presented significant difficulties to those organizations responsible for the early implementation of RNAV operations in continental airspace. In solving these, significant confusion has developed regarding concepts, terminology and definitions. Consequently, a divergence of implementation resulted in a lack of harmonization between RNP applications.

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 area navigation (RNAV) system functionality and applications and developed the PBN concept, which will allow global harmonization of existing implementations and create a basis for harmonizing of future operations.

While this manual provides the information on the consensus achieved on 2D and approach RNAV applications, the experience of RNP to date leads to the conclusion that as 3D and 4D applications are developed, there will be a need to review the impact of such developments on the performance-based navigation concept and to update this manual accordingly.

This manual supersedes the manual on *Required Navigation Performance (RNP)* (Doc 9613, Second Edition). Consequently, this affects a number of ICAO documents, including:

Annex 11 — *Air Traffic Services*

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

Procedures for Air Navigation Services — Aircraft Operations, Volumes I and II (PANS-OPS) (Doc 8168)

Regional Supplementary Procedures (Doc 7030)

Air Traffic Services Planning Manual (Doc 9426)

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

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 University Street
Montréal, Quebec, Canada H3C 5H7

REFERENCES

Note.— Documents referenced in this manual are affected by performance-based navigation.

ICAO documents

Annex 4 — *Aeronautical Charts*

Annex 6 — *Operation of Aircraft,* Part I — *International Commercial Air Transport — Aeroplanes*

Annex 6 — *Operation of Aircraft,* 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*

Annex 17 — *Security*

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

Procedures for Air Navigation Services — Aircraft Operations, Volumes I and II *(PANS-OPS)* (Doc 8168)

Regional Supplementary Procedures (Doc 7030)

Air Traffic Services Planning Manual (Doc 9426)

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

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

Manual on Testing of Radio Navigation Aids (Doc 8071)

Safety Management Manual (SMM) (Doc 9859)

Circular 311 (Draft), First Edition, *Assessment of ADS-B to Support Air Traffic Services and Guidelines for Implementation*

European Organisation for Civil Aviation Equipment (EUROCAE) documents

Minimum Operational Performance Specifications for Airborne GPS Receiving Equipment used for Supplemental Means of Navigation (ED-72A*)*

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

Standards for Processing Aeronautical Data (ED-76)

Standards for Aeronautical Information (ED-77)

RTCA, Inc. documents

Standards for Processing Aeronautical Data (DO-200A)

Standards for Aeronautical Information (DO-201A)

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-236B)

Aeronautical Radio, Inc. (ARINC) 424 documents

ARINC 424-15 Navigation System Database Specification
ARINC 424-16 Navigation System Database Specification
ARINC 424-17 Navigation System Database Specification
ARINC 424-18 Navigation System Database Specification

ABBREVIATIONS

ABAS	Aircraft-based augmentation system
ADS-B	Automatic dependent surveillance — broadcast
ADS-C	Automated dependent surveillance — contract
AFM	Aircraft flight manual
AIP	Aeronautical information publication
ANSP	Air navigation service provider
APV	Approach procedure with vertical guidance
ATM	Air traffic management
ATS	Air traffic service(s)
CDI	Course deviation indicator
CDU	Control and display unit
CFIT	Controlled flight into terrain
CRC	Cyclic redundancy check
CRM	Collision risk model
DME	Distance measuring equipment
DTED	Digital terrain elevation data
EASA	European Aviation Safety Agency
ECAC	European Civil Aviation Conference
EUROCAE	European Organisation for Civil Aviation Equipment
EUROCONTROL	European Organisation for the Safety of Air Navigation
FAA	Federal Aviation Administration
FTE	Flight technical error
FMS	Flight management system
FRT	Fixed radius transition
GBAS	Ground-based augmentation system
GNSS	Global navigation satellite system
GPS	Global positioning system
GRAS	Ground-based regional augmentation system

INS	Inertial navigation system
IRS	Inertial reference system
IRU	Inertial reference unit
JAA	Joint Aviation Authorities
LNAV	Lateral navigation
MCDU	Multifunction control and display unit
MEL	Minimum equipment list
MNPS	Minimum navigation performance specification
MSA	Minimum sector altitude
NAA	National airworthiness authority
NAVAID	Navigation aid
NSE	Navigation system error
OEM	Original equipment manufacturer
PBN	Performance-based navigation
PSR	Primary surveillance radar
RAIM	Receiver autonomous integrity monitoring
RF	Radius to fix
RNAV	Area navigation
RNP	Required navigation performance
SBAS	Satellite-based augmentation system
SID	Standard instrument departure
SSR	Secondary surveillance radar
STAR	Standard instrument arrival
STC	Supplemental type certificate
TLS	Target level of safety
TSE	Total system error
VNAV	Vertical navigation
VOR	Very high frequency (VHF) omnidirectional radio range

EXPLANATION OF TERMS

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 provides the outline and intended framework of 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 etc. Airspace Concepts can include details of the practical organization of the airspace and its users based on particular CNS/ATM assumptions, e.g. ATS route structure, separation minima, route spacing and obstacle clearance.

Approach procedure with vertical guidance (APV). An instrument procedure which utilizes lateral and vertical guidance but does not meet the requirements established for precision approach and landing operations.

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

Note.— Area navigation includes performance-based navigation as well as other RNAV operations that do not meet the definition of performance-based navigation.

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

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 variously, ADS-B, PSR, 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.

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.

Mixed navigation environment. An environment where different navigation specifications may be applied within the same airspace (e.g. RNP 10 routes and RNP 4 routes in the same airspace) or where operations using conventional navigation are allowed in the same airspace with RNAV or RNP applications.

Navigation aid (navaid) infrastructure. Navaid infrastructure refers to space-based and or ground-based navigation aids available to meet the requirements in the navigation specification.

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

Note.— The navigation application is one element, along with communication, 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 performance monitoring and alerting, designated by the prefix RNAV, e.g. RNAV 5, RNAV 1.

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

Note.— The Performance-based Navigation (PBN) Manual *(Doc 9613), Volume II, contains detailed guidance on navigation specifications.*

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 in terms of accuracy, integrity, continuity, availability and functionality needed for the proposed operation in the context of a particular airspace concept.

Procedural control. Air traffic control service provided by using information derived from sources other than an ATS surveillance system.

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 operations include the use of area navigation for operations which are not developed in accordance with this manual.

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 a flight management system (FMS).

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

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

RNP system. An area navigation system which supports on-board performance monitoring and alerting.

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.

Part A

THE PERFORMANCE-BASED NAVIGATION CONCEPT

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 system performance requirements be defined in terms of accuracy, integrity, availability, continuity and functionality required for the proposed operations in the context of a particular airspace concept, when supported by the appropriate navigation infrastructure. In that context, the PBN concept represents a shift from sensor-based to performance-based navigation. 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 provide specific implementation guidance for States and operators in order to facilitate global harmonization.

1.1.1.2 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 system.

1.1.2 Benefits

Performance-based navigation 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 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 for development of sensor-specific operations with each new 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 systems in different aircraft. The original Basic GNSS equipment is evolving due to the development of augmentations such as SBAS, GBAS and GRAS, while the introduction of Galileo and the modernization of GPS and GLONASS will further improve GNSS performance. The use of GNSS/inertial integration is also expanding;

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

d) clarifies the way in which RNAV systems are used; and

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

1.1.3 Context of PBN

1.1.3.1 PBN is one of several enablers of an airspace concept. Communications, ATS surveillance and ATM are also essential elements of an airspace concept. This is demonstrated in Figure I-A-1-1. The concept of performance-based navigation (PBN) relies on the use of an area navigation (RNAV) system. There are two core input components for the application of PBN:

1) the navaid infrastructure;

2) the navigation specification;

Applying the above components in the context of the airspace concept to ATS routes and instrument procedures results in a third component:

3) the navigation application.

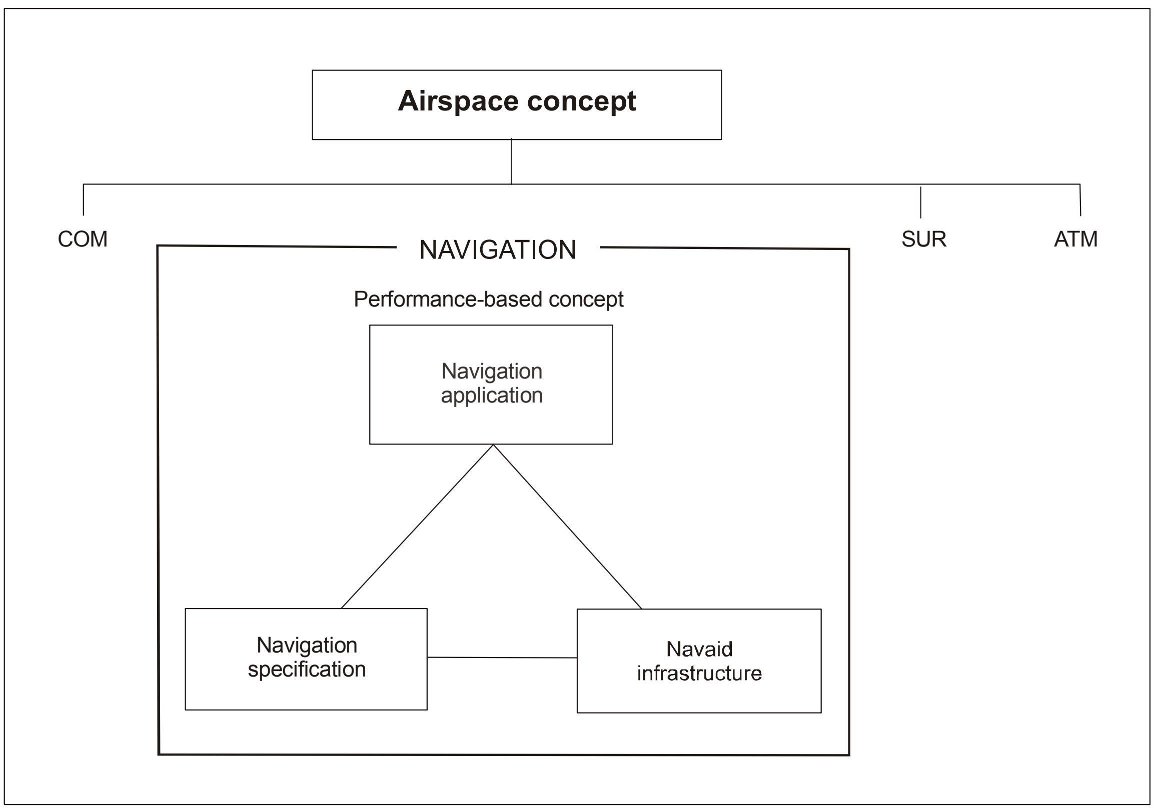


Figure I-A-1-1. Performance-based navigation concept

1.1.4 Scope of performance-based navigation

1.1.4.1 *Lateral performance*

For legacy reasons associated with the previous RNP concept, PBN is currently limited to operations with linear lateral performance requirements and time constraints. For this reason, operations with angular lateral performance requirements (i.e. approach and landing operations with vertical guidance for APV-I and APV-II GNSS performance levels, as well as ILS/MLS/GLS precision approach and landing operations) are not considered in this manual.

Note.— While at present the PBN manual does not provide any navigation specification defining longitudinal FTE (time of arrival or 4D control), the accuracy requirement of RNAV and RNP specifications are defined for the lateral and longitudinal dimensions, thereby enabling future navigation specifications defining FTE to be developed. (See Volume II, Part A, Chapter 2, 2.2.2 for a detailed discussion of longitudinal performance and Figure I-A-1-2.)

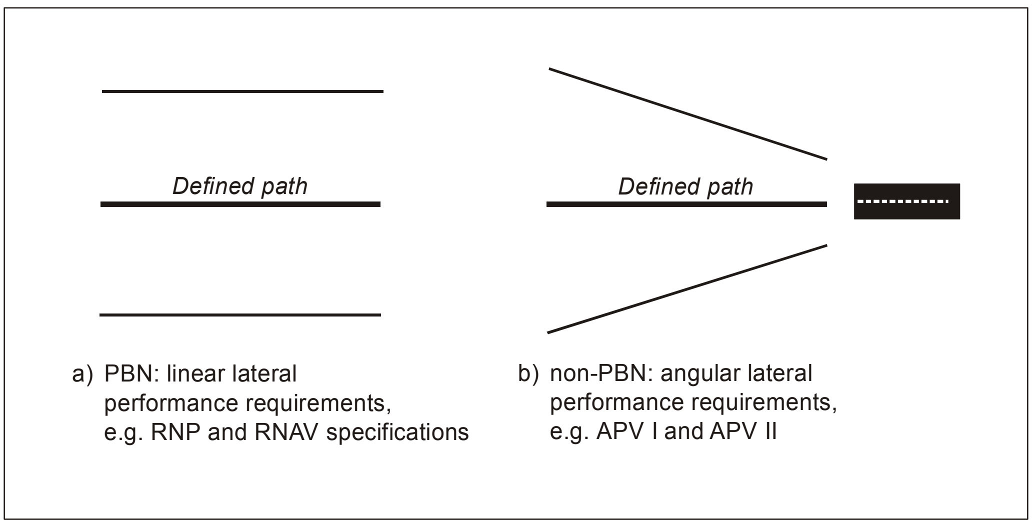


Figure I-A-1-2. Lateral performance requirements for PBN

1.1.4.2 *Vertical performance*

Unlike the lateral monitoring and obstacle clearance, for barometric VNAV systems (see Volume II, Attachment A), there is neither an alerting on vertical position error nor is there a two-times relationship between a 95 per cent required total system accuracy and the performance limit. Therefore, barometric VNAV is not considered vertical RNP.

1.2 NAVIGATION SPECIFICATION

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

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

1.2.3 On-board performance monitoring and alerting

1.2.3.1 On-board performance monitoring and alerting is the main element that determines if the navigation system complies with the necessary safety level associated to an RNP application; it relates to both lateral and longitudinal navigation performance; and it allows the aircrew to detect that the navigation system is not achieving, or cannot guarantee with 10^{-5} integrity, the navigation performance required for the operation. A detailed description of on-board performance monitoring and alerting and navigation errors is provided in Part A of Volume II.

1.2.3.2 RNP systems provide improvements on the integrity of operations; this may permit closer route spacing and can provide sufficient integrity to allow only RNAV systems to be used for navigation in a specific airspace. The use of RNP systems may therefore offer significant safety, operational and efficiency benefits.

1.2.4 Navigation functional requirements

1.2.4.1 Both RNAV and RNP 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 system, including the sensors.

1.2.4.2 More sophisticated navigation specifications include the requirement for navigation databases (see Attachment B) and the capability to execute database procedures.

1.2.5 Designation of RNP and RNAV specifications

1.2.5.1 *Oceanic, remote continental, en-route and terminal operations*

1.2.5.1.1 For oceanic, remote, en-route and terminal operations, an RNP specification is designated as RNP X, e.g. RNP 4. An RNAV specification is designated as RNAV X, e.g. RNAV 1. If two navigation specifications share the same value for X, they may be distinguished by use of a prefix, e.g. Advanced-RNP 1 and Basic-RNP 1.

1.2.5.1.2 For both RNP and RNAV designations, the expression “X” (where stated) refers to the lateral navigation accuracy 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.

Note.— A detailed discussion of navigation error components and alerting can be found in Volume II, Part A, 2.2 and Figure I-A-1-3.

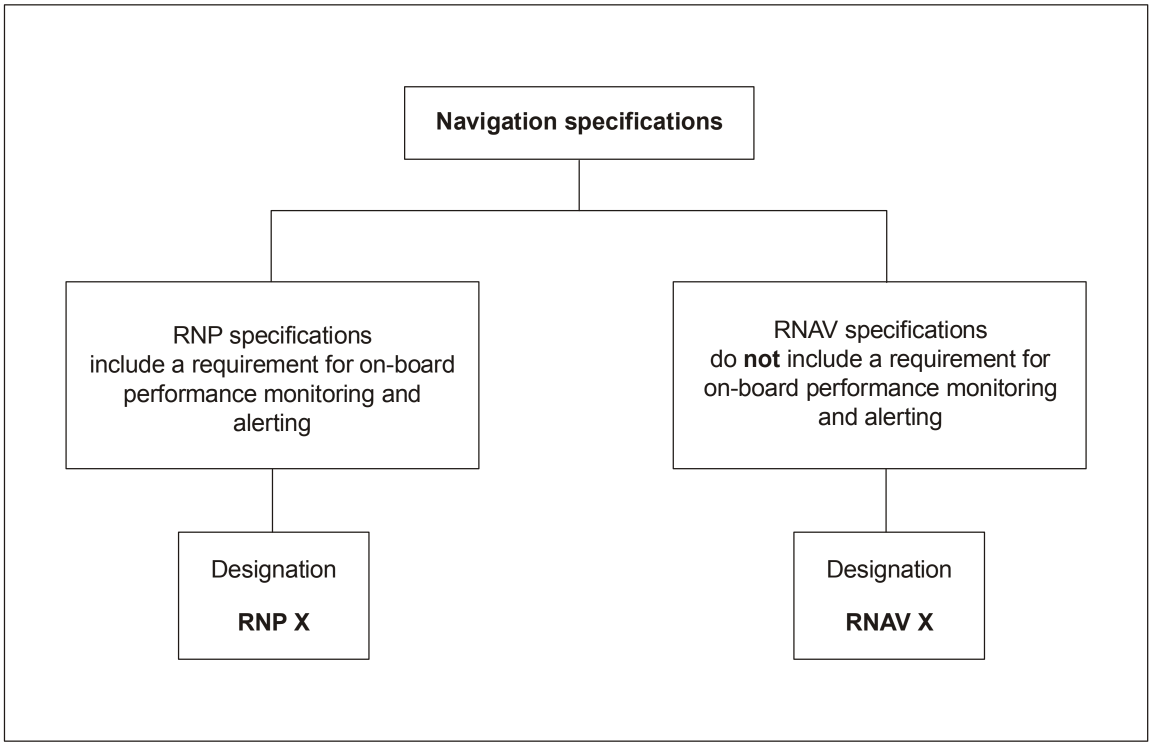


Figure I-A-1-3. Navigation specifications designations excluding those used on final approach

1.2.5.2 ***Approach***

Approach navigation specifications cover all segments of the instrument approach. RNP specifications are designated using RNP as a prefix and an abbreviated textual suffix, e.g. RNP APCH or RNP AR APCH. There are no RNAV approach specifications.

1.2.5.3 ***Understanding RNAV and RNP designations***

1.2.5.3.1 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 many performance requirements included in a navigation specification — see Example 1.

1.2.5.3.2 Because specific performance requirements are defined for each navigation specification, an aircraft approved for an RNP specification is not automatically approved for all RNAV specifications. Similarly, an aircraft approved for an RNP or RNAV specification having a stringent accuracy requirement (e.g. RNP 0.3 specification) is not automatically approved for a navigation specification having a *less* stringent accuracy requirement (e.g. RNP 4).

1.2.5.3.3 It may seem logical, for example, that an aircraft approved for Basic-RNP 1 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 specification which includes a requirement for 1 NM navigation accuracy among many other performance 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.

1.2.5.4 *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 ATC via the Flight Plan. Flight Plan procedures are addressed in *Procedures for Air Navigation Services — Air Traffic Management (PANS-ATM)* (Doc 4444).

1.2.5.5 *Accommodating inconsistent RNP designations*

1.2.5.5.1 The existing RNP 10 designation is inconsistent with PBN RNP and RNAV 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 approvals, etc., to an RNAV 10 designation would be an extensive and expensive task, which is not cost-effective. Consequently, any existing or new operational approvals will continue to be designated RNP 10, and any charting annotations will be depicted as RNP 10 (see Figure I-A-1-4).

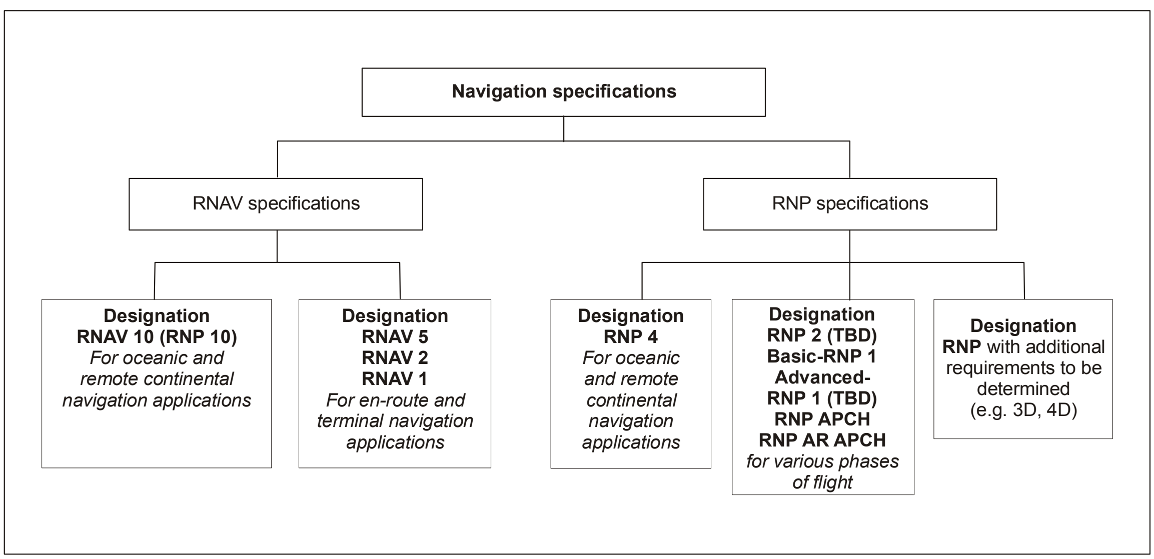


Figure I-A-1-4. Accommodating existing and future designations

1.2.5.5.2 In the past, the United States and member States of the European Civil Aviation Conference (ECAC) used regional RNAV specifications with different designators. The ECAC applications (P-RNAV and B-RNAV) will continue to be used only within those States. Over time, ECAC RNAV applications will migrate towards the international navigation specifications of RNAV 1 and RNAV 5. The United States migrated from the USRNAV Types A and B to the RNAV 1 specification in March 2007.

1.2.5.6 *Minimum navigation performance specifications (MNPS)*

Aircraft operating in the North Atlantic airspace are required to meet a minimum navigation performance specification (MNPS). The MNPS specification has intentionally been excluded from the above designation scheme because of its mandatory nature and because future MNPS implementations are not envisaged. The requirements for MNPS are set out in the *Consolidated Guidance and Information Material concerning Air Navigation in the North Atlantic Region* (NAT Doc 001) (available at http://www.nat-pco.org).

1.2.5.7 *Future RNP designations*

It is possible that RNP specifications for future airspace concepts may require additional functionality without changing the navigation accuracy requirement. Examples of such future navigation specifications may include requirements for vertical RNP and time-based (4D) capabilities. The designation of such specifications will need to be addressed in future developments of this manual.

1.3 NAVAID INFRASTRUCTURE

The navaid Infrastructure refers to ground- or space-based navigation aids. Ground-based navaids include DME and VOR. Space-based navaids include GNSS elements as defined in Annex 10 — *Aeronautical Telecommunications*.

1.4 NAVIGATION APPLICATIONS

A navigation application is the application of a navigation specification and associated navaid infrastructure to ATS routes, instrument approach procedures and/or defined airspace volume in accordance with the airspace concept, an RNP application is supported by an RNP specification. An RNAV application is supported by an RNAV specification. This can be illustrated in Example 2.

1.5 FUTURE DEVELOPMENTS

1.5.1 From a performance-based navigation perspective, it is likely that navigation applications will progress from 2D to 3D/4D, although timescales and operational requirements are currently difficult to determine. Consequently, on-board performance monitoring and alerting is still to be developed in the vertical plane (vertical RNP) and ongoing work is aimed at harmonizing longitudinal and linear performance requirements. It is also possible that angular performance requirements associated with approach and landing may be included in the scope of PBN in the future. Similarly, specifications to support helicopter-specific navigation applications and holding functional requirements may also be included.

1.5.2 As more reliance is placed on GNSS, the development of airspace concepts will increasingly need to ensure the coherent integration of navigation, communication and ATS surveillance enablers.

Example 2

The RNAV 1 specification in Volume II of this manual shows that any of the following navigation sensors can meet its performance requirements: GNSS or DME/DME/IRU 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, State A's AIP could stipulate GNSS as a requirement for its RNAV 1 specification because State A only has GNSS available in its navaid infrastructure. State B's AIP could require DME/DME/IRU for its RNAV 1 specification (policy decision to not allow GNSS).

Each of these navigation specifications would be implemented as an RNAV 1 application. However, aircraft equipped only with GNSS and approved for the RNAV 1 specification in State A would not be approved to operate in State B.

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 concept described in the previous chapter.

2.2 THE AIRSPACE CONCEPT

2.2.1 An airspace concept may be viewed as a general vision or a master plan for a particular airspace. Based on particular principles, an airspace concept is geared towards specific objectives. Airspace concepts need to include a certain level of detail if changes are to be introduced within an airspace. Details could explain, for example, airspace organization and management and the roles to be played by various stakeholders and airspace users. Airspace concepts may also describe the different roles and responsibilities, mechanisms used and the relationships between people and machines.

2.2.2 Strategic objectives drive the general vision of the airspace concept (see Figure I-A-2-1). These objectives are usually identified by airspace users, air traffic management (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 which most commonly drive airspace concepts are safety, capacity, efficiency, access and the environment. As Examples 1 and 2 below suggest, strategic objectives can result in changes being introduced to the airspace concept.

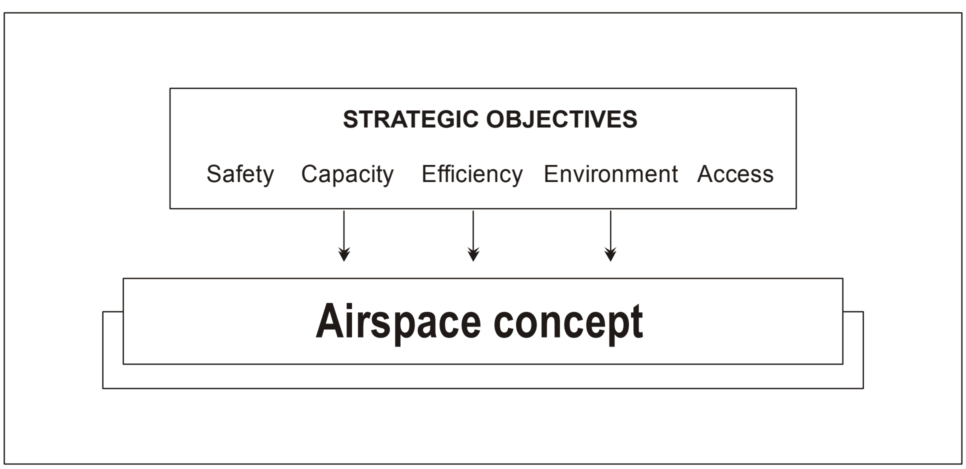


Figure I-A-2-1. Strategic objectives to airspace concept

Example 1

Safety: The design of RNP instrument approach procedures could be a way of increasing safety (by reducing Controlled Flights into Terrain (CFIT)).

Capacity: Planning the addition of an extra runway at an airport to increase capacity will trigger a change to the airpsace concept (new approaches to SIDs and STAR 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/arrivals/approaches (CDA), 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.

Example 2

Although GNSS is associated primarily with navigation, GNSS is also the backbone of ADS-B surveillance applications. As such, GNSS positioning and track-keeping functions are no longer “confined” to being a navigation enabler to an airspace concept. GNSS, in this case, is also an ATS surveillance enabler. The same is true of data-link communications: data are used by an ATS surveillance system (for example, in ADS-B and navigation).

2.2.3 Airspace concepts and navigation applications

2.2.3.1 The cascade effect from strategic objectives to the airspace concept places requirements on the various “enablers”, such as communication, navigation, ATS surveillance, air traffic management and flight operations. *Navigation functional requirements* — now within a performance-based navigation context — need to be identified, *see Part B, Chapter 2 of this volume*. These navigation functionalities are formalized in a *navigation specification* which, together with a *navaid infrastructure*, supports a particular *navigation application.* As part of an airspace concept, navigation applications also have a relationship to communication, ATS surveillance, ATM, ATC tools and flight operations. The airspace concept brings all these elements together in a cohesive whole (see Figure I-A-2-2).

2.2.3.2 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, i.e. how CNS/ATM will satisfy this concept and its concept of operations.

2.2.3.3 The role to be played by each enabler in the overall concept is identified. No “enabler” can be developed in isolation, i.e. communication, ATS surveillance and navigation enablers should form a cohesive whole. This can be illustrated by using an example.

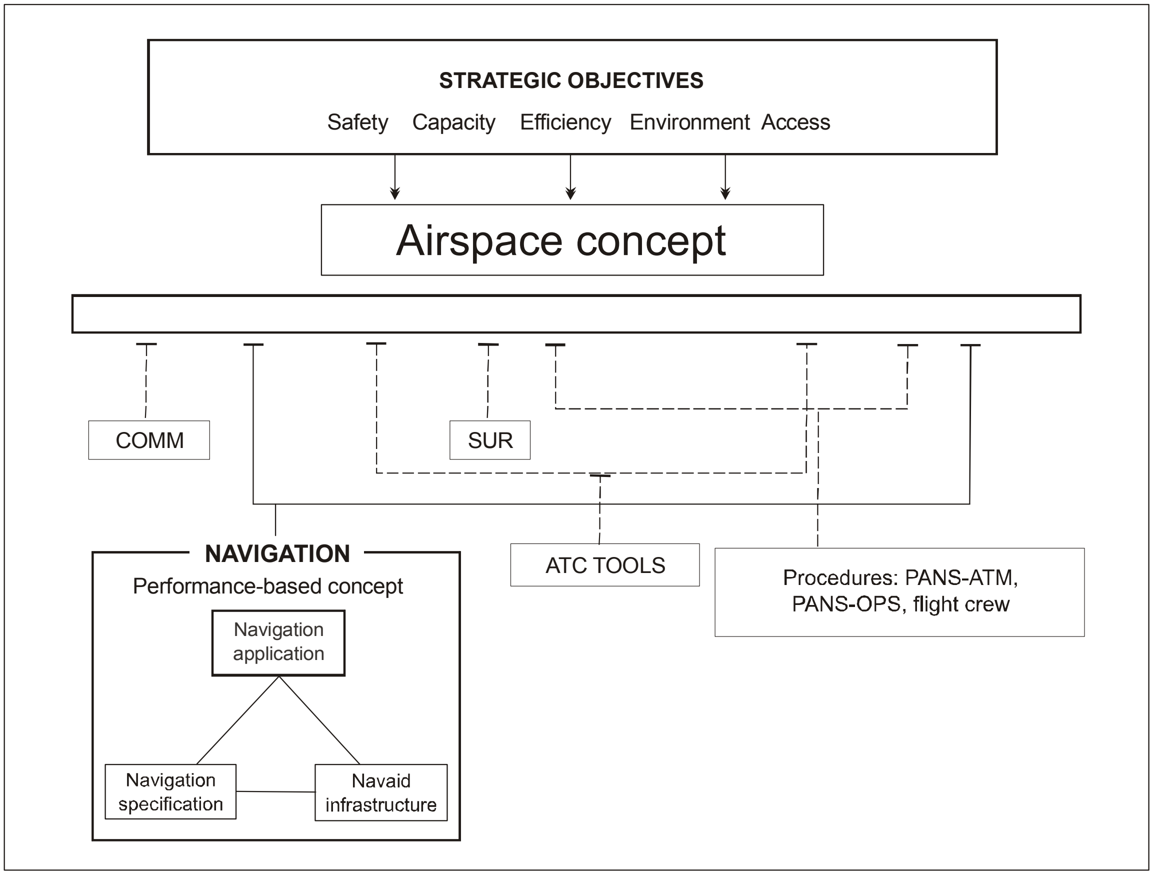


Figure I-A-2-2. Relationship: Performance-based navigation and airspace concept

2.3 AIRSPACE CONCEPTS BY AREA OF OPERATION

2.3.1 Oceanic and remote continental

Oceanic and remote continental airspace concepts are currently served by two navigation applications, RNAV 10 and RNP 4 (see 1.2.5.1). Both these navigation applications rely primarily on GNSS to support the navigation element of the airspace concept. In the case of the RNAV 10 application, no form of ATS surveillance service is required. In the case of the RNP 4 application, ADS contract (ADS-C) is used.

Note.— RNAV 10 retains the RNP 10 designation. See 1.2.5.5 in the previous chapter.

2.3.2 Continental en-route

Continental en-route airspace concepts are currently supported by RNAV applications. RNAV 5 is used in the Middle East (MID) and European (EUR) Regions but as of the publication date of this manual, it is designated as B-RNAV (Basic RNAV in Europe and RNP 5 in the Middle East (see 1.2.5.5). In the United States, an RNAV 2 application supports an en-route continental airspace concept. At present, continental RNAV applications support airspace concepts which include radar surveillance and direct controller pilot communication (voice).

2.3.3 Terminal airspace: arrival and departure

Existing terminal airspace concepts, which include arrival and departure, are supported by RNAV applications. These are currently used in the European (EUR) Region and the United States. The European terminal airspace RNAV application is known as P-RNAV (Precision RNAV). As shown in Volume II, although the RNAV 1 specification shares a common navigation accuracy with P-RNAV, this regional navigation specification does not satisfy the full requirements of the RNAV 1 specification shown in Volume II. As of the publication of this manual, the United States terminal airspace application formerly known as US RNAV Type B has been aligned with the PBN concept and is now called RNAV 1. Basic-RNP 1 has been developed primarily for application in non-radar, low-density terminal airspace. In future, more RNP applications are expected to be developed for both en-route and terminal airspace.

2.3.4 Approach

Approach concepts cover all segments of the instrument approach, i.e. initial, intermediate, final and missed approach. They will increasingly call for RNP specifications requiring a navigation accuracy of 0.3 NM to 0.1 NM or lower. Typically, three sorts of RNP applications are characteristic of this phase of flight: new procedures to runways never served by an instrument procedure, procedures either replacing or serving as backup to existing instrument procedures based on different technologies, and procedures developed to enhance airport access in demanding environments. The relevant RNP specifications covered in Volume II of this manual are RNP APCH and RNP AR APCH.

Chapter 3

STAKEHOLDER USES OF PERFORMANCE-BASED NAVIGATION

3.1 INTRODUCTION

3.1.1 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.

3.1.2 Stakeholders of performance-based navigation use the concept at different stages:

— 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.

— Also at a *strategic level*, but after the airspace planners and procedure designers have completed their work, airworthiness and regulatory authorities ensure that aircraft and aircrew satisfy the operating requirements of the intended implementation.

— 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.

3.1.3 *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-A-3-1.

3.1.3.1 *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, continuity and availability are to be achieved, they use the required performance of the navigation specification to determine route spacing and separation minima.

3.1.3.2 *Procedure designers* design instrument flight procedures 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 well as flight crew procedures. These specialists are also particularly interested in the navaid infrastructure because of the need to ensure that the IFP design takes into account the available or planned navaid infrastructure.

3.1.3.3 *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*.

3.1.3.4 *The navigation specification* can therefore be considered an anchor point for these three PBN stakeholders. This does not mean that stakeholders consider the navigation specification in isolation, but rather that it is their primary focus.

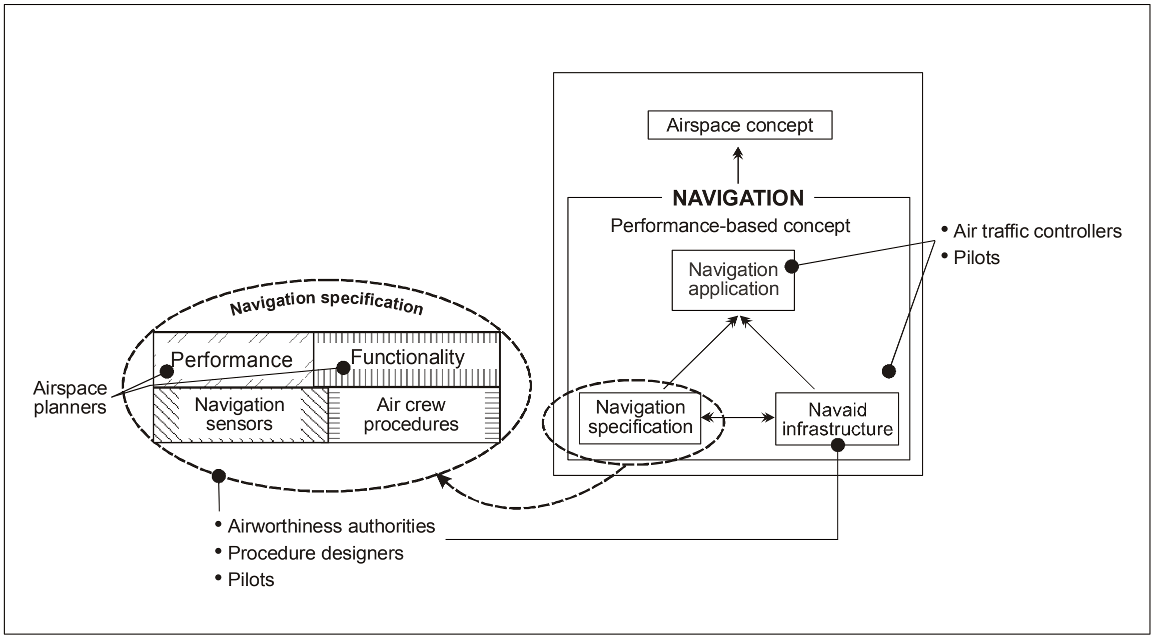


Figure I-A-3-1. PBN elements and specific points of interest of various stakeholders

3.1.4 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 an aircraft is using (i.e. RNAV 1 specification can have GNSS, DME/DME/IRU and/or DME/DME) on an ATS route, procedure or airspace, to understand the effect that a navaid outage can have on operations. 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.

3.1.5 Safety in PBN implementation

3.1.5.1 All users of the PBN concept are concerned with safety. Airspace planners and procedure designers, as well as aircraft manufacturers and air navigation service providers (ANSP), 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 then 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.

3.1.5.2 Demonstrating that safety requirements are being met is achieved in different ways by different stakeholders. 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 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) is a key reference document planners should consult.

3.2.2 Separation minima and route spacing can generally be described as being a function of three factors: navigation performance, aircraft's exposure to risk and the mitigation measures which are available to reduce risk — see Figure I-A-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-A-3-2 and I-A-3-3 depends on whether separation between two aircraft or route spacing criteria is being determined.

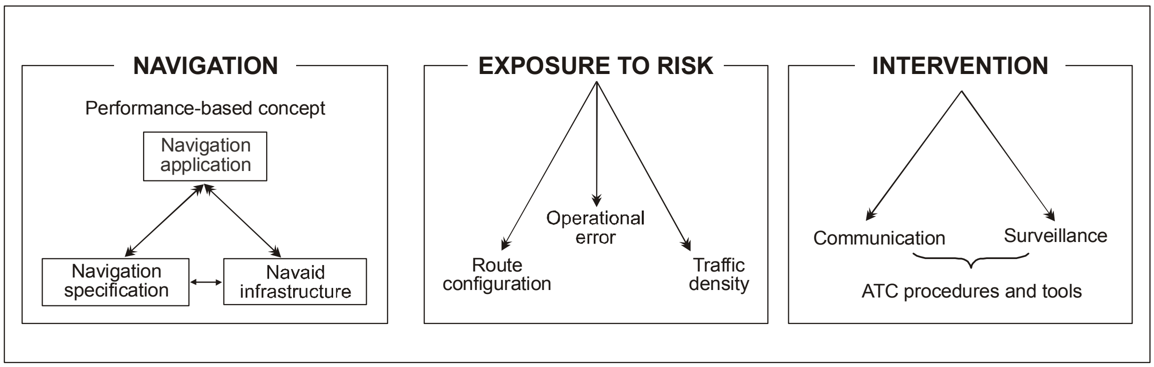
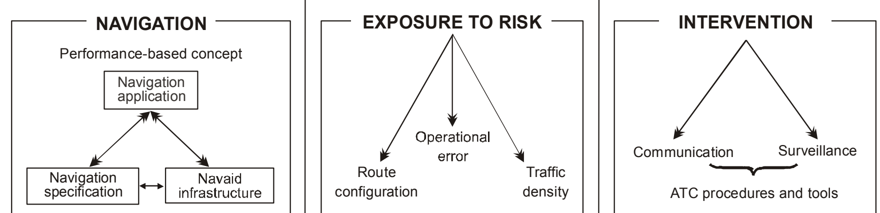


Figure I-A-3-2. Generic model used to determine separation and ATS route spacing



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

3.2.3 Aircraft to aircraft *separation,* for example, is usually 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.

3.2.4 The complexity of determining route spacing and separation minima is affected by the availability of an ATS surveillance service and the type of communication used. If an ATS surveillance service is available, this means that the risk can be mitigated by including requirements for ATC intervention. These interrelationships are reflected in Figure I-A-3-3 for separation and route spacing.

3.2.5 Impact of PBN on airspace planning

3.2.5.1 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 navigation aids such as VOR, DME or NDB. In contrast, PBN requires an RNAV 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.

3.2.5.2 It has been explained in Chapter 1 that the navigation performance required from the RNAV system is part of the navigation specification. To determine separation minima and route spacing, airspace planners fully exploit that part of the navigation specification which prescribes the performance required from the RNAV system. Airspace planners also make use of the required performance, namely, accuracy, integrity, availability and continuity to determine route spacing and separation minima.

3.2.5.3 Chapter 1 also explains that there are two types of navigation specifications: RNAV specifications and RNP specifications, and that the distinctive feature of RNP is a requirement for on-board performance monitoring and alerting. It is expected, for example, that the separation minima and route spacing derived from an RNP 1 specification will be smaller than those derived from an RNAV 1 specification, though the extent of this improvement has yet to be assessed.

3.2.5.4 In procedurally controlled airspace, separation minima and route spacing based on RNP specifications are expected to provide a greater benefit than those based on RNAV specifications. This is because the on-board performance monitoring and alerting function could alleviate the absence of ATS surveillance service by providing an alternative means of risk mitigation.

3.3 INSTRUMENT FLIGHT PROCEDURE DESIGN

3.3.1 Introduction

3.3.1.1 Instrument flight procedure 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 instrument flight procedures in their airspace can be flown safely by the relevant aircraft. Safety is not only accomplished by application of the technical criteria in the PANS-OPS (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, ground validation and flight 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 instrument flight procedure design describe conventional procedure design and sensor-dependent RNAV procedure design, their disadvantages and the issues that led up to PBN.

3.3.2 Non-RNAV: conventional procedure design

Conventional procedure design is applicable to non-RNAV applications when aircraft are navigating based on direct signals from ground-based radio navigation aids. The disadvantage to this type of navigation is that the routes are dependent on the location of the navigation beacons (see Figure I-A-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 navigation aids. Additionally, obstacle protection areas are comparatively large and the navigation system error increases as a function of the aircraft's distance from the navigation aid.

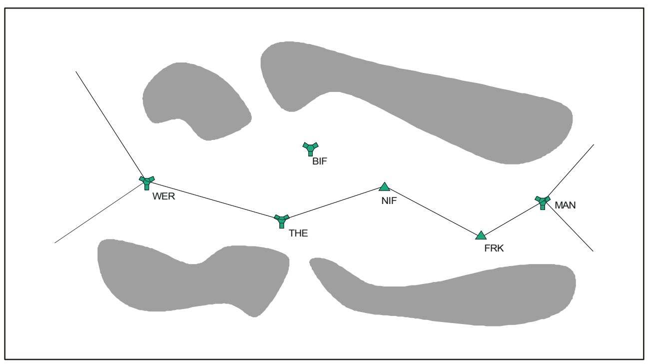


Figure I-A-3-4. Conventional instrument flight procedure design

3.3.3 Introduction of sensor-specific RNAV procedure design

3.3.3.1 Initially, RNAV was introduced using sensor-specific design criteria. A fundamental breakthrough with RNAV was the creation of fixes defined by name, latitude and longitude. RNAV 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-A-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-RNAV procedure design was based on heading, timing, or DME arcs. As RNAV navigation 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.

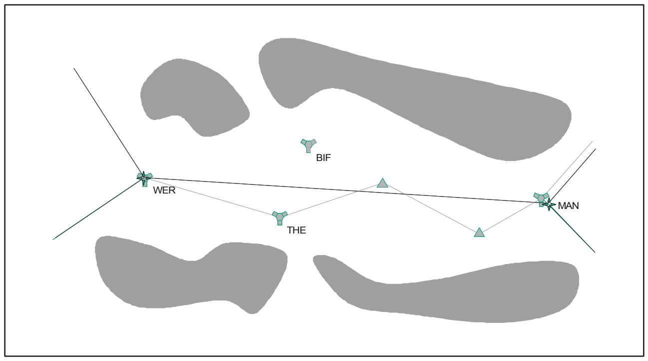


Figure I-A-3-5. RNAV procedure design

3.3.3.2 Despite the advantages, RNAV 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 RNAV operations grew, other important differences and characteristics were discovered. Aircraft RNAV 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 instrument flight procedures are being designed. Some of the system behaviour was the result of the development of RNAV 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.

3.3.4 RNP procedure design (pre-PBN)

RNP procedures were introduced in the PANS-OPS (Doc 8168), which became applicable in 1998. These RNP procedures were the predecessor of the current PBN concept, whereby the performance for operation on the route is defined, in lieu of simply identifying a required radio navigation system. However, due to the insufficient description of the navigation performance and operational requirements, there was little perceived difference between RNAV and RNP. In addition, the inclusion of conventional flight elements such as flyover procedures, variability in flight paths, and added airspace buffer resulted in no significant advantages being achieved in designs. As a result, there was a lack of benefits to the user-community and little or no implementation.

3.3.5 PBN procedure design

3.3.5.1 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 original 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. Examples of RNP APPROACH (RNP APCH) and RNP AUTHORIZATION REQUIRED APPROACH (RNP AR APCH) are shown in Figure I-A-3-6.

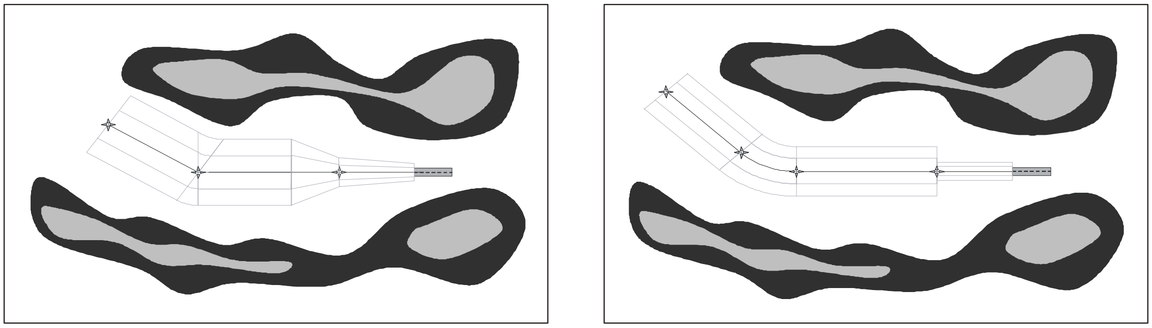


Figure I-A-3-6. Examples of RNP APCH (left) and RNP AR APCH (right) procedures design

3.3.5.2 The main change for the designers will be that they will not be designing for a specific sensor but according to a navigation specification (e.g. 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 navigation infrastructure would have to be basic GNSS or DME/DME, and aircraft would be required to utilize either to conduct operations. Volume II of this manual provides a more explicit and complete navigation specification for the aircraft and operator as compared to PANS-OPS (Doc 8168), Volume I. 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.

