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Subject: Guidance material for the issuance of performance based navigation (PBN) operational approvals

Action required: To note and take action where applicable in accordance with paragraph 5

Sir/Madam,

1. I have the honour to invite your attention to the guidance material concerning the implementation of performance based navigation (PBN) operations which is available in English and attached to the electronic version of this State letter on the ICAO-NET website (www.icao.int/icaoenet). The guidance material was prepared by the International Civil Aviation Organization (ICAO) with the assistance of the Required Navigation Performance Special Operations Requirements Study Group (RNPSORSG) to support the harmonized introduction of area navigation (RNAV) for all phases of flight. Attached please find background information on PBN.

2. The material provided contains the PBN implementation guidance for the Air Navigation Service Provider as well as guidance on the issuance of operational approvals for PBN for different phases of flight. This material will become Volume II of the new *Performance Based Navigation Manual* (Doc 9613) which will replace the *Manual on Required Navigation Performance* (RNP).

3. Noting the great demand expressed by States to commence implementation of ATS routes and instrument flight procedures based on PBN, and in order to avoid proliferation of operational approval requirements, the relevant guidance material taken from the manual is being distributed at an earlier date so that States may make advance use of this critical information prior to publication of the new edition of the manual.

4. In order to assist States and operators with the implementation of PBN operations, ICAO will organize workshops in all regions of the world. Details on these regional workshops will follow in a separate mailing.

5. All States wishing to implement PBN operations are urged to establish an appropriate approval process in accordance with the attached guidance material.

Accept, Sir/Madam, the assurances of my highest consideration.



Taïeb Chérif
Secretary General

Enclosures:

- A — Background information on PBN
- B — Guidance material concerning the implementation of performance based navigation (PBN) operations

**BACKGROUND INFORMATION ON PERFORMANCE BASED (PBN)
NAVIGATION**

1. Performance based navigation (PBN) is a concept that encompasses both area navigation (RNAV) and required navigation performance (RNP) and revises the current RNP concept. Performance based navigation is increasingly seen as the most practical solution for regulating the expanding domain of navigation systems.
2. Under the traditional approach, each new technology is associated with a range of system-specific requirements for obstacle clearance, aircraft separation, operational aspects (e.g. arrival and approach procedures), aircrew operational training and training for air traffic controllers. However, this system-specific approach imposes an unnecessary effort and expense on ICAO as well as on States, airlines and air navigation services (ANS) providers.
3. Performance based navigation eliminates the need for redundant investment in developing criteria and in operational modifications and training. Rather than build an operation around a particular system, under performance based navigation the operation is defined according to the operational goals, and the available systems are then evaluated to determine whether they are supportive.
4. The advantage of this approach is that it enables harmonized and predictable flight paths which result in more efficient use of existing aircraft capabilities, as well as improved safety, greater airspace capacity, better fuel efficiency, and resolution of noise issues.
5. The navigation specifications in Attachment B to this letter will be contained in the *Performance Based Navigation Manual* (Doc 9613). Currently these navigation specifications are limited to RNAV 10, RNAV 5, RNAV 1 and 2, RNP 4, Basic-RNP 1, RNP APCH, and RNP AR APCH. It is the intent that as operational needs arise in the future, additional navigation specifications will be created to address these requirements.

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ATTACHMENT B to State letter AN 11/45-07/22

**GUIDANCE MATERIAL CONCERNING THE IMPLEMENTATION
OF
PERFORMANCE BASED NAVIGATION (PBN) OPERATIONS**

TABLE OF CONTENTS

Foreword	viii
Abbreviations.....	ix
Explanation of Terms	x

PART A – GENERAL

CHAPTER 1 - INTRODUCTION

1.1. PBN CONCEPT REVIEW	A-1-1
1.2. USE AND SCOPE OF NAVIGATION SPECIFICATIONS	A-1-1
1.2.1. Scope of ICAO Navigation Specifications.....	A-1-3
1.2.2. Navigation Specifications and the Approval process.....	A-1-3

CHAPTER 2 - ON-BOARD PERFORMANCE MONITORING AND ALERTING

2.1. INTRODUCTION	A-2-1
2.2. NAVIGATION ERROR COMPONENTS AND ALERTING	A-2-1
2.2.1. Lateral Navigation.....	A-2-1
2.2.2. Longitudinal Navigation.....	A-2-2
2.3. ROLE OF ON-BOARD PERFORMANCE MONITORING AND ALERTING.....	A-2-2
2.3.1. Performance Monitoring and Alerting Requirements for RNP	A-2-4
2.3.1.1. RNP-4, Basic-RNP 1 and RNP APCH	A-2-4
2.3.1.2. Application of Performance Monitoring and Alerting to Aircraft	A-2-5
2.3.1.3. Application of Performance Monitoring and Alerting to Risk Evaluations	A-2-5
2.3.1.4. Application of Performance Monitoring and Alerting for RNP AR APCH	A-2-6
2.3.1.5. System performance, monitoring and alerting requirements	A-2-6

CHAPTER 3 - SAFETY ASSESSMENT CONSIDERATIONS

3.1. INTRODUCTION	A-3-1
3.2. AIRCRAFT PERFORMANCE	A-3-1
3.3. SYSTEM FAILURES	A-3-1
3.4. INFRASTRUCTURE.....	A-3-2
3.4.1. Failure of Navigation Aid environment.....	A-3-2
3.4.2. ATS Surveillance and Communication.....	A-3-2

PART B - IMPLEMENTING RNAV

CHAPTER 1 - IMPLEMENTING RNAV 10 (RNP 10)

1.1. INTRODUCTION	B-1-1
1.1.1. Background	B-1-1
1.1.2. Purpose.....	B-1-1
1.2. ANSP CONSIDERATIONS	B-1-1
1.2.1. Navaid Infrastructure.....	B-1-1
1.2.2. Communication and ATS Surveillance.....	B-1-1

1.2.3.	Obstacle Clearance and Route Spacing.....	B-1-2
1.2.4.	Additional Considerations	B-1-2
1.2.5.	Publication.....	B-1-2
1.2.6.	Controller Training.....	B-1-2
1.2.7.	Status Monitoring	B-1-2
1.2.8.	ATS System Monitoring	B-1-3
1.3.	NAVIGATION SPECIFICATION	B-1-3
1.3.1.	Background	B-1-3
1.3.2.	Approval Process	B-1-3
1.3.2.1.	Contents of an Application for an RNP 10 Operational Approval	B-1-4
1.3.2.2.	Operational Approval.....	B-1-5
1.3.3.	Aircraft Requirements	B-1-6
1.3.3.1.	System Performance, Monitoring and Alerting.....	B-1-6
1.3.3.2.	Criteria for Specific Navigation Services	B-1-7
1.3.4.	Operating Procedures	B-1-8
1.3.4.1.	Flight Planning.....	B-1-8
1.3.4.2.	Pre-Flight Procedures.....	B-1-9
1.3.4.3.	Navigation Equipment	B-1-9
1.3.4.4.	Flight Plan Designation	B-1-9
1.3.4.5.	Availability of Nav aids.....	B-1-9
1.3.4.6.	En Route.....	B-1-9
1.3.4.7.	Route Evaluation for RNP 10 Time Limits for Aircraft Equipped Only With INs or IRUs....	B-1-10
1.3.4.8.	Effect of En-route Updates	B-1-11
1.3.4.9.	Automatic Radio Position Updating.....	B-1-11
1.3.4.10.	Manual Radio Position Updating	B-1-11
1.3.5.	Pilot Knowledge and Training	B-1-12
1.3.6.	Navigation Database	B-1-12
1.3.7.	Oversight of Operators	B-1-12
1.4.	REFERENCES	B-1-12

CHAPTER 2 - IMPLEMENTING RNAV 5

2.1.	INTRODUCTION	B-2-1
2.1.1.	Background	B-2-1
2.1.2.	Purpose.....	B-2-1
2.2.	ANSP CONSIDERATIONS	B-2-2
2.2.1.	Navaid Infrastructure.....	B-2-2
2.2.2.	Communication & ATS Surveillance.....	B-2-2
2.2.3.	Obstacle Clearance and Route Spacing.....	B-2-2
2.2.4.	Additional Considerations	B-2-3
2.2.5.	Publication.....	B-2-3
2.2.6.	Controller Training.....	B-2-3
2.2.7.	Status monitoring	B-2-4
2.2.8.	ATS System Monitoring	B-2-4
2.3.	NAVIGATION SPECIFICATION	B-2-4
2.3.1.	Background	B-2-4
2.3.2.	Approval Process	B-2-5
2.3.2.1.	Aircraft Eligibility	B-2-5
2.3.2.2.	Operational Approval.....	B-2-5
2.3.3.	Aircraft Requirements	B-2-6
2.3.3.1.	System Performance, Monitoring and Alerting.....	B-2-6
2.3.3.2.	Criteria for Specific Navigation Services	B-2-7
2.3.3.3.	Functional Requirements	B-2-8
2.3.4.	Operating Procedures	B-2-8

2.3.5.	Pilot Knowledge and Training	B-2-10
2.3.6.	Navigation Data Base	B-2-11
2.3.7.	Oversight of Operators	B-2-11
2.4.	REFERENCES	B-2-12

CHAPTER 3 - IMPLEMENTING RNAV 1 AND RNAV 2

3.1.	INTRODUCTION	B-3-1
3.1.1.	Background	B-3-1
3.1.2.	Purpose.....	B-3-1
3.2.	ANSP CONSIDERATIONS	B-3-2
3.2.1.	Navaid Infrastructure.....	B-3-2
3.2.2.	Communication & ATS Surveillance.....	B-3-3
3.2.3.	Obstacle Clearance and Route Spacing.....	B-3-3
3.2.4.	Additional Considerations	B-3-4
3.2.5.	Publication.....	B-3-4
3.2.6.	Controller Training.....	B-3-4
3.2.7.	Status monitoring	B-3-5
3.2.8.	ATS System Monitoring	B-3-5
3.3.	NAVIGATION SPECIFICATION	B-3-5
3.3.1.	Background	B-3-5
3.3.2.	Approval Process	B-3-5
3.3.2.1.	Aircraft Eligibility	B-3-6
3.3.2.2.	Operational Approval.....	B-3-6
3.3.2.3.	PBN Navigation Specification and the Approval Process	B-3-7
3.3.2.4.	Migration Path to RNAV 1 and RNAV 2	B-3-7
3.3.2.5.	Summary of RNAV 1 / TGL-10 / AC 90-100 Insignificant Differences	B-3-9
3.3.3.	Aircraft Requirements	B-3-9
3.3.3.1.	System performance, monitoring and alerting	B-3-10
3.3.3.2.	Criteria For Specific Navigation Services	B-3-10
3.3.3.3.	Functional Requirements – Navigation Displays and Functions	B-3-14
3.3.4.	Operating Procedures	B-3-17
3.3.4.1.	Pre-flight Planning	B-3-17
3.3.4.2.	General Operating Procedures	B-3-18
3.3.4.3.	RNAV SID Specific Requirements	B-3-19
3.3.4.4.	RNAV STAR Specific Requirements.....	B-3-20
3.3.4.5.	Contingency Procedures	B-3-21
3.3.5.	Pilot Knowledge and Training	B-3-21
3.3.6.	Navigation Database	B-3-22
3.3.7.	Oversight of Operators	B-3-22
3.4.	REFERENCES	B-3-23

Appendix 1: Non-Significant differences between P-RNAV, US RNAV and RNAV 1

PART C – IMPLEMENTING RNP

CHAPTER 1- IMPLEMENTING RNP 4

1.1.	INTRODUCTION	C-1-1
1.1.1.	Background	C-1-1
1.1.2.	Purpose.....	C-1-1
1.2.	ANSP CONSIDERATIONS	C-1-1
1.2.1.	Navaid Infrastructure Considerations	C-1-1
1.2.2.	Communication and Surveillance Considerations.....	C-1-1

1.2.3.	Obstacle Clearance and Route Spacing.....	C-1-1
1.2.4.	Additional Considerations	C-1-2
1.2.5.	Publication.....	C-1-2
1.2.6.	Controller Training.....	C-1-2
1.2.7.	Status Monitoring	C-1-2
1.2.8.	ATS System Monitoring	C-1-3
1.3.	NAVIGATION SPECIFICATION	C-1-3
1.3.1.	Background	C-1-3
1.3.2.	Approval Process	C-1-3
1.3.2.1.	Aircraft Eligibility	C-1-3
1.3.2.2.	Operational Approval.....	C-1-4
1.3.3.	Aircraft Requirements	C-1-5
1.3.3.1.	System Performance, Monitoring and Alerting	C-1-6
1.3.3.2.	Functional Requirements.....	C-1-6
1.3.3.3.	Explanation of Required Functionalities	C-1-7
1.3.4.	Operating Procedures	C-1-9
1.3.5.	Pilot Knowledge and Training	C-1-10
1.3.6.	Navigation Database	C-1-11
1.3.7.	Oversight of Operators	C-1-11
1.4.	REFERENCES	C-1-11
1.4.1.	Websites	C-1-11
1.4.2.	Related Publications	C-1-11

CHAPTER 2 - IMPLEMENTING RNP 2 (to be developed)

CHAPTER 3 - IMPLEMENTING BASIC-RNP 1

3.1.	INTRODUCTION	C-3-1
3.1.1.	Background	C-3-1
3.1.2.	Purpose.....	C-3-1
3.2.	ANSP CONSIDERATIONS	C-3-1
3.2.1.	Navaid Infrastructure Considerations	C-3-1
3.2.2.	Communication & ATS Surveillance Considerations	C-3-1
3.2.3.	Obstacle Clearance and Horizontal Separation.....	C-3-2
3.2.4.	Additional Considerations	C-3-2
3.2.5.	Publication.....	C-3-2
3.2.6.	Controller Training.....	C-3-2
3.2.7.	Status monitoring	C-3-3
3.2.8.	ATS System Monitoring	C-3-3
3.3.	NAVIGATION SPECIFICATION	C-3-3
3.3.1.	Background	C-3-3
3.3.2.	Approval Process	C-3-3
3.3.2.1.	Aircraft Eligibility.....	C-3-3
3.3.2.2.	Operational Approval	C-3-4
3.3.3.	Aircraft Requirements	C-3-4
3.3.3.1.	System Performance, Monitoring and Alerting	C-3-5
3.3.3.2.	Criteria for Specific Navigation Systems.....	C-3-5
3.3.3.3.	Functional Requirements.....	C-3-5
3.3.4.	Operating Procedures	C-3-8

3.3.5.	Pilot Knowledge and Training	C-3-11
3.3.6.	Database	C-3-12
3.3.7.	Oversight of Operators	C-3-13
3.4.	REFERENCES	C-3-13

CHAPTER 4 - IMPLEMENTING ADVANCED-RNP 1 (to be developed)

CHAPTER 5 - IMPLEMENTING RNP APCH

5.1.	INTRODUCTION	C-5-1
5.1.1.	Background	C-5-1
5.1.2.	Purpose.....	C-5-1
5.2.	ANSP CONSIDERATIONS	C-5-1
5.2.1.	Navaid Infrastructure.....	C-5-1
5.2.2.	Communication & ATS Surveillance.....	C-5-2
5.2.3.	Obstacle Clearance	C-5-2
5.2.4.	Additional Considerations	C-5-2
5.2.5.	Publication.....	C-5-2
5.2.6.	Controller Training.....	C-5-2
5.2.7.	Status monitoring	C-5-3
5.2.8.	ATS System Monitoring	C-5-3
5.3.	NAVIGATION SPECIFICATION	C-5-3
5.3.1.	Background	C-5-3
5.3.2.	Approval Process	C-5-3
5.3.2.1	Aircraft Eligibility	C-5-4
5.3.2.2	Operational Approval.....	C-5-4
5.3.3.	Aircraft Requirements	C-5-5
5.3.3.1.	System Performance, Monitoring and Alerting	C-5-5
5.3.3.2.	Criteria for Specific Navigation Systems.....	C-5-6
5.3.3.3.	Functional Requirements.....	C-5-6
5.3.4.	Operating Procedures	C-5-7
5.3.4.1	Pre-flight Planning	C-5-8
5.3.4.2	Prior to Commencing the Procedure	C-5-8
5.3.4.3	During the Procedure	C-5-9
5.3.4.4	General Operating Procedures	C-5-10
5.3.4.5	Contingency Procedures	C-5-10
5.3.5.	Pilot Knowledge and Training	C-5-10
5.3.6.	Navigation Database	C-5-11
5.3.7.	Oversight of Operators	C-5-12
5.4.	REFERENCES	C-5-12

CHAPTER 6 - IMPLEMENTING RNP AR APCH

6.1.	INTRODUCTION	C-6-1
6.1.1	Background	C-6-1
6.1.2	Purpose.....	C-6-1
6.2	ANSP CONSIDERATIONS	C-6-1
6.2.1	Navaid Infrastructure Considerations	C-6-1
6.2.2	Communication & ATS Surveillance Considerations	C-6-1
6.2.3	Obstacle Clearance and Route Spacing.....	C-6-1

6.2.4	Additional Considerations	C-6-2
6.2.5	Publication.....	C-6-2
6.2.6	Controller Training.....	C-6-2
6.2.7	Status monitoring	C-6-3
6.2.8	ATS System Monitoring	C-6-3
6.3	NAVIGATION SPECIFICATION	C-6-3
6.3.1	Background	C-6-3
6.3.2	Approval Process	C-6-3
6.3.2.1	Aircraft Eligibility.....	C-6-4
6.3.2.2	Operational Approval	C-6-4
6.3.2.3	Approval Submittal.....	C-6-5
6.3.3	Aircraft Requirements	C-6-5
6.3.3.1	System Performance, Monitoring and Alerting	C-6-5
6.3.3.2	Criteria For Specific Navigation Services	C-6-6
6.3.3.3	Functional Requirements.....	C-6-7
6.3.4	Operating Procedures	C-6-12
6.3.5	Pilot/Dispatch/Operator Knowledge and Training.....	C-6-16
6.3.6	Navigation Database	C-6-21
6.3.7	Oversight of Operators	C-6-22
6.4	SAFETY ASSESSMENT	C-6-22
6.5	REFERENCES	C-6-24

ATTACHMENTS

Attachment A: Baro VNAV

1.1.	INTRODUCTION	Attachment A, Page-3
1.1.1.	Background.....	Attachment A, Page-3
1.1.2.	Purpose.....	Attachment A, Page-3
1.2.	ANSP CONSIDERATIONS	Attachment A, Page-3
1.2.1.	Application of BARO-VNAV	Attachment A, Page-3
1.2.2.	Obstacle Clearance	Attachment A, Page-3
1.3.	GENERAL CONSIDERATIONS FOR DEVELOPMENT OF BARO-VNAV SPECIFICATION	Attachment A, Page-3
1.3.1.	Navaid Infrastructure Considerations	Attachment A, Page-3
1.3.2.	Publication Considerations	Attachment A, Page-3
1.3.3.	Monitoring and investigation of navigation and system errors.....	Attachment A, Page-4
1.3.4.	Navigation Error Reports	Attachment A, Page-4
1.3.5.	Service Provider Assumptions.....	Attachment A, Page-4
1.3.6.	ATC Coordination	Attachment A, Page-4
1.4.	NAVIGATION SPECIFICATION	Attachment A, Page-4
1.4.1.	Background	Attachment A, Page-4
1.4.2.	Approval Process	Attachment A, Page-4
1.4.3.	Aircraft Requirements	Attachment A, Page-4
1.4.3.2.	Minimum Equipment List (MEL) Considerations.....	Attachment A, Page-5
1.4.4.	Aircraft System Requirements	Attachment A, Page-5
1.4.4.1.	Barometric Vertical Navigation (VNAV) System Performance.....	Attachment A, Page-5
1.4.4.2.	Vertical Navigation Functions	Attachment A, Page-7
1.4.4.3.	Guidance and Control	Attachment A, Page-8
1.4.4.4.	User Interface	Attachment A, Page-8
1.4.5.	Operating Procedures	Attachment A, Page-9
1.4.5.1.	General Operating Procedures.....	Attachment A, Page-9

1.4.5.2.	Contingency Procedures	Attachment A, Page-9
1.4.6.	Pilot Knowledge and Training	Attachment A, Page-9
1.4.7.	Database	Attachment A, Page-10
1.5.	REFERENCES	Attachment A, Page-10

FOREWORD

This guidance material will become Volume II of the Performance Based Navigation Manual (Doc 9613).

The Performance Based Navigation Manual will consist of two volumes:

Volume I: - Concept and Implementation Guidance.

Volume II: - Implementing RNAV and RNP

Volume II is comprised of three Parts:

Part A, General

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

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

Attachments to Volume II, contains one attachment on *Barometric VNAV*.

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

These chapter follows the same structure –

- Introduction
- ANSP considerations
- Navigation Specification
- References
- Attachments

Specific Remarks

The contents of this guidance material are the product of deliberations by ICAO's RNPSORSG and as such, the material it contains has relied to a large extent on the experiences of States which have used RNAV operations. This guidance material should not be read in isolation. It is an integral part and complementary to the Performance Based Navigation Manual (Doc 9613), Volume I, *Concept and Implementation Guidance* that is currently in final draft, available on the ICAO net. References are only provided at the end of each navigation specification in parts B and C of this guidance material.