3.3.5.3 Integration of the aircraft and operational criteria in this manual will enable procedure design criteria to be updated. A first effort to create such criteria is for the RNP AR APCH navigation specification. In this case, 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 APCH requires closer examination of aircraft qualification and operator approval, 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 APPROVAL

3.4.1 General

3.4.1.1 Aircraft should be equipped with an RNAV system able to support the desired navigation application. The RNAV 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, and operational considerations required for the RNAV system. The RNAV system installation should be certified in accordance with Annex 8 — *Airworthiness of Aircraft* and operational procedures should respect the applicable aircraft flight manual limitations, if any.

3.4.1.3 The RNAV system should be operated in accordance with recommended practices described in Annex 6 — *Operation of Aircraft* and PANS-OPS (Doc 8168), Volume I. 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. Review of these assumptions is necessary when proceeding to the airworthiness and operational approval process.

3.4.1.5 Operators and flight crew are responsible for checking that the installed RNAV system is operated in areas where the airspace concept and the navaid infrastructure described in the navigation specification is fulfilled. To ease this process, certification and/or operational documentation should clearly identify compliance with the related navigation specification.

3.4.1.6 The navigation specifications found in Volume II, Parts B and C of this manual 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 approval. This can be achieved either through a dedicated approval document or through recognition that existing regional RNAV or RNP implementation certification documents (e.g. FAA AC or EASA AMC) can be applied to satisfy the objectives set out in the PBN navigation specification.

3.4.2 Airworthiness approval process

3.4.2.1 The airworthiness approval process assures that each item of the RNAV 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 approval. Such limitations and other information relevant to the approval of the RNAV system installation are documented in the AFM, or AFM Supplement, as applicable. Information may also be repeated and expanded upon in other documents such as pilot operating handbooks or flight crew operating manuals. The airworthiness approval process is well established among States of the Operators 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.

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 The RNP system installed should be compliant with a set of basic RNP performance requirements, as described in the navigation specification, which should include an on-board performance monitoring and alerting function. It should also be compliant with a set of specific functional requirements, have a navigation database, and should 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 specification.

3.4.3 Operational approval

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

3.4.3.1.2 The State of the Operator is the authority responsible for approving flight operations.

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

3.4.3.2 *General RNAV approval process*

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

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

3.4.3.2.1.3 Normal procedures are provided in the navigation specification, including detailed necessary crew action to be conducted during preflight planning, prior to commencing the procedure and during the procedure.

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

3.4.3.2.1.5 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.).

3.4.3.2.1.6 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*

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 200A/EUROCAE ED 76.

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

3.5 FLIGHT CREW AND AIR TRAFFIC OPERATIONS

3.5.1 Pilots and air traffic controllers are the end-users of performance-based navigation, each having their own expectations of how the use and capability of the RNAV system affects their working methods and everyday operations.

3.5.2 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, and how their implementation affects control procedures, separation and phraseology. As importantly, an understanding of how RNAV systems work as well as their advantages and limitations are necessary for both controllers and pilots.

3.5.3 For pilots, one of the main advantages of using an RNAV 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 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 RNAV-based arrival and departure routes can complement, and even replace, radar 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, e.g. an RNP 4 route alongside a parallel RNP 10 route. Similarly, RNAV SIDs and STARs are featured extensively in some terminal airspaces. From an obstacle clearance perspective, the use of RNP applications may allow or increase access to an airport in terrain-rich environments where such access was limited or not previously possible.

3.5.4 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 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 radius to fix (RF) leg types and/or fixed-radius transitions (FRT) are used. Experience gained in States that have already implemented RNAV and RNP shows that such mistaken assumptions can be corrected by adequate training in performance-based navigation. ATC training in RNAV and RNP applications is essential before implementation so as to enhance controllers' understanding and confidence, and to gain ATC "buy-in". PBN implementation without adequate emphasis on controller training can have a serious impact on any RNP or RNAV project schedule (see the Controller Training paragraphs in each navigation specification in Volume II of this manual, Parts B and C).

3.5.5 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 (i.e. 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 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.

3.5.6 ATS procedures

3.5.6.1 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 (i.e. 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 having more stringent performance and functional requirements;

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

3.5.6.2 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 not able to maintain the prescribed level of navigation performance.

Part B

IMPLEMENTATION GUIDANCE

Chapter 1

INTRODUCTION TO IMPLEMENTATION PROCESSES

1.1 INTRODUCTION

The objective of this Part is to provide guidance for implementing RNAV or RNP applications in a given region, State or group of States. Part B builds upon the general PBN concept described in Part A of this volume, and provides a framework for using the ICAO navigation specifications published in Volume II of this manual.

1.2 PROCESS OVERVIEW

Three processes are provided to assist States in the implementation of PBN. They are used in sequence.

Process 1 — Determine requirements (see Figure I-B-2-1)

Process 2 — Identifying ICAO navigation specifications for implementation (see Figure I-B-3-1)

Process 3 — Planning and implementation (see Figure I-B-4-1)

Process 1 outlines steps for a State or region to determine whether strategic and operational requirements for performance-based navigation via an airspace concept. Fleet equipage and CNS/ATM infrastructure in the State or region will be assessed and navigation functional requirements will be identified.

Process 2 describes how a State or region determines whether implementation of an ICAO navigation specification achieves the objectives of the airspace concept, provides the required navigation functions, and can be supported by the fleet equipage and CNS/ATM infrastructure that have been identified from Process 1. Process 2 might lead to the need to review the airspace concept and required navigation functions identified in Process 1, to identify trade-offs that would allow a better fit with a particular navigation specification in Volume II.

Process 3 provides a hands-on guide to planning and implementation, so that the navigation requirement may be turned into an implementation reality.

1.3 DEVELOPMENT OF A NEW NAVIGATION SPECIFICATION

1.3.1 The above three processes are designed to enhance the application of harmonized global standards, and avoid proliferation of local/regional standards. Development of a new navigation specification would be considered in those very exceptional cases, where:

a) a State or region has determined that it is not possible to use an existing ICAO navigation specification to satisfy its intended airspace concept; and

b) it is not possible to change the elements of a proposed airspace concept so that an existing ICAO navigation specification can be used.

1.3.2 Chapter 5 of this part provides guidance for an ICAO-coordinated development of a new navigation specification. 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 effort leading to a globally harmonized specification.

Chapter 2

PROCESS 1: DETERMINE REQUIREMENTS

2.1 INTRODUCTION

The goal of Process 1 is to formulate an airspace concept and assess the existing fleet equipage and CNS/ATM infrastructure, with the overall aim of identifying the navigation functional requirements necessary to meet the airspace concept. A summary of Process 1 is provided at the end of this chapter in Figure I-B-2-1.

2.2 INPUT TO PROCESS 1

2.2.1 The input to start this process is the strategic objectives and operational requirements stemming from airspace users (i.e. military/civil, air carrier/business/general aviation, IFR/VFR operations), and ATM requirements (e.g. airspace planners, ATC). Policy directives such as those stemming from political decisions concerning environmental mitigation can also be inputs.

2.2.2 The process should consider the needs of the airspace user community in a broad context, i.e. IFR, VFR, military and civil aviation (e.g. air carrier, business and general aviation). Consideration should also be given to domestic and international user requirements, as well as airworthiness and operational approval for operators.

2.2.3 The overall safety, capacity and efficiency requirements of implementation should be balanced; an analysis of all requirements, and trade-offs among competing requirements, will need to be completed. Primary and alternate means of meeting requirements should be considered; methods for communicating to airspace users the requirements and availability (and outages) of services need to be identified; and detailed planning needs to be undertaken for the transition to the new airspace concept.

2.3 STEPS IN PROCESS 1

2.3.1 Step 1 — Formulate the airspace concept

2.3.1.1 An airspace concept is only useful if it is defined in sufficient detail so that supporting navigation functions can be identified. The elaboration of the airspace concept is therefore best undertaken by a multi-disciplinary team as opposed to a single specialization (see also Part A, Chapter 3 of this volume). This team should be expected to be made up of air traffic controllers and airspace planners (from the ANSP), pilots, procedure design specialists, avionics specialists, flight standards and airworthiness regulators, and airspace users. Together, this team would develop the airspace concept using the broad directions provided by the strategic objectives.

2.3.1.2 Factors that would be detailed include:

a) airspace organization and management (i.e. ATS route placement, SIDs/STARs, ATC sectorization);

b) separation minima and route spacing;

c) instrument approach procedure options;

d) how ATC is to operate the airspace;

e) expected operations by flight crew; and

f) airworthiness and operational approvals.

2.3.1.3 Insets 1 to 4 provide expanded information for the teams' consideration:

Inset 1 — Airspace user requirements

Airspace concept developers should consider the needs of the airspace user community in a broad context, i.e. IFR, VFR, military and civil aviation (e.g. air carrier, business and general aviation). Consideration should also be given to both domestic and international user requirements.

The overall safety, capacity and efficiency requirements of implementation should be balanced; an analysis of all requirements, and trade-offs among competing requirements, will need to be completed; primary and alternate means of meeting requirements should be considered; methods for communicating to airspace users the requirements and availability (and outages) of services need to be identified; and detailed planning needs to be undertaken for the transition to the new airspace concept.

Inset 2 — Airspace requirements

In order to identify the airspace requirements, it is necessary to:

a) gather and analyze data on current and expected traffic growth within and surrounding the specific airspace.

b) understand the traffic flows, volume of traffic, and the composition of air traffic both in the airspace under consideration and adjoining airspace. It is important to consider transition airspace and procedures for integrating operations across airspace boundaries and national borders.

c) Assess the surveillance, communications and navigation infrastructure available in the airspace.

d) ATS route and other procedure design criteria should be adopted from existing ICAO material to the maximum extent possible.

e) Identify the minimum navigation functions needed to support the operational requirement and compare these with the equipage of the aircraft fleets operating in the subject airspace.

f) define the required ATS route spacing prior to design of the airspace, route or procedure. ATS route spacing must be based on the overall safety, capacity and efficiency requirements of the airspace concept.

Airspace requirements may identify a need for on-board performance monitoring and alerting by, for example, specifying a need for closely spaced parallel routes (i.e. routes with consistent route spacing on both straight and turning segments). These types of requirements need to be carefully noted as they directly determine the required navigation functions discussed in 2.3.4.

Inset 3 — Approach requirements

As a general principle, approach requirements should take advantage of existing aircraft capabilities as much as possible. In addition, designers should use existing procedure design criteria to minimize the cost of operator approval and harmonize implementation across national boundaries.

In addition to the above considerations, the designer will need to determine which type(s) of approaches are required in order to meet the needs of the airspace. Considerations include:

a) straight-in or curved approach;

b) straight or curved missed approach;

c) single or multiple runways, such as:

   i) parallel or converging multiple runways;

   ii) independent or dependent runway approaches;

d) need for back-up approach procedures (e.g. if a local GPS outage occurs, what is available for approach guidance?).

Inset 4 — Other requirements

In designing the airspace concept (route or procedure), the designers should identify:

— environmental factors requiring consideration and accommodation; and
— any expected impacts to flight plan submission or processing.

2.3.2 Step 2 — Assessment of existing fleet capability and available navaid Infrastructure

2.3.2.1 Planners must understand the capability of the aircraft that will be flying in the airspace in order to determine the type of implementation that is feasible for the users. Understanding what is available in terms of navaid infrastructure is essential to determining how and if a navigation specification can be supported. The following considerations should be taken into account.

2.3.2.2 *Assessing aircraft fleet capability*

2.3.2.2.1 Aircraft fleets are not homogeneous in terms of RNAV system capability. This is because up to five generations of aircraft may be active in any large fleet, such as those operating in Europe, North America and the Far East. Therefore, the airspace has to accommodate aircraft operating with technology dating from the 1970s alongside aircraft manufactured in the 1980s, 1990s and since 2000. Often, it is not cost-effective to retrofit an old aircraft.

2.3.2.2.2 Since most States will need to support a mixed-equipage traffic environment for a significant time period, the airspace designer must know the characteristics and level of equipage of the fleet operating in the airspace. Questions that might arise include:

— Are sufficient aircraft equipped with GNSS capability?

— Can failures of GNSS be mitigated by other means of navigation (e.g. DME-based RNAV, conventional navigation or ATS surveillance service?)

— Do all IFR-approved aircraft carry VOR and DME equipment, and is that equipment integrated into the RNAV system?

— When there are insufficient navaids available to provide adequate signal coverage, can the gaps in coverage be accommodated by reliance on aircraft inertial systems?

2.3.2.2.3 Consideration must be given to accommodating users with varying levels of navigation equipage. If a mixed RNAV performance environment (or mixed RNAV and conventional environment) has been decided upon for the airspace concept, then air traffic control requirements must also be addressed for these operations. Experience suggests that handling traffic of mixed navigation equipage can, depending on the level of mixed equipment and operations, adversely affect capacity in an airspace and place an unsuitable workload on controllers.

2.3.2.3 *Assessing navaid infrastructure*

2.3.2.3.1 States currently provide a network of ground-based navaids to support en-route, terminal and approach operations. The use of RNAV routes and approaches is expanding, allowing operators to take advantage of on-board systems.

2.3.2.3.2 The introduction of satellite navigation, based on the global navigation satellite system (GNSS), has brought RNAV within reach of all operators, and makes it possible to consider a full transition to RNAV-based en-route and terminal operations. However, such a transition can be expected to take a number of years. In the meantime, most States can be expected to identify a need to maintain some ground-based navaids either to provide an alternative input to RNAV systems, to support a reversionary conventional navigation environment or to provide a conventional navigation environment for non-RNAV-equipped users.

2.3.2.3.3 Factors determining the scope of a ground navaids replacement programme include:

— the rate at which aircraft operators equip with GNSS-capable avionics;

— the extent of the requirement to retain some ground navaids for users not equipped with GNSS, or as back-up to GNSS (e.g. as partial mitigation to the potential hazard posed by interference with GNSS signals);

— the existence and age of the existing navaid infrastructure.

2.3.2.3.4 It is important that implementing an RNAV application does not in itself become the cause for installing new navaid infrastructure. The introduction of RNAV applications could result in being able to move some existing navaids (e.g. DMEs relocated when they no longer have to be co-located with VOR).

2.3.3 Step 3 — Assessment of the existing ATS surveillance system and communications infrastructure and the ATM system

2.3.3.1 An air traffic system is the sum of the CNS/ATM capabilities available. PBN is only the navigation component of CNS/ATM. It cannot be safely and successfully implemented without due consideration of the communication and ATS surveillance infrastructure available to support the operation. For example, an RNAV 1 route will require different ATS route spacing in a radar, or a non-radar, environment. The availability of communications between the aircraft and air traffic service provider may impact the level of air traffic intervention capability needed for safe operations.

2.3.3.2 *ATS surveillance infrastructure*

2.3.3.2.1 States currently provide primary and/or secondary surveillance radars to support en route, terminal and approach operations. Newer ATS surveillance systems, such as Automatic Dependent Surveillance-Broadcast (ADS-B), can be expected to play an increasing role, particularly in existing procedurally controlled environments. However, the dependence of ADS on the navigation solution has to be considered when undertaking the overall evaluation of the operation — see *Assessment of ADSP to Support Air Traffic Services and Guidelines for Implementation* (Circular 311).

2.3.3.2.2 Without robust ATS surveillance systems, RNAV route spacing is large. Implementation of RNP in such environments can compensate to a certain extent for the lack of ATS surveillance coverage.

2.3.3.3 *Communication infrastructure*

States currently provide voice communication services through VHF and HF radio. VHF service in particular is widely available and is expected to be maintained (with or without augmentation by data link communications).

2.3.3.4 *ATM systems*

The evolution of a State's ATM system to meet the needs of PBN implementation must be considered. If separation minima are reduced and this affects the alert limits of conflict detection tools, or if different separation minima are used for different route types or aircraft capabilities, this must be considered in the ATM system evolution. If required time of arrival is included in an airspace concept, the automation system will need to be designed accordingly. This same consideration applies with use of equipment classifications (e.g. flight plan suffixes), controller merging and spacing tools, and any other air traffic control automation features that enable or maximize the benefits of RNAV and RNP.

2.3.4 Step 4 — Identify necessary navigation performance and functional requirements

2.3.4.1 It should be noted that the decision on the choice of an ICAO RNAV or RNP navigation specification is not only determined by aircraft performance requirements (e.g. accuracy, integrity, continuity, availability), but may also be determined by the need for specific functional requirements (e.g. leg transitions/path terminators, parallel offset capabilities, holding patterns, navigation databases). (See Attachment A of this volume).

2.3.4.2 The proposed navigation functional requirements also need to consider:

a) the complexity of RNAV procedures envisaged; the number of waypoints needed to define the procedure; the spacing between waypoints and the need to define how a turn is executed; and

b) whether the procedures envisaged aim simply to connect with the en-route operations and can be restricted to operations above minimum vectoring altitude/minimum sector altitude, or are the procedures expected to provide approach guidance.

2.3.4.3 The next stage is ***Process 2***, where the effort is made to identify the appropriate ICAO navigation specification for implementation.

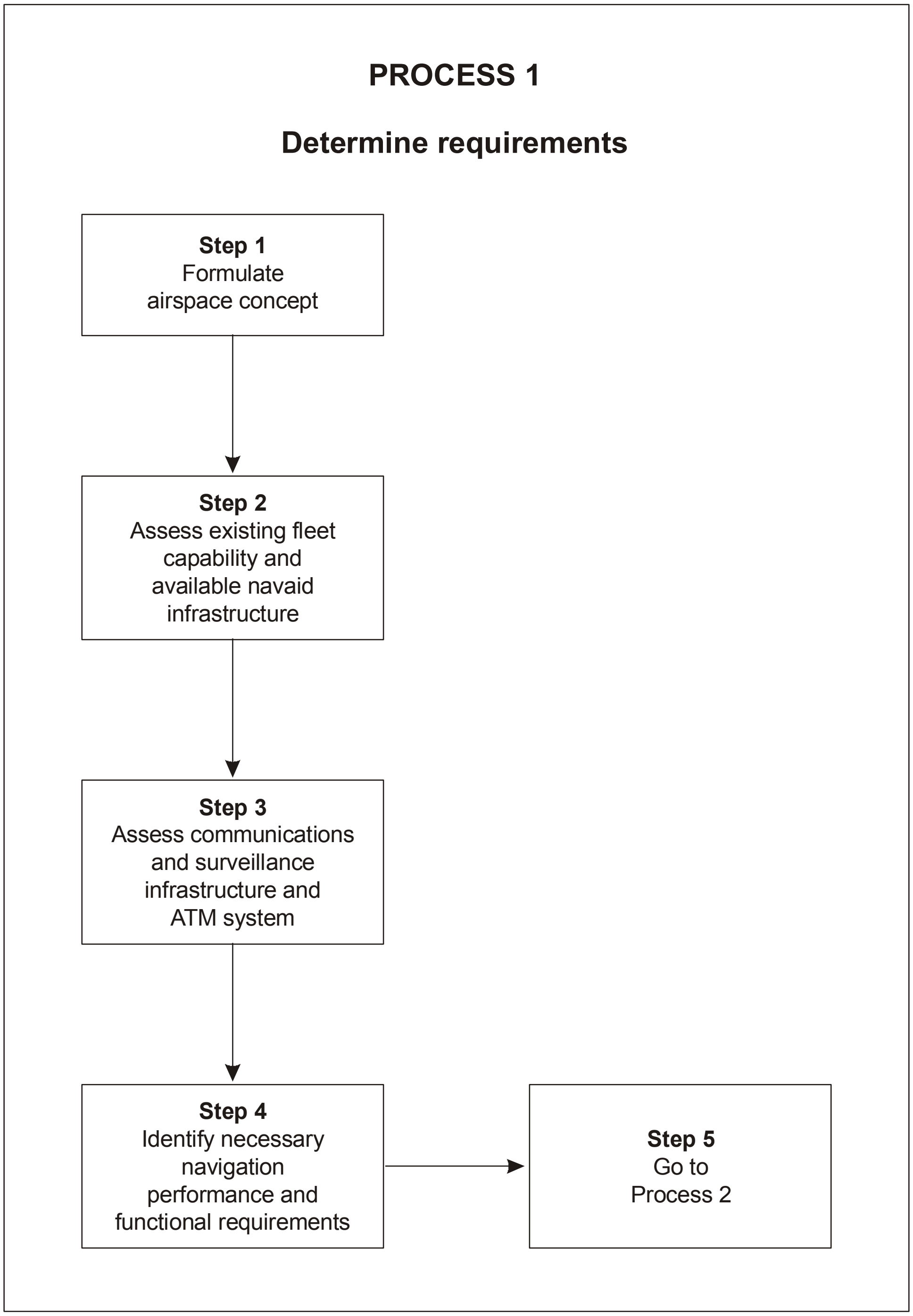


Figure I-B-2-1. Summary of Process 1

Chapter 3

PROCESS 2: IDENTIFYING ICAO NAVIGATION SPECIFICATION FOR IMPLEMENTATION

3.1 INTRODUCTION

The goal of Process 2 is to identify the ICAO navigation specification(s) that will support the airspace concept and navigation functional requirements as defined in Process 1. A summary of Process 2 is provided at the end of this chapter in Figure I-B-3-1.

3.2 INPUT TO PROCESS 2

The navigation functional requirements, fleet capability, and CNS/ATM capabilities will have been identified in Process 1. These will provide the specific context against which the planners will evaluate their ability to meet the requirements of a particular ICAO navigation specification.

3.3 STEPS IN PROCESS 2

3.3.1 Step 1 — Review ICAO navigation specifications in Volume II

a) The first step in Process 2 is aimed at finding a potential match between the requirements identified in Process 1 and those contained in one or more of the ICAO navigation specifications in Volume II.

b) In reviewing one or more possible ICAO navigation specifications, planners will need to consider the output of Process 1 with respect to:

   i) the ability of the existing aircraft fleet and available navaid infrastructure to meet the requirements of a particular ICAO navigation specification. (Step 1A in Figure I-B-3-1); and

   ii) the capabilities of their communications and ATS surveillance infrastructure, and ATM system to support implementation of this particular ICAO navigation specification (Step 1B in Figure I-B-3-1).

3.3.1.1 Examples of some questions to be considered when comparing the output from Process 1 with the ICAO navigation specifications can be found in Inset 5.

Inset 5 — Examples of questions to be considered when comparing the output from Process 1 with the ICAO navigation specifications

Is the anticipated route structure (from the airspace concept) compatible? Consider the spacing between individual routes and the existence of multiple routes.

Are the RNAV systems designed to operate with the same navaid infrastructure?
Is the available navaid infrastructure (assessed in Process 1) the same as the navaid infrastructure associated with the ICAO navigation specification?

3.3.2 Step 2 — Identify appropriate ICAO navigation specification to apply in the specific CNS/ATM environment

If planners determine that a particular ICAO navigation specification in Volume II can be supported by the fleet equipage, navaid infrastructure, communications, and ATS surveillance and ATM capabilities available in the State, proceed to Process 3: Planning and implementation. If an ICAO navigation specification cannot be supported, continue with Process 2, Step 3.

3.3.3 Step 3 — Identify trade-offs with airspace concept and navigation functional requirements (if necessary)

3.3.3.1 This step is followed when an exact match between a particular ICAO navigation specification and the fleet equipage, navaid infrastructure, communications, and ATS surveillance and ATM capabilities available in the State cannot be made. It is aimed at changing either the airspace concept or navigation functional requirements, in order to select an ICAO navigation specification. For example, operational requirements reflected in the airspace concept could be reduced, or alternate means identified to achieve a similar (if not identical) operational result.

Note.— Implementation of ICAO navigation specifications can improve safety by establishing uniform aircraft and navigation requirements across varying regions. Navigation specifications are also significant sources for cost control to operators. Navigation specifications have associated aircraft requirements, navaid infrastructure expectations, and route spacing requirements.

3.3.3.2 Planners should revisit the airspace concept and required navigation functions identified in Process 1 to determine what trade-offs can be made, so as to implement a particular existing ICAO navigation specification. The following are reasons which could explain the lack of a match:

a) The original analysis of the navigation functional requirements (from Process 1) did not correctly identify all functions required for the airspace concept. This could be because a functional capability was omitted or because it was unnecessarily identified. Initial analysis could have omitted some or all of the leg types required for RNAV in terminal airspace, or failed to require fixed radius transitions where closely spaced parallel tracks are to be implemented in en-route applications.

b) The navigation functional requirements identified in Process 1 were defined around existing fleet capability operating in the airspace, with the expectation that this capability would be appropriate for the airspace concept. If use of this fleet capability remains the target, then it will be necessary to change the airspace concept.

Example

Trade-off of a navigation functional requirement

If the only difference between the ICAO navigation specification and the navigation functional requirements identified in Process 1 is a requirement for parallel offset capability, it might be possible to adjust the functional requirement. An alternative to parallel offset capability in a continental airspace could be the creation of radar vectoring areas in which aircraft could be vectored off track to facilitate climb and descent of overtaking traffic.

3.3.3.3 In most instances, it will be possible to make sufficient trade-offs in the original airspace concept or required navigation functions from Process 1, such that an existing ICAO navigation specification can then be selected. Once trade-offs have been made that will allow selection of an ICAO navigation specification, proceed to Process 3: Planning and implementation.

3.3.3.4 However, if in the rare case that a State determines that it is impossible to make trade-offs in its airspace concept and/or navigational functional requirements, the State would have to develop a new navigation specification (see Chapter 5).

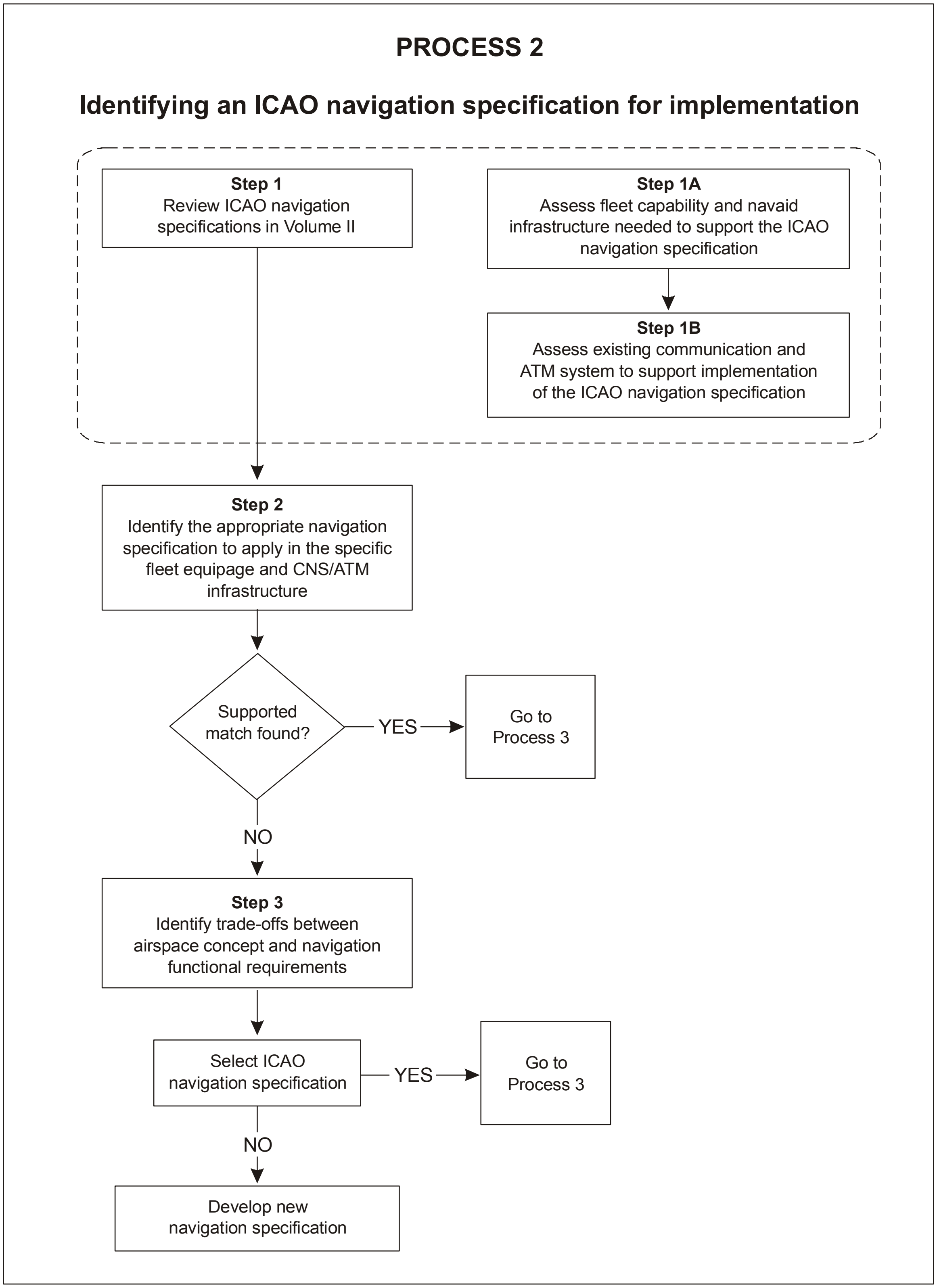


Figure I-B-3-1. Summary of Process 2

Chapter 4

PROCESS 3: PLANNING AND IMPLEMENTATION

4.1 INTRODUCTION

The process described in this chapter is concerned with planning and implementing performance-based navigation. It follows upon completion of Process 1 and 2. See Inset 6 for detailed discussion of some important considerations planners should keep in mind when framing the implementation plan. A summary of Process 3 is provided at the end of this chapter in Figure I-B-4-1.

Inset 6 — Implementation considerations

In applying one of the ICAO navigation specifications for oceanic, remote continental and continental en-route operations as described in Volume II, consideration should be given to the need for regional or multi-regional agreement. This is because connectivity and continuity with operations in adjoining airspace need to be considered to maximize benefits. For terminal and approach operations, the implementation of an ICAO navigation specification in Volume II is more likely to occur on a single-State basis. Some TMAs are adjacent to national borders for which multinational coordination would likely be required.

Where compliance with an ICAO navigation specification is prescribed for operation in an airspace or ATS routes, these requirements are to be indicated in the State's aeronautical information publication.

The decision to mandate a requirement for one or more ICAO RNAV or RNP specifications should only be considered after several factors have been taken into account. These include, but are not limited to:

a) the operational requirements of the airspace users (civil/military, IFR operations), as well as those of ANSPs;

b) regulatory requirements at both international and national levels;

c) the proportion of the aircraft population currently capable of meeting the specified requirements, and the cost to be incurred by operators that need to equip aircraft to meet the requirements of the navigation specification;

d) the benefits in terms of safety, capacity, improved access to airspace/airports or environment to be derived from implementing the airspace concept;

e) the impact on operators in terms of additional flight crew training;

f) the impact on flight crew in terms of workload; and

g) the impact on air traffic services in terms of controller workload and required facilities, (including automation and flight plan processing changes). Particular attention must be given to possible workload and efficiency impacts of operating mixed navigation environments. (See Inset 7 following Step 7 for further discussion of mixed equipage.)

4.2 INPUTS TO PROCESS 3

The navigation functional requirements, fleet capability, and CNS/ATM capabilities will have been identified in Process 1. The ICAO navigation specification(s) will have been selected in Process 2. Possible additional State or region requirements for implementation should be identified and incorporated.

4.3 STEPS IN PROCESS 3

4.3.1 Step 1 — Formulate safety plan

4.3.1.1 The first step in Process 3 is the formulation of a safety plan for the PBN implementation. Guidance for formulating a safety plan can be found in *Safety Management Manual (SMM)* (Doc 9859).

4.3.1.2 Depending on the nature of the implementation, this could be a State or regional safety plan. Normally, such a plan would be developed together with an ANSP safety bureau to the satisfaction of the regulatory authority. This safety plan details how the safety assessment is to be accomplished for the proposed RNAV or RNP implementation.

4.3.2 Step 2 — Validate airspace concept for safety

4.3.2.1 Validation of an airspace concept involves completing a safety assessment. From this assessment, additional safety requirements may be identified which need to be incorporated into the airspace concept prior to implementation.

4.3.2.2 Four validation means are traditionally used to validate an airspace concept:

a) airspace modelling;

b) fast-time simulation (FTS);

c) real-time simulation (RTS);

d) live ATC trials.

4.3.2.3 For simple airspace changes, it may be unnecessary to use all of the above validation means for any one implementation. For complex airspace changes, however, FTS and RTS can provide essential feedback on safety (and efficiency) issues and their use is encouraged. Application of new navigation specifications can range from simple through major changes to the airspace concept. All four types of validation are briefly discussed below.

4.3.2.4 *Airspace modelling*

Airspace modelling is a beneficial first step because it provides some understanding of how the proposed implementation will work, yet does not require the participation of controllers or pilots. Airspace models are computer-based, so it is possible to make changes quickly and effectively to ATS routes, holding patterns, airspace structures or sectorization to identify the most beneficial scenarios (i.e. those that are worth carrying forward to more sophisticated types of validation). Using a computer-based airspace model can make it easier to identify non-viable operating scenarios so that unnecessary expense and effort is not wasted on more advanced validation phases. The main role of the airspace model is to eliminate non-viable airspace scenarios and to support the qualitative assessment of further concept development.

4.3.2.5 *Fast-time simulation (FTS)*

Following the computer-based airspace modelling phase, it can be useful to run a fast-time simulation (FTS). A more sophisticated assessment than airspace modellers[1], an FTS returns more precise and realistic results while still not requiring the active participation of controllers or pilots; however, in terms of data collection and input, preparation can be demanding and time-consuming.

4.3.2.6 *Real-time simulation (RTS)*

The most realistic way to validate an airspace concept is to subject the viable scenarios to real-time simulation (RTS). These simulators realistically replicate ATM operations and require the active participation of proficient controllers and simulated or “pseudo” pilots. In some cases, sophisticated RTS can be linked to multi-cockpit simulators so that realistic flight performance is used during the simulation. One of the difficulties that can be encountered with real-time simulation is that the navigation performance of the aircraft is too perfect. “Aircraft” in RTS may operate with a navigation precision that is unrealistic, given realities of weather, individual aircraft performance, etc. In such cases, error rates from live operations are analysed and these can be scripted into the RTS.

4.3.2.7 *Live ATC trials*

Live ATC trials are generally used to verify operating practices or procedures when subtleties of the operation are such that FTS and RTS do not satisfy the validation requirements. It is important to note that Step 3 — Procedure Design must be completed before live ATC trials can be conducted.

4.3.3 Step 3 — Procedure design

4.3.3.1 A total system approach to the implementation of the airspace concept means that the procedure design process is an integral element. Therefore, the procedure designer is a key member of the airspace concept development team.

4.3.3.2 Procedure designers need to ensure that the procedures can be coded in ARINC 424 format. Currently, this is one of the major challenges facing procedure designers. Many are not familiar with either the path and terminators used to code RNAV systems or the functional capabilities of different RNAV systems (see Attachment A of this volume). Many of the difficulties can be overcome, however, if close cooperation exists between procedure designers and the data houses that provide the coded data to the navigation database providers.

4.3.3.3 Once these procedures have been validated and flight inspected (see Steps 4 and 6), they are published in the national AIP along with any changes to routes, holding areas, or airspace structures.

1. Some airspace modellers are incorporated in fast-time simulators.

4.3.3.4 The complexity involved in data processing for the RNAV system database means that in most instances, a lead period of two AIRAC cycles is required (see Volume I, Attachment B, Section 3 for more details).

4.3.4 Step 4 — Procedure ground validation

4.3.4.1 The development of an RNAV or RNP instrument flight procedure or ATS route follows a series of steps from the origination of data through survey to the final publication of the procedure and subsequent coding of it for use in an airborne navigation database (see Attachment B of this volume). At each step of the procedure design process, there should be quality control procedures in place to ensure that the necessary levels of accuracy and integrity are achieved and maintained. These quality control procedures are detailed in PANS-OPS (Doc 8168), Volume II.

4.3.4.2 After designing the procedure, and before an RNAV or RNP route or procedure is published, PANS-OPS (Doc 8168) requires that each procedure undergo a validation process. The objective of validation is to:

a) provide assurance that adequate obstacle clearance has been provided;

b) verify that the navigation data to be published, as well as that used in the design of the procedure, are correct;

c) verify that all required infrastructure, such as runway markings, lighting, and communications and navigation sources, are in place and operative;

d) conduct an assessment of flyability to determine that the procedure can be safely flown; and

e) evaluate the charting, required infrastructure, visibility and other operational factors.

4.3.4.3 Many of these factors can be evaluated, entirely or in part, during ground validation. Initial flyability checks should be conducted with software tools allowing the flyability of the procedure to be confirmed for a range of aircraft and in a full range of conditions (wind/temperature, etc.) for which the procedure is designed. The verification of the flyability of an RNAV or RNP procedure can also include independent assessments by procedure designers and other experts using specialized software or full-flight simulators. Flyability tests using flight inspection aircraft can be considered, but it must be borne in mind that this only proves that the particular aircraft used for the test can execute the procedure correctly. This is probably acceptable for the majority of less complex procedures. The size and speed of flight test aircraft can seldom fully represent the performance of a fully loaded B747 or A340 and therefore simulation is considered the most appropriate way to carry out the flyability test. Flight simulator tests should be conducted for those more complex procedures, such as RNP AR APCH, when there is any indication that flyability may be an issue. Software tools that use digital terrain data (typically digital terrain elevation data (DTED) level 1 being required) are available to confirm appropriate theoretical navaid coverage.

4.3.5 Step 5 — Implementation decision

4.3.5.1 It is usually during the various validation processes described above that it becomes evident whether the proposed design can be implemented. The decision whether or not to go ahead with implementation needs to be made at a pre-determined point in the life cycle of a project.

Note.— If the available tools and/or quality of data used in Step 4 warrant, it may be desirable to undertake Step 6 before a final implementation decision is taken.

4.3.5.2 The decision of whether to go ahead with implementation will be based on certain deciding factors. These include:

a) whether the ATS route/procedure design meets air traffic and flight operations needs;

b) whether safety and navigation performance requirements have been satisfied;

c) pilot and controller training requirements; and

d) whether changes to flight plan processing, automation, or AIP publications are needed to support the implementation.

4.3.5.3 If all implementation criteria are satisfied, the project team needs to plan for execution of the implementation, not only as regards their "own" airspace and ANSP, but in cooperation with any affected parties which may include ANSPs in an adjacent State.

4.3.6 Step 6 — Flight inspection and flight validation

4.3.6.1 Flight inspection of navaids involves use of test aircraft which are specially equipped to gauge the actual coverage of the navaid infrastructure required to support the procedures, arrival and departure routes designed by the procedure design specialist. Flight validation continues the procedure validation process noted in Step 4. It is used to confirm the validity of the terrain and obstruction data used to construct the procedure, and that the track definition takes the aircraft to the intended aiming point, as well as the other validation factors listed in Step 4.

4.3.6.2 Output from the above procedures may require the procedure design specialist to refine and improve the draft procedures. The *Manual on Testing of Radio Navigation Aids* (Doc 8071) provides general guidance on the extent of testing and inspection normally carried out to ensure that radio navigation systems meet the SARPs in Annex 10 — *Aeronautical Telecommunications*, Volume I. PANS-OPS (Doc 8168), Volume II, Part 1, Section 2, Chapter 4, Quality Assurance provides more detailed guidance on instrument flight procedure validation.

4.3.7 Step 7 — ATC system integration considerations

4.3.7.1 The new airspace concept may require changes to the ATC system interfaces and displays to ensure controllers have the necessary information on aircraft capabilities. Considerations arising from mixed equipage scenarios are discussed in Inset 7. Such changes could include, for example:

a) modifying the air traffic automation's flight data processor (FDP);

b) making changes, if necessary, to the radar data processor (RDP);

c) requiring changes to the ATC situation display; and

d) requiring changes to ATC support tools.

4.3.7.2 There may be a requirement for changes to ANSP methods for issuing NOTAMS.

Inset 7 — Mixed navigation environments

A mixed navigation environment introduces some complexities for ATS. From an ATC workload and associated automation system perspective, the system needs to include the capability of filtering different navigation specifications from the ATC flight plan and conveying relevant information to controllers. For air traffic control, particularly under procedural control, different separation minima and route spacing are applied as a direct consequence of the navigation specification.

Mixed navigation environments usually occur in one of three scenarios:

a) One RNAV or one RNP application has been implemented (but not as a mandate), and conventional navigation is retained. An example of this would be if RNAV 1 were the declared RNAV specification for a terminal airspace, with the availability also of procedures based on conventional navigation, for those aircraft not approved for RNAV 1.

b) A “mixed-mandate” is used within an airspace volume — usually en-route or oceanic/remote procedural operations. For example, it is mandatory to be approved to an RNAV 1 specification for operation along one set of routes, and RNAV 5 along another set of routes within the same airspace.

c) A mix of RNAV or RNP applications is implemented in airspace, but there is no mandate for operators to be able to perform them. Conventional navigation could be authorized for aircraft that are not approved to any of the navigation specifications.

Mixed navigation environments can potentially have a negative impact on ATC workload, particularly in dense en-route or terminal area operations. The acceptability of a mixed navigation environment to ATC is also dependent on the complexity of the ATS route or SID and STAR route structure and upon availability and functionality of ATC support tools. The increased ATC workload normally resulting from mixed-mode operations has sometimes resulted in the need to limit mixed-mode operations to a maximum of two types, where there is one main level of capability. In some cases, ATC has only been able to accept a mixed environment where 90 per cent of the traffic is approved to the required navigation specification; whereas in other instances, a 70 per cent rate has been workable.

For these reasons, it is crucial that operations in a mixed navigation environment be properly assessed in order to determine the viability of such operations.

4.3.8 Step 8 — Awareness and training material

The introduction of PBN can involve considerable investment in terms of training, education and awareness material for both flight crew and controllers. In many States, training packages and computer-based training have been effectively used for some aspects of education and training. ICAO provides additional training material and seminars. Each navigation specification in Volume II, Parts B and C addresses the education and training appropriate for flight crew and controllers.

4.3.9 Step 9 — Establishing operational implementation date

The State establishes an effective date in accordance with the requirements set out in Volume I, Attachment B, Data Processes. Experience has identified that an additional time period (e.g. one to two weeks) should be allocated prior to the operational implementation date. This additional period is to ensure ground and airborne system data are properly loaded and validated in databases.

4.3.10 Step 10 — Post-implementation review

4.3.10.1 After the implementation of PBN, the system needs to be monitored to ensure that safety of the system is maintained and to determine whether strategic objectives have been achieved. If after implementation, unforeseen events do occur, the project team should put mitigation measures in place as soon as possible. In exceptional circumstances, this could require the withdrawal of RNAV or RNP operations while specific problems are addressed.

4.3.10.2 A system safety assessment should be conducted after implementation and evidence collected to verify that the safety of the system is assured — *see the Safety Management Manual (SMM)* (Doc 9859).

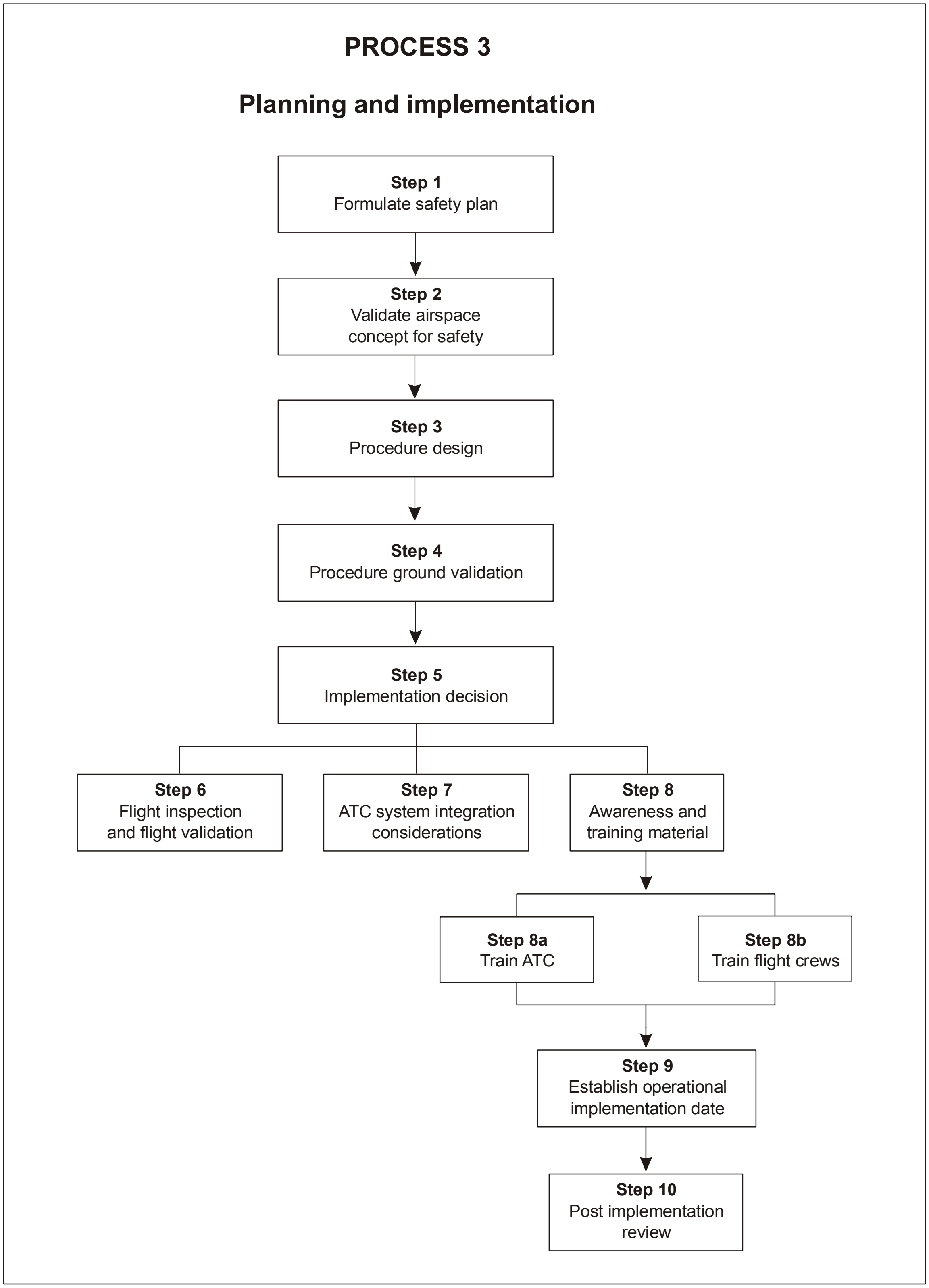


Figure I-B-4-1. Summary of Process 3

Chapter 5

GUIDELINES FOR DEVELOPMENT OF A NEW NAVIGATION SPECIFICATION

5.1 INTRODUCTION

5.1.1 In most instances, it will be possible to use an existing ICAO navigation specification from Volume II to satisfy the navigation requirements for a State or region's planned airspace concept. In the rare case that a State or region is not able to complete Process 2 and select an ICAO navigation specification, the State or region would have to develop a new navigation specification. In order to avoid proliferation of regional standards, a new navigation specification would be subject to ICAO review, and ultimately be available for global application. The guidelines in this chapter address this situation.