ABBREVIATIONS

ABAS	Aircraft-Based Augmentation System	MNPS	Minimum Navigation Performance Specification
ADS-B	Automated Dependent Surveillance-Broadcast	Navaid	Navigation Aid(s)
ADS-C	Automated Dependent Surveillance-Contract	NSE	Navigation System Error
AFE	Above Field Elevation	OEM	Original Equipment Manufacturer
AIP	Aeronautical Information Publication	PBN	Performance Based Navigation
ANSP	Air Navigation Service Provider	PDE	Path Definition Error
ATM	Air Traffic Management	PEE	Positioning Estimation Error
ATS	Air Traffic Services	PSR	Primary Surveillance Radar
CDI	Course Deviation Indicator	RAIM	Receiver Autonomous Integrity Monitoring
CDU	Control and Display Unit	RF	Radius to Fix
CFIT	Controlled Flight Into Terrain	RNAV	Area Navigation
CRC	Cyclic Redundancy Checking	RTCA	Radio Technical Commission on Aeronautics
CRM	Collision Risk Modelling	SBAS	Satellite-Based Augmentation System
DME	Distance Measuring Equipment	SID	Standard Instrument Departure
EASA	European Aviation Safety Agency	SSR	Secondary Surveillance Radar
ECAC	European Civil Aviation Conference	STAR	Standard Instrument Arrival
EUROCAE	European Organization for Civil Aviation Equipment	TLS	Target Level of Safety
EUROCONTROL	European Organisation for the Safety of Air Navigation	TSE	Total System Error
FAA	Federal Aviation Administration	VNAV	Vertical Navigation
FDE	Fault Detection and Exclusion	VOR	Very High Frequency Omni directional Radio Range
FTE	Flight Technical Error		
FMS	Flight Management System		
FRT	Fixed Radius Transition		
GNSS	Global Navigation Satellite System		
GPS	Global Positioning System		
INS	Inertial Navigation System		
IRS	Inertial Reference System		
IRU	Inertial Reference Unit		
JAA	Joint Aviation Authorities		
MCDU	Multi-Function Control and Display Unit		
MEL	Minimum Equipment List		

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 organisation 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.

ATS surveillance service. 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.

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.

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

Fault Detection and Exclusion (FDE). Fault Detection and exclusion (FDE) is 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 Function. The detailed capability of the navigation system (such as the execution of leg transitions, parallel offset capabilities, holding patterns, navigation data bases) required to meet the Airspace Concept.

Note: Navigational functional requirements are one of the drivers for selection of a particular Navigation Specification. Navigation functionalities (functional requirements) for each Navigation Specification can be found in Parts B and C of this guidance material.

Navigation specification. A set of aircraft and air crew requirements needed to support performance based navigation operations within a defined airspace.

Note. - There are two kinds of navigation specification: RNAV and RNP. A RNAV specification does not include requirements for on-board performance monitoring and alerting. A RNP specification includes requirements for on-board performance monitoring and alerting.

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 meeting the strategic objectives in a defined airspace concept.

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 defined 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 the PBN 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. A RNAV system may be included as part of a Flight Management System (FMS).

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.

RNP Operations: Aircraft operations using a RNP System for RNP applications.

Satellite-based augmentation system (SBAS). A wide coverage augmentation system in which the user receives augmentation 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. PBN CONCEPT REVIEW

The Performance Based Navigation concept is made up of three inter-related elements: the navigation specification, the Navaid infrastructure, and the navigation application.

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. The requirements placed on the area navigation system include:

- a) the performance being required of the area navigation system in terms of accuracy, integrity, continuity and availability;
- b) the functions that need to be available in the area navigation system so as to achieve the required performance
- c) the navigation sensors, integrated into the area navigation system, that may be used to achieve the required performance;
- d) flight crew and other procedures needed to achieve the performance being required of the area navigation system.

The Navaid infrastructure relates to space or ground-based Nav aids that are called up in each navigation specification.

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 there are a few differences and many common functional aspects to airplane systems that must perform the desired flight operations.

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. 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.

Note. – A detailed explanation of the PBN concept is presented at the *PBN Manual, Volume I, Part A, Chapter 1*.

1.2. USE AND SCOPE OF NAVIGATION SPECIFICATIONS

Most of the ICAO navigation specifications contained in this guidance material 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.

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.

Table 1-1: Application of Navigation Specification by Flight Phase

NAVIGATION SPECIFICATION	FLIGHT PHASE							
	En Route OCEANIC /REMOTE	En Route Continental	ARR	APPROACH				DEP
				Initial	Interm.	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	
RNP AR APCH				1-0.1	1-0.1	0.3 – 0.1	1-0.1	

Notes:

- The numbers given in the table refer to the 95% accuracy requirements (NM)
- RNAV 5 is an en-route navigation specification which may be used for the initial part of the STAR outside 30NM and above MSA
- RNP 2 and Advanced-RNP 1 are expected to be included in a future revision of the PBN Manual;
- 1a means that the navigation application is limited to use on STARs and SIDs only;
- 1b means that the area of application can only be used after the initial climb of a missed approach phase
- 1c means that beyond 30 NM from the airport reference point (ARP), the accuracy value for alerting becomes 2 NM

The above table shows the navigation specifications and their associated navigation accuracies published in Parts B and C of this guidance material. 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.

Most important, the above table 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 Advanced RNP 1 and RNP AR APCH.

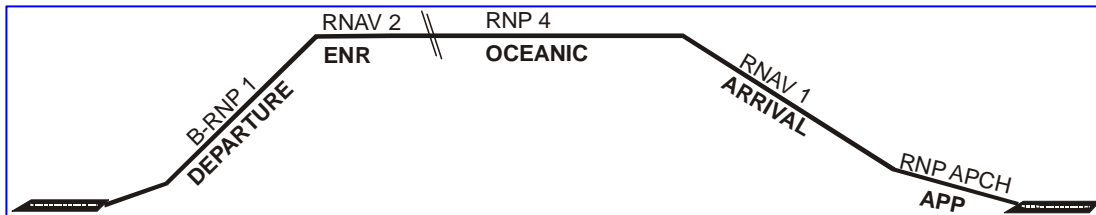


Figure 1-1: Example of an Application of RNAV and RNP Specifications to ATS Routes and Instrument Procedures

Table 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 (TSE). This does not imply that all of the specifications provide identical functional capability. As a result, 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.

The entire procedure that is to be flown by the RNAV system is to be coded into the data base and it shall be possible for the pilot to ensure that the system is capable of meeting the operational requirement for the whole procedure

1.2.1. Scope of ICAO Navigation Specifications

The ICAO navigation specifications (i.e. those included in this guidance material) 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). 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 that are required by the appropriate State authority before conducting flights into that airspace.

It is incumbent upon States to undertake a safety assessment in accordance with the provisions contained in Annex 11 and PANS-ATM, Chapter 2.

1.2.2. Navigation Specifications and the Approval process

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 (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.

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. These concepts are expected to evolve in future editions of the PBN Manual.

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 2-1. The distribution of these errors are 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.

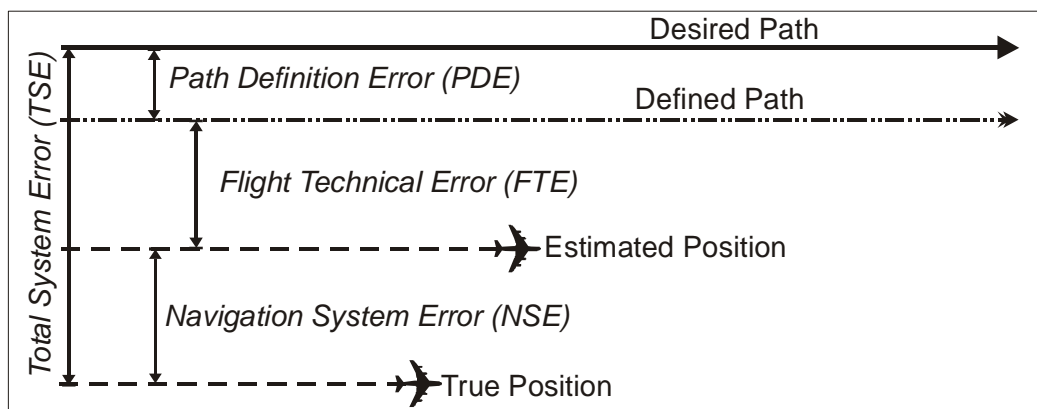


Figure 2-1: Lateral Navigation Errors (95%)

- 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 the PBN Manual, 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) are 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., CDI centering 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)*

2.2.2. Longitudinal Navigation

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).

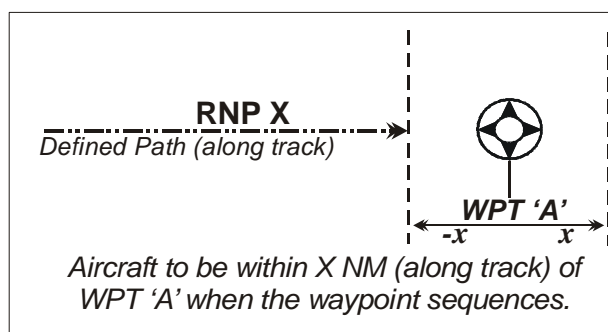


Figure 2-2: Along-Track Navigation Errors (95%)

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.

2.3. ROLE OF ON-BOARD PERFORMANCE MONITORING AND ALERTING

On-board performance monitoring and alerting capabilities fulfils two needs, one on board the aircraft and one within the airspace design. The assurance of airborne system performance has been 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 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.

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

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. 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.

The monitoring and alerting requirement could be satisfied by -

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

The net effect of the above is evident in TSE and can be illustrated in tabular form as shown in Table 2-1.

Table 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, 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.

Notice that the above table also reflects that 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.

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 has referred to the region within which the aircraft will remain 95% of the time. The associated terms have been *containment value* and *containment distance* and the related airspace protection on either side of a RNAV ATS route.
- b) Within the industry standards of RTCA/DO-236() and EUROCAE/ED-75, containment referred 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.

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

2.3.1. Performance Monitoring and Alerting Requirements for RNP

2.3.1.1. RNP-4, Basic-RNP 1 and RNP APCH

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% 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 paragraph.
- 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 and are the responsibility of the ANSP.

Of these requirements, the one that is truly unique to RNP navigation specifications is the performance monitoring requirement. 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 ergodic¹ 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: which navigation sensors 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

¹ An ergodic process is one in which every sequence or sizable sample is equally representative of the whole. It is realised 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.

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 transponder can have increasing range errors with increasing distance.

- c) Inertial reference units have error characteristics that increase with the time since being updated.

2.3.1.2. Application of Performance Monitoring and Alerting to Aircraft

Although the TSE can change significantly with 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% 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} .

Typically, the 10^{-5} TSE requirement provides the greater restriction on the 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 $2 \times (\text{accuracy value}) / 4.45 = \text{accuracy value} / 2.23$, while the 95% requirement would have allowed the standard deviation to be as large as the accuracy value / 1.96.

It is important to understand that whilst 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.

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.