5.1.2 Development of a new navigation specification should only be undertaken if it becomes impossible to make acceptable trade-offs between the defined airspace concept and navigational functional requirements that can be supported by a standard ICAO navigation specification.

5.1.3 It should be recognized that development of a new navigation specification involves a rigorous evaluation of navigation equipment and its operation. This will require even greater involvement by airworthiness authorities than required in Process 2. While a considerable amount of the preparatory work for development of a new navigation specification would initially be undertaken as part of Processes 1 and 2, the State or region concerned must undertake a full analysis at every step. Review and modifications to the work done in Processes 1 and 2 may also need to be accomplished in whole or in part.

5.2 STEPS FOR DEVELOPING A NEW NAVIGATION SPECIFICATION

5.2.1 Step 1 — Feasibility assessment and business case

5.2.1.1 When developing a new navigation specification, the question of the feasibility of establishing a new navigation specification that can realistically be met by aircraft manufacturers and operators, and achieving cost-effective implementation of that navigation specification, is particularly important. It is necessary to undertake a feasibility assessment and to develop a business case.

5.2.1.2 The business case assesses the benefits to be derived from the proposed airspace concept and the cost of implementing a new navigation specification. The cost information will be derived from the proposed functions included in the planned new navigation specification, together with estimates of installation and certification costs.

5.2.1.3 It should be understood that the timescales from initial definition of a new requirement to availability in new RNAV or FMS systems can be in excess of five to seven years. Development from this point to one where the majority of the aircraft fleet operating in a given airspace by natural (non-mandated) upgrading of the RNAV equipment can be in excess of 15 years. Thus, development of a new navigation specification normally involves using navigation functional requirements already provided by manufacturers without the existence of certification or operational approval.

5.2.1.4 *Outline of a new navigation specification*

The outline is a product of the business case and has to take due account of the functional requirements needed to meet the airspace concept. It has to be produced with sufficient detail to enable aircraft manufacturers to prepare cost estimates for the upgrades to RNAV systems (including RNP systems).

5.2.2 Step 2 — Development of a navigation specification

5.2.2.1 Contact should be made early with ICAO in identifying the airspace concept that is to be introduced and the foreseen need for a new navigation specification. The role of ICAO in this process will be to support the State or region in a detailed review of its requirements, in order to ensure subsequent global acceptability of the new navigation specification.

5.2.2.2 Starting from the airspace concept which developers identified at the beginning of their PBN implementation efforts, it will then be necessary to detail the requirements against which the aircraft and its operation will ultimately be approved. In its coordinating role, ICAO will be able to identify other States or regions which may be in the process of developing a new navigation specification with similar operational and/or navigational functions. In this situation, ICAO will support multi-State or multi-regional development of a new harmonized navigation specification. Once the new navigation specification is complete, it will ultimately be incorporated into Volume II of this manual.

5.2.2.3 Although the airspace concept and navigation functional requirements developed in Process 1 form the starting point of the development of a new navigation specification, it is likely that these will need iterative refinement, in order to align them with the details of the new navigation specification as it is being developed.

5.2.3 Step 3 — Identification and development of associated ICAO provisions

The development of a new navigation specification may require the development of new ICAO provisions, for example, procedure design (PANS-OPS (Doc 8168)) criteria or ATM procedures. While these tasks are formally carried out by experts, a State(s) or region(s) would be expected to identify changes that need to be introduced to enable the new navigation specification and applications.

5.2.4 Step 4 — Safety assessment

In accordance with the provisions included in Annex 11 — *Air Traffic Services* and PANS-ATM (Doc 4444), a full safety assessment of the new navigation specification should be completed (see the *Safety Management Manual (SMM)* (Doc 9859). This safety assessment is undertaken once the new navigation specification is sufficiently mature.

See Volume II, Part A, Chapter 2 — Safety Assessment, for a more detailed discussion of the necessary elements of safety assessment and risk modelling.

5.2.5 Step 5 — Follow-up

5.2.5.1 Where the above evaluation leads to the conclusion that the proposed new navigation specification can be applied in the ATM environment, the State or region will be required to formally notify ICAO of the proposed application. ICAO will take action to include the new navigation specification into Volume II of this manual.

5.2.5.2 Upon completion of the new navigation specification development, the State or region would then continue with Process 3: Planning and implementation.

ATTACHMENTS TO VOLUME I

Attachment 1

AREA NAVIGATION (RNAV) SYSTEMS

1. PURPOSE

This attachment provides informative material on area navigation systems, their capabilities, and their limitations.

2. BACKGROUND

2.1 RNAV is defined as “a method of navigation which permits aircraft operation on any desired flight path within the coverage of station-referenced navigation aids or within the limits of the capability of self-contained aids, or a combination of these.” This removes the restriction imposed on conventional routes and procedures where the aircraft must overfly referenced navigation aids, thereby permitting operational flexibility and efficiency. This is illustrated in Figure I-A-A1-1.

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 systems.

2.3 RNAV systems range from single-sensor-based systems to systems with multiple types of navigation sensors. The diagrams in Figure I-A-A1-2 are only intended as examples to show how the complexity and interconnectivity can vary greatly between different RNAV avionics.

2.4 The RNAV 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 equipment are common.

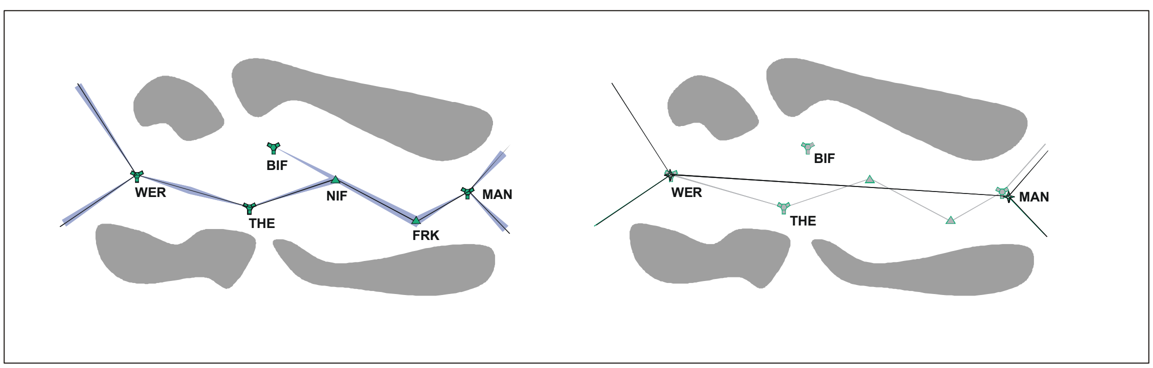


Figure I-A-A1-1. Navigation by conventional navigation compared to RNAV

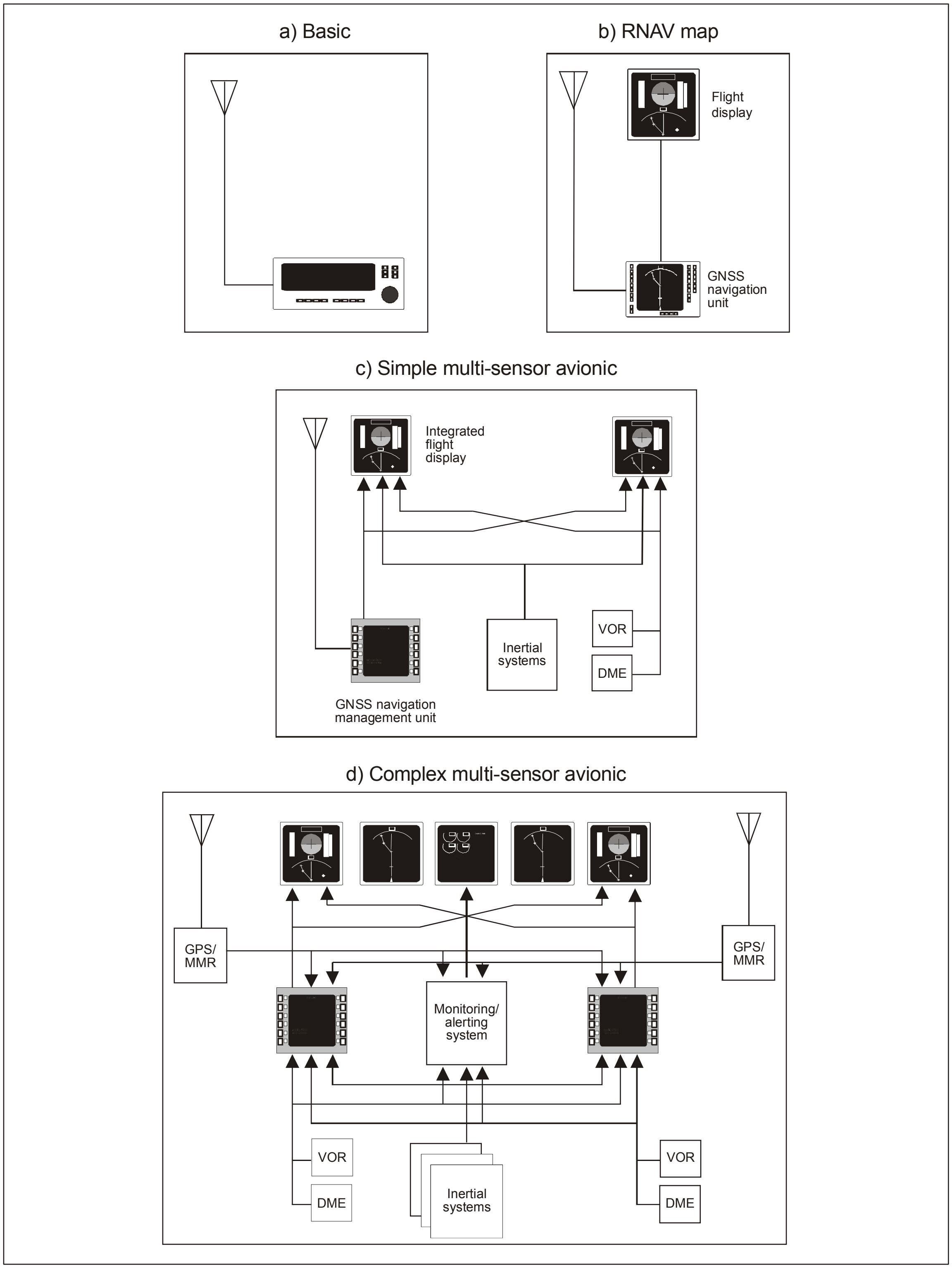


FIGURE I-A-A1-2. RNAV systems — from basic to complex

3. RNAV SYSTEM — BASIC FUNCTIONS

3.1 RNAV systems are designed to provide a given level of accuracy, with repeatable and predictable path definition, appropriate to the application. The RNAV system typically integrates information from sensors, such as air data, inertial reference, 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-A-A1-3):

— navigation;

— flight plan management;

— guidance and control;

— 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 systems. Such systems use a variety of navigation sensors including GNSS, DME, VOR and IRS 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.

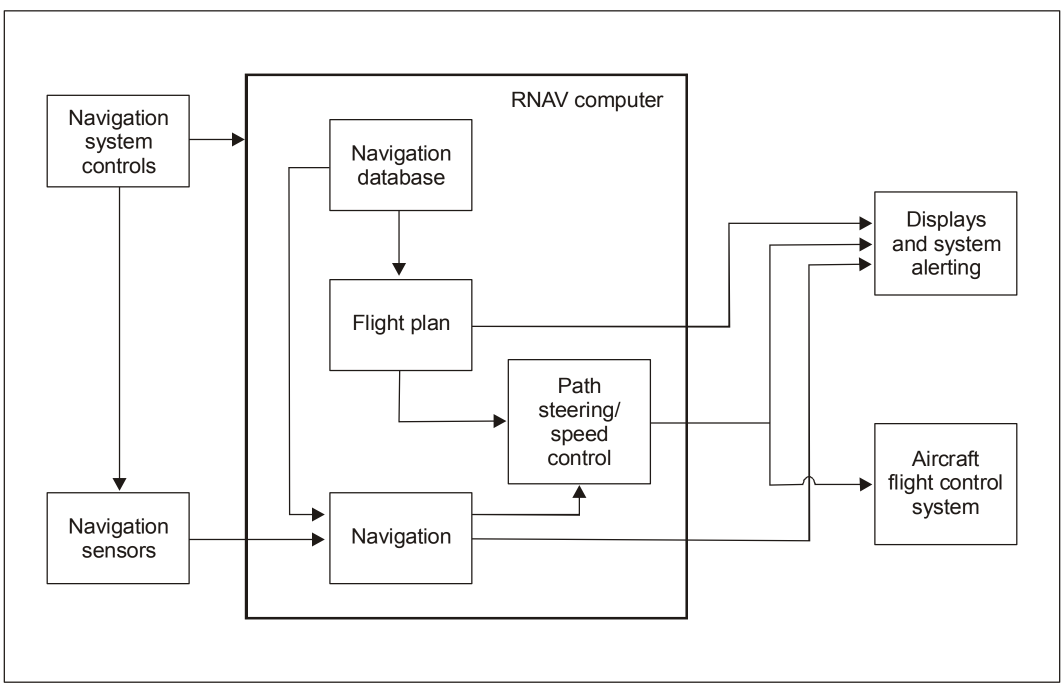


Figure I-A-A1-3. Basic RNAV systems functions

3.2.3 The RNAV system 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 rigorous 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 systems, if GNSS is not available for calculating position/velocity, then the system may automatically select a lower priority update mode such as 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.

3.2.4 As the aircraft progresses along its flight path, if the RNAV 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 the most accurate radio position.

3.2.5 Lateral and vertical guidance is made available to the pilot either on the RNAV system display itself or supplied to other display instruments. In many cases, the guidance is also supplied to an automatic flight guidance system. 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.

3.3 Navigation database

3.3.1 The RNAV 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 system will use such information for flight planning and may also conduct cross-checks between sensor information and the database.

3.4 Flight planning

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 navigation aids.

3.4.2 More advanced RNAV 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 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

An RNAV system provides 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 desired lateral flight path and then generates steering commands used to fly the aircraft along the desired 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 system. The flight path error 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 path error. These steering commands are output to a flight guidance system, 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 flight guidance system, 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:

— capability to follow a desired ground track with reliability, repeatability and predictability, including curved paths; and

— where vertical profiles are included for vertical guidance, use of vertical angles or specified altitude constraints to define a desired vertical path.

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

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

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

— cross track 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 navigation aids to prevent reversion to an inadequate sensor. RNP requirements may limit the modes of operation of the aircraft, e.g. for low RNP, where flight technical error 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. RNAV AND RNP SPECIFIC FUNCTIONS

5.1 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 system, but also may require specific functions to improve procedures, and airspace and air traffic operations. The system capabilities for established fixed radius paths, RNAV or RNP holding, and lateral offsets fall into this latter category.

5.2 Fixed radius paths

5.2.1 Fixed radius paths (FRP): The FRPs take two forms: one is the radius to fix (RF) leg type (see Figure I-A-A1-4). 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 RF leg is defined by radius, arc length, and 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.

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

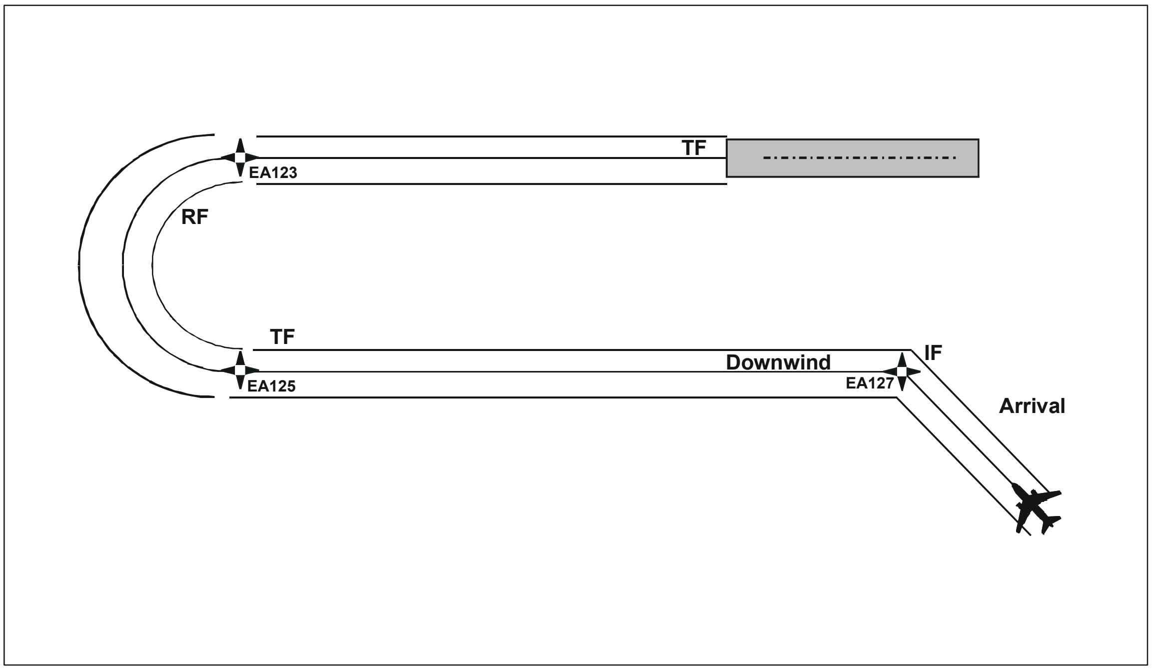


Figure I-A-A1-4. RF leg

5.2.2 The other form of the FRP 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-A-A1-5).

5.2.3 These turns have two possible radii, 22.5 NM for high altitude routes (above FL 195) and 15 NM for low altitude routes. Using such path elements in an RNAV ATS route enables improvement in airspace usage through closely spaced parallel routes.

5.3 Fly-by turns

Fly-by turns are a key characteristic of an RNAV flight path. The RNAV system uses information on aircraft 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 plane 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-A-A1-6).

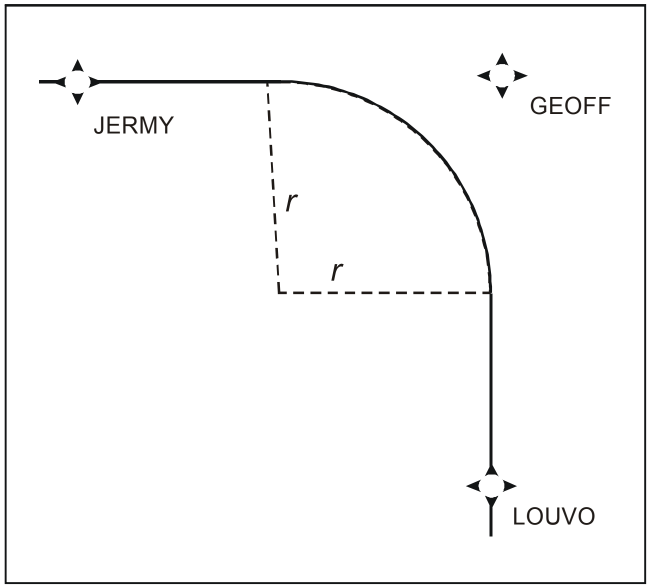


Figure I-A-A1-5. Fix radius transition

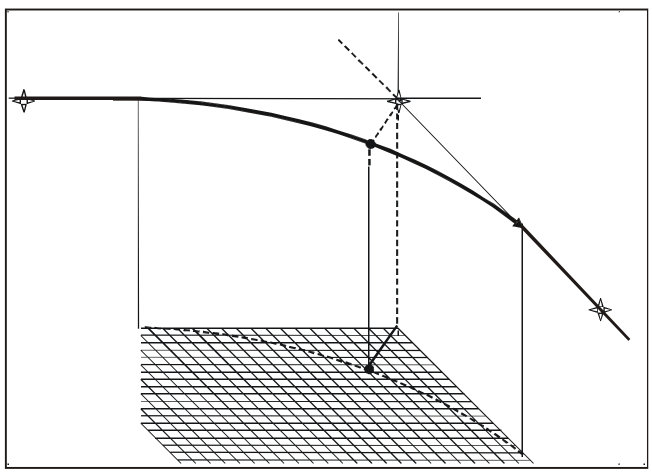


Figure I-A-A1-6. Fly-by turn

5.4 Holding pattern

The RNAV 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. For RNP systems, further improvement in holding is available. These RNP improvements include fly-by entry into the hold, minimizing the necessary protected airspace on the non-holding side of the holding pattern, consistent with the RNP limits provided. Where RNP holding is applied, a maximum of RNP 1 is suggested since less stringent values adversely affect airspace usage and design (see Figure I-A-A1-7).

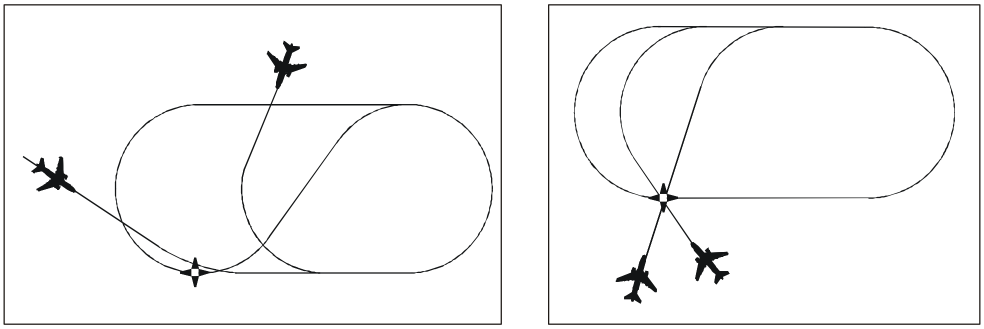


Figure I-A-A1-7. RNP holding pattern entries

5.5 Offset flight path

RNAV 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 RNAV system, the RNAV aircraft will depart the defined route and typically intercept the offset at a 45 degree or less angle. When the offset is cancelled, the aircraft returns to the defined route in a similar manner. Such offsets can be used both strategically, i.e. fixed offset for the length of the route, or tactically, i.e. temporarily. Most RNAV systems discontinue offsets in the terminal area or at the beginning of an approach procedure, at an RNAV hold, or during course changes of 90 degrees or greater. The amount of variability in these types of RNAV operations should be considered as operational implementation proceeds (see Figure I-A-A1-8).

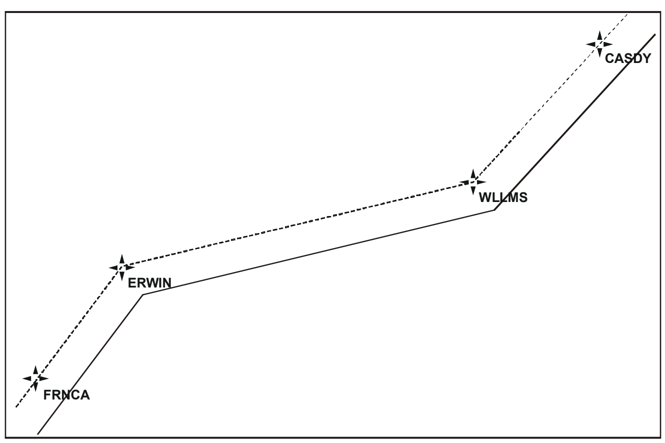


Figure I-A-A1-8. Offset flight path

Attachment 2

DATA PROCESSES

1. AERONAUTICAL DATA

1.1 All RNAV 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 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-A-A2-1).

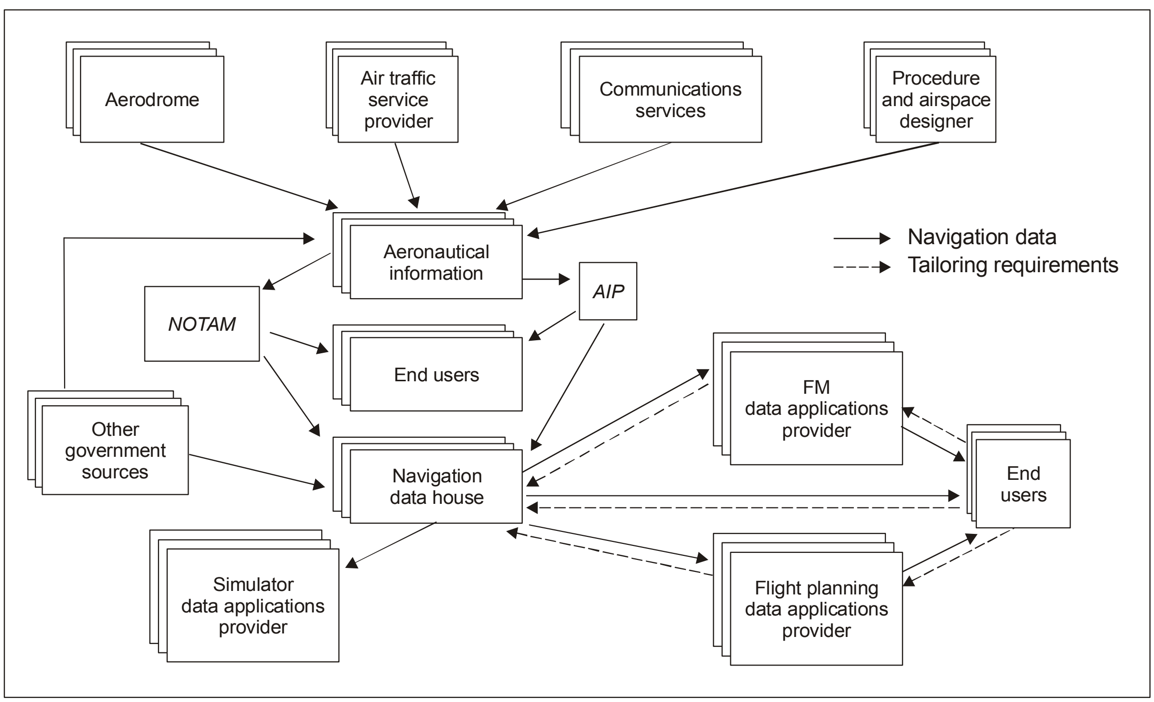


Figure I-A-A2-1. The data chain

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 Annex 15 — *Aeronautical Information Services,* which requires each Contracting State 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 each Contracting State 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-200A 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 in no way guaranteed. Its accuracy should be verified by ground and/or flight validation.

3. PROVISION OF AERONAUTICAL DATA

3.1 It is incumbent upon the national aviation authority in each State to 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.

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 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-A-A2-2.

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:

a) all coordinate data must be referenced to the World Geodetic System — 1984 (WGS-84);

b) all surveys must be based upon the International Terrestrial Reference Frame;

c) all data must be traceable to their source;

d) equipment used for surveys must be adequately calibrated;

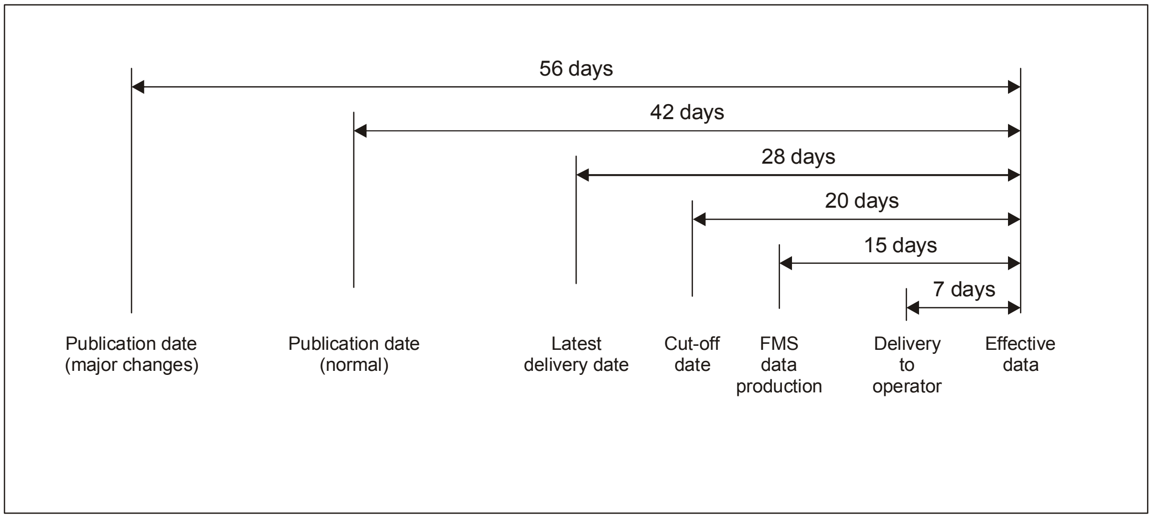


Figure I-A-A2-2. Data processing timeline

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) procedures must be subjected to ground validation and, where necessary, flight validation and flight inspection prior to publication;

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:

   i) a requirement to maintain quality records;

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

4. ALTERING AERONAUTICAL DATA

4.1 A data processor or data user shall not alter any data without informing the originator of the alteration and receiving concurrence. Altered data shall not be transmitted to a user if the originator rejects the alteration. Records shall be kept of all alterations and shall 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 cyclical redundancy check (CRC) algorithms should be used wherever possible throughout the navigation data chain.

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VOLUME II

IMPLEMENTING RNAV AND RNP

TABLE OF CONTENTS

PART C — IMPLEMENTING RNP

ATTACHMENT TO VOLUME II

FOREWORD

This manual consists of two volumes:

Volume I — *Concept and Implementation Guidance*
Volume II — *Implementing RNAV and RNP*

Organization and contents of Volume II:

Part A — *General*

Part B — *Implementing RNAV,* contains three chapters that describe how to implement RNAV 10, RNAV 5, and RNAV 1 and 2, respectively.

Part C — *Implementing RNP,* contains four chapters that describe how to implement RNP 4, Basic-RNP 1; RNP APCH, and RNP AR APCH. Two chapters are reserved for RNP 2 and Advanced-RNP 1.

Attachment A — *Barometric VNAV*

All of the chapters in Parts B and C are intended for the use of airworthiness authorities, ANSPs, airspace planners and PANS-OPS specialists.

These chapters all follow the same structure:

— Introduction
— ANSP considerations
— Navigation specification
— References
— Attachments

Specific remarks

This volume is based on the experiences of States which have used RNAV operations. It is an integral part and complementary to Volume I — *Concept and Implementation Guidance*. References are provided at the end of each navigation specification in Parts B and C of Volume II.

Future developments of this volume

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 University Street
Montréal, Quebec, Canada H3C 5H7

ABBREVIATIONS

ABAS	Aircraft-based augmentation system
ADS-B	Automatic dependent surveillance — broadcast
ADS-C	Automatic dependent surveillance — contract
AFE	Above field elevation
AIP	Aeronautical information publication
ANSP	Air navigation service provider
ATM	Air traffic management
ATS	Air traffic services
CDI	Course deviation indicator
CDU	Control and display unit
CF	Course to fix
CFIT	Controlled flight into terrain
CRC	Cyclic redundancy checking
CRM	Collision risk model
DA	Decision altitude
DME	Distance measuring equipment
EASA	European Aviation Safety Agency
ECAC	European Civil Aviation Conference
EFIS	Electronic flight instrument system
EUROCAE	European Organization for Civil Aviation Equipment
EUROCONTROL	European Organisation for the Safety of Air Navigation
FA	Fix to altitude
FAA	Federal Aviation Administration
FDE	Fault detection and exclusion
FMS	Flight management system
FRT	Fixed radius transition
FTE	Flight technical error
GNSS	Global navigation satellite system
GPS	Global positioning system
HSI	Horizontal situation indicator
IAF	Initial approach fix

INS	Inertial navigation system
IRS	Inertial reference system
IRU	Inertial reference unit
JAA	Joint aviation authorities
LRNS	Long-range navigation systems
MCDU	Multifunction control and display unit
MEL	Minimum equipment list
MNPS	Minimum navigation performance specification
Navaid	Navigation aid
NSE	Navigation system error
OEM	Original equipment manufacturer
PBN	Performance-based navigation
PDE	Path definition error
PEE	Positioning estimation error
PSR	Primary surveillance radar
RAIM	Receiver autonomous integrity monitoring
RF	Radius to fix
RNAV	Area navigation
RTCA	Radio Technical Commission on Aeronautics
SBAS	Satellite-based augmentation system
SID	Standard instrument departure
SSR	Secondary surveillance radar
STAR	Standard instrument arrival
TLS	Target level of safety
TOGA	Take-off/go-around
TSE	Total system error
TSO	Technical standard order
VNAV	Vertical navigation
VOR	Very high frequency (VHF) omnidirectional radio range

EXPLANATION OF TERMS

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 provides the outline and intended framework of 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 etc. airspace concepts can include details of the practical organization of the airspace and its users based on particular CNS/ATM assumptions, e.g. ATS route structure, separation minima, route spacing and obstacle clearance.

Approach procedure with vertical guidance (APV). An instrument procedure which utilizes lateral and vertical guidance but does not meet the requirements established for precision approach and landing operations.

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

Note.— Area navigation includes performance-based navigation as well as other RNAV operations that do not meet the definition of performance-based navigation.

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

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 variously, ADS-B, PSR, 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.

Critical DME. A DME facility that, when unavailable, results in a navigation service which is insufficient for DME/DME-based or DME/DME/IRU-based operations along a specific route or procedure.

Fault detection and exclusion (FDE). Fault detection and exclusion (FDE) is a function performed by some GNSS receivers, which can detect the presence of a faulty satellite signal and exclude it from the position calculation.

Navigation aid (navaid) infrastructure. Navaid infrastructure refers to space-based and or ground-based navigation aids available to meet the requirements in the navigation specification.

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

Note.— The navigation application is one element, along with communication, 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 Parts B and C of this volume.

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 performance monitoring and alerting, designated by the prefix RNAV, e.g. RNAV 5, RNAV 1.

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

Note.— The Performance-Based Navigation (PBN) Manual *(Doc 9613), Volume II, contains detailed guidance on navigation specifications.*

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 in terms of accuracy, integrity, continuity, availability and functionality needed for the proposed operation in the context of a particular airspace concept.

Procedural control. Air traffic control service provided by using information derived from sources other than an ATS surveillance system.

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 operations include the use of area navigation for operations which are not developed in accordance with this manual.

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 a flight management system (FMS).

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

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

RNP system. An area navigation system which supports on-board performance monitoring and alerting.

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.

Part A

GENERAL

Chapter 1

INTRODUCTION

1.1 PERFORMANCE-BASED NAVIGATION (PBN) 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, Part A, Chapter 1.

1.1.2 Navigation specifications are used by States as a basis for certification and operational approval. 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 approval against the navigation specification is prescribed. These requirements include:

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

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; and

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

The navaid infrastructure relates to space or ground-based navaids that are mentioned in each navigation specification.

1.1.3 Navigation specifications which require on-board performance monitoring and alerting are termed RNP specifications. Those that do not require on-board performance monitoring and alerting are known as RNAV specifications. The use of on-board performance monitoring and alerting to distinguish between RNP and RNAV is a convenience. This simplifies the fact that there are a few differences and many common functional aspects to airplane systems that must perform the desired flight operations.

1.1.4 A “navigation application” is when a navigation specification and associated navaid infrastructure are applied to ATS routes, instrument approach procedures and/or 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 SIDs and STARs, RNAV or RNP ATS routes, and RNP approach procedures.

1.2 USE AND SCOPE OF NAVIGATION SPECIFICATIONS

1.2.1 Most of the ICAO navigation specifications contained in this volume were originally developed for regional use to respond to the operational requirements of specific airspace concepts. Some of the applications of these navigation specifications are used in airspace concepts for oceanic or remote continental airspace; others are used in airspace concepts for continental or terminal airspace.

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

1.2.3 Table II-A-1-1 shows the navigation specifications and their associated navigation accuracies published in Parts B and C of this volume. It demonstrates, for example, that the designation of an oceanic/remote, en-route or terminal navigation specification includes an indication of the required navigation accuracy, and that the designation of navigation specifications used on final approach is different.

Table II-A-1-1. Application of navigation specification by flight phase

Notes.—

1. The numbers given in the table refer to the 95 per cent accuracy requirements (NM).

2. RNAV 5 is an en-route navigation specification which may be used for the initial part of the STAR outside 30 NM and above MSA.

3. RNP 2 and Advanced-RNP 1 are expected to be included in a future revision of the PBN manual.

Navigation specification	Flight phase							
	En-route oceanic/remote	En-route continental	Arrival	Approach				Departure
				Initial	Intermediate	Final	Missed	
RNAV 10	10							
RNAV 5		5	5					
RNAV 2		2	2					2
RNAV 1		1	1	1	1		1[b]	1
RNP 4	4							
Basic-RNP 1			1[a,c]	1[a]	1[a]		1[ab]	1[a,c]
RNP APCH				1	1	0.3	1	

a. The navigation application is limited to use on STARs and SIDs only.
b. The area of application can only be used after the initial climb of a missed approach phase.
c. Beyond 30 NM from the airport reference point (ARP), the accuracy value for alerting becomes 2 NM.

1.2.4 Most important, Table II-A-1-1 shows that for any particular PBN operation, it is possible that a sequence of RNAV and RNP applications is used. A flight may commence in an airspace using a Basic-RNP 1 SID, transit through en-route 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).

1.2.5 Table II-A-1-1 identifies, for example, in the approach and missed approach phases of flight, a number of instances where different navigation specifications can be applied on the same phases of flight providing identical total system errors (TSEs). This does not imply that all of the specifications provide identical functional capability. Consequently, in the design of the procedures, it is important to call up only that capability which is provided by the appropriate navigation specification and that the procedure is appropriately identified.

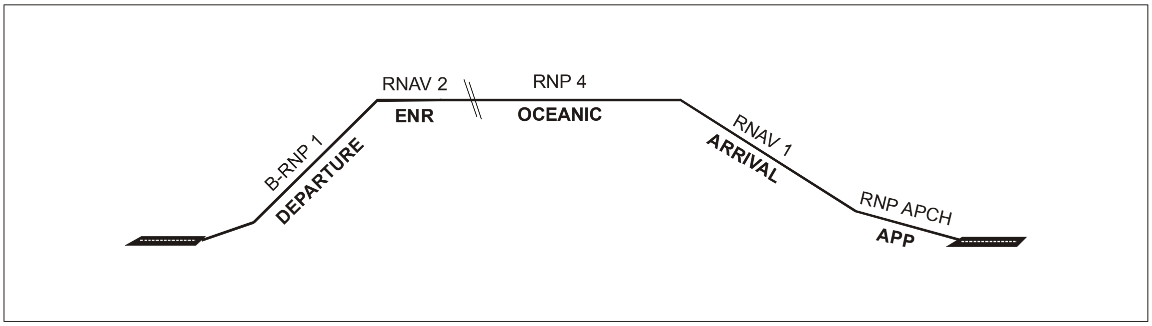

Figure II-A-1-1. Example of an application of RNAV and RNP specifications to ATS routes and instrument procedures

1.2.6 The procedure to be flown by the RNAV system is to be coded into the database; it must also be possible for the pilot to ensure that the system is capable of meeting the operational requirements for the whole procedure.

1.2.7 Scope of ICAO navigation specifications

1.2.7.1 The ICAO navigation specifications (i.e. those included in this volume) do not address all requirements that may be specified for operation in a particular airspace, route or in a particular area. Such additional requirements are specified in other documents such as operating rules, aeronautical information publications (AIPs) and the ICAO *Regional Supplementary Procedures* (Doc 7030). Operational approval primarily relates to the navigation requirements of the airspace; however, before conducting flights into an airspace, the appropriate State authority of that airspace requires that operators and flight crew take account of all operational documents relating to that airspace.
.

1.2.7.2 It is incumbent upon States to undertake a safety assessment in accordance with the provisions contained in Annex 11 — *Air Traffic Services* and PANS-ATM (Doc 4444), Chapter 2.

1.2.8 Navigation specifications and the approval process

1.2.8.1 A navigation specification found in this manual 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. Therefore, with RNAV 2/RNAV 1, for example, there is still a need to have an approval process. This could be either through a dedicated approval document or through recognition that existing regional RNAV implementation certification documents (i.e. TGL No. 10 and AC 90-100) can be applied with the necessary differences, to satisfy the objectives set out in the PBN navigation specification.

1.2.8.2 Compliance should be determined against each relevant navigation specification. Compliance with one navigation specification does not automatically imply compliance with another.

Chapter 2

ON-BOARD PERFORMANCE MONITORING AND ALERTING

2.1 INTRODUCTION

This chapter addresses the requirements associated with on-board performance monitoring and alerting for RNP, based on current implementations and navigation specifications. In order to do this, the chapter first provides an overview of the error sources associated with RNAV systems.

2.2 NAVIGATION ERROR COMPONENTS AND ALERTING

2.2.1 Lateral navigation

The inability to achieve the required lateral navigation accuracy may be due to navigation errors related to aircraft tracking and positioning. The three main errors in the context of on-board performance monitoring and alerting are path definition error (PDE), flight technical error (FTE), and navigation system error (NSE), as shown in Figure II-A-2-1. The distribution of these errors is assumed to be independent, zero-mean and Gaussian. Therefore, the distribution of total system error (TSE) is also Gaussian with a standard deviation equal to the root sum square (RSS) of the standard deviations of these three errors.

a) PDE occurs when the path defined in the RNAV system does not correspond to the desired path, i.e. the path expected to be flown over the ground. Use of an RNAV system for navigation presupposes that a defined path representing the intended track is loaded into the navigation database. A consistent, repeatable path cannot be defined for a turn that allows for a fly-by turn at a waypoint, requires a fly-over of a waypoint, or occurs when the aircraft reaches a target altitude (see Attachment A to Volume I for further explanation). In these cases, the navigation database contains a point-to-point desired flight path, but cannot account for the RNAV system defining a fly-by or fly-over path and performing a manoeuvre. A meaningful PDE and FTE cannot be established without a defined path, resulting in variability in the turn. In contrast, when a radius to fix (RF) leg transition or fixed radius transition (FRT) is used, as with some RNP specifications (see below), a path can be defined and therefore PDE and FTE can be determined. Also, a deterministic, repeatable path cannot be defined for paths based on heading and the resulting path variability is accommodated in the route design.

b) FTE relates to the air crew or autopilot's ability to follow the defined path or track, including any display error (e.g. course deviation indicator (CDI) centring error). FTE can be monitored by the autopilot or air crew procedures and the extent to which these procedures need to be supported by other means depends, for example, on the phase of flight and the type of operations. Such monitoring support could be provided by a map display.

   Note.— FTE is sometimes referred to as path steering error (PSE).

c) NSE refers to the difference between the aircraft's estimated position and actual position.

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

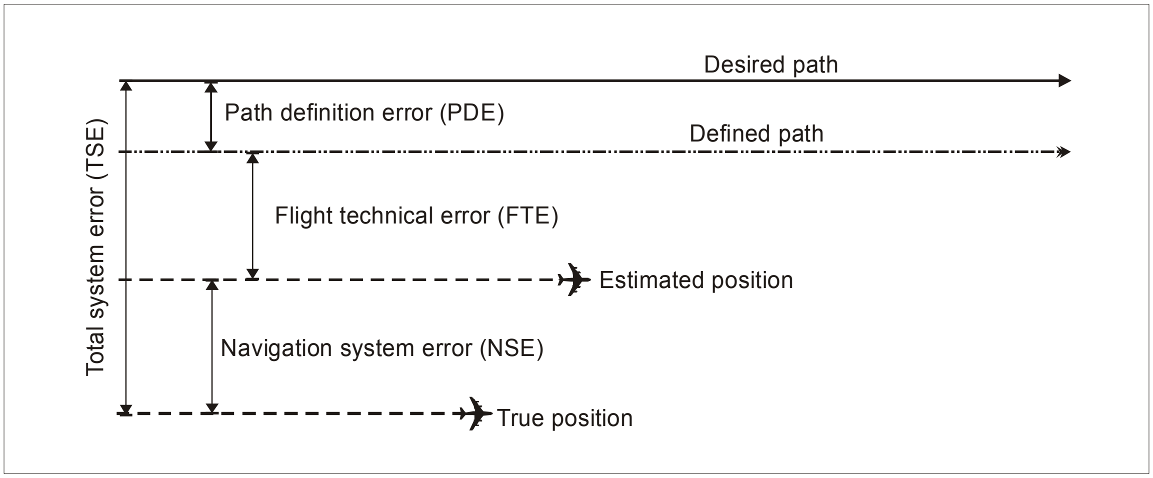

Figure II-A-2-1. Lateral navigation errors (95 per cent)

2.2.2 Longitudinal navigation

2.2.2.1 Longitudinal performance implies navigation against a position along the track (e.g. 4-D control). However, at the present time, there are no navigation specifications requiring 4-D control, and there is no FTE in the longitudinal dimension. The current navigation specifications define requirements for along-track accuracy, which includes NSE and PDE. PDE is considered negligible. The along-track accuracy affects position reporting (e.g. "10 NM to ABC") and procedure design (e.g. minimum segment altitudes where the aircraft can begin descent once crossing a fix).

2.2.2.2 The accuracy requirement of RNAV and RNP specifications are defined for the lateral and along-track dimensions. The on-board performance monitoring and alerting requirements of RNP specifications are defined for the lateral dimension for the purpose of assessing an aircraft's compliance. However, the NSE is considered as a radial error so that on-board performance monitoring and alerting is provided in all directions (see Figure II-A-2-2).

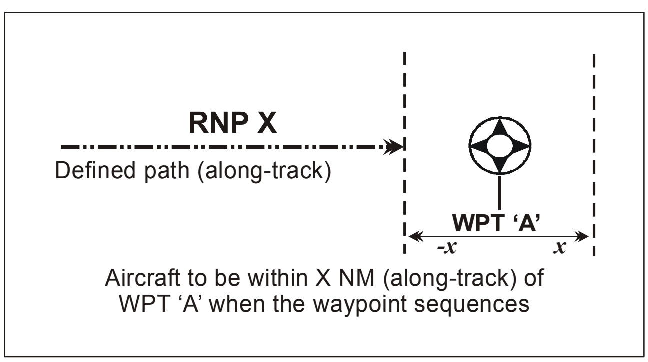

Figure II-A-2-2. Along-track navigation errors (95 per cent)

2.3 ROLE OF ON-BOARD PERFORMANCE MONITORING AND ALERTING

2.3.1 On-board performance monitoring and alerting capabilities fulfil two needs, one on board the aircraft and one within the airspace design. The assurance of airborne system performance is implicit for RNAV operations. Based upon existing airworthiness criteria, RNAV systems are only required to demonstrate intended function and performance using explicit requirements that are broadly interpreted. The result is that while the nominal RNAV system performance can be very good, it is characterized by the variability of the system functionality and related flight performance. RNP systems provide a means to minimize variability and assure reliable, repeatable and predictable flight operations.

2.3.2 On-board performance monitoring and alerting allow 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 relate to both lateral and longitudinal navigation performance.

2.3.3 On-board performance monitoring and alerting is concerned with the performance of the area navigation system.

— "on-board" explicitly means that the performance monitoring and alerting is effected on board the aircraft and not elsewhere, e.g. using a ground-based route adherence monitor or ATC surveillance. The monitoring element of on-board performance monitoring and alerting relates to FTE and NSE. Path definition error (PDE) is constrained through database integrity and functional requirements on the defined path, and is considered negligible.

— "monitoring" refers to the monitoring of the aircraft's performance as regards its ability to determine positioning error and/or to follow the desired path.