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 it is not appropriate to think of TSE prior to the alert as being close to twice the accuracy value: instead, it is simply that the likelihood of the TSE exceeding twice the accuracy value just prior to the alert is approximately 10^{-5} . Conversely, 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 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 FTE are important.

2.3.1.3. Application of Performance Monitoring and Alerting to Risk Evaluations

The performance monitoring and alerting requirements for RNP 4, Basic-RNP 1 and RNP APCH do not obviate the need for safety assessments to determine the separation minima and obstacle clearance criteria for these routes using a risk metric such as collisions per hour or excursions outside the obstacle clearance area during an approach. Since the relationship between 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. Very simplistically, 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).

The safety assessment may use the performance monitoring and alerting requirement to provide a bounding of the TSE distribution in each dimension, the resulting bounding of distribution will need to be validated. In addition, one needs to be aware of the scope of these bounding distributions as they do not cover human error, for example. Moreover, navigation database errors are not covered by the PBN-based navigation specifications (see Parts B and C of this guidance material). It is well known that blunder 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 SASP (formerly RGCSP).

Although the determination of obstacle clearance criteria by the ICAO OCP 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 performance 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.

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.

2.3.1.4. Application of Performance Monitoring and Alerting for RNP AR APCH

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 are applied to more tightly monitor or control each error source. There are basically two ways to determine obstacle clearance through analysis. One way is to derive obstacle clearance from the target level of safety, given pre-defined aircraft requirements and operational mitigations. The other way is to derive aircraft requirements and operational mitigations from the target level of safety, given pre-defined obstacle clearance criteria. It is of vital importance in understanding the methodology applied for RNP AR that the latter way was 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 (\pm 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.

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, and tighter performance monitoring and alerting requirements are defined for many of the individual error sources.

2.3.1.5. 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 RNP 1, the lateral total system error must be within ± 1 NM for at least 95% of the total flight time. The along-track error must also be within ± 1 NM for at least 95% 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 (ICAO Annex 10, Volume I, Table 3.7.2.4-1).

CHAPTER 3

SAFETY ASSESSMENT CONSIDERATIONS

3.1. Introduction

Parts B and C of this guidance material contain navigation specifications which are applied in an Airspace Concept. When applying a navigation specification, a number of safety considerations have to be assessed.

Planners should consult these key reference documents:

- ICAO Document 9859, *Safety Management Manual*, Chapter 13, provides guidance on performing safety assessments.
- ICAO Document 9689, *Manual on Airspace Planning Methodology for the Determination of Separation Minima*, provides information on means for quantifying the effect separation minima have on air traffic safety.
- ICAO Document 8168, Volume II, *PANS OPS* provides design criteria for ATS routes and procedures.
- ICAO Doc 4444, *PANS ATM* provides separation minima.

The following provides an overview of some of the performance characteristics that need to be considered in the Safety Assessment. A table providing cross-references to safety assessment references for the navigation specifications in Parts B and C of this guidance material concludes this section on safety assessment.

3.2. Aircraft Performance

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

Non-Normal Errors: Navigation specifications in Part B of this guidance material 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 guidance material 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

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

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 for the implementation.

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, then autonomous navigation capability (inertial or dead reckoning) may provide a sufficient reversion. In cases where there is a plan to implement closely spaced routes, a potential mitigation could be increased aircraft separation to enable safe operation in a procedural environment. In the case of an aircraft with unreported position errors in a non-surveillance environment, RNP navigation specifications address this through the requirements for on-board performance monitoring and alerting.

3.4. Infrastructure

3.4.1. Failure of Navigation Aid environment

The impact of failure of the Navaid environment depends upon the Nav aids being employed for the operation. For most ground-based Nav aids, the number of aircraft using a given aid is normally small. Depending on the number of Nav aids 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 Nav aids will need to be specifically studied. Inertial navigation capability should also be considered for mitigation of a sparsely populated ground based Navaid infrastructure.

Where 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. ICAO Doc 9849, Global Navigation Satellite System (GNSS) Manual, 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.

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 inertial navigation capability. Other potential mitigations, depending on the navigation specification being implemented, could be a requirement for either the availability of an alternative terrestrial Navaid input to the RNAV system.

3.4.2. ATS Surveillance and Communication

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.

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.

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, consideration of the reception strength of the communications (strong or weak signal) should be included.

The effectiveness of ATC intervention in the event of an aircraft not following the route centre line 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 3-1: Navigation Specification Safety Assessment References

Navigation Specification	Safety Assessment References	Notes
RNAV 10 (note: retains designation of RNP 10 in implementation)	(1) ICAO Regional Supplementary Procedures (Doc 7030/4, MID/ASIA, PAC RAC) (2) ICAO Manual on Airspace Planning Methodology for the Determination of Separation Minima (Doc 9689-AN/953) (3) ICAO Procedures for Air Navigation Services, Air Traffic Management (Doc 4444 PANS ATM/501)	
RNAV 5	EUROCONTROL B-RNAV Route Spacing Study ICAO EUR DOC 001, RNAV	
RNAV 2	To be developed	
RNAV 1	EUROCONTROL Safety Assessment of P-RNAV Route Spacing and Aircraft Separation	
RNP 4	(1) ICAO Regional Supplementary Procedures (Doc 7030/4, APAC-S 02/8-MID/ASIA/PAC/RAC) (2) ICAO Manual on Airspace Planning Methodology for the Determination of Separation Minima (Doc 9689-AN/953) (3) ICAO Procedures for Air Navigation Services, Air Traffic Management (Doc 4444 PANS ATM/501)	
RNP 2	To be developed	Navigation specification in development .
Basic RNP 1	ICAO Doc 8168, PANS OPS, Volume II,	
Advanced RNP 1	To be developed	Navigation specification in development .
RNP APCH	ICAO Doc 8168, PANS OPS, Volume II	
RNP AR APCH	Procedure Design for RNP AR APCH procedures	

PART B

– IMPLEMENTING RNAV –



CHAPTER 1

IMPLEMENTING RNAV 10 (DESIGNATED AND AUTHORISED 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 PBN 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. Recognizing the extent of existing airspace designations and operational approvals using the designation RNP 10, it is anticipated that any new airspace designations or aircraft approvals will continue to use the designation RNP 10. 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 be now known as “RNAV 10.”

1.1.2. Purpose

This material 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.

This guidance material does *not* address details of the communications 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 ICAO *Regional Supplementary Procedures* (Doc 7030). 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 that 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 operations 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 communications 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 ICAO *Regional Supplementary Procedures* (Doc 7030).

1.2.3. Obstacle Clearance and Route Spacing

Detailed guidance on obstacle clearance is provided in PANS-OPS (ICAO Doc 8168, Vol II). The general criteria in Part 1 and Part 3 apply, together with the en-route criteria from Doc 8168, Volume II, Part III, Section 1, Chapter 7 (10NM) and Section 3, Chapter 8.

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.

The minimum route spacing where RNP 10 is utilised 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

The AIP should clearly indicate the navigation application is RNP 10, where reference is to existing routes.

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 ICAO Annex 15.

All routes must be based upon WGS 84 coordinates

1.2.6. 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:

Core training

- a) How area navigation systems work (in 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
 - (iv) ATC contingency procedures
 - (v) Separation minima
 - (vi) Mixed equipage environment (impact of manual VOR tuning)
 - (vii) Transition between different operating environments
 - (viii) Phraseology

Training Specific To This Navigation Specification

- a) Reporting of GNEs (Gross Navigation Errors)

1.2.7. Status Monitoring

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

1.2.8. ATS System Monitoring

Demonstrated navigation accuracy provides one of the primary parameters 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 (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 reoccurrence. 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.

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;
- navigation system failures

1.3. NAVIGATION SPECIFICATION

1.3.1. Background

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 Operator/Registry) for operational approval.

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

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

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.

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.

1.3.2.1. Contents of an Application for an RNP 10 Operational Approval

Aircraft Eligibility

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. In these instances, 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.

Method 1: RNP Certification

Method 1 can be used to approve aircraft that already 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 will address RNP levels that have been demonstrated 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.

An 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 in a flight manual is based upon performance approval by the aviation authority and is only one element of the approval process. Aircraft that have had this wording entered into 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 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.

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 paragraph 1.3.3 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.

Method 3: Aircraft eligibility through data collection

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.

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 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 employs the use of a hand-held GNSS receiver as a baseline for collected INS data, which is described in FAA Order 8400.12A (as amended), Appendix 6 (Periodic Method). The data collected is 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.

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 paragraph 1.3.4) to determine the feasibility of the proposed operation.

1.3.2.2. Operational Approval

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
- e) Where required, control of navigation database process

The operational approval will likely be documented through the State endorsing the Air Operators Certificate (AOC) through issue of a letter of authorisation, appropriate operations specification (Ops Spec) or amendment to the operations manual.

1.3.2.2.1 Description of aircraft equipment

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

1.3.2.2.2 Training documentation

Commercial operators must have a training program addressing the 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 program or regimen if RNAV training is already an integrated element of a training program. However, it should be possible to identify what aspects of RNAV are covered within a training program.

Non-commercial operators must be familiar with the practices and procedures identified in paragraph 1.3.5 “Pilot Knowledge/Training” of this chapter.

1.3.2.2.3 Operations manuals and checklists

Operations manuals and checklists for commercial operators must address information/guidance on the standard operating procedures detailed in the “Operating procedures” section of this chapter. 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.

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.

Private operators must operate using the practices and procedures identified in paragraph 1.3.5 “Pilot Knowledge/Training” of this chapter.

1.3.2.2.4 Minimum Equipment List (MEL) considerations

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

All operators must have an established maintenance program for the individual navigation systems. For others installing navigation systems, the operator must submit those changes appropriate to their existing maintenance manual for review and acceptability.

1.3.2.2.5 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, maintenance, or the aircraft/navigation system modifications which are to be used.

1.3.3. Aircraft Requirements

RNP 10 requires that aircraft operating in oceanic and remote areas be equipped with at least two independent and serviceable long-range navigation systems (LRNSs) comprising an inertial navigation system (INS), an inertial referencing system (IRS)/flight management system (FMS) or a global navigation satellite system (GNSS), with an integrity such that the navigation system does not provide an unacceptable probability of misleading information.

1.3.3.1. 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% of the total flight time. The along-track error must also be within ± 10 NM for at least 95% 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, 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 long range navigation systems (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 (ICAO Annex 10, Table 3.7.2.4-1).

1.3.3.2. Criteria for Specific Navigation Services

1.3.3.2.1 Aircraft incorporating dual GNSS

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, meet the RNP 10 requirements without time limitations.

Multi-sensor systems integrating GNSS with FDE that are approved using the guidance contained in United States FAA Advisory Circular AC 20-130A (*Airworthiness Approval of Navigation or Flight Management Systems Integrating Multiple Navigation Sensors*), or its equivalent, meet RNP 10 requirements without time limitations.

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.

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.

1.3.3.2.2 Aircraft incorporating dual inertial navigation systems (INS) or inertial reference units (IRU) – Standard time limit

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) 14 CFR, Part 121, Appendix G (or a State's equivalent)
- b) Minimum Navigation Performance Specifications (MNPS)
- c) Approved for RNAV operations in Australia

The timing starts from when the systems are placed in the 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).

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 paragraph 1.4.4 for information on the adjustment factors for systems that are updated en route).

Note: Documents listed in paragraph 1.4 provide information on acceptable procedures for operators who wish to increase the 6.2 hour time limitation specified.

1.3.3.2.3 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 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 1.4.1).

1.3.3.2.4 Aircraft equipped with a single INS/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-C129() authorized and must have an approved fault detection and exclusion (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/GPS installation meets the appropriate aviation authority's requirements.

1.3.4. 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 ICAO *Annex 2 — Rules of the Air*.

1.3.4.1. 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.
-

1.3.4.2. 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 and ATC must be advised when the aircraft is no longer able to navigate to its RNP 10 approval capability.

1.3.4.3. Navigation Equipment

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

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

1.3.4.4. 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.

1.3.4.5. Availability of Nav aids

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

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.

1.3.4.6. En Route

At least two long-range navigation systems 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 routing which does not require that equipment or diverting for repairs.

Before entering oceanic airspace, the position of the aircraft must be checked as accurately as possible by using external navigation aids. 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.

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.

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.

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 onboard 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 $\pm 1/2$ 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 1 times the navigation accuracy (i.e. 10 NM), are allowable.

Note: Some aircraft do not display or compute a path during turns. As such, pilots of these aircraft may not be able to adhere to the $\pm 1/2$ accuracy standard during route turns but are still expected to satisfy the standard during intercepts following turns and on straight segments.

1.3.4.7. Route Evaluation for RNP 10 Time Limits for Aircraft Equipped Only With INSS or IRUs

An RNP 10 time limit must be established for aircraft equipped only with INSS or IRUs. 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.

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 the evaluation.

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.

Start point for calculation

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

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.

Sources of wind component data

The headwind component to be considered for the route may be obtained from any source found 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.

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).

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.

1.3.4.8. 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 distance measuring equipment (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 omni-directional 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.

1.3.4.9. Automatic Radio Position Updating

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.

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.

1.3.4.10. 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 be provided that show the update accuracy achieved in in-service operations. This factor must be considered when establishing the RNP 10 time limit for INSSs or IRUs.
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1.3.5. Pilot Knowledge and Training

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 and therefore certain items that have been included may not apply to all operators.

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.

Non-commercial operators should show the aviation authority that 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.

1.3.6. Navigation Database

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

1.3.7. Oversight of Operators

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 on the navigation equipment or changes in the operator's operational procedures.

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/ats/ato/130.htm>
<http://www.faa.gov> (See Regulations and Policies)
 - Civil Aviation Safety Authority (CASA), Australia.
<http://www.casa.gov.au/rules/1998casr/index.htm>
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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, 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*
 - 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 Document Sales Unit, ICAO, 999 University Street, Montreal, Quebec, Canada H3C 5H7)
 - RTCA. DO-236B, Minimum Aviation System Performance Standards (MASPS): Required Navigation Performance for Area Navigation
 - (Copies may be obtained from RTCA, Inc., 1828 L Street NW, Suite 805, Washington, DC 20036, United States)
 - EUROCAE. ED-75B, Minimum Aviation System Performance Specification Required Navigation Performance for Area Navigation
 - (Copies may be obtained from EUROCAE, 102 rue Etienne Dolet, 92240 Malakoff, France)
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CHAPTER 2

IMPLEMENTING RNAV 5

2.1. INTRODUCTION

2.1.1. Background

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.

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

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

2.1.2. Purpose

This chapter provides guidance to States implementing RNAV 5 in the en route phase of flight.

For the Air Navigation Service Provider, it provides an ICAO recommendation on the implementation requirements, avoiding the proliferation of standards and the need for multiple regional approvals. For the operator, it provides 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.

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.

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

This chapter does not address all requirements that may be specified for operation on a particular RNAV 5 route or in a particular RNAV 5 area. These requirements are specified in other documents such as operating rules, aeronautical information publications (AIPs) and, where appropriate, 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 that are required by the appropriate State authority before conducting flights into that airspace.

2.2. ANSP CONSIDERATIONS

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

2.2.1. Navaid Infrastructure

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

RNAV 5 operations are based upon the use of RNAV equipment that automatically determines aircraft position in the horizontal plane using inputs 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
- d) GNSS

The ANSP must undertake an assessment of the Navaid infrastructure. It should be shown to be sufficient for the proposed operations, including reversionary modes. It is acceptable for gaps in navigation aid coverage to be present. Where this occurs, route spacing and obstacle clearance surfaces need to take due account for the expected increase in lateral track keeping errors during the “dead reckoning” phase of flight.

2.2.2. Communication & ATS Surveillance

Direct pilot to ATC (voice) communication is required.

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

Radar monitoring by the Air Traffic Service 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

Detailed guidance on obstacle clearance is provided in PANS-OPS (ICAO Doc 8168, Vol II). The general criteria in Part 1 and Part 3 apply, together with the en-route criteria from Doc 8168, Volume II, Part III, Section 1, Chapter 7 (5NM) and Section 3, Chapter 8.

The State is responsible for route spacing and should account for the availability of ATS surveillance and monitoring tools to support detection and correction of navigation errors. Route spacing between RNAV 5 routes or between RNAV 5 routes and conventional routes should refer to applicable ICAO material. 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.

Where traffic density is lower, route spacing may be reduced. In an ATC surveillance environment, the route spacing will depend upon acceptable ATC workload and availability of controller tools. One regional RNAV 5 implementation adopted standard route spacing of 16.5 NM for same direction and 18 NM for opposite direction traffic. Moreover, route spacing as low as 10 NM has been used where ATC intervention capability permits.

The route design should account for the navigation performance achievable with the available Navaid infrastructure, and the functional capabilities required by this document. Two aspects are of particular importance:

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.

Along track distance between leg changes

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.

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

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.

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.

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

2.2.5. Publication

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 ICAO Annex 15.

All routes must be based upon WGS 84 coordinates.

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

A navigation database does not form part of the required functionality of RNAV 5. The absence of such a data base necessitates manual waypoint entry, increasing significantly 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:

Core training

- a) How area navigation systems work (in 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
 - (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

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.

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

When available, radar observations of each aircraft’s proximity to track and altitude are typically noted by Air Traffic Service (ATS) facilities and aircraft track-keeping capabilities are analyzed.

A process should be established to allow 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

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 a 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.

RNAV 5 does not require the carriage of a navigation database. Because of the specific limitations (e.g. workload and potential for data insertion 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

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.

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 material must be accepted by the State regulatory authority; and
- e) Operational approval should then be obtained in accordance with national operating rules.

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 then be issued by the State.

2.3.2.1. 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 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, etc.). Aircraft Flight Manual (AFM) entries are not required provided the State accepts manufacturer documentation.

2.3.2.2. Operational Approval

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 found 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
- e) Where required, control of navigation database process

Note: It is envisaged that an operational approval against either AMC 20-4 or AC 90-96 can lead to compliance with requirements in any RNAV 5 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.

The operational approval will likely be documented through the State endorsing the Air Operators Certificate (AOC) through issue of a letter of authorisation, appropriate operations specification (Ops Spec) or amendment to the operations manual.

2.3.2.2.1 Description of aircraft equipment

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

2.3.2.2.2 Training documentation

Commercial operators should have a training program addressing the 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 program or regimen if RNAV training is already an integrated element of a training program. However, it should be possible to identify what aspects of RNAV are covered within a training program.

Private operators should be familiar with the practices and procedures identified in section 2.3.5, Pilot Knowledge/Training.

2.3.2.2.3 Operations Manuals and Checklists

Operations manuals and checklists for commercial operators must address information/guidance on the standard operating procedures detailed in section 2.3.4 of this chapter. 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.

Private operators should operate using the practices and procedures identified in section 2.3.5, Pilot Knowledge/Training.

2.3.2.2.4 Minimum Equipment List (MEL) Considerations

Any minimum equipment list (MEL) revisions necessary to address RNAV 5 provisions must be approved. Operators must adjust the MEL, or equivalent, and specify the required dispatch conditions.

2.3.3. Aircraft Requirements

RNAV 5 operations are based upon the use of RNAV equipment automatically determining aircraft position using inputs 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
- 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% of the total flight time. The along-track error must also be within ± 5 NM for at least 95% 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, 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, RNAV computer, 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 navigation aids (e.g. VOR/DME or NDB).

2.3.3.2. Criteria for Specific Navigation Services

INS/IRS

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 provides augmentation to the basic position sensors as well as a reversionary position data source when out of cover of radio navigation sources.

INS without a function for automatic radio updating of aircraft position and approved in accordance with AC 25-4, 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 aircraft manufacturer's data, justifies extended use from the last position update.

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.

VOR

VOR accuracy can typically meet the accuracy requirements for RNAV 5 up to 60NM from the navigation aid and Doppler VOR up to 75 NM. Specific regions within the VOR coverage may experience larger errors due to propagation effects (e.g. multipath). Where such errors exist this can be accommodated by prescribing areas where the affected VOR may not be used. Alternative actions could be to take account of lower VOR performance in the setting up of the proposed RNAV routes by, for example, increasing by additional route spacing. Due account has to be taken of the availability of other navigation aids to 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.

DME

DME signals are considered sufficient to meet requirements of RNAV 5 wherever the signals are received and there is no closer DME on the same channel, regardless of the published coverage volume. Where the RNAV 5 system does not take account of published "Designated Operational Coverage" of the DME, the RNAV system must execute data integrity checks to confirm that the correct DME signal is being received.

The individual components of the Navaid infrastructure must meet the performance requirements detailed in ICAO Annex 10. Navigation aids that are not compliant with Annex 10 should not be published in the State AIP.

GNSS

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 paragraph 2.3.3.3.

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) Pseudorange step detection
 - (ii) Health word checking.
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Note: These two additional functions are required to be implemented in accordance with TSO-C129a / ETSO-C129a or equivalent criteria.

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.

Positioning data from other types of navigation sensors may be integrated with the GNSS data provided it does not cause position errors exceeding the track keeping accuracy requirements.

2.3.3.3. Functional Requirements

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 on a navigation display situated in his primary field of view
- b) Where the minimum flight crew is two pilots, indication of aircraft position relative to track to be displayed to the pilot not flying on a navigation display situated in his 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
- f) Appropriate failure indication of the RNAV system, including the sensors.

RNAV 5 Navigation Displays

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).

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.
- c) The lateral deviation display must have a scaling and full-scale deflection suitable for the RNAV 5 operation.

2.3.4. Operating Procedures

General

Airworthiness certification alone does not authorise flight 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.

Pre-flight Planning

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.

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 onboard navigation equipment necessary for the operation.