— "alerting" relates to monitoring: if the aircraft's navigation system does not perform well enough, this will be alerted to the air crew.

2.3.4 The monitoring and alerting requirements could be satisfied by:

a) an airborne navigation system having an NSE monitoring and alerting capability (e.g. RAIM or FDE algorithm) plus a lateral navigation display indicator (e.g. CDI) enabling the crew to monitor the FTE. On the assumption that PDE is negligible, the requirement is satisfied because NSE and FTE are monitored leading to a TSE monitoring; or

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

2.3.5 The net effect of the above is evident in TSE (see Table II-A-2-1).

2.3.6 In Table II-A-2-1, RNP X specifications which do not require RF or FRT, have much in common with RNAV specifications as regards PDE since the desired path is not defined; this results in the need to provide additional protected airspace on the turn.

2.3.7 The PBN concept uses the term on-board performance monitoring and alerting instead of the term containment. This is to avoid confusion between existing uses of containment in various documents by different areas of expertise. For example:

a) "Containment" refers to the region within which the aircraft will remain 95 per cent of the time. The associated terms have been "containment value" and "containment distance" and the related airspace protection on either side of an RNAV ATS route.

Table II-A-2-1. Effect of on-board performance monitoring and alerting on TSE

	RNAV specification	*RNP specifications*	
		RNP X specification not requiring RF or FRT	*RNP X specification* requiring RF or FRT
NSE *(monitoring and alerting)*	NSE only observed by pilot cross-checks; no alerting on position error.	Alerting on position accuracy and integrity.	
FTE *(monitoring)*	Managed by on-board system or crew procedure.	Managed by on-board system or crew procedure.	
PDE *(monitoring)*	Generally negligible; the desired path is not defined on fly-by, fly-over, and conditional turns.		Generally negligible; path defined on RF and FRT.
NET EFFECT ON **TSE**	TSE distribution not bounded. In addition, the wide variation in turn performance results in need for extra protection on turns.	TSE distribution bounded, but extra protection of the route needed on turns;	TSE distribution bounded; no extra protection of the route needed on turns if turns defined by RF or FRT.

b) Within the industry standards of 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 are "containment limit", "containment integrity", "containment continuity", and "containment region".

c) Within PANS-OPS material, "containment" has referred to the region used to define the obstacle clearance, and the aircraft is expected to remain within or above that surface (regardless of alerting) with very high probability. The associated terms have been "containment area", "airspace containment", "obstacle clearance containment" and related obstacle protection areas.

2.3.8 The previous ICAO expressions of "containment value" and "containment distance" have been replaced by the navigation accuracy of TSE.

2.3.9 Performance monitoring and alerting requirements for RNP

2.3.9.1 *RNP 4, Basic-RNP 1 and RNP APCH*

2.3.9.1.1 The performance monitoring and alerting requirements for RNP 4, Basic-RNP 1 and RNP APCH have common terminology and application. Each of these RNP navigation specifications includes requirements for the following characteristics:

a) Accuracy: The accuracy requirement defines the 95 per cent TSE for those dimensions where an accuracy requirement is specified. The accuracy requirement is harmonized with the RNAV navigation specifications and is always equal to the accuracy value. A unique aspect of the RNP navigation specifications is that the accuracy is one of the performance characteristics that is monitored, as described in the next subparagraph.

b) Performance monitoring: The aircraft, or aircraft 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 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 are evaluated for their effectiveness and equivalence.

c) Aircraft failures: Failure of the aircraft equipment is considered within airworthiness regulations. Failures are categorized by the severity of the aircraft level effect, and the system must be designed to reduce the likelihood of the failure or mitigate its effect. Both malfunction (equipment operating but not providing appropriate output) and loss of function (equipment ceases to function) are addressed. Dual system requirements are determined based on operational continuity (e.g. oceanic and remote operations). The requirements on aircraft failure characteristics are not unique to RNP navigation specifications.

d) Signal-in-space failures: Signal-in-space characteristics of navigation signals are addressed in Annex 10 — *Aeronautical Telecommunications* and are the responsibility of the ANSP.

2.3.9.1.2 The performance monitoring requirement is unique to RNP navigation specifications. The net effect of RNP navigation specifications is to provide bounding of the TSE distribution. Since path definition error is assumed to be negligible, the monitoring requirement is reduced to the other two components of TSE, i.e. FTE and NSE. It is assumed that FTE is an ergodic[1] stochastic process within a given flight control mode. As a result, the FTE distribution is constant over time within a given flight control mode. However, in contrast, the NSE distribution varies over time due to a number of changing characteristics, most notably:

a) selected navigation sensors: the navigation sensors which are being used to estimate position, such as GNSS or DME/DME;

b) the relative geometry of the aircraft position to the supporting navigation aids: all radio navaids have this basic variability, although the specific characteristics change. GNSS performance is affected by the relative geometry of the satellites as compared to the aircraft (lines of position should be well distributed in space to support good resolution in space and time). DME/DME navigation solutions are affected by the inclusion angle between the two DMEs at the aircraft (90 degrees being optimal) and the distance to the DMEs, since the aircraft DME transponder can have increasing range errors with increasing distance;

c) inertial reference units: error characteristics: errors increase over time since last being updated.

2.3.10 Application of performance monitoring and alerting to aircraft

2.3.10.1 Although the TSE can change significantly over time for a number of reasons, including those above, the RNP navigation specifications provide assurance that the TSE distribution remains suitable to the operation. This results from two requirements associated with the TSE distribution, namely:

a) the requirement that the TSE remains equal to or less than the required accuracy for 95 per cent of the flight time; and

b) the probability that the TSE of each aircraft exceeds the specified TSE limit (equal to two times the accuracy value) without annunciation is less than 10^{-5}.

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1. An ergodic process is one in which every sequence or sizable sample is equally representative of the whole. It is realized that this is not necessarily true for all operations envisaged by RNAV and RNP systems, especially where manual operation is involved, but when averaged over a large number of operations this assumption becomes valid.

2.3.10.2 Typically, the 10^{-5} TSE requirement provides a greater restriction on performance. For example, with any system that has TSE with a normal distribution of cross-track error, the 10^{-5} monitoring requirement constrains the standard deviation to be 2 × (accuracy value)/4.45 = accuracy value/2.23, while the 95 per cent requirement would have allowed the standard deviation to be as large as the accuracy value/1.96.

2.3.10.3 It is important to understand that while these characteristics define minimum requirements that must be met, they do not define the actual TSE distribution. The actual TSE distribution may be expected to be typically better than the requirement, but there must be evidence on the actual performance if a lower TSE value is to be used.

2.3.10.4 In applying the performance monitoring requirement to aircraft, there can be significant variability in how individual errors are managed:

a) Some systems monitor the actual cross-track and along-track errors individually, whereas others monitor the radial NSE to simplify the monitoring and eliminate dependency on the aircraft track, e.g. based on typical elliptical 2-D error distributions.

b) Some systems include the FTE in the monitor by taking the current value of FTE as a bias on the TSE distribution.

c) For Basic GNSS systems, the accuracy and 10^{-5} requirements are met as a by-product of the ABAS requirements that have been defined in equipment standards and the FTE distribution for standardized course deviation indicator (CDI) displays.

2.3.10.5 It is important that performance monitoring is not regarded as error monitoring. A performance monitoring alert will be issued when the system cannot guarantee, with sufficient integrity, that the position meets the accuracy requirement. When such an alert is issued, the probable reason is the loss of capability to validate the position data (insufficient satellites being a potential reason). For such a situation, the most likely position of the aircraft at that time is the exact same position indicated on the pilot display. Assuming the desired track has been flown correctly, the FTE would be within the required limits and therefore the likelihood of the TSE exceeding twice the accuracy value just prior to the alert is approximately 10^{-5}. However, it cannot be assumed that simply because there is no alert the TSE is less than twice the accuracy value: the TSE can be larger. An example is for those aircraft that account for the FTE based on a fixed error distribution: for such systems, if the FTE grows large, no alert is issued by the system even when the TSE is many times larger than the accuracy value. For this reason, the operational procedures to monitor the FTE are important.

2.3.11 Application of performance monitoring and alerting to risk evaluations

2.3.11.1 The performance monitoring and alerting requirements for RNP 4, Basic-RNP 1 and RNP APCH do not obviate the need for safety assessments, using a risk metric such as collisions per hour or excursions outside the obstacle clearance area during an approach, to determine the separation minima and obstacle clearance criteria for these routes. Since the relationship between the level of collision risk, accuracy and route spacing or obstacle clearance is generally complex, it is not appropriate to simply assume that the appropriate route spacing (track-to-track) is four-times the accuracy value, or to assume that the obstacle clearance is two-times the accuracy value. For example, the risk of collision between aircraft or between aircraft and obstacles depends on the probability of the loss of separation in the dimension under consideration and the exposure to that loss of separation. The exposure may be evaluated over time (e.g. the time it takes to conduct an approach operation) or over the number of risk events (e.g. the number of aircraft that will be passed in an hour).

2.3.11.2 The safety assessment may use the performance monitoring and alerting requirements to provide a bounding of the TSE distribution in each dimension, the resulting bounding of distribution will need to be validated. In addition, close attention should be paid to the scope of these bounding distributions since they do not cover, for example, human error. Moreover, navigation database errors are not covered by the PBN-based navigation specifications (see Parts B and C of this volume). It is well known that "blunder" type errors are a major source of errors in navigation and, as precision increases through application of GNSS, become the most significant source of risk. These have traditionally been taken into account in safety assessments for the determination of separation minima by the ICAO Separation and Airspace Safety Panel (SASP).

2.3.11.3 Although the determination of obstacle clearance criteria by the ICAO Instrument Flight Procedure Panel (IFPP) is traditionally based on the fault-free case, it has repeatedly been found that with modern navigation methods based on GNSS, integrity and continuity of service are of critical importance to the resulting level of safety. Deviations resulting from a mixture of fault-free performances and some (but not all) failures where these deviations are not annunciated have become apparent. Thus, considerable care is necessary with respect to the precise scope of the pertinent safety assessments.

2.3.11.4 In conducting a safety assessment, States may elect to take into account that the ensemble distribution (of all aircraft operating on the route or procedure) will have a TSE better than the bounding distribution allowed by the performance monitoring and alerting requirements. However, in doing so, there must be evidence as to the actual performance being achieved.

2.3.12 Application of performance monitoring and alerting for RNP AR APCH

2.3.12.1 The performance monitoring and alerting requirements for RNP AR APCH include many of the same characteristics as for RNP 4, Basic-RNP 1 and RNP APCH. However, in the case of RNP AR APCH, these requirements can be tighter and a number of additional requirements can be applied to more closely monitor or control each error source. There are basically two ways to determine obstacle clearance criteria through analysis. One way is to derive obstacle clearance from the target level of safety, given predefined aircraft requirements and operational mitigations. The other way is to derive aircraft requirements and operational mitigations from the target level of safety, given predefined obstacle clearance criteria. It is of vital importance in understanding the methodology used for RNP AR, when the latter method is followed, i.e. the obstacle clearance for RNP AR APCH operations was first established to have a total width of four-times the accuracy value (± two-times the accuracy value centred on the path) after which aircraft requirements and operational mitigations were then developed to satisfy the target level of safety.

2.3.12.2 In the case of GNSS, the signal-in-space requirement for RNP AR APCH is not set based on the NSE. Instead, it is described in terms of the TSE to ensure an acceptable risk that the aircraft will go outside the obstacle clearance area. The aircraft failure requirements are more constraining; more stringent performance monitoring and alerting requirements are defined for many of the individual error sources.

2.3.13 System performance monitoring and alerting requirements

The following examples are provided for Basic-RNP 1 values:

Accuracy: During operations in airspace or on routes designated as Basic-RNP 1, the lateral total system error 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.

Integrity: Malfunction of the aircraft navigation equipment is classified as a major failure condition under airworthiness regulations (i.e. 10^{-5} per hour).

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.

Performance monitoring and alerting: The RNP system, or the RNP system and pilot in combination, shall provide an alert if the accuracy requirement is not met, or if the probability that the lateral TSE exceeds 2 NM is greater than 10^{-5}.

Signal-in-space: If using GNSS, the aircraft navigation equipment shall provide an alert if the probability of signal-in-space errors causing a lateral position error greater than 2 NM exceeds 10^{-7} per hour (Annex 10, Volume I, Table 3.7.2.4-1).

Chapter 3

SAFETY ASSESSMENT CONSIDERATIONS

3.1 SAFETY ASSESSMENT CONSIDERATIONS

3.1.1 Introduction

3.1.1.1 Parts B and C of this volume contain navigation specifications which are applied in an airspace concept. When applying a navigation specification, a number of safety considerations have to be assessed.

3.1.1.2 Planners should consult these key reference documents:

— *Safety Management Manual (SMM)* (Doc 9859), Chapter 13, provides guidance on performing safety assessments.

— *Manual on Airspace Planning Methodology for the Determination of Separation Minima* (Doc 9689), provides information on quantifying the effect separation minima have on air traffic safety.

— *Procedures for Air Navigation Services — Aircraft Operations* (PANS-OPS) (Doc 8168), Volume II, provides design criteria for ATS routes and procedures.

— *Required Navigation Performance Authorization Required (RNP AR) Procedure Design Manual* (Doc 9905), provides design criteria for RNP AR procedures.

— *Procedures for Air Navigation Services — Air Traffic Management* (PANS-ATM) (Doc 4444), provides separation minima.

3.1.1.3 The following provides an overview of some of the performance characteristics that need to be considered in the safety assessment. Table II-A-3-1 providing cross-references to safety assessment references for the navigation specifications in Parts B and C of this volume concludes the section on safety assessment.

3.2 AIRCRAFT PERFORMANCE

3.2.1 *Normal performance:* Lateral accuracy is addressed in the individual navigation specifications in Parts B and C of this volume. Lateral accuracy is expressed in terms of a nautical mile value on either side of a desired track centreline. The aircraft is expected to be within that lateral value of the desired track centreline for 95 per cent of the time. Longitudinal accuracy is also defined as the accuracy of distance reporting or the fix location.

3.2.2 *Non-normal errors:* Navigation specifications in Part B of this volume do not define aircraft performance in cases of non-normal errors. Non-normal errors include RNAV system failures, as well as “blunder” type errors such as selection of the wrong route. Navigation specifications in Part C of this volume address some non-normal errors through the on-board performance monitoring and alerting requirements, including aircraft and signal-in-space failure conditions. Blunder errors are not included in the on-board performance monitoring and alerting requirements, and must be handled through crew procedure and training, detection through surveillance or additional separation.

3.3 SYSTEM FAILURES

3.3.1 The safety assessment must consider aircraft that have single navigation systems, where allowed in the particular navigation specification. Potential mitigations are identified by considering the nature of the aircraft system failure, availability of alternate means of navigation and the available CNS ATM environment.

3.3.2 In a surveillance environment, one aircraft with a failure of navigation capability could normally be handled successfully by ATC. Where there is no surveillance, it is necessary to consider two situations: 1) the complete failure of the RNAV system; and 2) the potential that an aircraft's navigation system has an unreported position error. In either case, mitigations will need to be identified and incorporated into the operating procedures in order to implement the navigation application.

3.3.3 Potential mitigations will depend upon the ATM environment. For example, in the case of complete navigation system failure on an aircraft, where the navigation application is implemented in a low-traffic environment, with no intent for future implementation of closely spaced tracks, autonomous navigation capability (inertial or dead reckoning) may provide sufficient reversion. In cases where there is a plan to implement closely spaced routes, a potential mitigation could be to increase aircraft separation to enable safe operation in a procedural environment. In a non-surveillance environment, RNP navigation specifications address the issue of unreported position errors through the requirements for on-board performance monitoring and alerting.

3.4 INFRASTRUCTURE

3.4.1 Failure of navigation aid (navaid) environment

3.4.1.1 The impact of failure of the navaid environment depends upon the navaids being employed for the operation. For most ground-based navaids, the number of aircraft using a given aid is normally small. Depending on the number of navaids available, the loss of a single VOR or DME facility may not result in the loss of position fixing capability. The navaid infrastructure environment and the degree of redundancy of navaids will need to be specifically studied. Inertial navigation capability should also be considered for mitigation of a sparsely populated ground-based navaid infrastructure.

3.4.1.2 When GNSS is planned to be the main or sole positioning source, consideration needs to be given to the impact of loss of navigation capability, not to just a single aircraft, but to a predetermined population of aircraft in a specified airspace. *Global Navigation Satellite System (GNSS) Manual* (Doc 9849) provides guidance when GNSS is planned to be used. Where ATS surveillance is proposed as the mitigation, consideration has to be given to the acceptability of the resulting ATC workload, in the event of a possibly near-simultaneous loss of navigation capability by a number of aircraft. The likelihood of GNSS outage should be considered in the evaluation.

3.4.1.3 If it is considered that the likelihood of an outage is unacceptable and the ATC workload would not be acceptable, and therefore that reliance only on ATS surveillance is an unacceptable mitigation solution, another mitigation could be an aircraft requirement for carriage of an alternative navigation capability. An example could be the requirement for the carriage of an inertial navigation capability. Other potential mitigations, depending on the navigation specification being implemented, could be a requirement for the availability of an alternative terrestrial navaid input to the RNAV system position solution.

3.4.2 ATS surveillance and communication

3.4.2.1 Along with considering the aircraft performance requirements of the navigation specification planned for implementation, and the available navaid infrastructure (both for primary and reversionary navigation capability), the contributions of ATS surveillance and communications to achieve the TLS for a desired route spacing, must be considered. ATS surveillance and communications can be examined to determine what mitigation to navigation errors they can be expected to provide.

3.4.2.2 The availability of ATS surveillance along the route is a major element in determining if the desired route spacing for the planned navigation implementation (i.e. the navigation application) will support the TLS. The amount of redundancy in the ATS surveillance capability must also be considered.

3.4.2.3 With the exception of navigation specifications implemented in oceanic or continental remote airspace, where HF, SATCOM and/or CPDLC can be encountered, the ATS communications requirement is VHF voice. In some States, UHF voice to support military operations is also available. In addition to accounting for the availability of communications, the reception strength of the communications (strong or weak signal) should be considered.

3.4.2.4 The effectiveness of ATC intervention in the event of an aircraft not following the route centreline must be considered. In particular, controller workload in a busy environment can delay ATC recognition of unacceptable route centreline deviation beyond the point where the TLS is maintained.

Table II-A-3-1. Navigation specification safety assessment references

Navigation specification	*Safety assessment references*	*Notes*
RNAV 10 *Note.— Retains designation of RNP 10 in implementation.*	1) *Regional Supplementary Procedures* (Doc 7030) 2) *Manual on Airspace Planning Methodology for the Determination of Separation Minima* (Doc 9689) 3) *Procedures for Air Navigation Services — Air Traffic Management* (PANS-ATM) (Doc 4444)	
RNAV 5	EUROCONTROL B-RNAV route spacing study European Region Area Navigation (RNAV) Guidance Material (ICAO EUR Doc 001, RNAV/5)	
RNAV 2	To be developed.	
RNAV 1	EUROCONTROL safety assessment of P-RNAV route spacing and aircraft separation	
RNP 4	1) *Regional Supplementary Procedures* (Doc 7030) 2) *Manual on Airspace Planning Methodology for the Determination of Separation Minima* (Doc 9689) 3) *Procedures for Air Navigation Services — Air Traffic Management* (PANS-ATM) (Doc 4444)	
RNP 2	To be developed.	Navigation specification in development.

Navigation specification	*Safety assessment references*	*Notes*
Basic-RNP 1	*Procedures for Air Navigation Services — Aircraft Operations* (PANS-OPS) (Doc 8168), Volume II	
Advanced-RNP 1	To be developed.	Navigation specification in development.
RNP APCH	*Procedures for Air Navigation Services — Aircraft Operations* (PANS-OPS) (Doc 8168), Volume II	
RNP AR APCH	*Required Navigation Performance Authorization Required (RNP AR) Procedure Design Manual* (Doc 9905)	

Part B

IMPLEMENTING RNAV

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 50 NM lateral and the 50 NM longitudinal distance-based separation minima in 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 approval as well as airspace/route designation remains “RNP 10” in order to “grandfather” the present publications and extensive approvals. Recognizing the extent of existing airspace designations and operational approvals 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 to States for implementing RNP 10 routes and developing an RNP 10 operational approval 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 approval.

1.1.2.2 This guidance material does not address details of communications or ATS surveillance requirements that may be specified for particular operations. These requirements are specified in other documents, such as aeronautical information publications (AIPs) and the *Regional Supplementary Procedures* (Doc 7030). While RNP 10 operational approval 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, which are required by the appropriate State authority, before conducting flights into that airspace.

1.2 ANSP 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 Communication and ATS surveillance

This guidance material does not address communication or ATS surveillance 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 aeronautical information publications (AIPs) and the *Regional Supplementary Procedures* (Doc 7030).

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* (PANS-OPS) (Doc 8168), Volume II; the general criteria in Parts I and III apply.

1.2.3.2 The rationale for having chosen the RNP 10 value was to support reduced lateral and longitudinal separation minima for application in oceanic and remote areas where the availability of navigation aids, communications and surveillance is limited.

1.2.3.3 The minimum route spacing where RNP 10 is utilized is 50 NM.

1.2.4 Additional considerations

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 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 navigation aids must meet the requirements of Annex 15 — *Aeronautical Information Services*. All routes must be based upon WGS-84 coordinates.

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):

   i) including functional capabilities and limitations of this navigation specification;

   ii) accuracy, integrity, availability and continuity;

   iii) GPS receiver, RAIM, FDE, and integrity alerts;

b) Flight plan requirements;

c) ATC procedures:

i) ATC contingency procedures;

ii) separation minima;

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

iv) transition between different operating environments; and

v) phraseology.

1.2.6.2 Training specific to a navigation specification

— reporting of GNEs (gross navigation errors).

1.2.7 Status monitoring

The navaid infrastructure to support radio navigation updating prior to entry into RNP 10 airspace should be monitored and maintained and timely warnings of outages (NOTAM) should be issued.

1.2.8 ATS system monitoring

1.2.8.1 Demonstrated navigation accuracy 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 (i.e. through monitoring programmes which use oceanic navigation error reports, oceanic altitude deviation reports or navigation error reports) and then investigated to prevent their recurrence. 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 approval that pilots/operators notify the relevant regulatory authority of any of the following:

— lateral navigational errors of 27.8 km (15 NM) or more;

— longitudinal navigational errors of 18.5 km (10 NM) or more;

— 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

— navigation system failures.

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 a specific operational approval in some cases. For example, some States require operators to apply to their national authority (State of the Operator/Registry) for operational approval.

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 Approval 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 approval process for Australian operators. This has since been replaced with Advisory Circular (AC) 91U-2(0). ICAO guidance material was originally published in ICAO Doc 9613, Appendix E, and has been updated and included in this manual.

1.3.2 Approval 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) flight crew 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 approval must then be obtained in accordance with national operating rules.

1.3.3 Contents of an application for an RNP 10 operational approval

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 approvals. Additional aircraft certification will only be necessary if the operator chooses to claim additional performance beyond that originally certified or stated in the aircraft flight manual 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 (e.g. navaid sensor requirements). Operational approval 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 INS/IRU certified 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 updating. The determination of flight duration starts when the system is placed in navigation mode. For flights which include airborne updating of navigation 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 approval to conduct RNP operations."
>
> *Note.— The above wording is based upon performance approval by the aviation authority and is only one element of the approval process. Aircraft with this wording in their flight manual will be eligible for approval through issuance of operations specifications or a Letter of Approval, 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 approval 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 flight crew 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 required 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 Order 8400.12A (as amended), Appendix 1. 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 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 (INS) data (as described in FAA Order 8400.12A (as amended), Appendix 6 (Periodic Method)). The data collected are then analysed as described in Appendix 6 to determine whether the system is capable of maintaining RNP 10 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) which meet the requirements of RNP 10 (e.g. 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 specified INS or IRU 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 approval

1.3.3.2.1 The assessment of a particular operator is made by the State of the Operator/Registry for that operator and in accordance with national operating rules (e.g. JAR-OPS 1, 14 CFR Part 121) supported through appropriate advisory and guidance material. The assessment should take into account:

a) evidence of aircraft eligibility;

b) assessment of the operating procedures for the navigation systems to be used;

c) control of those procedures through acceptable entries in the operations manual;

d) identification of flight crew training requirements; and

e) where required, control of the navigation database process.

1.3.3.2.2 The operational approval will likely be documented through the State endorsing the air operators certificate (AOC) by issuing a Letter of Authorization, an appropriate operations specification (Ops Spec) or an amendment to the operations manual.

1.3.3.2.1 *Description of aircraft equipment*

1.3.3.2.1.1 The operator must have a configuration list detailing pertinent components and equipment to be used for RNP 10 operations.

1.3.3.2.2 *Training documentation*

1.3.3.2.2.1 Commercial operators must have a training programme addressing operational practices, procedures and training items related to RNP 10 operations (e.g. initial, upgrade or recurrent training for flight crew, dispatchers or maintenance personnel).

Note.— It is not required to establish a separate training programme or regimen if RNAV training is already an integrated element of a training programme. However, it should be possible to identify which aspects of RNAV are covered within a training programme.

1.3.3.2.2.2 Non-commercial operators must be familiar with the practices and procedures identified in 1.3.9 "Pilot knowledge and training".

1.3.3.2.3 *Operations manuals and checklists*

1.3.3.2.3.1 Operations manuals and checklists for commercial operators must address information/guidance on the standard operating procedures detailed in 1.3.5 "Operating procedures". The appropriate manuals should contain navigation operating instructions and contingency procedures where specified. Manuals and checklists must be submitted for review as part of the application process.

1.3.3.2.3.2 Non-commercial operators must create appropriate instructions containing navigation operating instructions and contingency procedures. This information must be available to crews in flight and should be entered into the operations manual or pilot operating handbook, as appropriate. These manuals and manufacturer's instructions for operation of the aircraft navigation equipment, as appropriate, must be submitted for review as part of the application process.

1.3.3.2.3.3 Private operators must operate using the practices and procedures identified in 1.3.10 "Pilot knowledge and training".

1.3.3.2.4 *Minimum equipment list (MEL) considerations*

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

1.3.3.2.4.2 All operators must have an established maintenance programme for the individual navigation systems. For other installations, the operator must submit any changes to their existing maintenance manual for review and acceptability.

1.3.3.2.5 *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 (e.g. 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 INS, an IRS FMS or a GNSS, with an integrity such that the navigation system does not provide an unacceptable probability of misleading information.

1.3.4.1 System performance, monitoring and alerting

Accuracy: During operations in airspace or on routes designated as RNP 10, the lateral total system error must be within ±10 NM for at least 95 per cent of the total flight time. The along-track error must also be within ±10 NM for at least 95 per cent of the total flight time.

Note 1.— For RNP 10, operational approval of aircraft capable of coupling the area navigation (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, path definition error and display errors are considered to be insignificant for the purposes of RNP 10 approval.

Note 2.— When the data collection method described in Appendix 1 of FAA Order 8400.12A (as amended) is used as the basis for an RNP 10 operational approval, these error types are included in the analysis. However, when the data collection method described in Appendix 6 of FAA Order 8400.12A is used, these errors are not included since that method is more conservative. The Appendix 6 method uses radial error instead of cross-track and along-track error.

Integrity: Malfunction of the aircraft navigation equipment is classified as a major failure condition under airworthiness regulations (i.e. 10^{-5} per hour).

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 (excluding signal-in-space).

Signal-in-space: If using GNSS, the aircraft navigation equipment shall provide an alert if the probability of signal-in-space errors causing a lateral position error greater than 20 NM exceeds 10^{-7} per hour (Annex 10, Volume I, Table 3.7.2.4-1).

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 United States FAA Advisory Circular AC 20-130A, or its equivalent, also meet RNP 10 requirements without time limitations.

1.3.4.2.1.3 FAA Advisory Circular AC 20-138A provides an acceptable means of complying with installation requirements for aircraft that use GNSS but do not integrate it with other sensors. FAA AC 20-130A 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 (e.g. no INS or IRS) 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 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 approval.

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 (INS) or inertial reference units (IRU) — standard time limit*

1.3.4.2.2.1 Aircraft equipped with dual INS or IRU 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);

b) minimum navigation performance specifications (MNPS); and

c) approved for RNAV operations in Australia.

1.3.4.2.2.2 The timing starts from when the systems are placed in navigation mode or at the last point at which the systems are updated.

Note.—The 6.2 hours of flight time are based on an inertial 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 (e.g. 18.5 km (10 NM)/2.9678 km/h (1.6015 NM/h) = 6.2 hours)).

1.3.4.2.2.3 If the systems are updated en route, the operator must show the effect that the accuracy of the update has on the time limit (see FAA Order 8400.12.A, paragraph 12.e for information on the adjustment factors for systems that are updated en route).

Note.— FAA Order 8400.12.A, paragraph 12.d provides information on acceptable procedures for operators who wish to increase the 6.2 hour time limitation specified.

1.3.4.2.3 *Aircraft incorporating dual inertial navigation systems (INS) or inertial reference units (IRU) — extended time limit*

For aircraft with INS certified under United States 14 CFR, Part 121, Appendix G, additional certification is only necessary for operators who choose to certify INS accuracy to better than 3.7 km (2 NM) per hour radial error (2.9678 km (1.6015 NM) per hour cross-track error). However, the following conditions apply:

a) the certification of INS 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 operator must identify the standard against which the INS performance is to be demonstrated. This standard may be a regulatory (i.e. Appendix G), an industry or an operator-unique specification. A statement must be added to the flight manual identifying the accuracy standard used for certification (see FAA Order 8400.12.A, paragraph 12.a.2).

1.3.4.2.4 *Aircraft equipped with a single INS or IRU and a single GPS approved for primary means of navigation in oceanic and remote areas*

Aircraft equipped with a single INS or IRU and a single GNSS meet the RNP 10 requirements without time limitations. The INS or IRU must be approved to 14 CFR, Part 121, Appendix G. The GNSS must be TSO-C129a-authorized and must have an approved FDE availability prediction programme. The maximum allowable time for which the FDE capability is projected to be unavailable is 34 minutes on any one occasion. The maximum outage time must be included as a condition of the RNP 10 approval. The flight manual must indicate that the particular INS, IRU or GPS installation meets the appropriate aviation authority's requirements.

1.3.5 Operating procedures

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*.

1.3.5.1 Flight planning

During flight planning, the flight crew 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 approval, if required for a specific navigation system.

1.3.5.2 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, e.g. 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 approval capability and ATC must be advised.

1.3.6 Navigation equipment

1.3.6.1 All aircraft operating in RNP 10 oceanic and remote airspace must be fitted with two fully serviceable independent LRNSs with integrity such that the navigation system does not provide misleading information.

1.3.6.2 A State authority may approve the use of a single LRNS in specific circumstances (e.g. North Atlantic MNPS and 14 CFR 121.351(c) refer). An RNP 10 approval is still required.

1.3.7 Flight plan designation

Operators should use the appropriate ICAO flight plan designation specified for the RNP route flown. 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 to determine RNP requirements and the aircraft and operator have been approved on routes where RNP is a requirement for operation. Additional information needs to be displayed in the remarks section that indicates the accuracy capability, such as RNP 10 versus RNP 4.

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 which 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 VOR checks to determine navigation system errors 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 centrelines, 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 (i.e. 5 NM). Brief deviations from this standard (e.g. overshoots or undershoots) during and immediately after route turns, up to a maximum of one-times the navigation accuracy (i.e. 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 INS or IRU

1.3.9.6.1 An RNP 10 time limit must be established for aircraft equipped only with INS or IRU. 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, non-directional radio beacon (NDB)) and/or comes under ATC 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 if 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. Approvals 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 (e.g. 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 flight crew 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) flight crews 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 approval 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 updating is not specifically approved, manual 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 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 approval 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 flight crew qualification syllabus is found to provide effective pilot training; and

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

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 flight crews 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 (e.g. FAA Order 8700.1, General Aviation Operations Inspector's Handbook). 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 approval that the operator has ensured and will continue to ensure that flight crews are knowledgeable of the RNP 10 operating practices and procedures; and

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 approval, 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

Websites:

- Federal Aviation Administration (FAA), United States

  http://www.faa.gov (see Regulations & Policies)

- Civil Aviation Safety Authority (CASA), Australia

  http://www.casa.gov.au/rules/1998casr/index.htm

- International Civil Aviation Organization (ICAO)

  http://www.icao.int/pbn

Related publications

- Federal Aviation Administration (FAA), United States

  FAA Order 8400.12A (as amended), Required Navigation Performance 10 (RNP 10) Operational Approval

Code of Federal Regulations (CFR), Part 121, Subpart G, Manual Requirements

Advisory Circular (AC) 20-130A, Airworthiness Approval of Navigation or Flight Management Systems Integrating Multiple Navigation Sensors

AC 20-138A, Airworthiness Approval of Global Navigation Satellite System (GNSS) Equipment

- Joint Aviation Authorities

  EASA AMC 20-12 Recognition Of FAA Order 8400.12a for RNP-10 Operations
- Civil Aviation Safety Authority (CASA), Australia

  Advisory Circular (AC) 91U-2(0), Required Navigation Performance 10 (RNP 10) Operational Authorisation

- International Civil Aviation Organization (ICAO)

  Annex 6 — *Operation of Aircraft*

  Annex 11 — *Air Traffic Services*

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

  (Copies may be obtained from the Customer Services Unit, ICAO, 999 University Street, Montréal, Quebec, Canada H3C 5H7 / website: www.icao.int)

- RTCA, Inc.
  DO-236B, Minimum Aviation System Performance Standards: Required Navigation Performance for Area Navigation

  (Copies may be obtained from RTCA, Inc., 1828 L Street NW, Suite 805, Washington, DC 20036, United States / website: www.rtca.org)

- European Organization for Civil Aviation Equipment (EUROCAE)
  ED-75B, MASPS Required Navigation Performance for Area Navigation

  (Copies may be obtained from EUROCAE, 102 rue Etienne Dolet, 92240 Malakoff, France / website: www.eurocae.eu)

Chapter 2

IMPLEMENTING RNAV 5

2.1 INTRODUCTION

2.1.1 Background

2.1.1.1 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 EASA, this document has been re-issued as AMC 20-4.

2.1.1.2 The FAA published comparable material under AC 90-96 on 20 March 1998. These two documents provide identical functional and operational requirements.

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

2.1.2 Purpose

2.1.2.1 This chapter provides guidance to States implementing RNAV 5 in the en-route phase of flight and provides the air navigation service provider with an ICAO recommendation on the implementation requirements, avoiding the proliferation of standards and the need for multiple regional approvals. It provides the operator with criteria to enable operation in airspace where the carriage of RNAV meeting 5 NM lateral accuracy is already required (e.g. ECAC B-RNAV). It avoids the need for further approvals in other regions or areas needing to implement RNAV with the same lateral accuracy and functional requirements.

2.1.2.2 While primarily addressing requirements of RNAV operation in an ATS surveillance environment, RNAV 5 implementation has occurred in areas where there is no surveillance. This has required an increase in route spacing commensurate with the assurance of meeting the target level of safety.

2.1.2.3 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.

2.1.2.4 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, aeronautical information publications (AIPs) and, where appropriate, the *Regional Supplementary Procedures* (Doc 7030). While operational approval 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, which are required by the appropriate State authority, before conducting flights into that airspace.

2.2 AIR NAVIGATION SERVICE PROVIDER (ANSP) CONSIDERATIONS

2.2.1 Navaid infrastructure

2.2.1.1 States may prescribe the carriage of RNAV 5 on specific routes or for specific areas/flight levels of their airspace.

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) 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 Communication and ATS surveillance

2.2.2.1 Direct pilot to ATC (voice) communication is required.

2.2.2.2 When reliance is placed on the use of ATS surveillance to assist contingency procedures, its performance should be adequate for that purpose.

2.2.2.3 Radar monitoring by the ATS may be used to mitigate the risk of gross navigation errors, provided the route lies within the ATS surveillance and communications service volumes and the ATS resources are sufficient for the task.

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.

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. One State demonstrated a route spacing of 30 NM to meet the safety targets of 5×10^{-9} fatal accidents per flight hour in the absence of ATS surveillance and in a high traffic density environment.

2.2.3.3 Where traffic density is lower, route spacing may be reduced. In an ATC 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. Moreover, route spacing as low as 10 NM has been used where ATC intervention capability permits.

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 this document. Two aspects are of particular importance:

2.2.3.5 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.

2.2.3.6 Along track distance between leg changes

2.2.3.6.1 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.

2.2.3.6.2 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 Many aircraft have the capability to execute a holding pattern manoeuvre using their RNAV system, which can provide flexibility to ATC in designing RNAV operations.

2.2.4.3 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 navigation aids 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 (e.g. 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 flight crew by publishing fix data for selected waypoints on RNAV 5 routes.

2.2.6 Controller training

It is recommended that air traffic controllers providing control services in airspace where RNAV 5 is implemented should have completed training in the following areas:

2.2.6.1 Core training

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

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

  ii) accuracy, integrity, availability and continuity;

  iii) GPS receiver, RAIM, FDE, and integrity alerts;

b) Flight plan requirements;

c) ATC procedures:

  i) ATC contingency procedures;

  ii) separation minima;

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

  iv) transition between different operating environments; and

  v) phraseology.

2.2.7 Status monitoring

The navaid infrastructure should be monitored and maintained and timely warnings of outages (NOTAM) should be issued.

2.2.8 ATS 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;

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 Both lateral performance and failures need to be monitored in order to establish the overall system safety and to confirm that the ATS system meets the required target level of safety.

2.2.8.3 Radar 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 specific operational approval in some cases. Operators will be approved against their national operating rules. For example, in ECAC, JAR OPS 1 requires operators to apply to their national authority for operational approval. 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 approval.

2.3.1.2 RNAV 5 does not require the carriage of a navigation database. Because of the specific limitations (e.g. 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 Approval 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. The navigation specification provides the technical and operational criteria, and does not imply a need for recertification.

2.3.2.2 The following steps must be completed before conducting RNAV 5 operations:

a) aircraft equipment eligibility must be determined and documented, which may be accomplished taking credit for prior approval to AMC 20-4 or AC 90-96.

b) operating procedures for the navigation systems to be used must be documented;

c) flight crew training based upon the operating procedures must be documented;

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

e) operational approval should then be obtained in accordance with the national operating rules.

2.3.2.3 Following the successful completion of the above steps, an RNAV 5 operational approval, Letter of Authorization or appropriate operations specification (Ops Spec), if required, should be issued by the State.

2.3.2.4 Aircraft eligibility

The aircraft eligibility has to be determined through demonstration of compliance against the relevant airworthiness criteria, e.g. AMC 20-4 or AC 90-96. The original equipment manufacturer (OEM) or the holder of the installation approval for the aircraft, e.g. supplemental type certificate (STC) holder, will demonstrate compliance to their national airworthiness authority (NAA) (e.g. EASA, FAA) and the approval can be documented in the manufacturer's documentation (e.g. service letters). Aircraft flight manual (AFM) entries are not required provided the State accepts the manufacturer's documentation.

2.3.2.5 Operational approval

2.3.2.5.1 The assessment of a particular operator is made by the State of Operator/Registry for that operator and in accordance with national operating rules (e.g. JAR-OPS 1, 14 CFR Part 121) supported through the advisory and guidance material in documents such as AMC 20-4 or AC 90-96. The assessment should take into account:

a) evidence of aircraft eligibility;

b) assessment of the operating procedures for the navigation systems to be used;

c) control of those procedures through acceptable entries in the operations manual;

d) identification of flight crew training requirements; and

e) when required, control of the navigation database process.

Note.— Operational approval against either AMC 20-4 or AC 90-96 meets the requirements in any RNAV 5 designated route or airspace.

2.3.2.5.2 The operational approval will likely be documented through the State endorsing the air operator certificate (AOC) through issue of a Letter of Authorization, appropriate operations specification (Ops Spec) or an amendment to the operations manual.

2.3.2.5.3 *Description of aircraft equipment*

The operator must have a configuration list detailing pertinent components and equipment to be used for RNAV 5 operations.

2.3.2.5.4 *Training documentation*

2.3.2.5.4.1 Commercial operators should have a training programme addressing operational practices, procedures and training items related to RNAV 5 operations (e.g. initial, upgrade or recurrent training for flight crew, dispatchers or maintenance personnel).

Note.— It is not required to establish a separate training programme or regimen if RNAV training is already an integrated element of a training programme. However, it should be possible to identify which aspects of RNAV are covered within a training programme.

2.3.2.5.4.2 Private operators should be familiar with the practices and procedures identified in 2.3.5 "Pilot knowledge and training".

2.3.2.5.5 *Operations manuals and checklists*

2.3.2.5.5.1 Operations manuals and checklists for commercial operators must address information/guidance on the standard operating procedures detailed in 2.3.4 "Operating procedures". The appropriate manuals should contain navigation operating instructions and contingency procedures where specified. Manuals and checklists must be submitted for review as part of the application process.

2.3.2.5.5.2 Private operators should operate using the practices and procedures identified in 2.3.5 "Pilot knowledge and training".

2.3.2.5.6 *Minimum equipment list (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.

2.3.2.6 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 or IRS; and

d) GNSS.

2.3.3.1 System performance, monitoring and alerting

Accuracy: During operations in airspace or on routes designated as RNAV 5, the lateral total system error must be within 5 NM for at least 95 per cent of the total flight time. The along-track error must also be within ±5 NM for at least 95 per cent of the total flight time.

Integrity: Malfunction of the aircraft navigation equipment is classified as a major failure condition under airworthiness regulations (i.e. 10^{-5} per hour).

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.

Signal-in-space: If using GNSS, the aircraft navigation equipment shall provide an alert if the probability of signal-in-space errors causing a lateral position error greater than 10 NM exceeds 10^{-7} per hour (ICAO Annex 10, Volume I, Table 3.7.2.4-1).

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) (e.g. ND, HSI or CDI), provided that the system is monitored by the flight crew and that in the event of a system failure the aircraft retains the capability to navigate relative to ground-based navaids (e.g. VOR/DME or NDB).

2.3.3.2 Criteria for specific navigation services

2.3.3.2.1 *Inertial navigation system (INS)/inertial reference system (IRS)*

2.3.3.2.1.1 Inertial systems may be used either as a stand-alone inertial navigation system (INS) or an inertial reference system (IRS) acting as part of a multi-sensor RNAV system, where inertial 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 INS *without* automatic radio updating of aircraft position, but approved in accordance with AC 25-4, and when complying with the functional criteria of this chapter, may be used only for a maximum of 2 hours from the last alignment/position update performed on the ground. Consideration may be given to specific INS configurations (e.g. triple mix) where either equipment or the aircraft manufacturer's data justify extended use from the last position update.

2.3.3.2.1.3 INS *with* automatic radio updating of aircraft position, including those systems where manual selection of radio channels is performed in accordance with flight crew procedures, should be approved in accordance with AC-90-45A, AC 20-130A or equivalent material.

2.3.3.2.2 *Very high frequency (VHF) omnidirectional radio range (VOR)*

VOR accuracy can typically meet the accuracy requirements for RNAV 5 up to 60 NM (75 NM for Doppler VOR) from the navigation aid. Specific regions within the VOR coverage may experience larger errors due to propagation effects (e.g. 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 has to 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 *Distance measuring equipment (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.

2.3.3.2.3.2 The individual components of the navaid infrastructure must meet the performance requirements detailed in Annex 10, Volume I. Navigation aids that are not compliant with Annex 10 should not be published in the State AIP.

2.3.3.2.4 *Global navigation satellite system (GNSS)*

2.3.3.2.4.1 The use of GNSS to perform RNAV 5 operations is limited to equipment approved to ETSO-C129(), ETSO-C145(), ETSO-C146(), FAA TSO-C145(), TSO-C146(), and TSO-C129() or equivalent, and include the minimum system functions specified in 2.3.3.3.

2.3.3.2.4.2 Integrity should be provided by SBAS GNSS or receiver autonomous integrity monitoring (RAIM) or an equivalent means within a multi-sensor navigation system. In addition, GPS stand-alone equipment should include the following functions:

i) pseudo-range step detection; and

ii) 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 approval for RNAV 5 operations requires the use of traditional navigation equipment as a back-up in the event of loss of GNSS, the required navigation aids, as defined in the approval (i.e. 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 4; 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 (e.g. CDI, (E)HSI, 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 visible to the pilot when looking forward along the flight path;

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 approval is required. Operational approval 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 approval 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 navigation aids 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 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 (e.g. 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 (i.e. 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 required 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 Flight crews should cross-check the cleared 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 navigation aids 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 navigation aids 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 (e.g. full-scale deflection: ±5 NM).

2.3.4.4.8 All pilots are expected to maintain route centrelines, 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 (i.e. 2.5 NM). Brief deviations from this standard (e.g. overshoots or undershoots) during and immediately after procedure/route turns, up to a maximum of one-times the navigation accuracy (i.e. 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 communication to ATC must be in accordance with the authorized procedures (Doc 4444 or Doc 7030, as appropriate).

2.3.4.5.2 In the event of communications failure, the flight crew should continue with the flight plan in accordance with the published “lost communication” procedure.

2.3.4.5.3 Where stand-alone GNSS equipment is used:

a) In the event of that there is a loss of the RAIM detection function, the GNSS position may continue to be used for navigation. The flight crew should attempt to cross-check the aircraft position, with other sources of position information, (e.g. VOR, DME and/or NDB information) to confirm an acceptable level of navigation performance. Otherwise, the flight crew 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 flight crew 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 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:

  i) levels of automation, mode annunciations, changes, alerts, interactions, reversions, and degradation;

  ii) functional integration with other aircraft systems;

  iii) monitoring procedures for each phase of the flight (e.g. monitor PROG or LEGS page);

  iv) types of navigation sensors (e.g. DME, IRU, GNSS) utilized by the RNAV system and associated system prioritization/weighting/logic;

  v) turn anticipation with consideration to speed and altitude effects;

  vi) interpretation of electronic displays and symbols;

i) RNAV equipment operating procedures, as applicable, including how to perform the following actions:

   i) verify that the aircraft navigation data is current;

   ii) verify the successful completion of RNAV system self-tests;

   iii) initialize RNAV system position;

   iv) fly direct to a waypoint;

   v) intercept a course/track;

   vi) be vectored off and rejoin a procedure;

   vii) determine cross-track error/deviation;

   viii) remove and reselect navigation sensor input;

   ix) when required, confirm exclusion of a specific navigation aid or navigation aid type; and

   x) perform gross navigation error checks using conventional navigation aids.

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 navigation aids 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 approval for use of that equipment until the cause of the problem has been identified and rectified.