Where a navigation data base is used, it should be current and appropriate for the region of intended operation and must include the navigation aids, waypoints required for the route.

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 SBAS signal is unavailable.

ABAS Availability

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.

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.

In the event of a predicted, continuous loss of appropriate level of fault detection of more than five (5) minutes for any part of the RNAV 5 operation, the flight planning should be revised (e.g., delaying the departure or planning a different departure procedure).

RAIM availability prediction software does not guarantee the service, they are rather tools to assess 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.

General Operating Procedures

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.

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

Pilots of RNAV 5 aircraft must adhere to any AFM limitations or operating procedures required to maintain the navigation accuracy specified for the procedure.

Where a navigation database is installed, pilots must confirm its currency.

Flight crews should crosscheck 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.

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.

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 section 2.3.3.4, 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).

All pilots are expected to maintain route centrelines, as depicted by onboard 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 $\pm \frac{1}{2}$ 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 1 times the navigation accuracy (i.e., 5 nm), are allowable.

Note: Some aircraft do not display or compute a path during turns. As such, pilots of these aircraft may not be able to adhere to the $\pm \frac{1}{2}$ 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.

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.

Contingency Procedures

The pilot must notify ATC where the RNAV performance ceases to meet the requirements for RNAV 5. The communication to ATC must be in accordance with the authorised procedures (Doc 4444 or Doc 7030 as appropriate).

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

Where stand-alone GNSS equipment is used:

- a) In the event of 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 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 following items should be addressed in the pilot training program (for example, simulator, training device, or aircraft) for the aircraft's RNAV system:

- 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 in respect of the operation of 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 to 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 flight (for example, monitor PROG or LEGS page).
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- iv) Types of navigation sensors (for example, DME, IRU, GNSS) utilised 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 currency of aircraft navigation data.
 - ii) Verify 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.
 - x) Perform gross navigation error check using conventional navigation aids.

2.3.6. Navigation Data Base

Where a navigation data base is carried and used, it must be current and appropriate for the region of intended operation and must include the navigation aids, 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 navigation data, including suitability of navigation facilities used to define the routes for flight. Traditionally, this has been accomplished by verifying electronic data against paper products.

2.3.7. Oversight of Operators

A process needs to be established whereby navigation error reports can be submitted and analysed 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).

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.

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

DOCUMENT AVAILABILITY

Copies of ICAO documents may be purchased from Document Sales Unit, International Civil Aviation Organization, 999 University Street, Montreal, Quebec, Canada H3C 5H7, (Fax: 1 514 954 6769, or e-mail: sales_unit@icao.org) or through national agencies.

Copies of ARINC documents may be obtained from Aeronautical Radio Inc., 2551 Riva Road, Annapolis, Maryland 24101-7465, USA. Web site: <http://www.arinc.com>

Copies of EASA documents may be obtained from EASA (European Aviation Safety Agency), 101253, D-50452 Koln, Germany. <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) – Web site: www.eurocae.eu

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). Web site: <http://www.ecacnav.com>

Copies of FAA documents may be obtained from Superintendent of Documents, Government Printing Office, Washington, DC 20402-9325, USA. Web site: <http://www.faa.gov/certification/aircraft/> (Regulation and Guidance Library)

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 web site, <http://www.jaa.nl>, and on the IHS web sites <http://www.global.his.com>, and <http://www.avdataworks.com>.

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). Web site www.rtca.org.

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 guidance on U.S. Terminal and En Route Area Navigation (RNAV) Operations on 7 January 2005 through AC 90-100. While similar in functional requirements, differences exist between these two documents. ICAO sought harmonization between European and U.S. RNAV criteria with this single ICAO RNAV specification.

3.1.2. Purpose

This chapter provides guidance to States and Air Navigation Service Providers implementing en route and terminal area navigation (RNAV) applications. For the operator, it provides a combination of European P-RNAV and U.S. RNAV criteria. 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 paragraph 3.3.2.4 to see whether their system also gives automatic compliance to this specification. Compliance to ICAO RNAV 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 operations globally. The aircraft requirements for RNAV 1 and RNAV 2 are identical, while some operating procedures are different.

The RNAV 1 and RNAV 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.

RNAV 1 and RNAV 2 Navigation Specification were 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, accounting for lack of performance monitoring and alerting.

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

This chapter does *not* address all requirements that may be specified for operation on a particular route or in a particular area. These requirements are specified in other documents such as operating rules, 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 required by the appropriate State authority before conducting flights into that airspace.

3.2. ANSP CONSIDERATIONS

The ANSP is responsible for the development of the route as described in the PBN Manual, Volume I, 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

The route design should take account of the navigation performance, achievable 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 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.

If an IRU is not carried, then the aircraft can revert to dead reckoning. In such cases additional protection, in accordance with PANS-OPS (ICAO Doc 8168, Vol 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 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 does not exist, avionics and infrastructure variability pose serious challenges to standardization. Therefore, the criteria in this document only discusses 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 paragraph 3.3.

The Navaid infrastructure should be validated by modelling, and the anticipated performance should be adequately assessed and, where necessary, flight checked. The assessment should consider the aircraft capability described in this Chapter. For example, a DME signal can only be assured for use 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° and 150°. DME infrastructure assessment is significantly simplified when using a suitable screening tool which accurately matches ground infrastructure and aircraft performance and uses an accurate representation of the terrain. Guidance material concerning this assessment can be found in PANS-OPS (ICAO Doc 8168, Vol II) and the Manual on Testing of Radio Navigation Aids (ICAO Doc 8071).

DME signals are considered to meet signal-in-space accuracy tolerances everywhere the signals are received, regardless of the published coverage volume. Errors resulting from field strength below the minimum requirement or where co-channel or adjacent-channel interference may exist are considered receiver errors and are addressed in paragraph 3.3.3. Errors resulting from multipath 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 aids 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 ICAO Annex 10. 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.

For RNAV operations where reliance is placed upon IRS, some aircraft systems 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.

ANSPs should ensure operators of GNSS-equipped aircraft have access to a means of predicting the availability of fault detection using ABAS (e.g., RAIM). Where applicable, ANSPs should also ensure operators of SBAS-equipped aircraft have access to a means of predicting the availability of 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 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 (5) minutes for any part of the RNAV 1 and RNAV 2 operation. 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.

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 operation in the AIP or facilities associated with an ILS or MLS using a range offset.

Note 1: Database suppliers may exclude specific DME facilities, which 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.

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

3.2.2. Communication & ATS Surveillance

Where reliance is placed on the use of radar to assist contingency procedures, its performance should be adequate for that purpose. This means that the 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

Obstacle clearance guidance is provided in PANS-OPS (ICAO Doc 8168, Vol II). The general criteria in Part 1 and Part 3 apply; together with the following additional specific criteria:

- a) RNAV-1
 - i) Where a GNSS infrastructure is provided, apply the criteria from Doc 8168, Volume II, Part III, Section 1, Chapter 2 and the chapter in Section 3 for the appropriate phase of flight.
 - ii) Where a DME/DME Navaid infrastructure is provided apply the criteria for three-DME cover from Doc 8168, Volume II, Part III, Section 1, Chapter 3 and the chapter in Section 3 for the appropriate phase of flight. If the infrastructure does not support continuous DME/DME updating, consider basing the route on DME/DME/IRU or expanding the route width to accommodate a gap in coverage.
 - iii) Where both a GNSS and a DME/DME Navaid infrastructure are provided, apply the greater semi-area width from the two sets of criteria.
 - b) RNAV 2
 - i) Where a GNSS infrastructure is provided, apply the en-route criteria from Doc 8168, Volume II, Part III, Section 1, Chapter 2 and Section 3, Chapter 8.
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ii) Where a DME/DME Navaid infrastructure is provided, apply the criteria for pre-1989 two-DME cover from Doc 8168, Volume II, Part III, Section 1, Chapter 3 and Section 3, Chapter 8. If the infrastructure does not support continuous DME/DME updating, consider basing the route on DME/DME/IRU or expanding the route width to accommodate a gap in coverage.

iii) Where both a GNSS and a DME/DME Navaid infrastructure are provided, apply the greater semi-area width from the two sets of criteria.

States may prescribe RNAV 1 or RNAV 2 ATS routes. 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

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% values.

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.

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.

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

3.2.5. Publication

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.

The available Navaid infrastructure should be clearly designated on all appropriate charts (for example, GNSS, DME/DME or DME/DME/IRU).

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 will 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.

Core training

- a) How area navigation systems work (in 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 vs. fly-over concept (and different turn performance)
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- 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
 - (v) Phraseology

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 routeing 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 (NOTAM) should be issued.

3.2.8. 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. When available, radar observations of each aircraft's proximity to track and altitude are typically noted by Air Traffic Service (ATS) facilities and aircraft track-keeping capabilities are analyzed.

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 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 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.

This RNAV 1 and RNAV 2 specification constitutes harmonization between European Precision RNAV (P-RNAV) and U.S. RNAV criteria. Aircraft approved to RNAV 1 and RNAV 2 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

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.

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 then be obtained in accordance with national operating rules.

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.

3.3.2.1. 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, etc.). Aircraft Flight Manual (AFM) entries are not required provided the State accepts manufacturer documentation.

3.3.2.2. Operational Approval

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 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
- e) Where required, control of 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.

The operational approval will likely be documented through the State endorsing the Air Operators Certificate (AOC) through issue of a letter of authorisation, appropriate operations specification (Ops Spec) or amendment to the operations manual.

3.3.2.2.1 Description of aircraft equipment

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

3.3.2.2.2 Training documentation

Commercial operators should have a training program 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 program or regimen if RNAV training is already an integrated element of a training program. However, it should be possible to identify what aspects of RNAV are covered within a training program.

Private operators should be familiar with the practices and procedures identified in section 3.3.5, Pilot Knowledge/Training.

3.3.2.2.3 Operations manuals and checklists

Operations manuals and checklists for commercial operators must address information/guidance on the standard operating procedures detailed in section 3.3.4 of this chapter. 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.

Private operators should operate using the practices and procedures identified in section 3.3.5, Pilot Knowledge/Training.

3.3.2.2.4 Minimum Equipment List (MEL) Considerations

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.

3.3.2.3. PBN Navigation Specification and the Approval Process

The 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. 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 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.

3.3.2.4. Migration Path to RNAV 1 and RNAV 2

The following steps identify the transition path to RNAV 1 and RNAV 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), or to TGL No. 10 or AC 90-100 and then the differences to achieve an acceptable means of compliance to RNAV 1 and RNAV 2. Armed with evidence of aircraft eligibility, the operator will then be required to obtain the necessary
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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 is eligible to operate on US RNAV Type A and Type B and European P-RNAV routes and no further approval is required.
- c) An operator wishing to fly in just airspace designated for P-RNAV; should obtain a P-RNAV approval against TGL No. 10.
- d) An operator wishing to fly on just US RNAV Type A and Type B routes; should obtain an approval against AC 90-100.