2.4 REFERENCES

EASA acceptable means of compliance

a) AMC 25-11 electronic display systems

b) AMC 20-5 acceptable means of compliance for airworthiness approval and operational criteria for the use of the NAVSTAR global positioning system (GPS)

FAA Advisory Circulars

a) AC 25-4 Inertial Navigation Systems (INS)

b) AC 25-15 Approval of FMS in Transport Category Airplanes

c) AC 90-45 A Approval of Area Navigation Systems for use in the U S. National Airspace System

TSO/ETSOs

a) TSO/ETSO-C115b Airborne Area Navigation Equipment Using Multi Sensor Inputs

b) TSO/ETSO-C129a Airborne Supplemental Navigation Equipment Using the Global Positioning System (GPS)

c) TSO/ETSO-C145 Airborne Navigation Sensors Using the Global Positioning System (GPS) Augmented by the Wide Area Augmentation System (WAAS).

d) TSO/ETSO-C146 Stand-Alone Airborne Navigation Equipment Using the Global Positioning System (GPS) Augmented by the Wide Area Augmentation System (WAAS)

EUROCAE/RTCA documents

a) ED-27 Minimum Operational Performance Requirements (MOPR) for Airborne Area Navigation Systems, based on VOR and DME as sensors

b) ED-28 Minimum Performance Specification (MPS) for Airborne Area Navigation Computing Equipment based on VOR and DME as sensors

c) ED-39 MOPR for Airborne Area Navigation Systems, based on two DME as sensors

d) ED-40 MPS for Airborne Computing Equipment for Area Navigation System using two DME as sensors.

e) ED-58 Minimum Operational Performance Specification (MOPS) for Area Navigation Equipment using Multi-Sensor Inputs

f) ED-72A MOPS for Airborne GPS Receiving Equipment

g) ED-76 Standards for Processing Aeronautical Data

h) ED-77 Standards for Aeronautical Information

i) DO-180() Minimum Operational Performance Standards (MOPS) for Airborne Area Navigation Equipment Using a Single Collocated VOR/DME Sensor Input

j) DO-187 MOPS for Airborne Area Navigation Equipment Using Multi Sensor Inputs

k) DO-200 Preparation, Verification and Distribution of User-Selectable Navigation Data Bases

l) DO-201 User Recommendations for Aeronautical Information Services

m) DO-208 MOPS for Airborne Supplemental Navigation Equipment Using Global Positioning System (GPS)

Document availability

Copies of ICAO documents may be purchased from the International Civil Aviation Organization, Customer Services Unit, 999 University Street, Montréal, Quebec, Canada H3C 5H7, (Fax: +1 514 954 6769, or e-mail: sales_unit@icao.org) or through sales agents listed on the ICAO website: www.icao.int.

Copies of ARINC documents may be obtained from Airinc, Inc., 2551 Riva Road, Annapolis, Maryland 21401-7435, USA. Website: http://www.arinc.com/cf/store/index.cfm

Copies of EASA documents may be obtained from EASA (European Aviation Safety Agency), Postfach 101253, D-50452 Koeln, Germany. Website: http://www.easa.eu.int

Copies of EUROCAE documents may be purchased from EUROCAE, 102 rue Etienne Dolet, 92240 Malakoff, France (Fax: +33 1 46 55 62 65). Website: www.eurocae.eu/boutique/catalog

Copies of EUROCONTROL documents may be requested from EUROCONTROL, Documentation Centre, GS4, Rue de la Fusée, 96, B-1130 Brussels, Belgium; (Fax: +32 2 729 9109). Website: http://www.ecacnav.com

Copies of FAA documents may be obtained from Superintendent of Documents, Government Printing Office, Washington, DC 20402-9325, USA, or from the FAA website: http://www.faa.gov (Regulatory and Guidance Library)

Information on where and how to order copies of JAA documents is available on the JAA website: http://www.jaa.nl/publications/catalog.html

Copies of RTCA documents may be obtained from RTCA Inc., 1828 L St., N.W., Suite 805, Washington, DC 20036, USA, (Tel.: +1 202 833 9339). Website: www.rtca.org/onlinecart

Chapter 3

IMPLEMENTING RNAV 1 AND RNAV 2

3.1 INTRODUCTION

3.1.1 Background

The Joint Aviation Authorities (JAA) published airworthiness and operational approval 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. While similar in functional requirements, differences exist between these two documents. This chapter is the result of the harmonization of European and United States RNAV criteria into a single ICAO RNAV 1 and 2 specification.

3.1.2 Purpose

3.1.2.1 This chapter provides guidance to States and air navigation service providers implementing en-route and terminal area navigation (RNAV) applications. For existing systems, compliance with both P-RNAV (TGL-10) and U.S. RNAV (FAA AC 90-100) assures automatic compliance with this ICAO specification. Operators with compliance to only TGL-10 or AC 90-100 should refer to 3.3.2.7 to confirm whether their system gives automatic compliance to this specification. Compliance with ICAO RNAV 1 and 2 through either of the above obviates the need for further assessment or AFM documentation. In addition, an operational approval to this specification allows an operator to conduct RNAV 1 and/or 2 operations globally. 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 navigation specification is applicable to all ATS routes, including routes in the en-route domain, standard instrument departures (SIDs), and standard arrival routes (STARS). It also applies to instrument approach procedures up to the final approach fix.

3.1.2.3 The RNAV 1 and 2 navigation specification is primarily developed for RNAV operations in a radar environment (for SIDs, radar coverage is expected prior to the first RNAV course change). The Basic-RNP 1 navigation specification is intended for similar operations outside radar coverage. However, RNAV 1 and RNAV 2 may be used in a non-radar environment or below minimum vectoring altitude (MVA) if the implementing State ensures appropriate system safety and accounts for lack of performance monitoring and alerting.

3.1.2.4 RNAV 1 and RNAV 2 routes are envisioned to be conducted in direct controller-pilot communication environments.

3.1.2.5 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, aeronautical information publications (AIPs) and the ICAO *Regional Supplementary Procedures* (Doc 7030). While operational approval 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, which are required by the appropriate State authority, before conducting flights into that airspace.

3.2 AIR NAVIGATION SERVICE PROVIDER (ANSP) CONSIDERATIONS

The ANSP is responsible for the development of the route as described in Volume 1, Part B, 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

3.2.1.2 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: GNSS, DME/DME and DME/DME/IRU. Where DME is the only navigation service used for position updates, gaps in DME coverage can prevent position update. Integration of inertial reference units (IRUs) can permit extended gaps in coverage.

Note.— Based on evaluated IRU performance, the growth in position error after reverting to IRU can be expected to be less than 2 NM per 15 minutes.

3.2.1.3 If an IRU is not carried, then the aircraft can 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. In light of the *Global Air Navigation Plan for CNS/ATM Systems* (Doc 9750), 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 VOR/DME positioning is usually performed within a flight management computer when DME/DME positioning criteria do not exist, avionics and infrastructure variability pose serious challenges to standardization. Therefore, the criteria in this document only cover GNSS, DME/DME and DME/DME/IRU. This does not preclude the conduct of operations by systems that also use VOR provided they satisfy the criteria in 3.3.

3.2.1.4 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 chapter. 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 which accurately matches ground infrastructure and aircraft performance, as well as an accurate representation of the terrain. Guidance material concerning this assessment can be found in PANS-OPS (Doc 8168), Volume II and the *Manual on Testing of Radio Navigation Aids* (Doc 8071).

3.2.1.5 DME signals are considered to meet signal-in-space accuracy tolerances where signals are received, regardless of the published coverage volume. Field strength 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 flight crew) or may not authorize the use of DME/DME or DME/DME/IRU. The individual components of the navaid infrastructure must meet the performance requirements detailed in Annex 10 — *Aeronautical Communications*. Navigation aids 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.

3.2.1.6 For an RNAV 1 or 2 operation where reliance is placed upon IRS, some aircraft 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.

3.2.1.7 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 (e.g. 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 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.

3.2.1.8 Since DME/DME RNAV systems must only use DME facilities identified in State AIPs, the State must indicate facilities inappropriate for RNAV 1 and RNAV 2 operations in the AIP, including those facilities associated with an ILS or MLS that use a range offset.

Note 1.— Database suppliers may exclude specific DME facilities when the RNAV routes are within reception range of these facilities, and which could have a deleterious effect on the navigation solution from the aircraft's navigation database.

Note 2.— Where temporary restrictions occur, the publication of restrictions on the use of DME should be accomplished by use of a NOTAM to identify the need to exclude the DME.

3.2.2 Communication and ATS surveillance

Where reliance is placed on the use of radar to assist contingency procedures, its performance should be adequate for that purpose, i.e. radar coverage, its accuracy, continuity and availability should be adequate to ensure separation on the RNAV 1 and RNAV 2 ATS route structure and provide contingency in cases where several aircraft are unable to achieve the navigation performance prescribed in this navigation specification.

3.2.3 Obstacle clearance and route spacing

3.2.3.1 Obstacle clearance guidance is provided in PANS-OPS (Doc 8168, Volume II); the general criteria in Parts I and III apply.

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 intervention capability. Until specific standards and ATM procedures are developed, RNAV 1 and RNAV 2 applications can be implemented based on radar ATS surveillance.

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 Many aircraft have the capability to execute a holding pattern manoeuvre using their RNAV system. The purpose of this function is to provide flexibility to ATC in designing RNAV operations.

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

3.2.5 Publication

3.2.5.1 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 navigation aids must meet the requirements of ICAO Annex 15. All routes must be based upon WGS-84 coordinates.

3.2.5.2 The available navaid infrastructure should be clearly designated on all appropriate charts (e.g. GNSS, DME/DME or DME/DME/IRU).

3.2.5.3 Any DME facilities that are critical to RNAV 1 or RNAV 2 operations should be identified in the relevant publications.

3.2.6 Controller training

Air traffic controllers who provide RNAV terminal and approach control services in airspace where RNAV 1 and RNAV 2 is implemented, should have completed training that covers the items listed below:

3.2.6.1 Core training

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

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

   ii) accuracy, integrity, availability and continuity;

   iii) GPS receiver, RAIM, FDE, and integrity alerts;

   iv) waypoint fly-by versus fly-over concept (and differences in turn performance);

b) Flight plan requirements;

c) ATC procedures:

   i) ATC contingency procedures;

   ii) separation minima;

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

   iv) transition between different operating environments; and

   v) phraseology.

3.2.6.2 Training specific to this navigation specification

a) RNAV STARs, SIDs:

   i) related control procedures;

   ii) radar vectoring techniques;

   iii) open and closed STARs;

   iv) altitude constraints; and

   v) descend/climb clearances;

b) RNP approach and related procedures;

c) RNAV 1 and RNAV 2 related phraseology;

d) impact of requesting a change to routing during a procedure.

3.2.7 Status monitoring

The status of critical navaid infrastructure should be monitored and, where appropriate, maintained by the service provider and timely warnings of outages (NOTAMs) should be issued.

3.2.8 ATS system monitoring

3.2.8.1 Demonstrated navigation accuracy provides a basis for determining the lateral route spacing and separation minima necessary for traffic operating on a given route. When available, radar observations of each aircraft's proximity to track and altitude are typically noted by ATS facilities and aircraft track-keeping capabilities are analysed.

3.2.8.2 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.

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 a specific operational approval. For example, JAR-OPS 1 requires operators to apply to the State of the Operator/Registry, as appropriate, for operational approval.

3.3.1.2 RNAV 1 and RNAV 2 navigation specifications constitute harmonization between European Precision RNAV (P-RNAV) and United States RNAV (US-RNAV) criteria. 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 Approval 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. The navigation specification provides the technical and operational criteria, and does not imply a need for recertification.

3.3.2.2 The following steps must be completed before conducting RNAV 1 and RNAV 2 operations:

a) aircraft equipment eligibility must be determined and documented, which may be accomplished taking credit for prior approval to P-RNAV or US-RNAV. A comparison of TGL-10 and AC 90-100 is provided in this section;

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

c) flight crew training based upon the operating procedures must be documented;

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

e) operational approval should be obtained in accordance with national operating rules.

3.3.2.3 Following the successful completion of the above steps, an RNAV 1 and/or RNAV 2 operational approval, Letter of Authorization or appropriate operations specification (Ops Spec), if required, should then be issued by the State.

3.3.2.4 Aircraft eligibility

The aircraft eligibility has to be determined through demonstration of compliance against the relevant airworthiness criteria, e.g. TGL No. 10 or AC 90-100. The OEM or the holder of installation approval for the aircraft, e.g. STC holder, will demonstrate the compliance to their national airworthiness authority (NAA) (e.g. EASA, FAA) and the approval can be documented in manufacturer documentation (e.g. service letters). Aircraft flight manual (AFM) entries are not required provided the State accepts manufacturer documentation.

3.3.2.5 Operational approval

3.3.2.5.1 The assessment of a particular operator is made by the State of the Operator/Registry for that operator and in accordance with national operating rules (e.g. JAR-OPS 1, 14 CFR Part 121), supported through the advisory and guidance material found in documents such as TGL No. 10 and AC 90-100. The assessment should take into account:

a) evidence of aircraft eligibility;

b) assessment of the operating procedures for the navigation systems to be used;

c) control of those procedures through acceptable entries in the operations manual;

d) identification of flight crew training requirements; and

e) where required, control of the navigation database process.

Note.— It is envisaged that an operational approval against either TGL No. 10 or AC 90-100 can lead to compliance with requirements in any RNAV 1 or RNAV 2 designated route, subject to the approval process mentioned below. The *assessment, including the flight crew operating procedures and training, are linked to the aircraft operation and should take into account specific local requirements.*

3.3.2.5.2 The operational approval will likely be documented through the State endorsing the air operators certificate (AOC) through issue of a Letter of Authorization, appropriate operations specification (Ops Spec) or amendment to the operations manual.

3.3.2.5.3 *Description of aircraft equipment*

The operator must have a configuration list detailing pertinent components and equipment to be used for RNAV 1 and RNAV 2 operations.

3.3.2.5.4 *Training documentation*

3.3.2.5.4.1 Commercial operators should have a training programme addressing the operational practices, procedures and training items related to RNAV 1 and RNAV 2 operations (e.g. initial, upgrade or recurrent training for flight crew, dispatchers or maintenance personnel).

Note.— It is not required to establish a separate training programme or regimen if RNAV training is already an integrated element of a training programme. However, it should be possible to identify the aspects of RNAV that are covered within a training programme.

3.3.2.5.4.2 Private operators should be familiar with the practices and procedures identified in 3.3.5 “Pilot knowledge and training”.

3.3.2.5.4.3 *Operations manuals and checklists*

3.3.2.5.4.3.1 Operations manuals and checklists for commercial operators must address information/guidance on the standard operating procedures detailed in 3.3.4. The appropriate manuals should contain navigation operating instructions and contingency procedures, where specified. Manuals and checklists must be submitted for review as part of the application process.

3.3.2.5.4.3.2 Private operators should operate using the practices and procedures identified in 3.3.5 “Pilot knowledge and training”.

3.3.2.5.5 *Minimum equipment list (MEL) considerations*

Any MEL revisions necessary to address RNAV 1 and RNAV 2 provisions must be approved. Operators must adjust the MEL, or equivalent, and specify the required dispatch conditions.

3.3.2.6 PBN navigation specification and the approval process

The navigation specifications found in this manual do not constitute regulatory guidance material against which either the aircraft or the operator will be assessed and approved. OEMs manufacture their products against an airworthiness basis containing the basic code for the aircraft type and the relevant guidance material held in advisory material. Operators will be approved against their national operating rules. The navigation specification provides the technical and operational criteria. Therefore, with RNAV 1 and RNAV 2 operations there is still a need to have an approval process, either through a dedicated approval document or through recognition that existing regional RNAV implementation certification documents (TGL No. 10 and AC 90-100) can be applied with the necessary differences, to satisfy the objectives set out in the PBN navigation specification.

3.3.2.7 Migration path to RNAV 1 and RNAV 2

3.3.2.7.1 The following steps identify the transition path to RNAV 1 and RNAV 2 approval.

3.3.2.7.2 Operator holding no approval

An operator wishing to fly into RNAV 1 or RNAV 2 designated airspace:

a) First, establish the aircraft eligibility. This may be accomplished through prior documentation of compliance to the requirements of this navigation specification (e.g. compliance with AC 90-100A, TGL No. 10 or AC 90-100) and, second, establish the differences to achieve an acceptable means of compliance to RNAV 1 and RNAV 2. Having evidence of aircraft eligibility, the operator will then be required to obtain the necessary operational approval from their State authority who should again refer to the existing material and the deltas that satisfy the RNAV 1 or RNAV 2 standard.

b) An operator approved against the criteria for RNAV 1 and RNAV 2 operations is eligible to operate on US-RNAV Type A and Type B and European P-RNAV routes; no further approval is required.

c) An operator wishing to fly in airspace designated for P-RNAV should obtain a P-RNAV approval against TGL No. 10.

3.3.2.7.3 Operator holding P-RNAV approval

An operator already holding a P-RNAV approval in accordance with TGL No. 10:

a) is eligible to operate in any State where routes are predicated on TGL-10; and

b) must obtain an operational approval, with evidence provided of compliance against the deltas from TGL No. 10 to the criteria of the RNAV 1 and/or RNAV 2 navigation specification in order to fly into airspace designated as RNAV 1 or RNAV 2. This must be accomplished through RNAV 1 and/or RNAV 2 approval using Table II-B-3-1.

3.3.2.7.4 Operator holding US-RNAV AC 90-100 approval

An operator already holding an approval in accordance with FAA AC 90-100:

a) is eligible to operate in any State where routes are predicated on AC 90-100; and

b) must obtain an operational approval, with evidence provided of compliance against the deltas from AC 90-100 to the criteria of the RNAV 1 and RNAV 2 navigation specification in order to fly into airspace designated as RNAV 1 or RNAV 2. This must be accomplished through the RNAV 1 and RNAV 2 approval using Table II-B-3-2.

Note.— In many cases, the OEMs have already made an airworthiness assessment of their systems against both the TGL No. 10 and AC 90-100 standards and can provide supporting evidence of compliance through service letters or AFM statements. The operational differences are limited to the navigation database being obtained from an accredited source. In this way, the regulatory effort of migrating from one approval to another should be minimized, avoiding the need for time-consuming reinvestigation and costly assessment.

Table II-B-3-1. Additional requirements for obtaining an RNAV 1 and RNAV 2 approval from a TGL-10 approval

Operator has TGL-10	*Needs to confirm these performance capabilities for ICAO RNAV 1 and RNAV 2*	*Note*
If approval includes use of DME/VOR (DME/VOR may be used as the only positioning input where this is explicitly allowed.)	RNAV 1 does not accommodate any routes based on DME/VOR RNAV	RNAV system performance must be based on GNSS, DME/DME, or DME/DME/IRU. However, DME/VOR input does not have to be inhibited or deselected
If approval includes use of DME/DME	No action required if RNAV system performance meets specific navigation service criteria in this Chapter 3, 3.3.3.2.2 (DME/DME only) or 3.3.3.2.3 (DME/DME/IRU)	Operator can ask manufacturer or check FAA website for list of compliant systems (see the Note below this table)
RNAV SID specific requirement with DME/DME aircraft	RNAV guidance available no later than 500 ft above field elevation (AFE) on AC 90-100 Type B procedure	Operator should add these operational procedures
If approval includes use of GNSS	No action required	
Note.— http://www.faa.gov/about/office_org/headquarters_offices/avs/offices/afs/afs400/afs410/policy_guidance/		

Table II-B-3-2. Additional requirements for obtaining RNAV 1 and RNAV 2 approval from an AC 90-100 approval

Operator has AC 90-100	*Needs to confirm these performance capabilities to ICAO RNAV 1/RNAV 2*	*Note*
If approval is based on GNSS (TSO-C129)	GPS pseudo-range step detector and GPS health word checking is required in accordance with TSO C129a/ETSO C129a	The operator should check if pseudo-range step detector and health word checking is supported by the installed GPS receiver or check if GPS receiver is approved in accordance with TSO C129a/ETSO C129a
No navigation database updating process required under AC 90-100	Data suppliers and avionics data suppliers must have Letter of Acceptance (LOA) in accordance with 3.3.3.3 m)	The operator should ask the data supplier for the status of the RNAV equipment

3.3.2.8 Summary of RNAV 1 / TGL-10 / AC 90-100 insignificant differences

The Appendix to Part B contains a list of insignificant differences between RNAV 1, TGL-10 and AC 90-100.

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) Global navigation satellite system (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. The use of GNSS equipment approved to TSO-C129 () is limited to those systems which include the minimum functions specified in 3.3.3.3. As a minimum, integrity should be provided by an aircraft-based augmentation system. In addition, TSO-C129 equipment should include the following additional functions:

    i) pseudo-range step detection;

    ii) health word checking;

b) DME/DME RNAV equipment complying with the criteria listed in 3.3.3.2.2; and

c) DME/DME/IRU RNAV equipment complying with the criteria listed in 3.3.3.2.3.

3.3.3.1 System performance, monitoring and alerting

Accuracy: During operations in airspace or on routes designated as RNAV 1, the lateral total system error 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. During operations in airspace or on routes designated as RNAV 2, the lateral total system error 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.

Integrity: Malfunction of the aircraft navigation equipment is classified as a major failure condition under airworthiness regulations (i.e. 10^{-5} per hour).

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.

Signal-in-space: During operations in airspace or on routes designated as RNAV 1 if using GNSS, the aircraft navigation equipment shall provide an alert if the probability of signal-in-space errors causing a lateral position error greater than 2 NM exceeds 10^{-7} per hour (Annex 10, Volume I, Table 3.7.2.4-1). During operations in airspace or on routes designated as RNAV 2 if using GNSS, the aircraft navigation equipment shall provide an alert if the probability of signal-in-space errors causing a lateral position error greater than 4 NM exceeds 10^{-7} per hour (Annex 10, Volume I, Table 3.7.2.4-1).

3.3.3.2 Criteria for specific navigation services

3.3.3.2.1 *Criteria for GNSS*

3.3.3.2.1.1 The following systems meet the accuracy requirements of these criteria:

a) aircraft with TSO-C129/C129a sensor (Class B or C) and the requirements in a TSO-C115b FMS, installed for IFR use in accordance with FAA AC 20-130A;

b) aircraft with TSO-C145() sensor and the requirements in a TSO-C115B FMS, installed for IFR use IAW FAA AC 20-130A or AC 20-138A;

c) aircraft with TSO-C129/C129a Class A1 (without deviating from the functionality described in 3.3.3.3), installed for IFR use IAW FAA AC 20-138 or AC 20-138A; and

d) aircraft with TSO-C146() (without deviating from the functionality described in 3.3.3.3 of this document), installed for IFR use IAW AC 20-138A.

3.3.3.2.1.2 For routes and/or aircraft approvals requiring GNSS, if the navigation system does not automatically alert the flight crew 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 total system error (TSE) budget. Otherwise, means should be provided to deselect the other navigation sensor types.

3.3.3.2.2 *Criteria for distance measuring equipment (DME/DME RNAV system)*

Paragraph	*Criteria*	*Explanation*
a)	Accuracy is based on the performance standards of TSO-C66c.	
b)	Tuning and updating position of DME facilities	The DME/DME RNAV system must: i) position update within 30 seconds of tuning DME navigation facilities; ii) auto-tune multiple DME facilities ; and iii) provide continuous DME/DME position updating. A third DME facility or a second pair has been available for at least the previous 30 seconds, there must be no interruption in DME/DME positioning when the RNAV system switches between DME stations/pairs.
c)	Using facilities in the State AIPs	DME/DME RNAV systems must only use DME facilities identified in State AIPs. The systems must not use facilities indicated by the State as inappropriate for RNAV 1 and/or RNAV 2 operations in the AIP or facilities associated with an ILS or MLS that uses a range offset. This may be accomplished by: i) 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. ii) 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

		(e.g. 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	When needed to generate a DME/DME position, the RNAV system must use, as a minimum, DMEs with a relative include angle between 30° and 150°.
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: i) broadcasts an accurate facility identifier signal; ii) satisfies the minimum field strength requirements; and iii) 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: i) greater than or equal to 3 NM from the facility; and ii) 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. The use of DMEs associated with ILS or MLS is not required.*
f)	No requirement to use VOR, NDB, LOC, IRU or AHRS	There is no requirement to use VOR (VHF omnidirectional radio range), LOC (localizer), NDB (non-directional radio beacon), IRU (inertial reference unit) or AHRS (attitude and heading reference system) during normal operation of the DME/DME RNAV system.
g)	Position estimation error	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 the following equation: $2\sigma_{DME/DME} \le 2\frac{\sqrt{(\sigma^2_{1,air}+\sigma^2_{1,sis})+(\sigma^2_{2,air}+\sigma^2_{2,sis})}}{\sin(\alpha)}$ Where: σ_{sis} = 0.05 NM σ_{air} is MAX {0.085 NM, (0.125 per cent of distance)} $\propto$ inclusion angle (30° to 150°) *Note.— This performance requirement is met for any navigation system that uses two DME stations simultaneously, limits the DME inclusion angle*

		to between 30° and 150° and uses DME sensors that meet the accuracy requirements of TSO-C66c. If the RNAV system uses DME facilities outside of their published designated operational coverage, the DME signal-in-space error of valid facilities can still be assumed to be σ_{ground}=0.05 NM.
h)	Preventing erroneous guidance from other facilities	The RNAV system must ensure that the use of 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. This could be accomplished by including reasonableness checking when initially tuning a DME facility or excluding a DME facility when there is a co-channel DME within line-of-sight.
i)	Preventing erroneous VOR signals-in-space	VOR may be used by the RNAV system, however, the RNAV system must ensure an erroneous VOR signal-in-space does not affect the position error when in DME/DME coverage. For example, this may be accomplished by weighting and/or monitoring the VOR signal with DME/DME to ensure it does not mislead position results (e.g. through reasonableness checks (see 3.3.3.2.2 l)).
j)	Ensuring RNAV systems use operational facilities	The RNAV system must use operational DME facilities. DME facilities listed by NOTAM as unavailable (e.g. under test or other maintenance) could still reply to an airborne interrogation, therefore, non-operational facilities must not be used. An RNAV system may exclude non-operational facilities by checking the identification or inhibiting the use of facilities identified as not operational.
k)	Operational mitigations	Operational mitigations such as pilot monitoring of the RNAV system's navigation updating source(s), or time-intensive programming/de-selection of multiple DME stations, should be performed before any workload-intensive or critical phase of flight. *Note.— De-selecting single facilities listed by NOTAM as out-of-service and/or programming route-defined "critical" DME is acceptable when this mitigation requires no pilot action during a critical phase of flight. A programming requirement also does not imply the pilot should complete manual entry of DME facilities which are not in the navigation database.*
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: i) those the RNAV system uses after it acquires a new DME, where it compares the aircraft's position before using the DME to the aircraft's range to the DME; and ii) those the RNAV system continuously uses, based on redundant information (e.g. extra DME signals or IRU data). **General requirements.** The reasonableness checks are intended to prevent navigation aids from being used for navigation update in areas where the data can lead to radio position fix errors due to co-channel

		interference, multipath, and direct signal screening. In lieu of using the published service volume of the radio navigation aid, the navigation system should provide checks which preclude the use of duplicate frequency navaids within range, over-the-horizon navaids, and use of navaids with poor geometry. **Assumptions.** Under the following conditions, reasonableness checks can be invalid: i) A DME signal does not remain valid just because it was valid when acquired. ii) Extra DME signals may not be available. The intent of this specification is to support operations where the infrastructure is minimal (e.g. when only two DMEs are available for parts of the route). **Use of stressing conditions to test effectiveness.** When a reasonableness check is used to satisfy any requirement in these criteria, the effectiveness of the check must be tested under stressful conditions. An example of this condition is a DME signal that is valid at acquisition and ramps off during the test (similar to what a facility undergoing testing might do), when there is only one other supporting DME or two signals of equal strength.

3.3.3.2.3 *Criteria for distance measuring equipment (DME) and inertial reference unit (IRU) (DME/DME/IRU RNAV system)*

This section defines the minimum DME/DME/IRU (or D/D/I) RNAV system baseline performance. The performance standards for the DME/DME positioning are as detailed in 3.3.3.2.2.

Paragraph	Criteria	Explanation
a)	Inertial system performance must satisfy the criteria of US 14 CFR Part 121, Appendix G.	
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.	One means of accomplishing this objective is for RNAV systems to exclude VORs greater than 40 NM from the aircraft.

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, (E)HSI) 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 (e.g. CDI, (E)HSI), 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; 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. *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

Paragraph	Functional requirement	Explanation
		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 aeronautical information regulation and control (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 path definition error. 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 navigation aids, to enable the pilot to verify the route to be flown. 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.	
e)	The capability for automatic leg sequencing with the display of sequencing to the pilot.	

Paragraph	Functional requirement	Explanation
f)	The capability to execute ATS routes extracted from the on-board database, including the capability to execute flyover 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. — initial fix (IF) — course to fix (CF) — direct to fix (DF) — track to fix (TF)	*Note 1.— Path terminators are defined in ARINC Specification 424, and their application is described in more detail in RTCA documents DO-236B and DO-201A, and EUROCAE ED-75B 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 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 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)	The capability to load an RNAV ATS route from the database, by route name, into the RNAV system is a recommended function. However, if all or part of the RNAV route (not 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.	

Paragraph	Functional requirement	Explanation
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.	
m)	Database integrity	The navigation database suppliers should comply with RTCA DO-200A/EUROCAE document ED 76, Standards for Processing Aeronautical Data (see 3.3.6). A Letter of Acceptance (LOA), issued by the appropriate regulatory authority to each of the participants in the data chain demonstrates compliance with this requirement. 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 flight crew. Aircraft operators should consider the need to conduct periodic checks of the operational navigation databases in order to meet existing quality system requirements.

3.3.4 Operating procedures

Airworthiness certification alone does not authorize flight in airspace or along routes for which RNAV 1 or RNAV 2 approval is required. Operational approval is also required to confirm the adequacy of the operator's normal and contingency procedures for the particular equipment installation.

3.3.4.1 Pre-flight planning

3.3.4.1.1 Operators and pilots intending to conduct operations on RNAV 1 and RNAV 2 routes should file the appropriate flight plan suffixes.

3.3.4.1.2 The on-board navigation data must be current and appropriate for the region of intended operation and must include the navigation aids, 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.

3.3.4.1.3 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 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.

3.3.4.1.4 *Aircraft-based augmentation system (ABAS) availability*

3.3.4.1.4.1 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 (e.g. if sufficient satellites are available, a prediction may not be necessary). Operators should be familiar with the prediction information available for the intended route.

3.3.4.1.4.2 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.

3.3.4.1.4.3 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 flight plan should be revised (e.g. delaying the departure or planning a different departure procedure).

3.3.4.1.4.4 RAIM availability prediction software does not guarantee the service, they are rather tools to assess the expected capability to meet the required 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.

3.3.4.1.5 *Distance measuring equipment (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.

3.3.4.2 **General operating procedures**

3.3.4.2.1 The pilot should comply with any instructions or procedures identified by the manufacturer as necessary to comply with the performance requirements in this chapter.

3.3.4.2.2 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.

3.3.4.2.3 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.

3.3.4.2.4 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 flyover or vice versa.

3.3.4.2.5 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.

3.3.4.2.6 Flight crews should cross-check the cleared 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 navigation aids 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.

3.3.4.2.7 During the flight, where feasible, the flight crew should use available data from ground-based navigation aids to confirm navigational reasonableness.

3.3.4.2.8 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.

3.3.4.2.9 For RNAV 1 routes, pilots must use a lateral deviation indicator, flight director, or autopilot in lateral navigation mode.

3.3.4.2.10 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 (e.g. full-scale deflection: ±1 NM for RNAV 1, ±2 NM for RNAV 2, or ±5 NM for TSO-C129() equipment on RNAV 2 routes).

3.3.4.2.11 All pilots are expected to maintain route centrelines, 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, i.e. FTE) should be limited to ±½ the navigation accuracy associated with the procedure or route (i.e. 0.5 NM for RNAV 1, 1.0 NM for RNAV 2). Brief deviations from this standard (e.g. overshoots or undershoots) during and immediately after procedure/route turns, up to a maximum of one-times the navigation accuracy (i.e. 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 lateral navigation accuracy during procedural/route turns, but are still expected to satisfy the standard during intercepts following turns and on straight segments.

3.3.4.2.12 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.

3.3.4.2.13 Manually selecting aircraft bank limiting functions may reduce the aircraft's ability to maintain its desired track and are 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.

3.3.4.3 RNAV SID specific requirements

3.3.4.3.1 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.

3.3.4.3.2 *RNAV engagement altitude.* The pilot must be able to use RNAV equipment to follow flight guidance for lateral RNAV 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 (e.g. climb to 304 m (1 000 ft) then direct to …).

3.3.4.3.3 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.

3.3.4.3.4 *DME/DME aircraft.* Pilots of aircraft without GPS, using DME/DME sensors without IRU input, cannot use their RNAV system until the aircraft has entered adequate DME coverage. The air navigation service provider (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.

3.3.4.3.5 *DME/DME/IRU (D/D/I) aircraft.* Pilots of aircraft without GPS, using DME/DME RNAV systems with an IRU (DME/DME/IRU), should ensure the aircraft 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, if the pilot procedures and the display resolution allow for compliance with the 304 m (1 000 ft) tolerance requirement.

Note.— Based on evaluated IRU performance, the growth in position error after reverting to IRU can be expected to be less than 2 NM per 15 minutes.

3.3.4.3.6 *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-C145a/C146a 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.

3.3.4.4 RNAV STAR specific requirements

3.3.4.4.1 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 track angles and distances, any altitude or speed constraints, and, where possible, which waypoints are fly-by and which are flyover. If required by a route, a check will need to be made to confirm that updating will exclude a particular navigation aid. 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.

3.3.4.4.2 The creation of new waypoints by manual entry into the RNAV system by the flight crew would invalidate the route and is not permitted.

3.3.4.4.3 Where the contingency procedure requires reversion to a conventional arrival route, necessary preparations must be completed before commencing the RNAV route.

3.3.4.4.4 Route modifications in the terminal area may take the form of radar 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.

3.3.4.4.5 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.

3.3.4.4.6 Although a particular method is not mandated, any published altitude and speed constraints must be observed.

3.3.4.5 Contingency procedures

3.3.4.5.1 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.

3.3.4.5.2 In the event of communications failure, the flight crew 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 (e.g 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 (flyover 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, e.g. DME/DME, DME/DME/IRU, and GNSS;

f) RNAV system-specific information:

   i) levels of automation, mode annunciations, changes, alerts, interactions, reversions, and degradation;

   ii) functional integration with other aircraft systems;

   iii) the meaning and appropriateness of route discontinuities as well as related flight crew procedures;

   iv) pilot procedures consistent with the operation;

v) types of navigation sensors (e.g. DME, IRU, GNSS) utilized by the RNAV system and associated system prioritization/weighting/logic;

vi) turn anticipation with consideration to speed and altitude effects;

vii) interpretation of electronic displays and symbols;

viii) understanding of the aircraft configuration and operational conditions required to support RNAV operations, i.e. appropriate selection of CDI scaling (lateral deviation display scaling);

g) RNAV equipment operating procedures, as applicable, including how to perform the following actions:

i) verify currency and integrity of the aircraft navigation data;

ii) verify the successful completion of rnav system self-tests;

iii) initialize navigation system position;

iv) retrieve and fly a SID or a STAR with appropriate transition;

v) adhere to speed and/or altitude constraints associated with a SID or STAR;

vi) select the appropriate STAR or SID for the active runway in use and be familiar with procedures to deal with a runway change;

vii) perform a manual or automatic update (with take-off point shift, if applicable);

viii) verify waypoints and flight plan programming;

ix) fly direct to a waypoint;

x) fly a course/track to a waypoint;

xi) intercept a course/track;

xii) flying radar vectors and rejoining an RNAV route from “heading” mode;

xiii) determine cross-track error/deviation. More specifically, the maximum deviations allowed to support RNAV must be understood and respected;

xiv) resolve route discontinuities;

xv) remove and reselect navigation sensor input;

xvi) when required, confirm exclusion of a specific navigation aid or navigation aid type;

xvii) when required by the State aviation authority, perform gross navigation error checks using conventional navigation aids;

xviii) change arrival airport and alternate airport;

xix) 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;

xx) perform RNAV holding functions;

h) operator-recommended levels of automation for phase of flight and workload, including methods to minimize cross-track error to maintain route centreline;

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 200A/EUROCAE document ED 76, Standards for Processing Aeronautical Data and should be compatible with the intended function of the equipment (Annex 6, Part 1, Chapter 7). A Letter of Acceptance (LOA), issued by the appropriate regulatory authority to each of the participants in the data chain, demonstrates compliance with this requirement (e.g. FAA LOA issued in accordance with FAA AC 20-153 or EASA LOA issued in accordance with EASA IR 21 subpart G).

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 flight crew.

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.

3.3.7 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 approval 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

Copies of EUROCAE documents may be purchased from EUROCAE, 102 rue Etienne Dolet, 92240 Malakoff, France (Fax: +33 1 46 55 62 65). Website: www.eurocae.eu

Copies of FAA documents may be obtained from Superintendent of Documents, Government Printing Office, Washington, DC 20402-9325, USA. Website: http://www.faa.gov/aircraft_cert/ (Regulatory and Guidance Library)

Copies of RTCA documents may be obtained from RTCA Inc., 1140 Connecticut Avenue, N.W., Suite 1020, Washington, DC 20036-4001, USA, (Tel.: 1 202 833 9339). Website: www.rtca.org

Copies of ARINC documents may be obtained from Aeronautical Radio Inc., 2551 Riva Road, Annapolis, Maryland 24101-7435, USA. Website: http://www.arinc.com

Copies of JAA documents are available from JAA's publisher Information Handling Services (IHS). Information on prices, where and how to order, is available on the JAA website: http://www.jaa.nl and on the IHS websites: http://www.global.his.com and http://www.avdataworks.com

Copies of EASA documents may be obtained from EASA (European Aviation Safety Agency), 101253, D-50452 Koln, Germany.

Copies of ICAO documents may be purchased from the International Civil Aviation Organization, Customer Services Unit, 999 University Street, Montréal, Quebec, Canada H3C 5H7, (Fax: +1 514-954-6769 or e-mail: sales_unit@icao.int) or through sales agents listed on the ICAO website: www.icao.int

Appendix to Part B

Summary of RNAV 1/FAA AC 90-100 and JAA TGL-10 non-significant differences

	RNAV 1/FAA AC 90-100/ JAA TGL-10 differences	*RNAV 1*	*FAA AC 90-100*	*JAA TGL-10 (Rev.1)*	*Conclusion*
Aircraft equipment	ARINC 424 path terminator	IF,CF,DF,TF (3.4.3.7)	IF,CF,DF,TF (6.c)	IF,TF,CF,DF,FA	TGL-10 does not specify automatic versus manual leg management. FA path terminator required in TGL-10 could be manually conducted by pilot. There is no difference between TGL 10 and AC 90-100/RNAV 1.
	MCDU	No requirement.	The system must be capable of displaying lateral deviation with a resolution of at least 0.1 NM (6.c.12.)	Where the MCDU is to be used to support the accuracy checks of Section 10, display of lateral deviation with a resolution of 0.1 NM, (7.1.12)	It was agreed: 1) in P-RNAV its really good practice and not universal requirement; 2) RNAV 1 and 2 would be tailored for radar environments, where such checks are not required.
	Support gross error check	No requirement.	No requirement.	Alternative means of displaying navigation information, sufficient to perform the checking procedures of Section 10. (7.1.21)	It was agreed: 1) in P-RNAV its really good practice and not universal requirement; 2) RNAV 1 and 2 would be tailored for radar environments, where such checks are not required.
	General operating procedures (3.4.4.2)	During the flight, where feasible, the flight crew should use available data from ground-based navigation aids to confirm navigational reasonableness.	No requirement.	During the procedure, and where feasible, flight progress should be monitored for navigational reasonableness by cross-checks with conventional navigation aids using the primary displays in conjunction with the MCDU. (10.2.2.5, 10.2.3.4)	A navigational cross-check is only recommended in RNAV 1 and in TGL. It was agreed: 1) in PRNAV its really good practice and not universal requirement; 2) RNAV 1 and 2 would be tailored for radar environments, where such checks are not required.

	RNAV 1/FAA AC 90-100/ JAA TGL-10 differences	*RNAV 1*	*FAA AC 90-100*	*JAA TGL-10 (Rev.1)*	*Conclusion*
	RNAV STAR specific requirement (3.4.4.4)	Prior to the arrival phase, the flight crew should verify that the correct terminal route has been loaded. (3.4.4.4.1 Block)	No requirement.	Prior to the arrival phase, the flight crew should verify that the correct terminal procedure has been loaded. (10.2.3.1)	Covered in AC 90-100 as a general issue rather than specific to arrivals: *"Flight crews should cross-check the cleared flight plan against charts or other applicable resources, as well as the navigation system textual display and the aircraft map display, if applicable"* No discrepancy.
Operational requirement	RNAV STAR specific requirement (3.4.4.4)	The creation of new waypoints by manual entry into the RNAV system by the flight crew would invalidate the route and is not permitted. (3.4.4.4.1 Block 2)	No requirement.	The creation of new waypoints by manual entry into the RNAV system by the flight crew would invalidate the P-RNAV procedure and is not permitted. (10.2.3.2)	AC 90-100 specifies that: "Capacity to load from the database into the RNAV system the entire RNAV segment of the SID or STAR procedure(s) to be flown." and **"**Pilots must not fly an RNAV SID or STAR unless it is retrievable by procedure name from the on-board navigation database and conforms to the charted procedure." FAA did not include prohibition against altering flight plan in equipment, as the ATC clearance can amend procedure in some circumstances. No discrepancy.
		Where the contingency procedure requires reversion to a conventional arrival route, necessary preparations must be completed before commencing the RNAV route. (3.4.4.4.1 Block 3)	No requirement.	Where the contingency to revert to a conventional arrival procedure is required, the flight crew must make the necessary preparations. (10.2.3.3)	Under TGL-10, such contingency is required for below MOCA or outside radar coverage. RNAV 1 is intended for application within radar coverage (MOCA is not a significant constraint if the radar service is available and the aircraft is above MSA). Discrepancy resolved through the decision to base ICAO implementation on radar.

	RNAV 1/FAA AC 90-100/ JAA TGL-10 differences	*RNAV 1*	*FAA AC 90-100*	*JAA TGL-10 (Rev.1)*	*Conclusion*
		Route modifications in the terminal area may take the form of radar headings or "direct to" clearances and the flight crew must be capable of reacting in a timely fashion. (3.4.4.4.1 Block 4)	No requirement.	Route modifications in the terminal area may take the form of radar headings or "direct to" clearances and the flight crew must be capable of reacting in a timely fashion. (10.2.3.5)	In the United States, crew training includes knowledge of how to go direct, in addition to training in basic airmanship. No discrepancy.
	Contingency procedure (3.4.4.5)	Although a particular method is not mandated, any published altitude and speed constraints must be observed. (3.4.4.4. Block 5)	No requirement.	Although a particular method is not mandated, any published altitude and speed constraints must be observed. (10.2.3.6)	United States RNAV does not define any new requirements for altitude or airspeed (nor does TGL-10), so this statement is not included. No discrepancy.
		The pilot must notify ATC of any loss of the RNAV capability, together with the proposed course of action. (3.4.4.5. Block 1)	No requirement.	The flight crew must notify ATC of any problem with the RNAV system that results in the loss of the required navigation capability, together with the proposed course of action. (10.3.2)	It is specified in AC 90-100, 8d: "The pilot must notify ATC of any loss of the RNAV capability, together with the proposed course of action." No discrepancy.
Database requirement	Database integrity	Aircraft operators should consider the need to conduct periodic checks of the operational navigation databases in order to meet existing quality system requirements. (3.4.4 Database Block 3)	No requirement.	No requirement.	No specific requirement in TGL-10 and in AC 90-100. This requirement is recognized as a good practice. No discrepancy.
	Invalidated report	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 flight crew. (3.4.4 Database Block 2)	No requirement.	Discrepancies that invalidate a procedure must be reported to the navigation database supplier and affected procedures must be prohibited by a operator's notice to its flight crew. (8.2, 10.6.3)	No specific requirement for navigation database integrity in AC 90-100. Will not be the case in AC 90-100A.

	RNAV 1/FAA AC 90-100/ JAA TGL-10 differences	*RNAV 1*	*FAA AC 90-100*	*JAA TGL-10 (Rev.1)*	*Conclusion*
	Periodical checks	Aircraft operators should consider the need to conduct periodic checks of the operational navigation databases in order to meet existing quality system requirements. (3.4.4 Database Block 3)	No requirement.	No requirement.	No specific requirement in TGL-10 and in AC 90-100. This requirement is recognized as a good practice. No discrepancy.
Maintenance requirement	MEL revision	Any minimum equipment list (MEL) revisions necessary to address RNAV 1 and RNAV 2 provisions must be approved. Operators must adjust the MEL, or equivalent, and specify the required dispatch conditions. (3.4.2.4)	No specific requirement	No specific requirement.	Covered in TGL-10 (10.7.2) and in AC 90-100 as general guidance (not specific to MEL as a means to regulate it): "The pilot must also confirm availability of the on-board navigation equipment necessary for the route, SID, or STAR to be flown". No discrepancy.

Part C

IMPLEMENTING RNP

Chapter 1

IMPLEMENTING RNP 4

1.1 INTRODUCTION

1.1.1 Background

This chapter addresses the implementation of RNP 4 to support 30 NM lateral and the 30 NM longitudinal distance-based separation minima in oceanic or remote area airspace.

1.1.2 Purpose

1.1.2.1 This chapter provides guidance to States implementing RNP 4 to assist in developing operational approval or authorization processes. The operational approval process described herein is limited to aircraft which 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 supplemental type certificate (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 operating rules, aeronautical information publications (AIPs) and the *Regional Supplementary Procedures* (Doc 7030). While operational approval 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, which are required by the appropriate State authority, before conducting flights into that airspace.

1.2 AIR NAVIGATION SERVICES PROVIDER (ANSP) 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. 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 Communication and surveillance considerations

While this guidance material was developed to support the 30 NM lateral and longitudinal separation minima based on RNP 4, it should be noted that it addresses only the navigation requirements associated with these standards. It does not specifically address the communications or ATS surveillance requirements.

Note.— The provisions relating to these separation minima, including the communications and ATS surveillance requirements, can be found in 3.4.1 e) of Attachment B to Annex 11 and Section 5.4 of the PANS-ATM (Doc 4444).

Provided that they can support the increased reporting rate required, controller-pilot data link communications (CPDLC) and automatic dependent surveillance — contract (ADS-C) systems which meet the requirements for application of the 50 NM lateral and longitudinal minima based on RNP 10 will also meet the requirements for the application of the 30 NM lateral and longitudinal minima.

1.2.3 Obstacle clearance and route spacing

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

1.2.3.2 The separation minima are described in Section 5.4 of the PANS-ATM (Doc 4444).

1.2.3.3 RNP 4 may be used to support the application of separation standards/route spacing less than 30 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 30 NM standard.

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 Many aircraft have the capability to execute a holding pattern manoeuvre using their RNAV system. The purpose of this function is to provide flexibility to ATC in designing RNAV operations.

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

1.2.5 Publication

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 navigation aids must meet the requirements of Annex 15 — *Aeronautical Information Services*. All routes must be based upon WGS-84 coordinates.

1.2.6 Controller training

Air traffic controllers providing control services in airspace where RNP 4 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):

   i) including functional capabilities and limitations of this navigation specification;

   ii) accuracy, integrity, availability and continuity including on-board performance monitoring and alerting;

iii) GPS receiver, RAIM, FDE, and integrity alerts;

iv) waypoint fly-by versus flyover concept (and different turn performance);

b) Flight plan requirements;

c) ATC procedures:

i) ATC contingency procedures;

ii) separation minima;

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

iv) transition between different operating environments; and

v) phraseology.

1.2.6.2 Training specific to this navigation specification

For application of 30/30 separation minima:

a) CPDLC communication;

b) ADS-C system and simulation training; and

c) effect of periodic reporting delay/failure on longitudinal separation.

1.2.7 Status monitoring

The air traffic service provider must monitor the status of GNSS and issue timely warnings of outages (NOTAMS).

1.2.8 ATS system monitoring

Demonstrated navigation accuracy 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. 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.

1.3 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 a specific operational approval in some cases. For example, certain operational regulations require that operators to apply to their national authority (State of Registry) for operational approval.

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

1.3.2 Approval 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 4 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) flight crew training based upon the operating procedures must be documented if necessary;

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

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

1.3.2.3 Aircraft eligibility

1.3.2.3.1 *Airworthiness eligibility documents.* Relevant documentation acceptable to the State of Operator/Registry must be available to establish that the aircraft is equipped with an RNAV system meeting RNP 4 requirements. To avoid unnecessary regulatory activity, the determination of eligibility for existing systems should consider acceptance of manufacturer documentation of compliance, e.g. the EASA AMC 20 series.

1.3.2.3.2 Aircraft eligibility groups:

a) Group 1: RNP certification:

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.

The certification will not necessarily be limited to a specific RNP specification. The flight manual must address the RNP levels that have been demonstrated and any related provisions applicable to their use (e.g. navaid sensor requirements). Operational approval is based upon the performance stated in the flight manual.

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. Those standards listed in i) to iii) can be used to qualify aircraft under Group 2:

i) *Global navigation satellite systems (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 technical standard orders (TSO) c129a or c146(), and JAA joint technical standard orders (JTSO) c129a or c146(). In addition, an approved dispatch fault detection and exclusion (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 approval. If predictions indicate that the maximum allowable FDE outage will be exceeded, the operation must be rescheduled to a time when FDE is available.

ii) Multi-sensor systems integrating GNSS with integrity provided by receiver autonomous integrity monitoring (RAIM). Multi-sensor systems incorporating global positioning system (GPS) with RAIM and FDE that are approved under FAA AC20-130a, or other equivalent documents, meet the technical requirements specified in 1.3.3. Note that there is no requirement to use dispatch FDE availability prediction programmes when multi-sensor systems are fitted and used.

iii) *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-115b, JTSO c-115b or other equivalent documents. An example is the use of an inertial navigation system 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.

1.3.2.4 Operational approval

1.3.2.4.1 The assessment of a particular operator is made by the State of Operator/Registry for that operator and in accordance with national operating rules (e.g. JAR-OPS 1, 14 CFR Part 121) supported through appropriate advisory and guidance material. The assessment should take into account:

a) evidence of aircraft eligibility;

b) assessment of the operating procedures for the navigation systems to be used;

c) control of those procedures through acceptable entries in the operations manual;

d) identification of flight crew training requirements; and

e) where required, control of navigation database processes;

1.3.2.4.2 The operational approval will likely be documented through the State endorsing the air operator certificate (AOC) through issue of a Letter of Authorization, appropriate operations specification (Ops Spec) or amendment to the operations manual.

1.3.2.4.3 *Description of aircraft equipment*

The operator must have a configuration list detailing pertinent components and equipment to be used for RNP 4 operations.

1.3.2.4.4 *Training documentation*

1.3.2.4.4.1 Commercial operators must have a training programme addressing the operational practices, procedures and training items related to RNP 4 operations (e.g. initial, upgrade or recurrent training for flight crew, dispatchers or maintenance personnel).

Note.— It is not required to establish a separate training programme or regimen if RNAV training is already an integrated element of a training programme. However, it should be possible to identify the aspects of RNAV that are covered within a training programme.

1.3.2.4.4.2 Non-commercial operators must be familiar with the practices and procedures identified in 1.3.5 "Pilot knowledge and training".

1.3.2.4.5 *Operations manuals and checklists*

1.3.2.4.5.1 Operations manuals and checklists for commercial operators must address information/guidance on the standard operating procedures detailed in 1.3.4. The appropriate manuals should contain navigation operating instructions and contingency procedures where specified. Manuals and checklists must be submitted for review as part of the application process.

1.3.2.4.5.2 Non-commercial operators must create appropriate instructions containing navigation operating instructions and contingency procedures. This information must be available to crews in flight and should be entered into the operations manual or the pilot operating handbook, as appropriate. These manuals and manufacturer's instructions for operation of the aircraft navigation equipment, as appropriate, must be submitted for review as part of the application process.

1.3.2.4.5.3 Non-commercial operators must operate using the practices and procedures identified in 1.3.5 "Pilot knowledge and training".

1.3.2.4.6 *Minimum equipment list (MEL) considerations*

1.3.2.4.6.1 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.

1.3.2.4.6.2 All operators must submit their maintenance programme, including a reliability programme for monitoring the equipment, for approval at the time of application. The holder of the design approval, including either the type certificate (TC) or supplemental type certificate (STC) for each individual navigation system installation must furnish at least one set of complete instructions for continuing airworthiness.

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 approval 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 United States FAA Advisory Circular AC 20-138A, 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 20-130A 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 navigation approval.

1.3.3.5 System performance, monitoring and alerting

Accuracy: During operations in airspace or on routes designated as RNP 4, the lateral total system error 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. An FTE of 2.0 NM (95 per cent) may be assumed.

Integrity: Malfunction of the aircraft navigation equipment is classified as a major failure condition under airworthiness regulations (i.e. 10^{-5} per hour).

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 (excluding signal-in-space).

Performance monitoring and alerting: The RNP system, or the RNP system and pilot in combination, shall 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}.

Signal-in-space: If using GNSS, the aircraft navigation equipment shall provide an alert if the probability of signal-in-space errors causing a lateral position error greater than 8 NM exceeds 10^{-7} per hour (Annex 10, Volume I, Table 3.7.2.4-1).

Note.— Compliance with the performance monitoring and alerting requirement does not imply an automatic monitor of flight technical error. The on-board monitoring and alerting function should consist at least of a navigation system error (NSE) monitoring and alerting algorithm and a lateral deviation display enabling the crew to monitor the flight technical error (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 (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) track to fix (TF);

c) direct to fix (DF);

d) direct to function;

e) course to fix (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 course to fix;

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 (e.g. CDI, electronic horizontal situation indicator (E)HSI), 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 HSI selected course to the computed desired track.

 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.

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 flight crew. When in offset mode, the system must provide reference parameters (e.g. 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. Annunciation must be given to the flight crew 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 flight crew enters a direct-to routing, or until flight crew (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, boundaries of the transition area are defined. Path definition error is defined as the difference between the defined path and the theoretical transition area. If the path lies within the transition area, there is no path definition error. 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 flight crew 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 (e.g. 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 flight crew 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 flight crew 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 (e.g. 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 flight crew after input and verification by the flight crew.

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 course to fix*

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 *Path steering*

The system must provide data to enable the generation of command signals for autopilot/flight director/CDI, as applicable. In all cases, a path steering error (PSE) 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 PSE 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 PSE compliance. A measured value of PSE 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 containment compliance, any inaccuracies in the cross-track error computation (e.g. resolution) must be accounted for in the total system error.

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 airspace 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 (e.g. 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 path definition error (PDE). Errors induced by data resolution must also be considered.

1.3.4 Operating procedures

Airworthiness certification alone does not authorize RNP 4 operations. Operational approval is also required to confirm the adequacy of the operator’s normal and contingency procedures for the particular equipment installation.

1.3.4.1 Pre-flight planning

1.3.4.1.1 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 approval 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. Controller-pilot data link communications (CPDLC) and automatic dependent surveillance — contract (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.

1.3.4.1.2 The flight crew 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.

1.3.4.2 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.

1.3.4.3 En route

1.3.4.3.1 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.

1.3.4.3.2 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.

1.3.4.3.3 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.

1.3.4.3.4 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 (i.e. ±4 NM). All pilots are expected to maintain route centrelines, 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 (i.e. 2 NM). Brief deviations from this standard (e.g. overshoots or undershoots) during and immediately after route turns, up to a maximum of one-times the navigation accuracy (i.e. 4 NM), are allowable.

1.3.5 Pilot knowledge and training

1.3.5.1 Operators/owners must ensure that flight crews 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 approval that the operator/owner has ensured and will continue to ensure that flight crews 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 200A/EUROCAE document ED 76, Standards for Processing Aeronautical Data. A Letter of Acceptance (LOA) issued by the appropriate regulatory authority demonstrates compliance with this requirement (e.g. FAA LOA issued in accordance with FAA AC 20-153 or EASA LOA issued in accordance with EASA IR 21 subpart G).

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 flight crew.

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 path definition error, the database should comply with DO-200A/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 approval 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

1.4.1 Websites

— Federal Aviation Administration (FAA), United States

http://www.faa.gov/about/office_org/headquarters_offices/ato/service_units/enroute/oceanic

— Civil Aviation Safety Authority (CASA), Australia

http://www.casa.gov.au/rules/1998casr/index.htm

1.4.2 Related publications

— Federal Aviation Administration (FAA), United States

Code of Federal Regulations (CFR), Part 121, Appendix G

Advisory Circular (AC) 20-130A. Airworthiness Approval of Navigation or Flight Management Systems Integrating Multiple Navigation Sensors

AC 20-138A. Airworthiness Approval of Global Navigation Satellite System (GNSS) Equipment

FAA Order 7110.82. Monitoring of Navigation/Altitude Performance in Oceanic Airspace

FAA Order 8400.33. Procedures for Obtaining Authorization for Required Navigation Performance 4 (RNP 4) Oceanic and Remote Area Operations

— Civil Aviation Safety Authority (CASA), Australia

Advisory Circular (AC) 91U-3(0): Required Navigation Performance 4 (RNP 4) Operational Authorisation

— International Civil Aviation Organization (ICAO)

Annex 6 – *Operation of Aircraft*

Annex 11 – *Air Traffic Services*

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

Global Air Navigation Plan for CNS/ATM Systems (Doc 9750)

(Copies may be obtained from the International Civil Aviation Organization, Customer Services Unit, 999 University Street, Montréal, Quebec, Canada H3C 5H7)

— RTCA

Minimum Aviation System Performance Standards (MASPS): Required Navigation Performance for Area Navigation (DO 236B), RTCA

Minimum Operational Performance Standards (MOPS) for Required Navigation Performance for Area Navigation (DO 283), RTCA

Standards for Processing Aeronautical Data (DO 200A), RTCA

(Copies may be obtained from RTCA, Inc., 1828 L Street NW, Suite 805, Washington, DC 20036, United States)

— EUROCAE

Minimum Aviation System Performance Specification required Navigation Performance for Area Navigation (ED-75B)

Standards for Processing Aeronautical Data (ED-76)

(Copies may be obtained from EUROCAE, 102 rue Etienne Dolet, 92240 Malakoff, France (Fax: +33 1 46 55 62 65). Website: www.eurocae.eu)

Chapter 2

IMPLEMENTING RNP 2

To be developed.

Chapter 3

IMPLEMENTING BASIC-RNP 1

3.1 INTRODUCTION

3.1.1 Background

The Basic-RNP 1 navigation specification provides a means to develop routes for connectivity between the en-route structure and terminal airspace (TMA) with no or limited ATS surveillance, with low to medium density traffic.

3.1.2 Purpose

This chapter provides guidance to States implementing Basic-RNP 1 for arrival and departure procedures. This chapter does not address all the requirements that may be specified for particular operations. These requirements are specified in other documents, such as operating rules, aeronautical information publications (AIPs) and the *Regional Supplementary Procedures* (Doc 7030). While operational approval 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, which are required by the appropriate State authority, before conducting flights into that airspace.

3.2 AIR NAVIGATION SERVICE PROVIDER (ANSP) CONSIDERATIONS

3.2.1 Navaid infrastructure considerations

3.2.1.1 GNSS will be the primary navigation system to support Basic-RNP 1. While DME/DME-based RNAV systems are capable of Basic-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. The increased complexity in the DME infrastructure requirements and assessment means it is not practical or cost-effective for widespread application.

3.2.1.2 ANSPs should ensure operators of GNSS-equipped aircraft have the means to predict fault detection using ABAS (e.g. RAIM). Where applicable, ANSPs should also ensure operators of 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 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 Basic-RNP 1 operation.

3.2.1.3 Basic-RNP 1 shall 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 Communication and ATS surveillance considerations

This navigation specification is intended for environments where ATS surveillance is either not available or limited. Basic-RNP 1 SIDs/STARs are primarily intended to be conducted in direct controller-pilot communication environments.

3.2.3 Obstacle clearance and horizontal separation

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

3.2.3.2 Route spacing for Basic-RNP 1 depends on the route configuration, air traffic density and intervention capability. Horizontal separation standards are published in PANS-ATM (Doc 4444).

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 airport reference point (ARP).

3.2.5 Publication

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 navigation aids must meet the requirements of Annex 15 — *Aeronautical Information Services*. All procedures must be based upon WGS-84 coordinates.

3.2.6 Controller training

Air traffic controllers who provide RNP terminal and approach control services where Basic-RNP 1 is implemented, should have completed training that covers the items listed below.

3.2.6.1 Core training

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

   i) including functional capabilities and limitations of this navigation specification;

   ii) accuracy, integrity, availability and continuity including on-board performance monitoring and alerting;

   iii) GPS receiver, RAIM, FDE, and integrity alerts;

   iv) waypoint fly-by versus flyover concept (and different turn performance);

b) Flight plan requirements;

c) ATC procedures;

i) ATC contingency procedures;

ii) separation minima;

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

iv) transition between different operating environments; and

v) phraseology.

3.2.6.2 Training specific to this navigation specification

a) Basic-RNP 1 STARs, SIDs, related control procedures:

i) radar vectoring techniques (where appropriate);

(ii) open and closed STARs;

iii) altitude constraints; and

iv) descend/climb clearances;

b) RNP approach and related procedures;

c) Basic-RNP 1 related phraseology; and

d) impact of requesting a change to routing during a procedure.

3.2.7 Status monitoring

3.2.7.1 The navaid infrastructure should be monitored and, when appropriate, maintained by the service provider. Timely warnings of outages (NOTAMs) should be issued.

3.2.7.2 Status information should be provided in accordance with Annex 11 — *Air Traffic Services* for navigation facilities or services that may be used to support the operation.

3.2.8 ATS system monitoring

3.2.8.1 Demonstrated navigation accuracy provides a basis for determining the lateral route spacing and horizontal separation minima necessary for traffic operating on a particular procedure. When available, radar observations of each aircraft's proximity to track and altitude are typically noted by ATS facilities and aircraft track-keeping capabilities are analysed.

3.2.8.2 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.

3.3 NAVIGATION SPECIFICATION

3.3.1 Background

This chapter identifies the operational requirements for Basic-RNP 1 operations. Operational compliance with these requirements should be addressed through national operational regulations, and may require a specific operational approval in some cases. For example, JAR-OPS 1 requires operators to apply to the State of the Operator/Registry, as appropriate, for operational approval.

3.3.2 Approval 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. The navigation specification provides the technical and operational criteria, and does not imply a need for recertification.

3.3.2.2 The following steps must be completed before conducting Basic-RNP 1 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) flight crew training based upon the operating procedures must be documented;

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

e) operational approval should then be obtained in accordance with the national operating rules.

3.3.2.3 Following the successful completion of the above steps, a Basic-RNP 1 operational approval, Letter of Authorization or appropriate operations specification (Ops Spec), if required, should then be issued by the State.

3.3.2.4 Aircraft eligibility

The aircraft eligibility has to 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, e.g. STC holder, will demonstrate compliance to their national airworthiness authority (NAA) (e.g. EASA, FAA) and the approval can be documented in manufacturer documentation (e.g. service letters). Aircraft flight manual (AFM) entries are not required provided the State accepts manufacturer documentation.

3.3.2.5 Operational approval

3.3.2.5.1 The assessment of a particular operator is made by the State of Registry for that operator and in accordance with national operating rules (e.g. JAR-OPS 1, 14 CFR Part 121) supported through appropriate advisory and guidance material. The assessment should take into account:

a) evidence of aircraft eligibility;

b) assessment of the operating procedures for the navigation systems to be used;

c) control of those procedures through acceptable entries in the operations manual;

d) identification of flight crew training requirements; and

e) where required, control of the navigation database process.

3.3.2.5.2 The operational approval will likely be documented through the State endorsing the air operators certificate (AOC) through issue of a Letter of Authorization, appropriate operations specification (Ops Spec) or amendment to the operations manual.

3.3.2.5.3 *Description of aircraft equipment*

The operator must have a configuration list detailing pertinent components and equipment to be used for Basic-RNP 1.

3.3.2.5.4 *Training documentation*

3.3.2.5.4.1 Commercial operators should have a training programme addressing the operational practices, procedures and training items related to Basic-RNP 1 operations (e.g. initial, upgrade or recurrent training for flight crew, dispatchers or maintenance personnel).

Note.— It is not required to establish a separate training programme or regimen if RNAV training is already an integrated element of a training programme. However, it should be possible to identify the aspects of RNP that are covered within a training programme.

3.3.2.5.4.2 Private operators should be familiar with the practices and procedures identified in 3.3.5 "Pilot knowledge and training".

3.3.2.5.5 *Operations manuals and checklists*

3.3.2.5.5.1 Operations manuals and checklists for commercial operators must address information/guidance on the standard operating procedures detailed in 3.3.4. The appropriate manuals should contain navigation operating instructions and contingency procedures, where specified. Manuals and checklists must be submitted for review as part of the application process.

3.3.2.5.5.2 Private operators should operate using the practices and procedures identified in 3.3.5 "Pilot knowledge and training".

3.3.2.5.6 *Minimum equipment list (MEL) considerations*

Any MEL revisions necessary to address Basic-RNP 1 provisions must be approved. Operators must adjust the MEL, or equivalent, and specify the required dispatch conditions.

3.3.3 Aircraft requirements

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-C115b FMS, installed for IFR use in accordance with FAA AC 20-130A;

b) aircraft with E/TSO-C129a Class A1 or E/TSO-C146() equipment installed for IFR use in accordance with FAA AC 20-138 or AC 20-138A;

c) aircraft with RNP capability certified or approved to equivalent standards.

3.3.3.1 System performance, monitoring and alerting

Accuracy: During operations in airspace or on routes designated as Basic-RNP 1, the lateral total system error 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).

Integrity: Malfunction of the aircraft navigation equipment is classified as a major failure condition under airworthiness regulations (i.e. 10^{-5} per hour).

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.

Performance monitoring and alerting: The RNP system, or the RNP system and pilot in combination, shall provide an alert if the accuracy requirement is not met, or if the probability that the lateral TSE exceeds 2 NM is greater than 10^{-5}.

Signal-in-space: If using GNSS, the aircraft navigation equipment shall provide an alert if the probability of signal-in-space errors causing a lateral position error greater than 2 NM exceeds 10^{-7} per hour (Annex 10, Volume I, Table 3.7.2.4-1).

Note.— Compliance with the performance monitoring and alerting requirements does not imply automatic monitoring of flight technical errors. The on-board monitoring and alerting function should consist at least of a navigation system error (NSE) monitoring and alerting algorithm and a lateral deviation display enabling the crew to monitor the flight technical error (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).

3.3.3.2 Criteria for specific navigation systems

Basic-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 total system error (TSE) budget. Otherwise, means should be provided to deselect the other navigation sensor types.

3.3.3.3 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 to/from indication and a failure indicator, must be displayed on a lateral deviation display (CDI, (E)HSI)) 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 (e.g. CDI, (E)HSI)), 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. 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.
b)	The following system functions are required as a minimum within any Basic-RNP 1 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 aeronautical information regulation and control (AIRAC) cycle and from which ATS routes can

Paragraph	*Functional requirement*	*Explanation*
		be retrieved and loaded into the RNAV system. The stored resolution of the data must be sufficient to achieve negligible path definition error. 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 navigation aids, to enable the pilot to verify the route to be flown. 5) The capacity to load from the database into the Basic-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 Basic-RNP 1 procedure.*
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 execute Basic-RNP 1 terminal procedures extracted from the on-board database, including the capability to execute flyover 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. — initial fix (IF) — course to fix (CF) — direct to fix (DF) — track to fix (TF)	*Note 1.— Path terminators are defined in ARINC Specification 424, and their application is described in more detail in RTCA documents DO-236B/EUROCAE ED-75B and DO-201A/EUROCAE ED-77.* *Note 2.— Numeric values for courses and tracks must be automatically loaded from the RNP system database.*

Paragraph	*Functional requirement*	*Explanation*
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.	
i)	The aircraft must have the capability to 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)	The capability to load a Basic-RNP 1 procedure from the database, by procedure name, into the RNAV system.	
k)	The capability to display an indication of the Basic-RNP 1 system failure, in the pilot's primary field of view.	
l)	Database integrity	The navigation database suppliers should comply with RTCA DO-200A/EUROCAE document ED 76, Standards for Processing Aeronautical Data. A Letter of Acceptance (LOA), issued by the appropriate regulatory authority to each of the participants in the data chain demonstrates compliance with this requirement. 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 flight crew. Aircraft operators should consider the need to conduct periodic checks of the operational navigation databases in order to meet existing quality system requirements.

3.3.4 Operating procedures

Airworthiness certification alone does not authorize Basic-RNP 1 operations. Operational approval is also required to confirm the adequacy of the operator's normal and contingency procedures for the particular equipment installation.

3.3.4.1 Pre-flight planning

3.3.4.1.1 Operators and pilots intending to conduct operations on Basic-RNP 1 SIDs and STARs should file the appropriate flight plan suffixes.

3.3.4.1.2 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.

3.3.4.1.3 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 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.

3.3.4.2 ABAS availability

3.3.4.2.1 RAIM levels required for Basic-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 (e.g. if sufficient satellites are available, a prediction may not be necessary). Operators should be familiar with the prediction information available for the intended route.

3.3.4.2.2 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.

3.3.4.2.3 In the event of a predicted, continuous loss of appropriate level of fault detection of more than five minutes for any part of the Basic-RNP 1 operation, the flight planning should be revised (e.g. delaying the departure or planning a different departure procedure).

3.3.4.2.4 RAIM availability prediction software does not guarantee the service, rather, they are tools to asses the expected capability to meet the required navigation performances. 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.

3.3.4.3 General operating procedures

3.3.4.3.1 The pilot should comply with any instructions or procedures identified by the manufacturer as necessary to comply with the performance requirements in this chapter.

Note.— Pilots must adhere to any AFM limitations or operating procedures required to maintain Basic-RNP 1 performance for the SID or STAR.

3.3.4.3.2 Operators and pilots should not request or file Basic-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 a Basic-RNP 1 procedure, the pilot must advise ATC that he/she is unable to accept the clearance and must request alternate instructions.

3.3.4.3.3 At system initialization, pilots must confirm that 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 that the waypoint sequence depicted by their navigation system matches the route depicted on the appropriate chart(s) and their assigned route.

3.3.4.3.4 Pilots must not fly a Basic-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 flyover or vice versa.

3.3.4.3.5 Flight crews should cross-check the cleared 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 navigation aids 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.

3.3.4.3.6 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 shall be reported to ATC.

3.3.4.3.7 For Basic-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 (e.g. full-scale deflection: ±1 NM for Basic-RNP 1).

3.3.4.3.8 All pilots are expected to maintain centrelines, as depicted by on-board lateral deviation indicators and/or flight guidance during all Basic-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, i.e. FTE) should be limited to ±½ the navigation accuracy associated with the procedure (i.e. 0.5 NM for Basic-RNP 1). Brief deviations from this standard (e.g. overshoots or undershoots) during and immediately after turns, up to a maximum of one-times the navigation accuracy (i.e. 1.0 NM for Basic-RNP 1) 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 lateral navigation accuracy during turns, but are still expected to satisfy the standard during intercepts following turns and on straight segments.

3.3.4.3.9 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 Basic-RNP 1 route, the specified accuracy requirement does not apply.

3.3.4.3.10 Manually selecting aircraft bank limiting functions may reduce the aircraft's ability to maintain its desired track and are 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.

3.3.4.4 Aircraft with RNP selection capability

Pilots of aircraft with RNP input selection capability should select RNP 1 or lower, for Basic-RNP 1 SIDs and STARs.

3.3.4.5 Basic-RNP 1 SID specific requirements

3.3.4.5.1 Prior to commencing take-off, the pilot must verify the aircraft's Basic-RNP 1 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 a Basic-RNP 1 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.

3.3.4.5.2 *Engagement altitude.* The pilot must be able to use Basic-RNP 1 equipment to follow flight guidance for lateral RNAV no later than 153 m (500 ft) above airport elevation.

3.3.4.5.3 Pilots must use an authorized method (lateral deviation indicator/navigation map display/flight director/autopilot) to achieve an appropriate level of performance for Basic-RNP 1.

3.3.4.5.4 *GNSS aircraft.* When using GNSS, the signal must be acquired before the take-off roll commences. For aircraft using TSO-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. If the Basic-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 Basic-RNP 1 SID.

3.3.4.5.5 For aircraft using a lateral deviation display (i.e. navigation map display), the scale must be set for the Basic-RNP 1 SID, and the flight director or autopilot should be used.

3.3.4.6 Basic-RNP 1 STAR specific requirements

3.3.4.6.1 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 track angles and distances, any altitude or speed constraints, and, where possible, which waypoints are fly-by and which are flyover. If required by a route, a check will need to be made to confirm that updating will exclude a particular navigation aid. 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.

3.3.4.6.2 The creation of new waypoints by manual entry into the Basic-RNP 1 system by the flight crew would invalidate the route and is not permitted.

3.3.4.6.3 Where the contingency procedure requires reversion to a conventional arrival route, necessary preparations must be completed before commencing the Basic-RNP 1 procedure.

3.3.4.6.4 Procedure modifications in the terminal area may take the form of radar 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.

3.3.4.6.5 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.

3.3.4.6.6 Although a particular method is not mandated, any published altitude and speed constraints must be observed.

3.3.4.6.7 Aircraft with TSO-C129a GNSS RNP systems: If the Basic-RNP 1 STAR begins beyond 30 NM from the ARP and a lateral deviation indicator is used, its 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 (i.e. navigation map display), the scale must be set for the Basic-RNP 1 STAR, and the flight director or autopilot should be used.

3.3.4.7 Contingency Procedures

3.3.4.7.1 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 a Basic-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 Basic-RNP 1 requirements of the route.

3.3.4.7.2 In the event of communications failure, the flight crew should continue with the published lost communications procedure.

3.3.5 Pilot knowledge and training

The training programme should provide sufficient training (e.g. 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 (flyover and fly-by) and path terminators (provided in 3.3.3.3 AIRINC 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 Basic-RNP 1 SIDs, and STARs;

f) RNP system-specific information:

   i) levels of automation, mode annunciations, changes, alerts, interactions, reversions, and degradation;

   ii) functional integration with other aircraft systems;

   iii) the meaning and appropriateness of route discontinuities as well as related flight crew procedures;

   iv) pilot procedures consistent with the operation;

   v) types of navigation sensors utilized by the RNP system and associated system prioritization/ weighting/logic;

vi) turn anticipation with consideration to speed and altitude effects;

vii) interpretation of electronic displays and symbols;

viii) understanding of the aircraft configuration and operational conditions required to support Basic-RNP 1 operations, i.e. appropriate selection of CDI scaling (lateral deviation display scaling);

g) RNP system operating procedures, as applicable, including how to perform the following actions:

i) verify currency and integrity of the aircraft navigation data;

ii) verify the successful completion of RNP system self-tests;

iii) initialize navigation system position;

iv) retrieve and fly a Basic-RNP 1 SID or a STAR with appropriate transition;

v) adhere to speed and/or altitude constraints associated with a Basic-RNP 1 SID or STAR;

vi) select the appropriate Basic-RNP 1 SID or STAR for the active runway in use and be familiar with procedures to deal with a runway change;

vii) verify waypoints and flight plan programming;

viii) fly direct to a waypoint;

ix) fly a course/track to a waypoint;

x) intercept a course/track;

xi) flying radar vectors and rejoining a Basic-RNP 1 route from “heading” mode;

xii) determine cross-track error/deviation. More specifically, the maximum deviations allowed to support Basic-RNP 1 must be understood and respected;

xiii) resolve route discontinuities;

xiv) remove and reselect navigation sensor input;

xv) when required, confirm exclusion of a specific navigation aid or navigation aid type;

xvi) change arrival airport and alternate airport;

xvii) 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;

xviii) perform RNAV holding function;

h) operator-recommended levels of automation for phase of flight and workload, including methods to minimize cross-track error to maintain route centerline;

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 must be obtained from a supplier that complies with RTCA DO 200A/EUROCAE document ED 76, Standards for Processing Aeronautical Data, and should be compatible with the intended function of the equipment (reference ICAO Annex 6, Part 1, Chapter 7). A Letter of Acceptance (LOA), issued by the appropriate regulatory authority to each of the participants in the data chain demonstrates compliance with this requirement (e.g. FAA LOA issued in accordance with FAA AC 20-153 or EASA LOA issued in accordance with EASA IR 21 subpart G).

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 flight crew.

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 path definition error, the database should comply with DO 200A, or an equivalent operational means must be in place to ensure database integrity for the Basic-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 approval 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

Copies of EUROCONTROL documents may be requested from EUROCONTROL, Documentation Centre, GS4, Rue de la Fusee, 96, B-1130 Brussels, Belgium; (Fax: 32 2 729 9109). Website: http://www.ecacnav.com

Copies of EUROCAE documents may be purchased from EUROCAE, 102 rue Etienne Dolet, 92240 Malakoff, France (Fax: +33 1 46 55 62 65). Website: www.eurocae.eu

Copies of FAA documents may be obtained from Superintendent of Documents, Government Printing Office, Washington, DC 20402-9325, USA. Website: http://www.faa.gov/aircraft_cert/ (Regulatory and Guidance Library)

Copies of RTCA documents may be obtained from RTCA Inc., 1140 Connecticut Avenue, N.W., Suite 1020, Washington, DC 20036-4001, USA, (Tel.: 1 202 833 9339). Website: www.rtca.org

Copies of ARINC documents may be obtained from Aeronautical Radio Inc., 2551 Riva Road, Annapolis, Maryland 24101-7465, USA. Website: http://www.arinc.com

Copies of JAA documents are available from JAA's publisher Information Handling Services (IHS). Information on prices, where and how to order, is available on the JAA website: http://www.jaa.nl and on the IHS websites: http://www.global.his.com and http://www.avdataworks.com

Copies of EASA documents may be obtained from EASA (European Aviation Safety Agency), 101253, D-50452 Koln, Germany.

Copies of ICAO documents may be purchased from the International Civil Aviation Organization, Customer Services Unit, 999 University Street, Montréal, Quebec, Canada H3C 5H7 (Fax: 1 514 954 6769 or e-mail: sales_unit@icao.org) or through sales agents listed on the ICAO website: www.icao.int

Chapter 4

IMPLEMENTING ADVANCED-RNP 1

To be developed.

Chapter 5

IMPLEMENTING RNP APCH

5.1 INTRODUCTION

5.1.1 Background

5.1.1.1 This chapter addresses approach applications based on GNSS which are classified RNP APCH in accordance with the PBN concept.

5.1.1.2 RNP approach (RNP APCH) procedures include existing RNAV(GNSS) approach procedures designed with a straight segment. RNP APCH procedures are expected to be authorized by a number of regulatory agencies including the European Aviation Safety Agency (EASA) and the United States Federal Aviation Administration (FAA). The FAA has issued airworthiness criteria, AC20-138A, for GNSS equipment and systems that are eligible for such operations. EASA is developing certification material (AMC20 series) for airworthiness approval and operational criteria for RNP approach (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 standard.

5.1.2 Purpose

5.1.2.1 This chapter provides guidance to States implementing RNP APCH operations (excluding RNP AR APCH operations) and provides the ANSP with an ICAO recommendation on implementation requirements. It provides the operator with a combination of European and United States RNAV airworthiness and operational criteria. For existing stand-alone and multi-sensor RNAV systems using GNSS, compliance with both European (EASA AMC 20) and United States (FAA AC 20-138A, AC 20-130A or TSO C115b) guidance assures automatic compliance with this ICAO specification, obviating the need for further assessment or AFM documentation. An operational approval to this standard allows an operator to conduct RNP APCH operations globally.

Note.— The multi-sensor systems may use other sensor combinations such as DME/DME or DME/DME/IRU 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.

5.1.2.2 This chapter addresses only the requirement for the lateral navigation aspect (2D navigation) along straight segments. Curved approaches are addressed in RNP AR APCH. The barometric-based vertical navigation aspect is addressed in Attachment A to this volume.

5.2 ANSP CONSIDERATIONS

5.2.1 Navaid infrastructure

5.2.1.1 GNSS is the primary navigation system to support RNP APCH procedures.

5.2.1.2 The missed approach segment may be based upon the conventional navaid (e.g. VOR, DME, NDB).

5.2.1.3 The acceptability of the risk of loss of RNP APCH capability for multiple aircraft due to satellite failure or loss of on-board monitoring and alerting functions (e.g. RAIM holes), must be considered by the responsible airspace authority.

5.2.2 Communication and ATS surveillance

RNP APCH does not include specific requirements for communication or ATS surveillance. Adequate obstacle clearance is achieved through aircraft performance and operating procedures.

5.2.3 Obstacle clearance

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

5.2.3.2 Missed approach procedures may be supported by either RNAV or conventional (e.g. based on NDB, VOR, DME) segments.

5.2.3.3 Procedure design must take account of the absence of a vertical navigation capability on the aircraft.

5.2.4 Additional considerations

5.2.4.1 Many aircraft have the capability to execute a holding pattern manoeuvre using their RNP system.

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

5.2.5 Publication

The AIP should clearly indicate the navigation application is RNP APCH. The procedure design should rely on normal descent profiles and the State publication should identify minimum segment altitude requirements, including an LNAV OCA(H). 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 navigation aids 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 Controller training

Air traffic controllers, who provide control services at airports where RNP approaches have been implemented, should have completed training that covers the items listed below.

5.2.6.1 Core training

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

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

ii) accuracy, integrity, availability and continuity including on-board performance monitoring and alerting;

iii) GPS receiver, RAIM, FDE, and integrity alerts;

iv) waypoint fly-by versus flyover concept (and different turn performances);

b) Flight plan requirements;

c) ATC procedures;

i) ATC contingency procedures;

ii) separation minima;

iii) mixed equipage environment;

iv) transition between different operating environments; and

v) phraseology.

5.2.6.2 Training specific to this navigation specification

a) Related control procedures:

— radar vectoring techniques (where appropriate);

b) RNP approach and related procedures:

i) including T and Y approaches; and

ii) approach minima;

c) impact of requesting a change to routing during a procedure.

5.2.7 Status monitoring

5.2.7.1 The navaid infrastructure should be monitored and, where appropriate, maintained by the service provider. Timely warnings of outages (NOTAMs) should be issued.

5.2.7.2 Status information should be provided in accordance with Annex 11 — *Air Traffic Services* for navigation facilities or services that may be used to support the operation.

5.2.8 ATS 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 a specific operational approval. For example, certain operational regulation requires operators to apply to their national authority (State of Registry) for operational approval.

5.3.1.2 This chapter addresses only the lateral part of the navigation system. If the system is approved for an APV-Baro VNAV operation, the installation must be compliant with the requirements in Attachment A "Barometric VNAV".

5.3.2 Approval 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. The navigation specification provides the technical and operational criteria, and does not imply a need for recertification.

5.3.2.2 The following steps must be completed before conducting RNP APCH 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) flight crew 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 approval must then be obtained in accordance with national operating rules.

5.3.2.3 Following the successful completion of the above steps, an RNP APCH operational approval, Letter of Authorization or appropriate operations specification (Ops Spec), if required, should then be issued by the State.

5.3.2.4 Aircraft eligibility

Airworthiness eligibility documents. Relevant documentation acceptable to the State of the Operator/Registry must be available in order to establish that the aircraft is equipped with an RNAV system meeting RNP APCH requirements. To avoid unnecessary regulatory activity, the determination of eligibility for existing systems should consider acceptance of manufacturer documentation of compliance, e.g. as with the EASA AMC 20 series. RNP AR APCH systems are considered as qualified for RNP APCH operations without further examination.

5.3.2.5 Operational approval

5.3.2.5.1 The assessment of a particular operator is made by the State of the Operator/Registry for that operator and in accordance with national operating rules (e.g. JAR-OPS 1, 14 CFR Part 121) supported through appropriate advisory and guidance material. The assessment should take into account:

a) evidence of aircraft eligibility;

b) assessment of the operating procedures for the navigation systems to be used;

c) control of those procedures through acceptable entries in the operations manual;

d) identification of flight crew training requirements; and

e) where required, control of the navigation database process.

5.3.2.5.2 The operational approval will likely be documented through the State endorsing the operation specifications associated with the air operator certificate (AOC) through issue of a Letter of Authorization, appropriate operations specification (Ops Spec) or amendment to the operations manual.

5.3.2.5.3 *Description of aircraft equipment*

The operator must have a configuration list detailing pertinent components and equipment to be used for RNP APCH operation.

5.3.2.5.4 *Training documentation*

5.3.2.5.4.1 Commercial operators must have a training programme addressing the operational practices, procedures and training items related to RNP APCH operations (e.g. initial, upgrade or recurrent training for flight crew, dispatchers or maintenance personnel).

Note.— It is not required to establish a separate training programme or regimen if RNAV training is already an integrated element of a training programme. However, it should be possible to identify the aspects of RNAV that are covered within a training programme.

5.3.2.5.4.2 Private operators must be familiar with the practices and procedures identified in 5.3.5 “Pilot knowledge and training”.

5.3.2.5.5 *Operations manuals and checklists*

5.3.2.5.5.1 Operations manuals and checklists for commercial operators must address information/guidance on the standard operating procedures detailed in 5.3.4. The appropriate manuals should contain navigation operating instructions and contingency procedures, where specified. Manuals and checklists must be submitted for review as part of the application process.

5.3.2.5.5.2 Private operators must operate using the practices and procedures identified in 5.3.5 “Pilot knowledge and training”.

5.3.2.5.6 *Minimum equipment list (MEL) considerations*

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

5.3.3 Aircraft requirements

5.3.3.1 System performance monitoring and alerting

5.3.3.1.1 *Accuracy:* During operations on the initial and intermediate segments and for the RNAV missed approach, of an RNP APCH, the lateral total system error 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.

5.3.3.1.2 During operations on the final approach segment of an RNP APCH, the lateral total system error 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.

5.3.3.1.3 To satisfy the accuracy requirement, the 95 per cent FTE should not exceed 0.5 NM on the initial and intermediate segments, and for the RNAV missed approach, of an RNP APCH. The 95 per cent FTE should not exceed 0.25 NM on the final approach segment of an RNP APCH.

Note.— The use of a deviation indicator with 1 NM full-scale deflection on the initial and intermediate segments, and for the RNAV missed approach and 0.3 NM full-scale deflection on the final approach segment, 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).

5.3.3.1.4 *Integrity:* Malfunction of the aircraft navigation equipment is classified as a major failure condition under airworthiness regulations (i.e. 10^{-5} per hour).

5.3.3.1.5 *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. If the missed approach procedure is based on conventional means (e.g. NDB, VOR, DME), related navigation equipment must be installed and be serviceable.

5.3.3.1.6 *Performance monitoring and alerting:* During operations on the initial and intermediate segments and for the RNAV missed approach of an RNP APCH, the RNP system, or the RNP system and pilot in combination, shall provide an alert if the accuracy requirement is not met, or if the probability that the lateral TSE exceeds 2 NM is greater than 10^{-5}. During operations on the final approach segment of an RNP APCH, the RNP system, or the RNP system and pilot in combination, shall 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 10^{-5}.

5.3.3.1.7 *Signal-in-space:* During operations on the initial and intermediate segments and for the RNAV missed approach of an RNP APCH, the aircraft navigation equipment shall provide an alert if the probability of signal-in-space errors causing a lateral position error greater than 2 NM exceeds 10^{-7} per hour (Annex 10, Volume I, Table 3.7.2.4-1). During operations on the final approach segment of an RNP APCH, the aircraft navigation equipment shall provide an alert if the probability of signal-in-space errors causing a lateral position error greater than 0.6 NM exceeds 10^{-7} per hour (Annex 10, Volume I, Table 3.7.2.4-1).

Note 1.— There are no RNP APCH requirements for the missed approach if it is based on conventional means (VOR, DME, NDB) or on dead reckoning.

Note 2.— Compliance with the performance monitoring and alerting requirement does not imply automatic monitoring of a flight technical error. The on-board monitoring and alerting function should consist at least of a navigation system error (NSE) monitoring and alerting algorithm and a lateral deviation display enabling the crew to monitor the flight technical error (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 (5.3.6) and crew procedures (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 A1 or E/TSO-C146() Class Gamma and operational class 1, 2 or 3;

b) GNSS sensors used in multi-sensor system (e.g. 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. For GNSS receiver approved in accordance with E/TSO-C129(), capability for satellite fault detection and exclusion (FDE) is recommended to improve continuity of function; and

c) multi-sensor systems using GNSS should be approved in accordance with AC20-130A or TSO-C115b, as well as having been demonstrated for RNP APCH capability.

5.3.3.2 Criteria for specific navigation systems

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 total system error (TSE) budget, or if means are provided to deselect the other navigation sensor types.

5.3.3.3 Functional requirements

5.3.3.3.1 Navigation displays and required functions

5.3.3.3.1.2 Navigation data, including a to/from indication, and a failure indication, must be displayed on a lateral deviation display (CDI, (E)HSI) 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 total system error (TSE) requirement. Scaling is ±1 NM for the initial and intermediate segments and ±0.3 NM for the final segment;

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;

f) it is highly recommended that the course selector of the deviation display is automatically slaved to the RNAV 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.

g) a flight director and/or autopilot is not required for this type of operation, however, if the lateral TSE cannot be demonstrated without these systems, it becomes mandatory. In this case, coupling to the flight director and/or automatic pilot from the RNAV system must be clearly indicated at the cockpit level; and

h) enhanced navigation display (e.g. electronic map display or enhanced EHSI) to improve lateral situational awareness, navigation monitoring and approach verification (flight plan verification) could become mandatory if the RNAV installation doesn't support the display of information necessary for the accomplishment of these crew tasks.

5.3.3.3.1.3 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 RNAV 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 aeronautical information regulation and control (AIRAC) cycle and from which approach procedures can be retrieved and loaded into the RNAV 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.

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 navigation aids, to enable the pilot to verify the procedure to be flown.

e) Capacity to load from the database into the RNAV system the whole approach to be flown. The approach must be loaded from the database, into the RNAV 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:

   i) the identification of the active (To) waypoint;

   ii) the distance and bearing to the active (To) waypoint; and

   iii) The ground speed or time to the active (To) waypoint.

g) The means to display the following items on a readily accessible display page:

   i) the display of distance between flight plan waypoints;

   ii) the display of distance to go;

   iii) the display of along-track distances; and

   iv) 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 flyover and fly-by turns.

k) The capability to automatically execute leg transitions and maintain tracks consistent with the following ARINC 424 path terminators, or their equivalent:

- ARINC 424 path terminators
- Initial fix (IF)
- Track to fix (TF)
- Direct to fix (DF)

Note.— Path terminators are defined in ARINC Specification 424, and their application is described in more detail in RTCA documents DO 236B and DO-201A.

l) The capability to display an indication of the RNAV 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").

5.3.4 Operating procedures

Airworthiness certification alone does not authorize an operator to conduct an RNP APCH operation. Operational approval is also required to confirm the adequacy of the operator's normal and contingency procedures for the particular equipment installation.

5.3.4.1 Pre-flight 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 pre-flight 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 pre-flight 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 flight crews 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 (VOR, NDB), operators and flight crews 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 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 the SBAS signal is unavailable.

5.3.4.2 ABAS availability

5.3.4.2.1 RAIM levels required for RNP APCH 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 (e.g. if sufficient satellites are available, a prediction may not be necessary). Operators should be familiar with the prediction information available for the intended route.

5.3.4.2.2 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.

5.3.4.2.3 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 flight planning should be revised (e.g. delaying the departure or planning a different departure procedure).

5.3.4.2.4 RAIM availability prediction software does not guarantee the service, rather they are tools to assess the expected capability of meeting the required navigation performances. 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.

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 flight crew 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 final approach segment.

Note.— As a minimum, this check could be a simple inspection of a suitable map display that achieves the objectives of this paragraph.

5.3.4.3.2 The crew must also check using the published charts, the map display or control display unit (CDU), which waypoints are fly-by and which are flyover.

5.3.4.3.3 For multi-sensor systems, the crew 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 is predicated on the availability of ABAS, the flight crew should perform a new RAIM availability check if ETA is more than 15 minutes different from the ETA used during the preflight planning. This check is also processed automatically 2 NM before the FAF for an E/TSO-C129a Class A1 receiver.

5.3.4.3.6 ATC tactical interventions in the terminal area may include radar headings, “direct to” clearances which 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 flight crew should be aware of the implications for the RNP system:

a) the manual entry of coordinates into the RNAV system by the flight crew for operation within the terminal area is not permitted; and

b) “direct to” clearances may be accepted to the intermediate fix (IF) provided that the resulting track change at the IF does not exceed 45 degrees.

Note.— “Direct to” clearance to FAF is not acceptable.

5.3.4.3.7 The lateral definition of the flight path between the FAF and the missed approach point (MAPt) must not be revised by the flight crew under any circumstances.

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 (e.g. 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 RNAV-computed desired path (DTK); 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 loss of integrity alerting function; or

c) if integrity alerting function is annunciated 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 RNAV system during the missed approach is acceptable, provided:

a) the RNAV system is operational (e.g 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 (e.g. 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 (i.e. ±1.0 NM for the initial and intermediate segments, ±0.3 NM for the final approach segment, and ±1.0 NM for the missed approach segment). All pilots are expected to maintain procedure centrelines, 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 RNAV system computed path and the aircraft position relative to the path) should be limited to ±½ the navigation accuracy associated with the procedure (i.e. 0.5 NM for the initial and intermediate segments, 0.15 NM for the final approach segment, and 0.5 NM for the missed approach segment). Brief deviations from this standard (e.g. overshoots or undershoots) during and immediately after turns, up to a maximum of one-times the navigation accuracy (i.e. 1.0 NM for the initial and intermediate segments), are allowable.

5.3.4.4.7 When Barometric VNAV is used for vertical path guidance during the final approach segment, deviations above and below the Barometric VNAV path must not exceed +30 m/–15 m (+100 ft/–50 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 chapter.

5.3.4.5.3 While operating on RNAV segments, 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 flight crew must continue with the RNP APCH in accordance with the published lost communication procedure.

5.3.5 Pilot knowledge and training

The training programme must provide sufficient training (e.g. simulator, training device, or aircraft) on the aircraft's RNAV 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 (flyover 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:

   i) levels of automation, mode annunciations, changes, alerts, interactions, reversions, and degradation;

   ii) functional integration with other aircraft systems;

   iii) the meaning and appropriateness of route discontinuities as well as related flight crew procedures;

   iv) monitoring procedures for each phase of flight;

   v) types of navigation sensors utilized by the RNP system and associated system prioritization/weighting/logic;

   vi) turn anticipation with consideration to speed and altitude effects; and

   vii) interpretation of electronic displays and symbols;

g) knowledge of RNAV equipment operating procedures, as applicable, including how to perform the following actions:

   i) verify currency of the aircraft navigation data;

   ii) verify the successful completion of RNP system self-tests;

   iii) initialize RNP system position;

   iv) retrieve and fly an RNP APCH;

v) adhere to speed and/or altitude constraints associated with an approach procedure;

vi) fly interception of an initial or intermediate segment of an approach following ATC notification;

vii) verify waypoints and flight plan programming;

viii) fly direct to a waypoint;

ix) determine cross-track error/deviation;

x) insert and delete route discontinuity;

xi) when required by the State aviation authority, perform gross navigation error check using conventional navigation aids; and

xii) 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 centreline;

i) knowledge of radio telephony phraseology for RNP applications; and

j) ability to conduct contingency procedures following RNP system failures.