Operator Already 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,
- 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 following Table 3-1.

Table 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 to ICAO RNAV 1 and RNAV 2	Note
If approval includes use of DME/VOR. (DME/VOR may only 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 inputs do 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 (DME/DME only) or 3.3.3.3.3 (DME/DME/IRU)	Operator can ask manufacturer or check FAA website for list of compliant systems - see Note below this table.
RNAV SID Specific Requirement with DME/DME Aircraft	RNAV guidance available no later than 500ft 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/

Operator Already 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,
- 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 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 following Table 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 through Service Letters or AFM statements that compliance has been shown. The operational differences are limited to the navigation database being obtained from an accredited source. In this way, the regulatory effort from migrating from one approval to another should be minimised, avoiding the need for time consuming re-investigation and costly assessment.

Table 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 based on GNSS (TSO-C129)	GPS pseudorange step detector and GPS health word checking is required in accordance with TSO C129a/ETSO C129a.	Operator should check if pseudorange 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 supplier and avionics data supplier must have letter of acceptance (LOA) in accordance with this chapter, paragraph 3.3.3.4.m.	Operator should ask data supplier for status for the RNAV equipment

3.3.2.5. Summary of RNAV 1 / TGL-10 / AC 90-100 Insignificant Differences

Appendix 1 contains a list of insignificant differences between TGL-10 and AC 90-100.

3.3.3. Aircraft Requirements

Navigation systems. RNAV 1 and RNAV 2 operations are based upon the use of RNAV equipment that automatically determines aircraft position in the horizontal plane using inputs 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 it does not cause position errors exceeding the total system accuracy requirements. The use of GNSS equipment approved to TSO-C129 () is limited to those which include the minimum system functions specified in section 3.3.3.4. 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) Pseudorange step detection
 - (ii) Health word checking.
- b) DME/DME RNAV equipment complying with the criteria listed in section 3.3.3.2.2.
 - c) DME/DME/IRU RNAV equipment complying with the criteria listed in section 3.3.3.3.3.

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% of the total flight time. The along-track error must also be within ± 1 NM for at least 95% 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% of the total flight time. The along-track error must also be within ± 2 NM for at least 95% 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 (ICAO Annex 10, 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 (ICAO Annex 10, Table 3.7.2.4-1).

3.3.3.2. Criteria For Specific Navigation Services

3.3.3.2.1 Criteria for GNSS

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 3.3.3.4) installed for IFR use IAW FAA AC 20-138 or AC 20-138A.
- d) Aircraft with TSO-C146() (without deviating from the functionality described in section 3.3.3.4 of this document) installed for IFR use IAW AC 20-138A.

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.

Positioning data from other types of navigation sensors may be integrated with the GNSS data provided it does not cause position errors exceeding the Total System Error (TSE) budget. Otherwise, means should be provided to deselect the other navigation sensor types.

3.3.3.3.2 *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	<p>The DME/DME RNAV system must:</p> <ul style="list-style-type: none"> (i) Position update within 30 seconds of tuning DME navigation facilities. (ii) Auto-tune multiple DME facilities. (iii) Provide continuous DME/DME position updating. (Given 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	<p>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/or RNAV 2 operation in the AIP or facilities associated with an ILS or MLS that uses a range offset. This may be accomplished by:</p> <ul style="list-style-type: none"> 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 known these DME facilities. ii) Using an RNAV system which 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 section 3.3.3.3.2.1.
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	<p>The RNAV system may use any valid receivable DME facility (listed in the AIP) regardless of its location. A valid DME facility:</p> <ul style="list-style-type: none"> 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. <p>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:</p> <ul style="list-style-type: none"> 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.

		<p><i>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.</i></p>
f)	No Requirement to Use VOR, NDB, LOC, IRU or AHRS	There is no requirement to use VOR (VHF omni-range), LOC (localizer), NDB (non-directional beacon), IRU (inertial reference unit) or AHRS (attitude heading reference system) during normal operation of the DME/DME RNAV system.
g)	Position Estimation Error	<p>When using a minimum of two DME facilities satisfying the criteria in paragraph 3.3.3.3.2.e, and any other DME facilities not meeting that criteria, the 95% position estimation error must be better than or equal to the following equation:</p> $2\sigma_{DME/DME} \leq 2 \frac{\sqrt{(\sigma_{1,air}^2 + \sigma_{1,sis}^2) + (\sigma_{2,air}^2 + \sigma_{2,sis}^2)}}{\sin(\alpha)}$ <p>Where: $\sigma_{sis} = 0.05$ NM σ_{air} is MAX {(0.085 NM, (0.125% of distance)) α = inclusion angle (30° to 150°)</p> <p><i>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 $\sigma_{ground}=0.05$ NM.</i></p>
h)	Preventing Erroneous Guidance from Other Facilities	The RNAV system must ensure 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 (for example, through reasonableness checks (see section 3.3.3.3.2.1)).
j)	Ensuring RNAV Systems Use Operational Facilities	The RNAV system must use operational DME facilities. DME facilities listed by NOTAM as unavailable (for example, 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	<p>Operational mitigations such as pilot monitoring of the RNAV system's navigation updating source(s), or time intensive programming/ blackballing of multiple DME stations, should be performed before any workload intensive or critical phase of flight.</p> <p><i>Note: Blackballing 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.</i></p>
l)	Reasonableness Checks	<p>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:</p> <ul style="list-style-type: none"> (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 (for example, extra DME signals or IRU data). <p>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 fixing errors due to co-channel interference, multipath, and direct signal screening. In lieu of using radio navigation aid published service volume, the navigation system should provide checks, which preclude use of duplicate frequency Nav aids within range, over-the-horizon Nav aids, and use of Nav aids with poor geometry.</p> <p>Assumptions. Under certain conditions, reasonableness checks can be invalid:</p> <ul style="list-style-type: none"> (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 (for example, when only two DMEs are available for parts of the route). <p>Use of Stressing Conditions to Test Effectiveness.</p> <p>When a reasonableness check is used to satisfy any requirement in these criteria, the effectiveness of the check must be tested under stressing 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 under test might do), when there is only one other supporting DME or two signals of equal strength.</p>

3.3.3.3.3 Criteria For Distance Measuring Equipment and Inertial Reference Unit (IRU) (DME/DME/IRU RNAV System)

This section defines the minimum DME/DME/IRU (or abbreviated D/D/I) RNAV system baseline performance. The performance standards for the DME/DME positioning are as detailed in section 3.3.3.3.2.

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.	<i>Note: Operators/pilots should contact manufacturers to discern if any annunciation of inertial coasting is suppressed following loss of radio updating.</i>
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:	<p>Non-numeric lateral deviation display (for example, 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:</p> <ol style="list-style-type: none"> 1) The displays must be visible to the pilot and located in the primary field of view (± 15 degrees from 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

		<p>display should be automatically slewed to the RNAV computed path.</p> <p>As an alternate means, a navigation map display should give equivalent functionality to a lateral deviation display as described in section 3.3.3.4.a (1-5), with appropriate map scales (scaling may be set manually by the pilot), and giving equivalent functionality to a lateral deviation display.</p> <p><i>Note: A number of modern aircraft eligible for this specification utilize a map display as an acceptable method to satisfy the stated requirements.</i></p>
b)	The following system functions are required as a minimum within any RNAV 2 or RNAV 1 equipment:	<ol style="list-style-type: none"> 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 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) Capacity to load from the database into the RNAV system the entire RNAV segment of the SID or STAR to be flown. <p><i>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.</i></p>
c)	The means to display the following items, either in the pilot's primary field of view, or on a readily accessible display page:	<ol style="list-style-type: none"> 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 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 ATS routes extracted from the onboard database including the capability to execute fly-over and fly-by turns.	
g)	The aircraft must have the capability to automatically execute leg transitions and maintain tracks consistent with the following ARINC 424 path terminators, or their equivalent. <ul style="list-style-type: none"> • Initial Fix (IF) • Course to Fix (CF) • Direct to Fix (DF) • Track to Fix (TF) 	<p><i>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.</i></p> <p><i>Note 2: Numeric values for courses and tracks must be automatically loaded from the RNAV system database.</i></p>
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 waypoint must be flown in the same manner as a TF leg in terminal airspace.	

k)	The capability to display an indication of the RNAV system failure, including the associated sensors, in the pilot's primary field of view.	
l)	For multi-sensor systems, the capability for automatic reversion to an alternate RNAV sensor if the primary RNAV sensor fails. This does not preclude providing a means for manual navigation source selection.	
m)	Data base Integrity	The navigation data base suppliers should comply with RTCA DO-200A/EUROCAE document ED 76, Standards for Processing Aeronautical Data (see paragraph 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 data base 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 data bases in order to meet existing quality system requirements.

3.3.4. Operating Procedures

Airworthiness certification alone does not authorise flight in airspace or along routes for which RNAV 2 or RNAV 1 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

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

The onboard 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 the 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 navigation data, including suitability of navigation facilities used to define the routes and procedures for flight.

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 SBAS signal is unavailable.

ABAS Availability

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.

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.

In the event of a predicted, continuous loss of appropriate level of fault detection of more than five (5) minutes for any part of the RNAV 1 or RNAV 2 operation, the flight planning should be revised (e.g., delaying the departure or planning a different departure procedure).

RAIM availability prediction software does not guarantee the service, they are rather tools to assess 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.

DME Availability

For navigation relying on DME, NOTAMs should be checked to verify the health 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

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

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.

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.

Pilots must not fly an RNAV 1 or RNAV 2 SID or STAR unless it is retrievable by route name from the onboard navigation database and conforms to the charted route. However, the route may subsequently be modified through the insertion or deletion of specific waypoints in response to ATC clearances. The manual entry, or creation of new waypoints, by manual entry of latitude and longitude or rho/theta values is not permitted. Additionally, pilots must not change any RNAV SID or STAR database waypoint type from a fly-by to a fly-over or vice versa.

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.

Flight crews should crosscheck 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° or less may result from equipment manufacturer's application of magnetic variation and are operationally acceptable.

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

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 to a lateral deviation indicator as described in section 3.3.3.4.a (1-5), without a flight director or autopilot.

For RNAV 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 RNAV 1, ± 2 nm for RNAV 2, or ± 5 nm for TSO-C129() equipment on RNAV 2 routes).

All pilots are expected to maintain route centrelines, as depicted by onboard 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 $\pm \frac{1}{2}$ 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 1 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. As such, pilots of these aircraft may not be able to adhere to the $\pm \frac{1}{2}$ Lateral navigation accuracy during procedural/route turns but are still expected to satisfy the standard during intercepts following turns and on straight segments.

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.

Manually selecting aircraft bank limiting functions may reduce the aircraft's ability to maintain its desired track and are not recommended. Pilots should recognize 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 Airplane 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

Prior to commencing takeoff, 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 takeoff. A final check of proper runway entry and correct route depiction, shortly before takeoff, is recommended.