5.3.6 Navigation database

5.3.6.1 The navigation database should be obtained from a supplier that complies with RTCA DO 200A/EUROCAE document ED 76, Standards for Processing Aeronautical Data. A Letter of Acceptance (LOA) issued by the appropriate regulatory authority demonstrates compliance with this requirement (e.g. FAA LOA issued in accordance with FAA AC 20-153 or EASA LOA issued in accordance with EASA IR 21 subpart G).

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 flight crew.

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 approval 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

Copies of EUROCONTROL documents may be requested from EUROCONTROL, Documentation Centre, GS4, Rue de la Fusee, 96, B-1130 Brussels, Belgium; (Fax: 32 2 729 9109). Website: http://www.ecacnav.com

Copies of EUROCAE documents may be purchased from EUROCAE, 102 rue Etienne Dolet, 92240 Malakoff, France (Fax: +33 1 46 55 62 65). Website: www.eurocae.eu

Copies of FAA documents may be obtained from Superintendent of Documents,

government Printing Office, Washington, DC 20402-9325, USA. Website: http://www.faa.gov/aircraft_cert/ (Regulatory and Guidance Library)

Copies of RTCA documents may be obtained from RTCA Inc., 1140 Connecticut Avenue, N.W., Suite 1020, Washington, DC 20036-4001, USA, (Te.l: 1 202 833 9339). Website: www.rtca.org

Copies of ARINC documents may be obtained from Aeronautical Radio Inc., 2551 Riva Road, Annapolis, Maryland 24101-7465, USA. Website: http://www.arinc.com

Copies of JAA documents are available from JAA's publisher Information Handling Services (IHS). Information on prices, where and how to order, is available on the JAA website: http://www.jaa.nl and on the IHS websites: http://www.global.his.com and http://www.avdataworks.com

Copies of EASA documents may be obtained from EASA (European Aviation Safety Agency), 101253, D-50452 Koln, Germany.

Copies of ICAO documents may be purchased from The International Civil Aviation Organization, Customer Services Unit, 999 University Street, Montréal, Quebec, Canada H3C 5H7 (Fax: 1 514 954 6769 or e-mail: sales_unit@icao.org) or through sales agents listed on the ICAO website: www.icao.int

Chapter 6

IMPLEMENTING RNP AR APCH

6.1 INTRODUCTION

6.1.1 Background

The Federal Aviation Administration (FAA) published approval guidance for RNP procedures with special aircraft and aircrew authorization required on 15 December 2005 through AC 90-101. RNP authorization required approaches (RNP AR APCH) represent the ICAO version to FAA RNP special aircraft and aircrew authorization required (SAAAR) operations. The European Aviation Safety Agency (EASA) is developing equivalent guidance.

6.1.2 Purpose

6.1.2.1 This chapter provides an ICAO recommendation and a method of compliance with RNP AR APCH instrument approach procedure (IAP) requirements.

6.1.2.2 This chapter addresses operational and airworthiness issues. It does not address all the requirements that may be specified for operations on a procedure. These requirements are specified in other documents such as operating rules, aeronautical information publications (AIPs) and the *Regional Supplementary Procedures* (Doc 7030). While operational approval 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, which are required by the appropriate State authority, before conducting flights into that airspace.

6.2 ANSP CONSIDERATIONS

6.2.1 Navaid infrastructure considerations

RNP AR APCHs are only authorized based on GNSS as the primary navaid infrastructure. The use of DME/DME as a reversionary capability may be authorized for individual operators where the infrastructure supports the required performance. RNP AR APCH shall not be used in areas of known navigation signal (GNSS) interference.

Note.— Most modern RNAV systems will prioritize inputs from GNSS and then DME/DME positioning. Although VOR/DME positioning is usually performed within a flight management computer when DME/DME positioning criteria do not exist, avionics and infrastructure variability pose serious challenges to standardization.

6.2.2 Communication and ATS surveillance considerations

RNP AR APCHs do not require any unique communication or ATS surveillance considerations.

6.2.3 Obstacle clearance and route spacing

6.2.3.1 Guidance for the design of RNP AR approach procedures is provided in the ICAO *Required Navigation Performance Authorization Required (RNP AR) Procedure Design Manual* (Doc 9905).

6.2.3.2 Terrain and obstacle data in the vicinity of the approach should be published in accordance with Annex 15 — *Aeronautical Information Services*.

6.2.3.3 Obstacle clearance must be ensured in accordance with the ICAO *Required Navigation Performance Authorization Required (RNP AR) Procedure Design Manual* (Doc 9905). A safety assessment must be conducted upon determining the route spacing.

6.2.4 Additional considerations

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

6.2.4.2 Current local pressure settings must be provided to support RNP AR APCHs, when the aircraft's achieved vertical path is dependent on that setting. Failure to report a correct setting can lead to the aircraft leaving the obstacle clearance area.

6.2.4.3 The criteria in this navigation specification must meet the safety assessment criteria listed in 6.4. As a result, the safety assessment for each procedure need only focus on areas of unique operational risk.

6.2.4.4 Ground and flight validation

6.2.4.4.1 As RNP AR approaches do not have a specific underlying navigation facility, there is no requirement for flight inspection of navigation signals. Due to the importance of publishing correct data, validation (ground and flight) of the procedure must be conducted in accordance with PANS-OPS, Volume II, Part I, Section 2, Chapter 4, 4.6. The validation process prior to publication should confirm obstacle data, basic flyability, track lengths, bank angles, descent gradients, runway alignment and compatibility with predictive terrain hazard warning functions (e.g. terrain awareness and warning systems) as well as the other factors listed in PANS-OPS. When the State can verify, by ground validation, the accuracy and completeness of all obstacle data considered in the procedure design, and any other factors normally considered in the flight validation, then the flight validation requirement may be dispensed with regarding those particular factors.

6.2.4.4.2 Because of the unique nature of RNP AR approach procedures, simulator assessment of the procedure should be accomplished during the ground validation to evaluate the factors, including basic flyability, to be considered in the flight validation, to the extent possible, prior to the flight validation. Due to variations in aircraft speeds, flight control system design, and navigation system design, the ground and flight validation does not confirm flyability for all of the various aircraft conducting RNP AR approach procedures. A thorough flyability assessment is therefore not required prior to publication, since flyability is individually assessed by the operator as part of their database updating and maintenance process.

6.2.5 Publication

6.2.5.1 The AIP should clearly indicate the navigation application is RNP AR APCH and that specific authorization is required. All routes must be based upon WGS-84 coordinates.

6.2.5.2 The navigation data published in the State AIP for the procedures and supporting navigation aids 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 operators to verify their navigation data. The navigation accuracy for all RNP AR APCH procedures should be clearly published in the AIP.

6.2.6 Controller training

Air traffic controllers, who provide control services at airports where RNP approaches have been implemented, should have completed training that covers the items listed below.

6.2.6.1 Core training

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

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

   ii) accuracy, integrity, availability and continuity including on-board performance monitoring and alerting;

   iii) GPS receiver, RAIM, FDE, and integrity alerts;

   iv) waypoint fly-by versus flyover concept (and different turn performances);

b) Flight plan requirements;

c) ATC procedures:

   i) ATC contingency procedures;

   ii) separation minima;

   iii) mixed equipage environment;

   iv) transition between different operating environments; and

   v) phraseology.

6.2.6.2 Training specific to this navigation specification

a) Related control procedures:

   i) Radar Vectoring Techniques (where appropriate):

      — RF leg limitations;

      — airspeed constraints;

b) RNP approach and related procedures:

   i) approach minima;

   ii) additional requests for altimeter settings;

c) impact of requesting a change to routing during a procedure.

6.2.7 Status monitoring

6.2.7.1 The navaid infrastructure should be monitored and, when appropriate, maintained by the service provider. Timely warnings of outages (NOTAMs) should be issued.

6.2.7.2 Status information should be provided in accordance with Annex 11 — *Air Traffic Services* for navigation facilities or services that may be used to support the operation.

6.2.8 ATS system monitoring

When available, radar observations of each aircraft's proximity to track and altitude 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 the track or altitude should be determined and steps taken to prevent a recurrence.

6.3 NAVIGATION SPECIFICATION

6.3.1 Background

This section identifies the operational requirements for RNP AR APCH operations. Operational compliance with these requirements shall be addressed through national operational regulations. In addition, authorization is required from the State responsible for the specific RNP AR APCH procedure.

6.3.2 Approval process

6.3.2.1 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.

6.3.2.2 Any operator with an appropriate operational approval may conduct RNP AR APCH instrument approach procedures, in a similar manner that operators with the proper authorization may conduct CAT II and CAT III ILS operations.

6.3.2.3 Due to the unique requirements for RNP AR APCH operations and the need for crew procedures that are specific to each particular aircraft and navigation system, RNP AR APCH operational support documentation is required from the manufacturer. The documentation should describe the navigation capabilities of the applicant's aircraft in the context of RNP AR APCH operations, and provide all the assumptions, limitations and supporting information necessary for the safe conduct of RNP AR APCH operations. This document is primarily intended for use by operators in order to support operational approval by the appropriate regulatory authorities.

6.3.2.4 Operators should use the manufacturer recommendations when developing their procedures and applying for approval. Installation of equipment is not sufficient by itself to obtain approval for use on RNP AR APCHs.
6.3.2.5 The following steps must be completed before conducting RNP AR APCH operations:

6.3.2.6 Aircraft eligibility

The aircraft eligibility has to be determined through demonstration of compliance against the relevant airworthiness criteria. Aircraft flight manual (AFM) entries are not required provided the State accepts the manufacturer's documentation. Aircraft equipment eligibility must include:

a) aircraft qualification;

b) established maintenance procedures; and

c) MEL revision.

6.3.2.7 Operational approval

6.3.2.7.1 The assessment of a particular operator is made by the State of Registry for that operator and in accordance with national operating rules (e.g. JAR-OPS 1, 14 CFR Part 121), which are supported through appropriate advisory and guidance material. The assessment should take into account:

a) evidence of aircraft eligibility;

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

   i) navigation database validation programme (see 6.3.6 for additional information);

   ii) operational procedure requirements;

   iii) RNP monitoring programme (see 6.3.7 for additional information);

   iv) Dispatch/flight following procedures;

c) control of dispatch/flight following procedures through acceptable entries in the operations manual;

d) identification of flight crew training requirements;

e) where required, control of the navigation database process; and

f) flight crew and dispatch training, based upon the operating procedures, must be documented.

6.3.2.7.2 The operational approval will likely be documented through the State endorsing the air operators certificate (AOC) through issue of a Letter of Authorization (LOA), appropriate operations specification (Ops Spec) or amendment to the operations manual.

6.3.2.7.3 *Description of aircraft equipment*

The operator must have a configuration list detailing pertinent components and equipment to be used for RNP AR APCH.

6.3.2.7.4 *Training documentation*

6.3.2.7.4.1 Commercial operators should have a training programme addressing the operational practices, procedures and training items related to RNP AR APCH operations (e.g. initial, upgrade or recurrent training for flight crew, dispatchers or maintenance personnel).

Note.— It is not required to establish a separate training programme or regimen if these items are already an integrated element of a training programme. The operator should identify which aspects of RNP are covered within a training programme.

6.3.2.7.4.2 Private operators should be familiar with the practices and procedures identified in 6.3.5 "Pilot dispatch/operator knowledge and training".

6.3.2.7.5 *Operations manuals and checklists*

6.3.2.7.5.1 Operations manuals and checklists for commercial operators must address information/guidance on the standard operating procedures detailed in 6.3.4. The appropriate manuals should contain navigation operating instructions and contingency procedures, where specified. Manuals and checklists must be submitted for review as part of the application process.

6.3.2.7.5.2 Private operators should operate using the practices and procedures identified in 6.3.5 "Pilot dispatch/operator knowledge and training".

6.3.2.7.6 *Minimum equipment list (MEL) considerations*

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

6.3.2.8 Approval submittal

6.3.2.8.1 Following the successful completion of the above steps, the above material must be accepted by the State regulatory authority; operational approval (subject to any conditions or limitations) should be obtained in accordance with national operating rules.

6.3.2.8.2 The safety assessment items listed in 6.4 should be considered prior to implementation.

6.3.2.8.3 An RNP AR APCH operational approval (Letter of Authorization, appropriate operations specification (Ops Spec), or amendment to the operations manual), should then be issued by the State.

6.3.2.8.4 Once approval is received from the State of Registry, operators desiring to perform RNP AR APCH operations in other States will require authorization from that State authority.

6.3.2.8.5 The approval should identify the type of procedures for which the operator is approved: the lowest navigation accuracy, procedures with RF legs, and procedures with required accuracy in the missed approach less than 1.0 NM. Equipment configurations, selected modes and crew procedures must be defined for each type of RNP AR APCH procedure.

6.3.3 Aircraft requirements

This section describes the aircraft performance and functional criteria for aircraft to qualify for RNP AR APCH. In addition to the specific guidance in this chapter, the aircraft must comply with FAA AC 20-129 and either FAA AC 20-130 or AC 20-138, or equivalent.

6.3.3.1 System performance monitoring and alerting

6.3.3.1.1 This section defines the general performance requirements for aircraft qualification. The requirements for RNP AR APCH are unique due to the reduced obstacle clearance and advanced functionality, therefore the requirements in this section do not use the same structure as RNP 4, Basic-RNP 1 and RNP APCH.

6.3.3.1.2 *Path definition.* Aircraft performance is evaluated around the path defined by the published procedure and RTCA/DO-236B Section 3.2; EUROCAE ED-75B. All vertical paths used in conjunction with the final approach segment will be defined by a flight path angle (RTCA/DO 236B Section 3.2.8.4.3) as a straight line emanating to a fix and altitude.

6.3.3.1.3 *Lateral accuracy.* All aircraft operating on RNP AR APCH procedures must have a cross-track navigation error no greater than the applicable accuracy value (0.1 NM to 0.3 NM) for 95 per cent of the flight time. This includes positioning error, flight technical error (FTE), path definition error (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.

6.3.3.1.4 *Vertical accuracy*. The vertical system error includes altimetry error (assuming the temperature and lapse rates of the International Standard Atmosphere), the effect of along-track error, system computation error, data resolution error, and flight technical error. The 99.7 per cent of system error in the vertical direction must be less than the following (in feet):

$$\sqrt{\left((6076.115)(1.225)\mathbf{RNP}\cdot \tan\theta\right)^2+(60\tan\theta)^2+75^2+\left(\left(-8.8\cdot 10^{-8}\right)(\mathbf{h}+\mathbf{\Delta h})^2+\left(6.5\cdot 10^{-3}\right)(\mathbf{h}+\mathbf{\Delta h})+50\right)^2}$$

where $\boldsymbol{\theta}$ is the vertical navigation (VNAV) path angle, **h** is the height of the local altimetry reporting station and Δ**h** is the height of the aircraft above the reporting station.

6.3.3.1.5 *System monitoring.* A critical component of RNP are the RNP requirements of the approach, the ability of the aircraft navigation system to monitor its achieved navigation performance, and to identify, for the pilot, whether the operational requirement is or is not being met during an operation (e.g. “Unable RNP”, “Nav Accur Downgrad”).

6.3.3.1.6 *Airspace containment:*

a) RNP and Barometric VNAV aircraft. This chapter provides a detailed acceptable means of compliance for aircraft that use an RNP system based primarily on GNSS, and a VNAV system based on barometric altimetry. Aircraft and operations complying with this navigation specification provide the requisite airspace contaiNMent through a variety of monitoring and alerting (e.g. “Unable RNP”, GNSS alert limit, and path deviation monitoring).

b) Other systems or alternate means of compliance. For other systems or alternate means of compliance, the probability of the aircraft exiting the lateral and vertical extent of the obstacle clearance volume (defined in the

ICAO *Required Navigation Performance Authorization Required (RNP AR) Procedure Design Manual* (Doc 9905) (in preparation)) must not exceed 10^{-7} per approach, including the approach and missed approach. This requirement may be satisfied by an operational safety assessment applying:

i) appropriate quantitative numerical methods;

ii) qualitative operational and procedural considerations and mitigations; or

iii) an appropriate combination of both quantitative and qualitative methods.

Note 1.— This requirement applies to the total probability of excursion outside the obstacle clearance volume, including events caused by latent conditions (integrity) and by detected conditions (continuity) if the aircraft does not remain within the obstacle clearance volume after the failure is annunciated (considering the aircraft wingspan). The monitor limit of the alert, the latency of the alert, the crew reaction time, and the aircraft response should all be considered when ensuring that the aircraft does not exit the obstacle clearance volume. The requirement applies to a single approach, considering the exposure time of the operation and the navaid geometry and navigation performance available for each published approach.

Note 2.— This containment requirement is derived from the operational requirement which is notably different than the containment requirement specified in RTCA/DO 236B (EUROCAE ED-75B). The requirement in RTCA/DO-236B (EUROCAE ED-75B) was developed to facilitate airspace design and does not directly equate to obstacle clearance.

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 APCHs.

6.3.3.2.2 Global positioning system (GPS):

a) The sensor must comply with the guidelines in AC 20-138(). For systems that comply with AC 20-138(), the following sensor accuracies can be used in the total system accuracy analysis without additional substantiation: GPS sensor accuracy is better than 36 m (119 ft) (95 per cent), and augmented GPS (GBAS or SBAS) sensor 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 (e.g. horizontal integrity limit (HIL) equal to the horizontal alert limit), the probability that the aircraft remains within the obstacle clearance volume used to evaluate the procedure must be greater than 95 per cent (both laterally and vertically).

Note.— GNSS-based sensors output a HIL, also known as a horizontal protection level (HPL) (see AC 20-138A, Appendix 1 and RTCA/DO-229C for an explanation of these terms). The HIL is a measure of the position estimation error assuming a latent failure is present. In lieu of a detailed analysis of the effects of latent failures on the total system error, an acceptable means of compliance for GNSS-based systems is to ensure the HIL remains less than twice the navigation accuracy, minus the 95 per cent of FTE, during the RNP AR APCH operation.

6.3.3.2.3 *Inertial reference system (IRS).* An inertial reference system must satisfy the criteria of US 14 CFR part 121, Appendix G, or equivalent. 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 RNAV 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 8 NM/hour for the first 30 minutes (95 per cent) without further substantiation. Aircraft manufacturers and applicants can demonstrate improved inertial performance in accordance with the methods described in Appendix 1 or 2 of FAA Order 8400.12A.

Note.— Integrated GPS/INS position solutions reduce the rate of degradation after loss of position updating. For "tightly coupled" GPS/IRUs, RTCA/DO-229C, Appendix R, provides additional guidance.

6.3.3.2.4 *Distance measuring equipment (DME).* Initiation of all RNP AR APCH procedures is based on GNSS updating. Except where specifically designated on a procedure as "Not Authorized", DME/DME updating can be used as a reversionary mode during the approach or missed approach when the system complies with the navigation accuracy. The manufacturer should identify any constraints on the DME infrastructure or the procedure for a given aircraft to comply with this requirement.

6.3.3.2.5 *VHF omnidirectional range (VOR) station.* For the initial RNP AR APCH implementation, the RNAV system may not use VOR updating. The manufacturer should identify any constraints on the VOR infrastructure or the procedure for a given aircraft to comply with this requirement.

Note.— This requirement 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 or executing a missed approach, if reverting to VOR updating, may meet this requirement.

6.3.3.2.6 For multi-sensor systems, there must be automatic reversion to an alternate RNAV sensor if the primary RNAV sensor fails. Automatic reversion from one multi-sensor system to another multi-sensor system is not required.

6.3.3.2.7 The 99.7 per cent aircraft altimetry system error for each aircraft (assuming the temperature and lapse rates of the International Standard Atmosphere) must be less than or equal to the following with the aircraft in the approach configuration:

$$\mathbf{ASE} = -8.8 \cdot 10^{-8} \cdot \mathbf{H}^2 + 6.5 \cdot 10^{-3} \cdot \mathbf{H} + 50 \text{ (ft)}$$

Where **H** is the true altitude of the aircraft.

6.3.3.2.8 *Temperature compensation systems.* Systems that provide temperature-based corrections to the barometric VNAV guidance must comply with RTCA/DO-236B, Appendix H.2. This applies to the final approach segment. Compliance to this standard should be documented to allow the operator to conduct RNP approaches when the actual temperature is below or above the published procedure design limit. Appendix H also provides guidance on operational issues associated with temperature compensated systems, such as intercepting the compensated path from uncompensated procedure altitudes.

6.3.3.3 Functional requirements

Note.— Additional guidance and information concerning many of the required functions are provided in EUROCAE ED-75A/ RTCA DO-236B.

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:

    i) a geodesic line between two fixes;

ii) a direct path to a fix;

iii) a specified track to a fix, defined by a course; and

iv) a specified track to an altitude.

Note 1.— Industry standards for these paths can be found in EUROCAE ED-75A/ RTCA DO-236B and ARINC Specification 424, which refer to them as TF, DF, CF, and FA path terminators. Also, certain procedures require RF legs. EUROCAE ED-75A/ RTCA DO-236B and ED 77/ DO-201A describe the application of these paths in more detail.

Note 2.— The navigation system may accommodate other ARINC 424 path terminators (e.g. heading to manual terminator (VM)), and the missed approach procedure may use these types of paths when there is no requirement for RNP containment.

b) *Fly-by and flyover fixes.* The aircraft must have the capability to execute fly-by and flyover fixes. For fly-by turns, the navigation system must limit the path definition within the theoretical transition area defined in EUROCAE ED-75B/ RTCA DO-236B and under the wind conditions identified in the ICAO *Required Navigation Performance Authorization Required (RNP AR) Procedure Design Manual* (Doc 9905) (in preparation). The flyover turn is not compatible with RNP flight tracks and will only be used when there is no requirement for repeatable paths.

c) *Waypoint resolution error.* The navigation database must provide sufficient data resolution to ensure the navigation 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 internally for construction of flight plan waypoints. The navigation database must contain vertical angles (flight path angles) stored to a resolution of hundredths of a degree, with computational resolution such that the system-defined path is within 1.5 m (5 ft) of the published path.

d) *Capability for a "direct-to" function.* The navigation system must have a "direct-to" function that 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.

e) *Capability to define a vertical path.* The navigation system must be capable of defining a vertical path by a flight path angle to a fix. The system must also be capable of specifying a vertical path between altitude constraints at two fixes in the flight plan. Fix altitude constraints must be defined as one of the following:

i) an "AT" or "ABOVE" altitude constraint (e.g. 2400A may be appropriate for situations where bounding the vertical path is not required);

ii) an "AT" or "BELOW" altitude constraint (e.g. 4800B may be appropriate for situations where bounding the vertical path is not required);

iii) an "AT" altitude constraint (e.g. 5200); or

iv) a "WINDOW" constraint (e.g. 2400A, 3400B).

Note.— For RNP AR APCH procedures, any segment with a published vertical path will define that path based on an angle to the fix and altitude.

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 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. This includes the approach (including vertical angle), the missed approach and the approach transitions for the selected airport and runway.

i) *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 navigation aids.

j) *Magnetic variation.* For paths defined by a course (course to fix (CF) and fix to altitude (FA) path terminators), the navigation system must use the magnetic variation value for the procedure in the navigation database.

k) *Changes in navigation accuracy.* RNP changes to lower navigation accuracy must be completed by the fix defining the leg with the lower navigation accuracy, considering the alerting latency of the navigation system. Any operational procedures necessary to accomplish this must be identified.

l) *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.

m) A display of the altitude restrictions associated with flight plan fixes must be available to the pilot. If there is a specified navigation database procedure with a flight path angle associated with any flight plan leg, the equipment must display the flight path angle for that leg.

6.3.3.3.1.2 *Demonstration of path steering performance.* The demonstration of path steering performance (flight technical error) must be completed in a variety of operational conditions, i.e. rare-normal conditions and non-normal conditions (e.g. see FAA AC 120-29A, 5.19.2.2 and 5.19.3.1). Realistic and representative procedures should be used (e.g. number of waypoints, placement of waypoints, segment geometry, leg types, etc.) The non-normal assessment should consider the following:

a) Acceptable criteria to be used for assessing probable failures and engine failure during the aircraft qualification will demonstrate that the aircraft trajectory is maintained within a 1xRNP corridor, and 22 m (75 ft) vertical. Proper documentation of this demonstration in the aircraft flight manual (AFM), AFM extension, or appropriate aircraft operational support document, alleviates the operational evaluations.

b) RNP-significant improbable failure cases should be assessed to show that, under these conditions, the aircraft can be safely extracted from the procedure. Failure cases might include dual system resets, flight control surface runaway and complete loss of flight guidance function.

c) The aircraft performance demonstration during the operational evaluations can be based on a mix of analyses and flight technical evaluations using expert judgement.

6.3.3.3.1.3 Displays:

a) *Continuous display of deviation.* 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 (both lateral and vertical deviation). The display must allow the pilot to readily distinguish if the cross-track deviation exceeds the navigation accuracy (or a smaller value) or if the vertical deviation exceeds 22 m (75 ft) (or a smaller value).

It is recommended that an appropriately scaled non-numeric deviation display (i.e. lateral deviation indicator and vertical deviation indicator) be located in the pilot's primary optimum field of view. A fixed-scale CDI is acceptable as long as the CDI demonstrates appropriate scaling and sensitivity for the intended navigation accuracy and operation. With a scalable CDI, the scale should be derived from the selection of RNP, and not require the separate selection of a CDI scale. Alerting and annunciation limits must also match the scaling values. If the equipment uses default navigation accuracy to describe the operational mode (e.g. en route, terminal area and approach), then displaying the operational mode is an acceptable means from which the flight crew may derive the CDI scale sensitivity.

Numeric display of deviation or graphic depiction on a map display, without an appropriately scaled deviation indicator, is generally not considered acceptable for monitoring deviation. The use of numeric display and map display may be feasible depending on the flight crew workload, the display characteristics, and the flight crew procedures and training. Additional initial and recurrent flight crew training (or line experience) is necessary, therefore, such a solution could increase flight crew workload during the approach and impose additional costs to the operator to support the training requirements.

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.

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 ground speed and time to the active (To) waypoint.* The navigation system must provide the display of ground speed 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) *Display of To/From the active fix.* The navigation system must provide a To/From display in the pilot's primary optimum field of view.

f) *Desired track display.* The navigation system must have the capability to continuously display to the pilot flying the desired aircraft track. This display must be on the primary flight instruments for navigation of the aircraft.

g) *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.

h) *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.

i) *Slaved course selector.* The navigation system must provide a course selector automatically slaved to the RNP computed path.

j) *RNP path display.* The navigation 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.

k) *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.

l) *Display of distance between flight plan waypoints.* The navigation system must provide the ability to display the distance between flight plan waypoints.

m) *Display of deviation.* The navigation system must provide a numeric display of the vertical deviation with a resolution of 3 m (10 ft) or less, and the lateral deviation with a resolution of 0.01 NM or less.

n) *Display of barometric altitude.* The aircraft must display barometric altitude from two independent altimetry sources, one in each of the pilot's primary optimum field of view.

Note 1.— This display supports an operational cross-check (comparator monitor) of altitude sources. If the aircraft altitude sources are automatically compared, the output of the independent altimetry sources, including independent aircraft static air pressure systems, must be analysed to ensure that they can provide an alert in the pilot's primary optimum field of view when deviations between the sources exceed 30 m (±100 ft). This comparator monitor function should be documented as it may eliminate the need for an operational mitigation.

Note 2.— The altimeter setting input must be used simultaneously by the aircraft altimetry system and by the RNP system. A single input is necessary to prevent possible crew error. Separate altimeter settings for the RNP system is prohibited.

o) *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 to be acceptable.

6.3.3.3.1.4 *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 on an RNP AR APCH.

Note.— The display of misleading lateral or vertical RNP guidance is considered a hazardous (severe-major) failure condition for RNP AR APCHs with a navigation accuracy less than RNP-0.3. Systems designed consistent with this effect should be documented as it may eliminate the need for some operational mitigations for the aircraft.

6.3.3.3.1.5 *Navigation database.* The aircraft navigation system must use an on-board navigation database which can receive updates in accordance with the AIRAC cycle and allow retrieval and loading of RNP AR APCH procedures into the RNP system. The on-board navigation database must be protected against flight crew modifications of the stored data.

Note.— 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.

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.

6.3.3.3.2 *Requirements for RNP AR approaches with RF legs*

6.3.3.3.2.1 The navigation system must have the capability to execute leg transitions and maintain tracks consistent with an RF leg between two fixes.

6.3.3.3.2.2 The aircraft must have an electronic map display of the selected procedure.

6.3.3.3.2.3 The FMC, the flight director system and autopilot must be capable of commanding a bank angle up to 25 degrees above 121 m (400 ft) AGL and up to 8 degrees below 121 m (400 ft) AGL.

6.3.3.3.2.4 Upon initiating a go-around or missed approach (through activation of TOGA or other means), the flight guidance mode should remain in LNAV to enable continuous track guidance during an RF leg.

6.3.3.3.2.5 When evaluating a flight technical error on RF legs, the effect of rolling into and out of the turn should be considered. The procedure is designed to provide a 5 degree manoeuvrability margin, to enable the aircraft to get back on the desired track after a slight overshoot at the start of the turn.

6.3.3.3.3 *Requirements for RNP AR Approaches to less than RNP 0.3*

6.3.3.3.3.1 *No single point of failure.* No single point of failure can cause the loss of guidance compliant with the navigation accuracy associated with the approach. Typically, the aircraft must have at least the following equipment: dual GNSS sensors, dual flight management systems, dual air data systems, dual autopilots, and a single inertial reference unit (IRU).

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, where RNP less than 0.3 is required to avoid obstacles or terrain while executing an approach.

Note.— For RNP AR APCH operations requiring less than 0.3 to avoid obstacles or terrain, the loss of the display of lateral guidance is considered a hazardous (severe-major) failure condition. The AFM should document systems designed consistent with this effect. This documentation should describe the specific aircraft configuration or mode of operation that achieves navigation accuracy less than 0.3. Meeting this requirement can substitute for the general requirement for dual equipment described above.

6.3.3.3.3.3 *Go-around guidance.* Upon initiating a go-around or missed approach (through activation of take-off/go-around (TOGA) or other means), the flight guidance mode should remain in LNAV to enable continuous track guidance during an RF leg. If the aircraft does not provide this capability, the following requirements apply:

a) If the aircraft supports RF legs, the lateral path after initiating a go-around (TOGA), (given a minimum 50-second straight segment between the RF end point and the DA), must be within 1 degree of the track defined by the straight segment through the DA point. The prior turn can be of arbitrary angular extent and radius as small as 1 NM, with speeds commensurate with the approach environment and the radius of the turn.

b) The flight crew must be able to couple the autopilot or flight director to the RNP system (engage LNAV) by 121 m (400 ft) AGL.

6.3.3.3.3.4 *Loss of GNSS.* After initiating a go-around or missed approach following loss of GNSS, the aircraft must automatically revert to another means of navigation that complies with the navigation accuracy.

6.3.3.3.4 *Requirements for approaches with missed approach less than RNP 1.0*

6.3.3.3.4.1 *Single point of failure.* No single point of failure can cause the loss of guidance compliant with the navigation accuracy associated with a missed approach procedure. Typically, the aircraft must have at least the following equipment: dual GNSS sensors, dual flight management systems, dual air data systems, dual autopilots, and a single inertial reference unit (IRU).

6.3.3.3.4.2 *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 where RNP less than 1.0 is required to avoid obstacles or terrain while executing a missed approach.

Note.— For RNP AR APCH missed approach operations requiring less than 1.0 to avoid obstacles or terrain, the loss of the display of lateral guidance is considered a hazardous (severe-major) failure condition. The AFM should document systems designed consistent with this effect. This documentation should describe the specific aircraft configuration or mode of operation that achieves navigation accuracy less than 1.0. Meeting this requirement can substitute for the general requirement for dual equipment described above.

6.3.3.3.4.3 *Go-around guidance.* Upon initiating a go-around or missed approach (through activation of TOGA or other means), the flight guidance mode should remain in LNAV to enable continuous track guidance during an RF leg. If the aircraft does not provide this capability, the following requirements apply:

a) If the aircraft supports RF legs, the lateral path after initiating a go-around (TOGA) (given a minimum 50-second straight segment between the RF end point and the DA) must be within 1 degree of the track defined by the straight segment through the DA point. The prior turn can be of arbitrary angular extent and the radius as small as 1 NM, with speeds commensurate with the approach environment and the radius of the turn.

b) The flight crew must be able to couple the autopilot or flight director to the RNP system (engage LNAV) by 122 m (400 ft) AGL.

6.3.3.3.4.4 *Loss of GNSS.* After initiating a go-around or missed approach following loss of GNSS, the aircraft must automatically revert to another means of navigation that complies with the navigation accuracy.

6.3.4 Operating procedures

6.3.4.1 Pre-flight considerations

6.3.4.1.1 *Minimum equipment list (MEL).* The operator's MEL should be developed/revised to address the equipment requirements for RNP AR APCH instrument approaches. Guidance for these equipment requirements is available from the aircraft manufacturer. The required equipment may depend on the intended navigation accuracy and whether the missed approach requires an RNP less than 1.0. For example, GNSS and autopilot are typically required for small navigation accuracy. Dual equipment is typically required for approaches when using a line of minima less than RNP 0.3 and/or where the missed approach has an RNP less than 1.0. An operable Class A terrain awareness warning system (TAWS) is required for all RNP AR APCH procedures. It is recommended that the TAWS use an altitude that compensates for local pressure and temperature effects (e.g. corrected barometric and GNSS altitude), and includes significant terrain and obstacle data. The flight crew must be cognizant of the required equipment.

6.3.4.1.2 *Autopilot and flight director.* RNP AR APCH procedures with a navigation accuracy less than RNP 0.3 or with RF legs require the use of an autopilot or flight director driven by the RNP system in all cases. Thus, the autopilot/flight director must operate with suitable accuracy to track the lateral and vertical paths required by a specific RNP AR APCH procedure. When the dispatch of a flight is predicated on flying an RNP AR APCH requiring the autopilot at the destination and/or alternate, the dispatcher must determine that the autopilot is installed and operational.

6.3.4.1.3 *Dispatch RNP assessment.* The operator must have a predictive performance capability which can forecast whether or not the specified RNP will be available at the time and location of a desired RNP AR APCH operation. This capability can be a ground service and need not be resident in the aircraft's avionics equipment. The operator must establish procedures requiring use of this capability as both a pre-flight dispatch tool and as a flight-following tool in the event of reported failures. The RNP assessment must consider the specific combination of the aircraft capability (sensors and integration).

a) RNP assessment when GNSS updating. This predictive capability must account for known and predicted outages of GNSS satellites or other impacts on the navigation system's sensors. The prediction programme should not use a mask angle below 5 degrees, as operational experience indicates that satellite signals at low elevations are not reliable. The prediction must use the actual GPS constellation with the (RAIM) (or equivalent) algorithm identical to that used in the actual equipment. For RNP AR APCHs with high terrain, use a mask angle appropriate to the terrain.

b) Initially, RNP AR APCH procedures require GNSS updating.

6.3.4.1.4 *Navaid exclusion.* The operator must establish procedures to exclude navaid facilities in accordance with NOTAMs (e.g. DMEs, VORs, localizers). Internal avionics reasonableness checks may not be adequate for RNP AR APCH operations.

6.3.4.1.5 *Navigation database currency.* During system initialization, pilots of aircraft equipped with an RNP-certified system, must confirm that the navigation database is current. Navigation databases are expected to be current for the duration of the flight. If the AIRAC cycle will change during flight, operators and pilots must establish procedures to ensure the accuracy of the navigation data, including the suitability of the navigation facilities used to define the routes and procedures for the flight. Traditionally, this has been accomplished by verifying electronic data against paper products. One acceptable means is to compare aeronautical charts (new and old) to verify navigation fixes prior to dispatch. If an amended chart is published for the procedure, the database must not be used to conduct the operation.

6.3.4.2 In-flight considerations

6.3.4.2.1 *Modification of the flight plan.* Pilots are not authorized to fly a published RNP AR APCH 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 accepting a clearance to go direct to a fix in the approach procedure that is before the FAF and that does not immediately precede an RF leg. The only other modification allowed to the loaded procedure is to change the altitude and/or airspeed waypoint constraints on the initial, intermediate, or missed approach segments (e.g. to apply cold temperature corrections or comply with an 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 APCHs or alternate methods to address in-flight equipment failures prohibiting RNP AR APCHs (e.g. a quick reference handbook).

6.3.4.2.3 *RNP management.* The flight crew's operating procedures must ensure the navigation system uses the appropriate navigation accuracy throughout the approach. If multiple lines of minima associated with a different navigation accuracy are shown on the approach chart, the crew must confirm that the desired navigation accuracy is entered in the RNP system. If the navigation system does not extract and set the navigation accuracy from the on-board navigation database for each leg of the procedure, then the flight crew's operating procedures must ensure that the smallest navigation accuracy required to complete the approach or the missed approach is selected before initiating the approach (e.g. before the initial approach fix (IAF)). Different IAFs may have a different navigation accuracy, which are annotated on the approach chart.

6.3.4.2.4 *GNSS updating.* Initially, all RNP AR APCH instrument approach procedures require GNSS updating of the navigation position solution. The flight crew must verify that GNSS updating is available prior to commencing the RNP AR APCH. During the approach, if at any time GNSS updating is lost and the navigation system does not have the performance to continue the approach, the flight crew must abandon the RNP AR APCH unless the pilot has in sight the visual references required to continue the approach.

6.3.4.2.5 *Radio updating.* Initiation of all RNP AR APCH procedures is based on the availability of GNSS updating. Except where specifically designated on a procedure as "Not Authorized", DME/DME updating can be used as a reversionary mode during the approach or missed approach when the system complies with the navigation accuracy. VOR updating is not authorized at this time. The flight crew must comply with the operator's procedures for inhibiting specific facilities.

6.3.4.2.6 *Approach procedure confirmation.* The flight crew must confirm that the correct procedure has been selected. This process includes confirmation of the waypoint sequence, reasonableness of track angles and distances, and any other parameters that can be altered by the pilot, such as altitude or speed constraints. A procedure must not be used if the validity of the navigation database is in doubt. A navigation system textual display or navigation map display must be used.

6.3.4.2.7 *Track deviation monitoring.* Pilots must use a lateral deviation indicator, flight director and/or autopilot in lateral navigation mode on RNP AR APCH procedures. Pilots of aircraft with a lateral deviation indicator must ensure that lateral deviation indicator scaling (full-scale deflection) is suitable for the navigation accuracy associated with the various segments of the RNP AR APCH procedure. All pilots are expected to maintain procedure centrelines, 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 RNP system computed path and the aircraft position relative to the path) should be limited to ±½ the navigation accuracy associated with the procedure segment. Brief lateral deviations from this standard (e.g. overshoots or undershoots) during and immediately after turns, up to a maximum of one-times the navigation accuracy of the procedure segment are allowable.

6.3.4.2.8 The vertical deviation must be within 22 m (75 ft) during the final approach segment. Vertical deviation should be monitored above and below the glide path; while being above the glide path provides margin against obstacles on the final approach, it can result in a go-around decision closer to the runway and reduce the margin against obstacles in the missed approach.

6.3.4.2.9 Pilots must execute a missed approach if the lateral deviation exceeds 1 × RNP or the vertical deviation exceeds 22 m (75 ft), unless the pilot has in sight the visual references required to continue the approach.

a) Some aircraft navigation displays do not incorporate lateral and vertical deviations scaled for each RNP AR APCH operation in the primary optimum field of view. Where a moving map, low-resolution vertical deviation indicator (VDI), or numeric display of deviations are to be used, flight crew training and procedures must ensure the effectiveness of these displays. Typically, this involves the demonstration of the procedure with a number of trained crews and inclusion of this monitoring procedure in the recurrent RNP AR APCH training programme.

b) For installations that use a CDI for lateral path tracking, the aircraft flight manual (AFM) or aircraft qualification guidance should state which navigation accuracy and operations the aircraft supports and the operational effects on the CDI scale. The flight crew must know the CDI full-scale deflection value. The avionics may automatically set the CDI scale (dependent on the phase of flight) or the flight crew may manually set the scale. If the flight crew manually selects the CDI scale, the operator must have procedures and training in place to assure the selected CDI scale is appropriate for the intended RNP operation. The deviation limit must be readily apparent given the scale (e.g. full-scale deflection).

6.3.4.2.10 *System cross-check.* For approaches with a navigation accuracy less than RNP 0.3, the flight crew must monitor the lateral and vertical guidance provided by the navigation system by ensuring it is consistent with other available data and displays that are provided by an independent means.

Note.— This cross-check may not be necessary if the lateral and vertical guidance systems have been developed consistent with a hazardous (severe-major) failure condition for misleading information and if the normal system performance supports airspace containment.

6.3.4.2.11 *Procedures with RF legs.* An RNP AR APCH procedure may require the ability to execute an RF leg to avoid terrain or obstacles. As not all aircraft have this capability, flight crews must be aware of whether they can conduct these procedures. When flying an RF leg, flight crew compliance with the desired path is essential to maintain the intended ground track.

a) If initiating a go-around during or shortly after the RF leg, the flight crew must be aware of the importance of maintaining the published path as closely as possible. Operational procedures are required for aircraft that do not stay in LNAV when a go-around is initiated to ensure the RNP AR APCH ground track is maintained.

b) Pilots must not exceed the maximum airspeeds shown in Table II-C-6-1 throughout the RF leg segment. 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 missed approach prior to decision altitude (DA) may require the segment speed for that segment be maintained.

Table II-C-6-1. Maximum airspeed by segment and category

Indicated airspeed (knots)					
Segment	*Indicated airspeed by aircraft category*				
	Cat A	*Cat B*	*Cat C*	*Cat D*	*Cat E*
Initial and intermediate (IAF to FAF)	150	180	240	250	250
Final (FAF to DA)	100	130	160	185	As specified
Missed approach (DA to MAHF)	110	150	240	265	As specified
Airspeed restriction*	As specified				

* Airspeed restrictions may be used to reduce turn radius regardless of aircraft category.

6.3.4.2.12 *Temperature compensation.* For aircraft with temperature compensation capabilities, flight crews may disregard the temperature limits on RNP AR APCH procedures if the operator provides pilot training on the use of the temperature compensation function. Temperature compensation by the system is applicable to the VNAV guidance and is not a substitute for the flight crew compensating for the cold temperature effects on minimum altitudes or the decision altitude. Flight crews should be familiar with the effects of the temperature compensation on intercepting the compensated path described in EUROCAE ED-75B/ RTCA DO-236B Appendix H.

6.3.4.2.13 *Altimeter setting.* Due to the reduced obstruction clearance inherent in RNP AR APCH instrument approach procedures, the flight crew must verify that the current airport local altimeter is set prior to the final approach fix (FAF). Execution of an RNP AR APCH instrument approach procedure requires the current altimeter setting for the airport of intended landing. Remote altimeter settings are not allowed.

6.3.4.2.14 *Altimeter cross-check.* The flight crew must complete an altimetry cross-check ensuring both pilots' altimeters agree within 30 m (±100 ft) prior to the FAF but no earlier than the IAF. If the altimetry cross-check fails then the procedure must not be continued. If the avionics systems provide a comparator warning system for the pilots' altimeters, the flight crew procedures should address actions to take if a comparator warning for the pilots' altimeters occurs while conducting an RNP AR APCH procedure.

Note.— This operational cross-check is not necessary if the aircraft automatically compares the altitudes to within 30 m (100 ft) (see also 6.3.3.3.1.3, Displays, (n) Display of barometric altitude).

6.3.4.2.15 *VNAV altitude transitions.* The aircraft barometric VNAV system provides fly-by vertical guidance, and may result in a path that starts to intercept the glide path prior to the FAF to ensure a smooth transition. The small vertical displacement which may occur at a vertical constraint (e.g. the FAF is considered operationally acceptable, and desirable, to ensure an asymptotic capture of a new (next) vertical segment. This momentary deviation below the published minimum procedure altitude is acceptable provided the deviation is limited to no more than 30 m (100 ft) and is a result of a normal VNAV capture. This applies to both “level off” or “altitude acquire” segments following a climb or descent, or vertical climb or descent segment initiation, or joining of climb or descent paths with different gradients.

6.3.4.2.16 *Non-standard climb gradient.* When the operator plans to use the DA associated with a non-standard missed approach climb gradient, he/she must ensure the aircraft will be able to comply with the published climb gradient for the planned aircraft loading, atmospheric conditions and operating procedures before conducting the operation. Where operators have performance specialists who determine whether their aircraft can comply with published climb gradients, this information should be provided to the pilots indicating the climb gradient they can expect to achieve.

6.3.4.2.17 *Engine-out procedures.* Aircraft may demonstrate an acceptable flight technical error with one engine inoperative to conduct RNP AR APCHs. Otherwise, flight crews are expected to take appropriate action in the event of engine failure during an approach so that no specific aircraft qualification is required. The aircraft qualification should identify any performance limits in the event of engine failure to support definition of the appropriate flight crew procedures. Particular attention should be given to procedures with published non-standard climb gradients.

6.3.4.2.18 *Go-around or missed approach.* Where possible, the missed approach will require RNP 1.0. The missed approach portion of these procedures is similar to a missed approach of an RNP APCH approach. Where necessary, navigation accuracy less than RNP 1.0 will be used in the missed approach. Approval to conduct these approaches, equipage and procedures must meet criteria in 6.3.3.3.4 “Requirements for approaches with missed approach less than RNP 1.0”.

6.3.4.2.19 In many aircraft when executing a go-around or missed approach, activating take-off/go-around (TOGA) may cause a change in lateral navigation, i.e. TOGA disengages the autopilot and flight director from LNAV guidance, and the flight director reverts to track-hold derived from the inertial system. In these cases, LNAV guidance to the autopilot and flight director should be re-engaged as quickly as possible.

6.3.4.2.20 The flight crew procedures and training must address the impact on navigation capability and flight guidance if the pilot initiates a go-around while the aircraft is in a turn. When initiating an early go-around, the flight crew should follow the rest of the approach track and missed approach track unless ATC has issued a different clearance. The flight crew should also be aware that RF legs are designed based on the maximum true airspeed at normal altitudes, and initiating an early go-around will reduce the manoeuvrability margin and potentially even make holding the turn impractical at missed approach speeds.

6.3.4.2.21 Upon loss of GNSS updates, the RNAV guidance may begin to “coast” on IRU, if installed, and drift, degrading the navigation position solution. Thus, when the RNP AR APCH missed approach operations rely on IRU “coasting”, the inertial guidance can only provide RNP guidance for a specified amount of time.

6.3.4.2.22 *Contingency procedures — failure while en route.* The aircraft RNP capability is dependent on operational aircraft equipment and GNSS. The flight crew must be able to assess the impact of equipment failure on the anticipated RNP AR APCH and take appropriate action. As described in 6.3.4.1.3 “Dispatch RNP assessment”, the flight crew also must be able to assess the impact of changes in the GNSS constellation and take appropriate action.

6.3.4.2.23 *Contingency procedures — failure on approach.* The operator’s contingency procedures need to address at least the following conditions: Failure of the RNP system components, including those affecting lateral and vertical deviation performance (e.g. failures of a GPS sensor, the flight director or automatic pilot); and loss of navigation signal-in-space (loss or degradation of external signal).

6.3.5 Pilot/dispatch/operator knowledge and training

The operator must provide training for key personnel (e.g. flight crew members and dispatchers) in the use and application of RNP AR APCH procedures. A thorough understanding of the operational procedures and best practices is critical to the safe operation of aircraft during RNP AR APCH operations. This programme must provide sufficient detail on the aircraft’s navigation and flight control systems to enable the pilots to identify failures affecting the aircraft’s RNP capability and the appropriate abnormal/emergency procedures. Training must include both knowledge and skill assessments of the crew members’ and dispatchers’ duties.

6.3.5.1 Operator responsibilities

a) Each operator is responsible for the training of flight crews for the specific RNP AR APCH operations exercised by the operator. The operator must include training on the different types of RNP AR APCH procedures and required equipment. Training must include discussion of RNP AR APCH regulatory requirements. The operator must include these requirements and procedures in their flight operations and training manuals (as applicable). This material must cover all aspects of the operator’s RNP AR APCH operations including the applicable operational authorization (e.g. operations specifications). An individual must have completed the appropriate ground and or flight training segment before engaging in RNP AR APCH operations.

b) Flight training segments must include training and checking modules representative of the type of RNP AR APCH operations the operator conducts during line-oriented flying activities. Many operators may train for RNP AR APCH procedures under the established training standards and provisions for advanced qualification programmes (AQP). They may conduct evaluations in line-oriented flight training (LOFT) scenarios, selected event training (SET) scenarios or in a combination of both. The operator may conduct required flight training modules in flight training devices, aircraft simulators, and other enhanced training devices as long as these training devices accurately replicate the operator’s equipment and RNP AR APCH operations.

c) Operators must address initial RNP AR APCH training and qualifications during initial, transition, upgrade, recurrent, differences, or stand-alone training and qualification programmes in the respective qualification category. The qualification standards assess each pilot’s ability to properly understand and use RNP AR APCH procedures (RNP AR APCH initial evaluation). The operator must also develop recurrent qualification standards to ensure their flight crews maintain appropriate RNP AR APCH knowledge and skills (RNP AR APCH recurrent qualification).

d) Operators may address RNP AR APCH operation topics separately or integrate them with other curriculum elements. For example, an RNP AR APCH flight crew qualification may focus on a specific aircraft during transition, upgrade, or differences courses. General training may also address RNP AR APCH qualification, e.g. during 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 qualification programme may also address RNP AR APCH training, e.g. by completion of a special RNP AR APCH curriculum at an operator’s training centre or at designated crew bases.

e) Operators intending to receive credit for RNP training, when their proposed programme relies on previous training (e.g. Special RNP IAPs), must receive specific authorization from their principal operations inspector/flight operations inspector. In addition to the current RNP training programme, the air carrier will need to provide differences training between existing training programme and the RNP AR APCH training requirements.

f) Training for flight dispatchers must include: the explanation of the different types of RNP AR APCH procedures, the importance of specific navigation equipment and other equipment during RNP AR APCH operations and the RNP AR APCH regulatory requirements and procedures. Dispatcher procedure and training manuals must include these requirements (as applicable). This material must cover all aspects of the operator's RNP AR APCH operations including the applicable authorizations (e.g. Ops Specs, operations manual, MSpecs or LOA). An individual must have completed the appropriate training course before engaging in RNP AR APCH operations. Additionally, the dispatchers' training must address how to determine: RNP AR APCH availability (considering aircraft equipment capabilities), MEL requirements, aircraft performance, and navigation signal availability (e.g. GPS RAIM/predictive RNP capability tool) for destination and alternate airports.

6.3.5.2 Ground training segments content

6.3.5.2.1 Ground training segments must address the following subjects, as training modules, in an approved RNP AR APCH academic training programme during the initial introduction of a crew member to RNP AR APCH systems and operations. For recurrent programmes, the curriculum need only review initial curriculum requirements and address new, revised, or emphasized items.

6.3.5.2.2 General concepts of RNP AR APCH operation. RNP AR APCH academic training must cover RNP AR APCH systems theory to the extent appropriate to ensure proper operational use. Flight crews must understand basic concepts of RNP AR APCH systems operation, classifications, and limitations. The training must include general knowledge and operational application of RNP AR APCH instrument approach procedures. This training module must address the following specific elements:

a) definition of RNP AR APCH;

b) the differences between RNAV and RNP;

c) the types of RNP AR APCH procedures and familiarity with the charting of these procedures;

d) the programming and displaying of RNP and aircraft specific displays (e.g. actual navigation performance (ANP display));

e) how to enable and disable the navigation updating modes related to RNP;

f) the navigation accuracy appropriate for different phases of flight and RNP AR APCH procedures and how to select the navigation accuracy, if required;

g) the use of GPS RAIM (or equivalent) forecasts and the effects of RAIM availability on RNP AR APCH procedures (flight crew and dispatchers);

h) when and how to terminate RNP navigation and transfer to traditional navigation due to loss of RNP and/or required equipment;

i) how to determine database currency and whether it contains the navigational data required for use of GNSS waypoints;

j) explanation of the different components that contribute to the total system error and their characteristics (e.g. effect of temperature on baro-VNAV and drift characteristics when using IRU with no radio updating).

k) temperature compensation — flight crews operating avionics systems with compensation for altimetry errors introduced by deviations from ISA may disregard the temperature limits on RNP AR APCH procedures, if pilot training on the use of the temperature compensation function is provided by the operator and the compensation function is utilized by the crew. However, the training must also recognize the temperature compensation by the system is applicable to the VNAV guidance and is not a substitute for the flight crew compensating for the cold temperature effects on minimum altitudes or the decision altitude.

6.3.5.2.3 *ATC communication and coordination for use of RNP AR APCH.* Ground training must instruct the flight crews on proper flight plan classifications and any air traffic control (ATC) procedures applicable to RNP AR APCH operations. The flight crews must receive instructions on the need to advise ATC immediately when the performance of the aircraft's navigation system is no longer suitable to support continuation of an RNP AR APCH procedure. Flight crews must also know what navigation sensors form the basis for their RNP AR APCH compliance, and they must be able to assess the impact of a failure of any avionics or a known loss of ground systems on the remainder of the flight plan.

6.3.5.2.4 *RNP AR APCH equipment components, controls, displays, and alerts.* Academic training must include a discussion of RNP terminology, symbology, operation, optional controls, and display features including any items unique to an operator's implementation or systems. The training must address applicable failure alerts and equipment limitations. The flight crews and dispatchers should achieve a thorough understanding of the equipment used in RNP operations and any limitations on the use of the equipment during those operations.

6.3.5.2.5 *AFM information and operating procedures.* The AFM or other aircraft eligibility evidence must address normal and abnormal flight crew operating procedures, responses to failure alerts, and any equipment limitations, including related information on RNP modes of operation. Training must also address contingency procedures for loss or degradation of RNP capability. The flight operations manuals approved for use by the flight crews (e.g. flight operations manual (FOM) or pilot operating handbook (POH)) should contain this information.

6.3.5.2.6 *MEL operating provisions.* Flight crews must have a thorough understanding of the MEL requirements supporting RNP AR APCH operations.

6.3.5.3 Flight training segments — content

6.3.5.3.1 Training programmes must cover the proper execution of RNP AR APCH procedures in concert with the OEM's documentation. The operational training must include: RNP AR APCH procedures and limitations; standardization of the set-up of the cockpit's electronic displays during an RNP AR APCH procedure; recognition of the aural advisories, alerts and other annunciations that can impact compliance with an RNP AR APCH procedure; and the timely and correct responses to loss of RNP AR APCH capability in a variety of scenarios, embracing the scope of the RNP AR APCH procedures which the operator plans to complete. Such training may also use approved flight training devices or simulators. This training must address the following specific elements:

a) Procedures for verifying that each pilot's altimeter has the current setting before beginning the final approach of an RNP AR APCH procedure, including any operational limitations associated with the source(s) for the altimeter setting and the latency of checking and setting the altimeters approaching the FAF.

b) The use of aircraft radar, TAWS, GPWS, or other avionics systems to support the flight crew's track monitoring and weather and obstacle avoidance.

c) The effect of wind on aircraft performance during RNP AR APCH procedures and the need to remain within RNP containment area, including any operational wind limitation and aircraft configuration essential to safely complete an RNP AR APCH procedure.

d) The effect of ground speed on compliance with RNP AR APCH procedures and bank angle restrictions impacting the ability to remain on the course centreline. For RNP AR APCH procedures, aircraft are expected to maintain the standard speeds associated with the applicable category.

e) The relationship between RNP and the appropriate approach minima line on an approved published RNP AR APCH procedure and any operational limitations, if the available RNP degrades or is not available prior to an approach (this should include flight crew procedures outside the FAF versus inside the FAF).

f) Concise and complete flight crew briefings for all RNP AR APCH procedures and the important role cockpit resource management (CRM) plays in successfully completing an RNP AR APCH procedure.

g) Alerts from the loading and use of improper navigation accuracy data for a desired segment of an RNP AR APCH procedure.

h) The performance requirement to couple the autopilot/flight director to the navigation system's lateral guidance on RNP AR APCH procedures requiring an RNP of less than RNP 0.3.

i) The importance of aircraft configuration to ensure the aircraft maintains any required speeds during RNP AR APCH procedures.

j) The events triggering a missed approach when using the aircraft's RNP capability.

k) Any bank angle restrictions or limitations on RNP AR APCH procedures.

l) The potentially detrimental effect on the ability to comply with an RNP AR APCH procedure when reducing the flap setting, reducing the bank angle or increasing airspeed.

m) Flight crew knowledge and skills necessary to properly conduct RNP AR APCH operations.

n) Programming and operating the FMC, autopilot, auto throttles, radar, GPS, INS, EFIS (including the moving map), and TAWS in support of RNP AR APCH procedures.

o) The effect of activating TOGA while in a turn.

p) FTE monitoring and impact on go-around decision and operation.

q) Loss of GNSS during a procedure.

r) Performance issues associated with reversion to radio updating and limitations on the use of DME and VOR updating.

s) Flight crew contingency procedures for a loss of RNP capability during a missed approach. Due to the lack of navigation guidance, the training should emphasize the flight crew contingency actions that achieve separation from terrain and obstacles. The operator should tailor these contingency procedures to their specific RNP AR APCH procedures.

t) As a minimum, each pilot must complete two RNP approach procedures that employ the unique RNP AR APCH characteristics of the operator's approved procedures (i.e. RF legs and RNP missed approach). One procedure must culminate in a transition to landing and one procedure must culminate in the execution of an RNP missed approach procedure.

6.3.5.4 Evaluation module

6.3.5.4.1 *Initial evaluation of RNP AR APCH knowledge and procedures.* The operator must evaluate each individual flight crew member's knowledge of RNP AR APCH procedures prior to employing RNP AR APCH procedures. As a minimum, the review must include a thorough evaluation of pilot procedures and specific aircraft performance requirements for RNP AR APCH operations. An acceptable means for this initial assessment includes one of the following:

a) an evaluation by an authorized instructor/evaluator or check-airman using an approved simulator or training device;

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) line-oriented flight training (LOFT)/line-oriented evaluation (LOE) programmes using an approved simulator that incorporates RNP operations that employ the unique RNP AR APCH characteristics (i.e. RF legs, RNP missed approach) of the operator's approved procedures.

6.3.5.4.2 *Evaluation content.* Specific elements that must be addressed in this evaluation module are:

a) demonstrate the use of any RNP limits that may impact various RNP AR APCHs;

b) demonstrate the application of radio-updating procedures, such as enabling and disabling ground-based radio updating of the FMC (i.e. DME/DME and VOR/DME updating) and knowledge of when to use this feature. If the aircraft's avionics do not include the capability to disable radio updating, then the training must ensure the flight crew is able to accomplish the operational actions that mitigate the lack of this feature;

c) demonstrate the ability to monitor the actual lateral and vertical flight paths relative to the programmed flight path and complete the appropriate flight crew procedures when exceeding a lateral or vertical FTE limit;

d) demonstrate the ability to read and adapt to a RAIM (or equivalent) forecast, including forecasts predicting a lack of RAIM availability;

e) demonstrate the proper set-up of the FMC, the weather radar, TAWS, and moving map for the various RNP AR APCH operations and scenarios the operator plans to implement;

f) demonstrate the use of flight crew briefings and checklists for RNP AR APCH operations with emphasis on CRM;

g) demonstrate knowledge of and ability to perform an RNP AR APCH missed approach procedure in a variety of operational scenarios (i.e. loss of navigation or failure to acquire visual conditions);

h) demonstrate speed control during segments requiring speed restrictions to ensure compliance with an RNP AR APCH procedure;

i) demonstrate competent use of RNP AR APCH plates, briefing cards, and checklists;

j) demonstrate the ability to complete a stable RNP AR APCH bank angle, speed control, and remain on the procedure's centreline; and

k) knowledge of the operational limit for deviation below the desired flight path on an RNP AR APCH and how to accurately monitor the aircraft's position relative to the vertical flight path.

6.3.5.5 Recurrent training

6.3.5.5.1 The operator should incorporate recurrent RNP training that employs the unique (AR) approach characteristics of the operator's approved procedures as part of the overall programme.

6.3.5.5.2 A minimum of two RNP AR APCHs must be flown by each pilot for each duty position (pilot flying and pilot monitoring), with one culminating in a landing and one culminating in a missed approach, and may be substituted for any required "precision-like" approach.

Note.— Equivalent RNP approaches may be credited toward this requirement.

6.3.6 Navigation database

The procedure stored in the navigation database defines the lateral and vertical guidance. Navigation database updates occur every 28 days, and the navigation data in every update are critical to the integrity of every RNP AR APCH operation. Given the reduced obstacle clearance associated with these approaches, validation of navigation data warrants special consideration. This section provides guidance for the operator's procedures for validating the navigation data associated with RNP AR APCHs.

6.3.6.1 Data process

6.3.6.1.1 The operator must identify the responsible manager for the data updating process within their procedures.

6.3.6.1.2 The operator must document a process for accepting, verifying and loading navigation data into the aircraft.

6.3.6.1.3 The operator must place their documented data process under configuration control.

6.3.6.1.4 *Initial data validation.* The operator must validate every RNP AR APCH procedure before flying the procedure in instrument meteorological conditions (IMC) to ensure compatibility with their aircraft and to ensure the resulting path matches the published procedure. As a minimum, the operator must:

a) compare the navigation data for the procedure(s) to be loaded into the flight management system with the published procedure;

b) validate the loaded navigation data for the procedure, either in a simulator or in the actual aircraft in visual meteorological conditions (VMC). The depicted procedure on the map display must be compared to the published procedure. The entire procedure must be flown to ensure the path does not have any apparent lateral or vertical path disconnects, and is consistent with the published procedure; and

c) once the procedure is validated, retain and maintain a copy of the validated navigation data for comparison to subsequent data updates.

6.3.6.1.5 *Data updates.* Upon receipt of each navigation data update, and before using the navigation data in the aircraft, the operator must compare the update to the validated procedure. This comparison must identify and resolve any discrepancies in the navigation data. If there are significant changes (any change affecting the approach path or performance) to any portion of a procedure and source data verifies the changes, the operator must validate the amended procedure in accordance with initial data validation.

6.3.6.1.6 *Data suppliers.* Data suppliers must have a Letter of Acceptance (LOA) for processing navigation data (e.g. FAA AC 20 153, EASA Conditions for the issuance of Letters of Acceptance for navigation database Suppliers by the Agency, or equivalent). An LOA recognizes the data supplier as one whose data quality, integrity and quality management practices are consistent with the criteria of DO-200A/ED-76. The operator's supplier (e.g. FMS company) must have a Type 2 LOA, and their respective suppliers must have a Type 1 or 2 LOA.

6.3.6.1.7 *Aircraft modifications.* If an aircraft system required for RNP AR APCH is modified (e.g. software change), the operator is responsible for validating of RNP AR APCH procedures using the navigation database and the modified system. This may be accomplished without any direct evaluation if the manufacturer verifies that the modification has no effect on the navigation database or path computation. If no such assurance from the manufacturer is available, the operator must conduct an initial data validation using the modified system.

6.3.7 Oversight of operators

6.3.7.1 A regulatory authority may consider any anomaly reports in determining remedial action. Repeated navigation error occurrences attributed to a specific piece of navigation equipment may result in the cancellation of the approval for use of that equipment.

6.3.7.2 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.

6.3.7.3 Operators must have an RNP monitoring programme to ensure continued compliance with the guidance of this chapter and to identify any negative trends in performance. At a minimum, this programme must address the following information. During the interim approval, operators must submit the following information every 30 days to the authority granting their authorization. Thereafter, operators must continue to collect and periodically review these data to identify potential safety concerns, as well as maintain summaries of these data:

a) total number of RNP AR APCH procedures conducted;

b) number of satisfactory approaches by aircraft/system (satisfactory if completed as planned without any navigation or guidance system anomalies);

c) reasons for unsatisfactory approaches, such as:

   i) UNABLE REQ NAV PERF, NAV ACCUR DOWNGRAD, or other RNP messages during approaches;

   ii) excessive lateral or vertical deviation;

   iii) TAWS warning;

   iv) autopilot system disconnect;

v) navigation data errors; and

vi) pilot report of any anomaly;

d) crew comments.

6.4 SAFETY ASSESSMENT

6.4.1 Flight Operational Safety Assessment

6.4.1.1 The safety objective for RNP AR APCH operations is to provide for safe flight operations. Traditionally, operational safety has been defined by a target level of safety and specified as a risk of collision of 10^{-7} per approach. For RNP AR APCH a flight operational safety assessment (FOSA) methodology is used. The FOSA is intended to provide a level of flight safety that is equivalent to the traditional TLS, but instead using methodology oriented to performance-based flight operations. Using the FOSA, the operational safety objective is met by considering more than the aircraft navigation system alone. The FOSA blends quantitative and qualitative analyses and assessments for navigation systems, aircraft systems, operational procedures, hazards, failure mitigations, normal, rare-normal and abnormal conditions, hazards, and the operational environment. The FOSA relies on the detailed criteria for aircraft qualification, operator approval and instrument procedure design to address the majority of general technical, procedural and processing factors. Additionally, technical and operational expertise and experience are essential to the conduct and conclusion of the FOSA.

6.4.1.2 An overview of the hazards and mitigations is provided to assist States in applying these criteria. Safety of RNP AR APCH operations rests with the operator and the air navigation service provider as described in this chapter.

6.4.1.3 A FOSA should be conducted for RNP AR APCH procedures where aircraft specific characteristics, operational environment, obstacle environment, etc., warrant an additional review to ensure operational safety objectives are still achieved. The assessment should give proper attention to the interdependence of the elements of design, aircraft capability, crew procedures and operating environment.

6.4.2 Hazard conditions

6.4.2.1 The following hazard conditions are examples of some of the more significant hazards and mitigations addressed by the specific aircraft and operational and procedural criteria of this navigation specification. Where operational requirements result in a change or adjustment to the RNP AR APCH procedure criteria, aircraft requirements or crew procedures, a unique FOSA should be conducted.

6.4.2.2 To facilitate the discussion of hazard conditions, it is necessary to first differentiate between normal and rare-normal or abnormal performance. In this context, the following definitions apply:

6.4.2.3 *Normal performance:* Lateral and vertical are addressed in the aircraft requirements, aircraft and systems operate normally in standard configurations and operating modes, and individual error components are monitored/truncated through system design or crew procedure.

6.4.2.4 *Rare-normal and abnormal performance:* Lateral and vertical accuracy are evaluated for aircraft failures as part of the determination of aircraft qualification. Additionally, other rare-normal and abnormal failures and conditions for ATC operations, crew procedures, navaid infrastructure and operating environment are also assessed. Where the failure or condition results are not acceptable for continued operation, mitigations are developed or limitations established for the aircraft, crew and/or operation.

6.4.2.5 Aircraft failures

1. System failure: Failure of a navigation system, flight guidance system, flight instrument system for the approach, missed approach or departure (e.g. loss of GNSS updating, receiver failure, autopilot disconnect, FMS failure, etc.) Depending on the aircraft, this may be addressed through aircraft design or operational procedure to cross-check guidance (e.g. dual equipage for lateral errors, use of terrain awareness and warning systems).

2. Malfunction of air data system or altimetry: crew procedure cross-check between two independent systems mitigates this risk.

6.4.2.6 Aircraft performance

1. Inadequate performance to conduct the approach: the aircraft qualification and operational procedures ensure the performance is adequate on each approach, as part of flight planning and in order to begin or continue the approach. Consideration should be given to aircraft configuration during approach and any configuration changes associated with a go-around (e.g. engine failure, flap retraction).

2. Loss of engine: loss of an engine while on an RNP AR APCH approach is a rare occurrence due to high engine reliability and the short exposure time. Operators will take appropriate action to mitigate the effects of loss of engine, initiating a go-around and manually taking control of the aircraft, if necessary.

6.4.2.7 Navigation services

1. Use of a navigation aid outside of designated coverage or in test mode: aircraft requirements and operational procedures have been developed to address this risk.

2. Navigation database errors: procedures are validated through flight validation specific to the operator and aircraft, and the operator is required to have a process defined to maintain validated data through updates to the navigation database.

6.4.2.8 ATC operations

1. Procedure assigned to incapable aircraft: operators are responsible for declining the clearance.

2. ATC vectors aircraft onto approach such that performance cannot be achieved: ATC training and procedures must ensure obstacle clearance until the aircraft is established on the procedure, and ATC should not intercept on or just prior to curved segments of the procedure.

6.4.2.9 Flight crew operations

1. Erroneous barometric altimeter setting: crew entry and cross-check procedures mitigate this risk.

2. Incorrect procedure selection or loading: crew procedure to verify loaded procedure matches published procedure, aircraft requirement for map display.

3. Incorrect flight control mode selected: training on importance of flight control mode, independent procedure to monitor for excessive path deviation.

4. Incorrect RNP entry: crew procedure to verify RNP loaded in system matches the published value.

5. Go-around/missed approach: balked landing or rejected landing at or below DA/H.

6. Poor meteorological conditions: loss or significant reduction of visual reference that may result in or require a go-around.

6.4.2.10 Infrastructure

1. GNSS satellite failure: this condition is evaluated during aircraft qualification to ensure obstacle clearance can be maintained, considering the low likelihood of this failure occurring.

2. Loss of GNSS signals: relevant independent equipage (e.g. IRU) is required for RNP AR APCH approaches with RF legs and approaches where the accuracy for the missed approach is less than 1 NM. For other approaches, operational procedures are used to approximate the published track and climb above obstacles.

3. Testing of ground navaid in the vicinity of the approach: aircraft and operational procedures are required to detect and mitigate this event.

6.4.2.11 Operating conditions

1. Tailwind conditions: excessive speed on RF legs will result in the inability to maintain track. This is addressed through aircraft requirements on the limits of command guidance, inclusion of 5 degrees of bank manoeuvrability margin, consideration of speed effect, and crew procedure to maintain speeds below the maximum authorized.

2. Wind conditions and effect on flight technical error: nominal flight technical error is evaluated under a variety of wind conditions, and crew procedure to monitor and limit deviations ensure safe operation.

3. Extreme temperature effects of barometric altitude (e.g. extreme cold temperatures, known local atmospheric or weather phenomena, high winds, severe turbulence, etc.): the effect of this error on the vertical path is mitigated through the procedure design and crew procedures, with an allowance for aircraft that compensate for this effect to conduct procedures regardless of the published temperature limit. The effect of this error on minimum segment altitudes and the decision altitude are addressed in an equivalent manner to all other approach operations.

6.5 REFERENCES

Copies of EUROCAE documents may be purchased from EUROCAE, 102 rue Etienne Dolet, 92240 Malakoff, France (Fax: +33 1 46 55 62 65). Website: www.eurocae.eu

— EUROCAE/ED-12B Software Considerations in Airborne Systems and Equipment Certification

— EUROCAE/ED-58 MOPS for Area Navigation Equipment using Multi-sensor Inputs

— EUROCAE/ED-54 MOPR for Distance Measuring Equipment Interrogators (DMLE/N and DME/P)operating within the Radio Frequency Range 960 – 1215 Mhz (airborne equipment)

— EUROCAE/ED-72A Minimum Operational Performance Specification for airborne GPS receiving equipment intended used for supplemental means of navigation

— EUROCAE/ED-75B Minimum Aviation System Performance Specification required Navigation Performance for Area Navigation

— EUROCAE/ED-76 Standards for Processing Aeronautical Data

— EUROCAE/ED-77 Standards for Aeronautical Information

Copies of FAA documents may be obtained from Superintendent of Documents, Government Printing Office, Washington, DC 20402-9325, USA. Website: http://www.faa.gov/aircraft_cert/ (Regulatory and Guidance Library)

— TSO-C115B, Airborne Area Navigation Equipment Using Multi-Sensor Inputs

— TSO-C129A, Airborne Supplemental Navigation Equipment Using the Global Positioning System (GPS)

— TSO C145A, Airborne Navigation Sensors Using the Global Positioning System (GPS) Augmented by the Wide Area Augmentation System (WAAS)

— TSO C146A, Stand-Alone Airborne Navigation Equipment Using the Global Positioning System (GPS) Augmented by the Wide Area Augmentation System (WAAS)

— AC 20-129, Airworthiness Approval for Vertical Navigation (VNAV) Systems for Use in the U.S. National Airspace System (NAS) and Alaska

— AC 20-130A, Airworthiness Approval of Navigation or Flight Management Systems Integrating Multiple Navigation Sensors

— AC 20-138A, Airworthiness Approval of Global Positioning System (GPS) Navigation Equipment for Use as a VFR and IFR Supplemental Navigation System

— AC 20-153, Acceptance of Data Processes and Associated Navigation Databases

— AC 25-1309-1A, System Design and Analysis

— AC 25-15, Approval of Flight Management Systems in Transport Category Airplanes

— AC 23-1309-1C, Equipment, Systems and Installations in Part 23 Airplanes

— AC 120-29A, Criteria for Approval of Category I and Category II Weather Minima for Approach

— AC 90-101, Approval Guidance for RNP Procedures with Special Aircraft and Aircrew Authorization Required

Copies of RTCA documents may be obtained from RTCA Inc., 1140 Connecticut Avenue, N.W., Suite 1020, Washington, DC 20036-4001, USA, (Tel.: 1 202 833 9339). Website: www.rtca.org

— RTCA/DO-178B, Software Considerations in Airborne Systems and Equipment Certification

— RTCA/DO-187, Minimum Operational Performance Standards for Airborne Area Navigation Equipment Using Multi-Sensor Inputs

— RTCA/DO-189, Minimum Performance Standard for Airborne Distance Measuring Equipment (DME) Operating Within the Radio Frequency Range of 960-1215 Megahertz

— RTCA/DO-200A, Standards for Processing Aeronautical Data

— RTCA/DO-201A, User Recommendations for Aeronautical Information Services

— RTCA/DO-208, Minimum Operational Performance Standards for Airborne Supplemental Navigation Equipment Using Global Positioning System (GPS)

— RTCA/DO-229C, Minimum Operations Performance Standards for Airborne GPS/Wide Area Augmentation System Equipment

— RTCA/DO-236B, Minimum Aviation System Performance Standards: Required Navigation Performance for Area Navigation

— RTCA/DO-283A, Minimum Operational Performance Standards for Required Navigation Performance for Area Navigation

Copies of EASA documents may be obtained from EASA (European Aviation Safety Agency),101253, D-50452 Koln, Germany.

Copies of ICAO documents may be purchased from the International Civil Aviation Organization, Customer Services Unit, 999 University Street, Montréal, Quebec, Canada H3C 5H7 (Fax: 1 514 954 6769 or e-mail: sales_unit@icao.org) or through sales agents listed on the ICAO website: www.icao.int

Attachment to Volume II

ATTACHMENT

BAROMETRIC VNAV

1. INTRODUCTION

1.1 Background

This navigation specification addresses those systems based upon the use of barometric altitude and RNAV information in the definition of vertical flight paths, and vertical tracking to a path. The final approach segment of VNAV instrument flight procedures are performed using vertical guidance to a glide path computed by the on-board RNAV system. The glide path is contained in the specification of the instrument procedure within the RNAV system navigation database. For other phases of flight, Barometric VNAV (Baro-VNAV) provides vertical path information that can be defined by vertical angles or altitudes at fixes in the procedure.

1.2 Purpose

1.2.1 This specification provides guidance to States implementing instrument flight procedures where Barometric VNAV is authorized for RNP APCH approaches and RNP AR APCH, where approved. For the air navigation service provider, it provides a consistent ICAO recommendation on what to implement. For the operator, this reflects airworthiness guidance material that has existed for over 20 years. This specification is intended to facilitate operational approval for existing Barometric VNAV systems that have demonstrated their capabilities and obtained regulatory approval for usage. An operational approval based upon this standard allows an operator to conduct Barometric VNAV operations globally.

1.2.2 This specification provides airworthiness and operational criteria for the approval of an RNAV system using barometric altimetry as a basis for its vertical navigation capability.

2. ANSP CONSIDERATIONS

2.1 Application of Barometric VNAV

Barometric VNAV is intended to be applied where vertical guidance and information are provided to the flight crew on instrument approach procedures containing a vertical flight path defined by a vertical path angle. Barometric VNAV may also be defined by altitude constraints but only for flight phases other than approach. Guidance for operational use is provided in PANS-OPS (Doc 8168), Volume I.

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 PANS-OPS criteria do not provide specific guidance for the design of a Barometric VNAV overlay to a conventional non-precision procedure continuous descent final approach (CDFA). In such cases, many other considerations must be made to ensure continued obstacle clearance, flyability, charting consistency and compatibility with airborne systems.

3. GENERAL CONSIDERATIONS FOR DEVELOPMENT OF BAROMETRIC VNAV SPECIFICATION

3.1 Navaid infrastructure considerations

The procedure design does not have unique infrastructure requirements. These criteria are based upon the use of barometric altimetry by an airborne RNAV system whose performance capability supports the required operation. The procedure design should take into account the functional capabilities required by this document.

3.2 Publication considerations

Charting should follow the Standards of Annex 4 — *Aeronautical Charts* for the designation of an RNAV procedure where the vertical flight path is specified by a glide path angle. The charting designation will remain consistent with the current convention (e.g. if the lateral procedure is predicated on GNSS, the charting will indicate RNAV (GNSS)).

3.3 Monitoring and investigation of navigation and system errors

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.

3.4 Navigation error reports

3.4.1 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 approval for use of that equipment.

3.4.2 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.

3.5 Service provider assumptions

It is expected that air navigation service providers will provide data and information to enable correct and accurate altimeter settings on board the aircraft, as well as local temperature. These data must be from measurement equipment at the airport where the approach is to take place. The specific medium for transmission of these data and information to the aircraft may include voice communication, ATIS or other media. In support of this, it is also expected that service providers will assure the accuracy, currency and availability of meteorological data supporting VNAV operations.

3.6 ATC coordination

It is expected that ATC will be familiar with aircraft VNAV capabilities, as well as issues associated with altimeter setting and temperature data required by the aircraft.

4. NAVIGATION SPECIFICATION

4.1 Background

This section identifies the operational requirements for VNAV in conjunction with RNP APCH operations. It assumes the airworthiness approval of the aircraft and systems have been completed. This means the basis for the VNAV function and performance have already been established and approved based upon appropriate levels of analysis, testing and demonstration. Additionally, as part of this activity, the normal procedures, as well as any limitations for the function, have been documented, as appropriate, in the aircraft flight and operations manuals. Compliance with the operational requirements herein should be addressed through national operational regulations, and may, in some cases, require a specific operational approval. For example, certain operational regulations require operators to apply to their national authority (State of Registry) for operational approval.

4.2 Approval process

4.2.1 The following steps must be completed before the use of Barometric VNAV in the conduct of RNP AR APCH operations:

a) aircraft equipment eligibility must be determined and documented;

b) operating procedures must be documented;

c) flight crew training based upon the operating procedures must be documented;

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

e) operational approval should then be obtained in accordance with national operating rules.

4.2.2 Following the successful completion of the above steps, an operational approval for the use of VNAV, a Letter of Authorization or appropriate operations specification (Ops Spec), or an amendment to the operations manual, if required, should then be issued by the State.

4.3 Aircraft requirements

4.3.1 Aircraft eligibility

4.3.1.1 Relevant documentation acceptable to the State of operation must be available to establish that the aircraft is equipped with an RNAV system with a demonstrated VNAV capability. Eligibility may be established in two steps, one recognizing the qualities and qualifications of the aircraft and equipment, and the second determining the acceptability for operations. The determination of eligibility for existing systems should consider acceptance of manufacturer documentation of compliance, e.g. AC20-129.

Note.— RNP AR systems: RNAV systems demonstrated and qualified for RNP AR operations including VNAV are considered qualified with recognition that the RNP approaches are expected to be performed consistent with the operators RNP AR approval. No further examination of aircraft capability, operator training, maintenance, operating procedures, databases, etc. is necessary.

a) Description of aircraft equipment. The operator must have a configuration list detailing pertinent components and equipment to be used for approach operation.

Note.— Barometric altimetry and related equipment such as air data systems are a required basic capability and already subject to minimum equipment requirements for flight operations.

b) Training documentation. Commercial operators should have a training programme addressing the operational practices, procedures and training related to VNAV in approach operations (e.g. initial, upgrade or recurrent training for flight crew, dispatchers or maintenance personnel).

Note.— It is not required to establish a separate training programme or regimen if RNAV and VNAV training is already an integrated element of a training programme. However, it should be possible to identify what aspects of VNAV are covered within a training programme. Private operators should be familiar with the practices and procedures identified in 4.21 "Pilot knowledge and training".

c) Operations manuals and checklists. Operations manuals and checklists for commercial operators must address information/guidance on the standard operating procedures detailed in 4.16. The appropriate manuals should contain navigation operating instructions and contingency procedures, where specified. Manuals and checklists must be submitted for review as part of the application process.

4.3.1.2 Private operators should operate using the practices and procedures identified in 4.21 "Pilot knowledge and training".

4.4 Minimum equipment list (MEL) considerations

Any unique MEL revisions necessary to address VNAV for approach provisions must be approved. Operators must adjust the MEL, or equivalent, and specify the required dispatch conditions.

Note.— Barometric altimetry and related systems are minimum equipment for all operations. Any unique dispatch or operational assumptions should be documented.

4.5 Aircraft system requirements

4.5.1 Barometric vertical navigation (VNAV) system performance

Barometric VNAV approach operations are based upon the use of RNAV equipment that automatically determines aircraft position in the vertical plane using inputs from equipment that can include:

a) FAA TSO-C106, Air Data Computer;

b) air data system, ARINC 706, Mark 5 Air Data System;

c) barometric altimeter system, DO-88 Altimetry, ED-26 MPS for Airborne Altitude Measurements and Coding Systems, ARP-942 Pressure Altimeter Systems, ARP-920 Design and Installation of Pitot Static Systems for Transport Aircraft; and

d) type certified integrated systems providing an air data system capability comparable to item b).

Note 1.— Positioning data from other sources may be integrated with the barometric altitude information provided it does not cause position errors exceeding the track keeping accuracy requirements.

Note 2.— Altimetry system performance is demonstrated separately through the static pressure systems certification (e.g. FAR or CS 25.1325), where performance must be 30 ft per 100 KIAS. Altimetry systems meeting such a requirement will satisfy the altimetry system error (ASE) requirements for Barometric VNAV. No further demonstration or compliance is necessary.

4.6 System accuracy

a) For instrument approach operations, the error of the airborne VNAV equipment, excluding altimetry, should have been demonstrated to be less than that shown below on a 99.7 per cent probability basis:

	Level flight segments and climb/descent intercept altitude region of specified altitudes	*Climb/descent along specified vertical profile (angle)*
At or below 1 500 m (5 000 ft)	15 m (50 ft)	30 m (100 ft)
1 500 m to 3 000 m (5 000 ft to 10 000 ft)	15 m (50 ft)	45 m (150 ft)
Above 3 000 m (10 000 ft)	15 m (50 ft)	67 m (220 ft)

Notes.—

1. *Maximum operating altitudes to be predicated on a compliance with total accuracy tolerance.*

2. *VNAV guidance may be used in level flight en route as in the case of altitude hold control laws, which are integrated with speed control laws to provide an energy trade. The incremental error component contributed by the VNAV equivalent must be offset by a corresponding reduction in other error components, such as flight technical error, to ensure that the total error budget is not exceeded.*

3. *Altimetry error refers to the electrical output and includes all errors attributable to the aircraft altimetry installation including position effects resulting from normal aircraft flight attitudes. In high performance aircraft, it is expected that altimetry correction will be provided. Such a correction should be done automatically. In lower performance aircraft, upgrading of the altimetry system may be necessary.*

4. *VNAV equipment error includes all errors resulting from the vertical guidance equipment installation. It does not include errors of the altimeter system, but does include any additional errors resulting from the addition of the VNAV equipment. This error component may be zero in level en-route flight if the operation is limited to guidance by means of the altimeter only. It should not be disregarded in terminal and approach operations where the pilot is expected to follow the VNAV indications.*

5. *The vertical error component of an along track positioning error is bounded by the following equipment qualification requirements for Barometric VNAV, and is directly reflected in the along-track tolerance offset used in Barometric VNAV procedure design criteria:*

— GNSS navigation systems certified for approach or multi-sensor systems using IRU in combination with GNSS;

or

— RNP systems approved for RNP 0.3 or less;
— serviceable VNAV equipment;
— VNAV system certified for Barometric VNAV approach operations;
— Equipped with integrated LNAV/VNAV system with accurate source of barometric altitude; and
— VNAV altitudes and procedure information from a navigation database with integrity through quality assurance.

b) Flight technical (pilotage) errors. With satisfactory displays of vertical guidance information, flight technical errors should have been demonstrated to be less than the values shown below on a three-sigma basis.

	Level flight segments and climb/descent intercept altitude region of specified altitudes	*Climb/descent along specified vertical profile (angle)*
At or below 1 500 m (5 000 ft)	45 m (150 ft)	60 m (200 ft)
1 500 m to 3 000 m (5 000 ft to 10 000 ft)	73 m (240 ft)	91 m (300 ft)
Above 3 000 m (10 000 ft)	73 m (240 ft)	91 m (300 ft)

Sufficient flight tests of the installation should have been conducted to verify that these values can be maintained. Smaller values for flight technical errors may be achieved especially in the cases where the VNAV system is to be used only when coupled to an autopilot or flight director. However, at least the total system vertical accuracy shown below should be maintained.

If an installation results in larger flight technical errors, the total vertical error of the system (excluding altimetry) may be determined by combining equipment and flight technical errors using the root sum square (RSS) method. The result should be less than the values listed below.

	Level flight segments and climb/descent intercept altitude region of specified altitudes	*Climb/descent along specified vertical profile (angle)*
At or below 1 500 m (5 000 ft)	48 m (158 ft)	68 m (224 ft)
1 500 m to 3 000 m (5 000 ft to 10 000 ft)	74 m (245 ft)	102 m (335 ft)
Above 3 000 m (10 000 ft)	74 m (245 ft)	113 m (372 ft)

An acceptable means of complying with these accuracy requirements is to have an RNAV system approved for VNAV approaches in accordance with the criteria of FAA AC20-129 and an altimetry system approved in accordance with FAR/CS 25.1325 or equivalent.

4.7 Continuity of function

4.7.1 For operations predicated on the use of barometric VNAV capability, at least one RNAV system is required.

4.7.2 Vertical navigation functions

4.7.2.1 *Path definition*

4.7.2.1.1 The requirements for defining the vertical path are governed by the two general requirements for operation: allowance for aircraft performance, and repeatability and predictability in path definition. This operational relationship leads to the specifications in the following sections that are based upon specific phases of flight and flight operations.

4.7.2.1.2 The navigation system must be capable of defining a vertical path by a flight path angle to a fix. The system must also be capable of specifying a vertical path between altitude constraints at two fixes in the flight plan. Fix altitude constraints must be defined as one of the following:

a) An “AT or ABOVE” altitude constraint (e.g. 2400A, may be appropriate for situations where bounding the vertical path is not required);

b) An “AT or BELOW” altitude constraint (e.g. 4800B, may be appropriate for situations where bounding the vertical path is not required);

c) An “AT” altitude constraint (e.g. 5200); or

d) A “WINDOW” constraint (e.g. 2400A3400B).

Note.— For RNP AR approach procedures, any segment with a published vertical path will define that path based on an angle to the fix and altitude.

4.8 Vertical constraints

Altitudes and/or speeds associated with published procedures must be automatically extracted from the navigation database upon selecting the approach procedure.

4.9 Path construction

The system must be able to construct a path to provide guidance from the current position to a vertically constrained fix.

4.10 Capability to load procedures from the navigation database

The navigation system must have the capability to load and modify the entire procedure(s) to be flown, based upon ATC instructions, into the RNAV system from the on-board navigation database. This includes the approach (including vertical angle), the missed approach and the approach transitions for the selected airport and runway. The navigation system should preclude modification of the procedure data contained in the navigation database.

4.11 Temperature limits

For aircraft using Barometric VNAV without temperature compensation to conduct the approach, low temperature limits are reflected in the procedure design and identified along with any high temperature limits on the charted procedure. Cold temperatures reduce the actual glide path angle, while high temperatures increase the actual glide path angle. Aircraft using Barometric VNAV with temperature compensation or aircraft using an alternate means for vertical guidance (e.g. SBAS) may disregard the temperature restrictions.

4.12 Guidance and control

For the vertical performance requirements, the path steering error budget must reflect altitude reference as well as other factors, such as roll compensation and speed protection, as applicable.

4.13 User interface

4.13.1 Displays and control

The display resolution (readout) and entry resolution for vertical navigation information should be as follows:

Parameter	*Display resolution (readout)*	*Entry resolution*
Altitude	Flight level or (1 ft)	Flight level or (1 ft)
Vertical path deviation	10 ft	Not applicable
Flight path angle	0.1°	0.1°
Temperature	1°	1°

4.14 Path deviation and monitoring

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 vertically defined path. The display must allow the pilot to readily distinguish if the vertical deviation exceeds +30 m/–15 m (+100 ft/–50 ft). The deviation should be monitored, and action taken to minimize errors.

a) It is recommended that an appropriately-scaled non-numeric deviation display (i.e. vertical deviation indicator) be located in the pilot's primary optimum field of view. A fixed-scale deviation indicator is acceptable as long as it demonstrates appropriate scaling and sensitivity for the intended operation. Any alerting and annunciation limits must also match the scaling values.

   Note.— Existing systems provide for vertical deviation scaling with a range of ±500 ft. Such deviation scaling should be assessed consistent with the above requirement on discernability.

b) In lieu of appropriately scaled vertical deviation indicators in the pilot's primary optimum field of view, a numeric display of deviation may be acceptable depending on the flight crew workload and the numeric display characteristics. A numeric display may require additional initial and recurrent flight crew training.

c) Since vertical deviation scaling and sensitivity varies widely, eligible aircraft must also be equipped with and operationally using either a flight director or autopilot capable of following the vertical path.

4.15 Barometric altitude

The aircraft must display barometric altitude from two independent altimetry sources, one in each pilot's primary optimum field of view. Operator procedures should ensure current altimeter settings for the selected instrument procedure and runway.

4.16 Operating procedures

Airworthiness certification alone does not authorize operators to utilize VNAV capability during the conduct of flight operations. Operational approval is required to confirm the adequacy of the operator's normal and contingency procedures for the particular equipment installation. Pilots should use a flight director or autopilot when flying a vertical path based on VNAV.

4.17 General operating procedures

The pilot should comply with any instructions or procedures identified by the manufacturer as necessary to comply with the performance requirements in this chapter.

4.18 Altimeter setting

Flight crews should take precautions to switch altimeter settings at appropriate times or locations and request a current altimeter setting if the reported setting may not be recent, particularly at times when pressure is reported or is expected to be rapidly decreasing. Remote altimeter settings are not allowed.

4.19 Cold temperature

When cold weather temperatures exist, the pilot should check the chart for the instrument approach procedure to determine the limiting temperature for the use of Barometric VNAV capability. If the airborne system contains a temperature compensation capability, the manufacturer's instructions should be followed for the use of the Barometric VNAV function.

4.20 Contingency procedures

Where the contingency procedure requires reversion to a conventional procedure, necessary preparations should be completed before commencing the RNAV procedure, consistent with operator practices.

4.21 Pilot knowledge and training

4.21.1 The training programme should provide sufficient training (e.g. simulator, training device, or aircraft) on the aircraft's VNAV capability to the extent that the pilots are not just task-oriented, including:

a) the information in this chapter;

b) the meaning and proper use of aircraft systems;

c) procedure characteristics, as determined from chart depiction and textual description:

   i) depiction of waypoint types (flyover and fly-by) and path terminators and any other types used by the operator) as well as associated aircraft flight paths;

   ii) RNAV system-specific information;

   iii) levels of automation, mode annunciations, changes, alerts, interactions, reversions, and degradation;

   iv) functional integration with other aircraft systems;

   v) the meaning and appropriateness of vertical path discontinuities as well as related flight crew procedures;

   vi) monitoring procedures for each phase of flight (e.g. monitor “PROGRESS” or “LEGS” page);

   vii) turn anticipation with consideration to speed and altitude effects; and

   viii) interpretation of electronic displays and symbols.

4.21.2 VNAV equipment operating procedures, as applicable, including how to perform the following actions:

a) adhere to speed and/or altitude constraints associated with an approach procedure;

b) verify waypoints and flight plan programming;

c) fly direct to a waypoint;

d) determine vertical-track error/deviation;

e) insert and delete route discontinuity;

f) change arrival airport and alternate airport;

g) contingency procedures for VNAV failures;

h) there should be a clear understanding of crew requirements for comparisons to primary altimeter information, altitude cross-checks (e.g. altimetry comparisons of 30 m (100 ft), temperature limitations for instrument procedures using VNAV, and procedures for altimeter settings for approach; and

i) discontinuation of a procedure based upon loss of systems or performance and flight conditions, e.g. inability to maintain required path tracking, loss of required guidance, etc.

4.21.3 Additional operations guidance related to the considerations reflected in the procedure design are included in PANS-OPS, (Doc 8168), Volume I.

4.22 Navigation database

4.22.1 The navigation database should be obtained from a supplier holding an EASA or FAA Letter of Acceptance (LOA). This LOA demonstrates compliance with EUROCAE/RTCA document ED-76/DO-200A, Standards for

Processing Aeronautical Data. FAA AC 20-153/EASA IR 21 sub-part G provides additional guidance on Type 1 and Type 2 LOAs.

4.22.2 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 flight crew.

4.22.3 Aircraft operators should consider the need to conduct periodic checks of the operational navigation databases in order to meet existing quality system requirements.

4.23 REFERENCES

Copies of EUROCAE documents may be purchased from EUROCAE, 102 rue Etienne Dolet, 92240 Malakoff, France (Fax: +33 1 46 55 62 65). Website: www.eurocae.eu

— EUROCAE/ED-76 Standards for Processing Aeronautical Data

— EUROCAE/ED-77 Standards for Aeronautical Information

Copies of FAA documents may be obtained from Superintendent of Documents, Government Printing Office, Washington, DC 20402-9325, USA. Website: http://www.faa.gov/aircraft_cert/ (Regulatory and Guidance Library)

— AC 20-129, Airworthiness Approval for Vertical Navigation (VNAV) Systems for Use in the U.S. National Airspace System (NAS) and Alaska

— AC 20-153, Acceptance of Data Processes and Associated Navigation Databases

Copies of RTCA documents may be obtained from RTCA Inc., 1140 Connecticut Avenue, N.W., Suite 1020, Washington, DC 20036-4001, USA, (Tel.: 1 202 833 9339). Website: www.rtca.org

— RTCA/DO-200A, Standards for Processing Aeronautical Data

— RTCA/DO-201A, User Recommendations for Aeronautical Information Services

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