RNAV Engagement Altitude. The pilot must be able to use RNAV equipment to follow flight guidance for lateral RNAV no later than 500 feet above airport elevation. The altitude at which RNAV guidance begins on a given route may be higher (e.g., climb to 1000 ft then direct to...).

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.

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.

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 1,000 feet (0.17 NM) of a known position, at the start point of 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 pilot procedures and display resolution allow for compliance with the 1,000-foot 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.

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

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 fly-over. 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.

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

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

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.

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.

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

3.3.4.5. Contingency Procedures

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 Air Traffic Service 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.

In the event of communications failure, the flight crew should continue with the RNAV route in accordance with established lost communication procedures.

3.3.5. Pilot Knowledge and Training

The following items should be addressed in the pilot training program (for example, simulator, training device, or aircraft) for the aircraft's RNAV system.

- a) The information in this chapter.
 - b) The meaning and proper use of Aircraft Equipment/Navigation Suffixes.
 - c) Procedure characteristics as determined from chart depiction and textual description.
 - d) Depiction of waypoint types (fly-over and fly-by) and path terminators (provided in section 3.3.3.4 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 aircraft navigation data.
 - ii) Verify 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 takeoff point shift, if applicable)
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- 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 check using conventional navigation aids.
 - xviii) Change arrival airport and alternate airport.
 - xix) Perform parallel offset function 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 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
 - j) Contingency procedures for RNAV/RNP failures.

3.3.6. Navigation Database

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 (reference ICAO Annex 6, part 1, chapter 7.4). 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).

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. 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 operation 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

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.

Information that indicates the potential for repeated errors may require modification of an operator's training program. Information that attributes multiple errors to a particular pilot crew may necessitate remedial training or license 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) – Web site: www.eurocae.eu

Copies of FAA documents may be obtained from Superintendent of Documents, Government Printing Office, Washington, DC 20402-9325, USA. Web site: <http://www.faa.gov/certification/aircraft/> (Regulation 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). Web site www.rtca.org.

Copies of ARINC documents may be obtained from Aeronautical Radio Inc., 2551 Riva Road, Annapolis, Maryland 24101-7465, USA. Web site: <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 web site, <http://www.jaa.nl> , and on the IHS web sites <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 Document Sales Unit, International Civil Aviation Organization, 999 University Street, Montreal, Quebec, Canada H3C 5H7, (Fax: 1 514 954 6769, or e-mail: sales_unit@icao.org) or through national agencies.

Appendix 1: Summary of RNAV 1/TGL 10/ AC 90-100 non significant difference

	Difference of RNAV 1/AC 90-100/TGL-10	NAV-1	FAA AC90-100	JAA TGL- 10(Rev.1)	Conclusion
Aircraft Equipment	ARINC424 Path Terminator	IF,CF,DF,TF 3.4.3.7	IF,CF,DF,TF, 6.c	IF,TF,CF,DF,FA	TGL 10 doesn't specify automatic versus manual leg management. F.A. 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 0.1NM, 7.1.12	It WAS agreed: 1) in PRNAV its really good practice and not universal requirement; 2) RNAV 1&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 PRNAV its really good practice and not universal requirement; 2) RNAV 1&2 would be tailored for radar environments where such checks are not required.

	General Operating Procedure 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	Navigation 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&2 would be tailored for radar environments where such checks are not required.
	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: <i>“Flight crews should crosscheck 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”</i> 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 Block2)	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)	<p>AC 90-100 specifies that:</p> <p>“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</p> <p>“Pilots must not fly an RNAV SID or STAR unless it is retrievable by procedure name from the onboard navigation database and conforms to the charted procedure.”</p> <p>FAA did not include prohibition against altering flight plan in equipment as ATC clearance can amend procedure in some circumstances.</p> <p>No discrepancy.</p>

		<p>Where the contingency procedure requires reversion to a conventional arrival route, necessary preparation must be completed before commencing the RNAV route. (3.4.4.4.1 Block3)</p>	No requirement	<p>Where the contingency to revert to a conventional arrival procedure is required, the flight crew must make the necessary preparation.(10.2.3.3)</p>	<p>Under TGL-10, such contingency is required for below MOCA or outside radar coverage. RNAV 1 is intended for application within radar coverage (MOCA not significant constraint if radar service is available and aircraft above MSA). Discrepancy resolved through decision to base ICAO implementation on radar.</p>
		<p>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 Block4)</p>	No requirement	<p>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)</p>	<p>In US, crew training includes knowledge of how to go direct, rest is basic airmanship. No discrepancy.</p>

	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 . Block5)	No requirement	Although a particular method is not mandated, any published altitude and speed constraints must be observed.(10.2.3.6)	USRNAV 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. Block1)	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 Block3)	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 Block2)	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 nav data base integrity in AC 90-100. Will not be the case in AC 90-100A.
	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 Block3)	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 2/RNAV 1 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 means to regulate it): "The pilot must also confirm availability of the onboard navigation equipment necessary for the route, SID, or STAR to be flown". No discrepancy.
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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

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).

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 that are required by the appropriate State authority before conducting flights into that airspace.

1.2. ANSP CONSIDERATIONS

1.2.1. Navaid Infrastructure Considerations

RNP 4 was developed for operations in oceanic and remote airspace and, as such, 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 paragraph 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

Detailed guidance on obstacle clearance is provided in PANS-OPS (ICAO Doc 8168, Vol II). The general criteria in Part 1 and Part 3 apply, together with the en-route criteria from Doc 8168, Volume II, Part III, Section 1, Chapter 7 (4 NM) and Section 3, Chapter 8.

The separation minima are described in Section 5.4 of the Procedures for Air Navigation Services — Air Traffic Management (PANS-ATM, Doc 4444).

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 to those for a 30 NM standard.

1.2.4. Additional Considerations

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.

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.

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 ICAO Annex 15.

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:

Core training

- a) How area navigation systems work (in 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 vs. fly-over 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
 - (v) Phraseology

Training Specific To This Navigation Specification

For application of 30/30 separation minima

- a) CPDLC communication ;
- b) ADS-C system and simulation training;
- 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 the 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 Nav aids 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

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 regulation requires operators to apply to their national authority (State of registry) for operational approval.

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

1.3.2. Approval Process

This Navigation Specification does not in itself constitute regulatory guidance material against which either the aircraft or the operator will be assessed and approved. Aircraft are certified by their State of manufacture. Operators are approved in accordance with their National Operating Rules. The Navigation Specification provides the technical and operational criteria, and does not imply a need for recertification.

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 material must be accepted by the State regulatory authority; and
- e) Operational approval must then be obtained in accordance with national operating rules.

1.3.2.1 Aircraft Eligibility

Eligibility airworthiness documents. Relevant documentation acceptable to the State of Operator/Registry must be available to establish that the aircraft is equipped with an RNAV systems 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. as with EASA AMC 20 series document.

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 the case where certification is received through a 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 below in subparagraphs 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 paragraph 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 program 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 paragraph 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.

1.3.2.2 Operational Approval

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
- e) Where required, control of navigation database process

The operational approval will likely be documented through the State endorsing the Air Operators Certificate (AOC) through issue of a letter of authorisation, appropriate operations specification (Ops Spec) or amendment to the operations manual.

1.3.2.2.1 Description of aircraft equipment

The operator must have a configuration list detailing pertinent components and equipment to be used for RNP 4 operation.

1.3.2.2.2 Training documentation

Commercial operators must have a training program 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 program or regimen if RNAV training is already an integrated element of a training program. However, it should be possible to identify what aspects of RNAV are covered within a training program.

Non-commercial operators must be familiar with the practices and procedures identified in paragraph 1.3.5 “Pilot Knowledge/Training” of this chapter.

1.3.2.2.3 Operations manuals and checklists

Operations manuals and checklists for commercial operators must address information/guidance on the standard operating procedures detailed in section 1.3.4 of this chapter. 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.

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.

Non-commercial operators must operate using the practices and procedures identified in paragraph 1.3.5 “Pilot Knowledge/Training” of this chapter.

1.3.2.2.4 Minimum Equipment List (MEL) considerations

Any minimum equipment list (MEL) revisions necessary to address RNP 4 provisions must be approved.

Operators must adjust the MEL, or equivalent, and specify the required dispatch conditions.

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

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. It can be used as either a stand-alone navigation system or as one of the sensors to a multi-sensor system.

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.

The equipment configuration used to demonstrate the required accuracy must be identical to the configuration specified in the MEL or flight manual.

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.

1.3.3.1. 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% of the total flight time. The along-track error must also be within ± 4 NM for at least 95% of the total flight time.

An FTE of 2.0 NM (95%) 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 (ICAO 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 (paragraph 1.3.6) and crew procedures (paragraph 1.3.4).

1.3.3.2. 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 data base access;
 - o) WGS 84 geodetic reference system, and
 - p) automatic radio position updating.
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1.3.3.3. Explanation of Required Functionalities

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 instruments for navigation of the aircraft, for manoeuvre anticipation, and for failure/status/integrity indication, with the following attributes:
 1. 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 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.

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 (for example, 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 geodesic portion of DF leg types.

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 (referred as when the aircraft barometric altitude is less than FL 195); and

- b) Course changes do not exceed 70 degrees for high altitude transitions (referred as when the aircraft barometric altitude is equal to or greater than FL 195).

User interface displays

General user interface display features must provide for presentation of 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) Use of context sensitive help capability and error messages (for example, invalid inputs 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.

Displays and controls

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, it is intended that provisions of certification documents such as AC 25-11, AMJ 25-11 and other applicable documents should be satisfied.

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.

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 whose presence or continuation would be detrimental to the continued performance of the system. System controls must be arranged to provide adequate protection against inadvertent system shutdown.

Flight planning path selection

The navigation system must provide the capability for the crew to create, review and activate a flight plan. The system must provide the capability for modification (for example, 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 outputs must not be affected until modification(s) is/are activated. Activation of any flight plan modification must require positive action by the flight crew after input and verification by the flight crew.

Flight planning fix sequencing

The navigation system must provide the capability for automatic sequencing of fixes.

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.

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 (for example, resolution) must be accounted for in the total system error.

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.

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 navigation database data 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.

Geodetic reference system

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. 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.

Pre-flight Planning

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 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 routes. Controller-Pilot Data Link Communication (CPDLC) and Automatic Dependent Surveillance-Contract (ADS-C) will also be required when the separation standard is 30 nm lateral and/or longitudinal.

The onboard 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.

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.

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, to include the availability of FDE, if appropriate for the operation.

En-route

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 routing, or diversion for repairs.

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.

Crews must advise ATC of any deterioration or failure of the navigation equipment that causes navigation performance to fall below the required level, and/or any deviations required for a contingency procedure.

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 section 1.3.3.3.b. 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 route (i.e. +/- 4 NM). All pilots are expected to maintain route centrelines, as depicted by onboard 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 1 times the navigation accuracy (i.e. 4 NM), are allowable.

1.3.5. Pilot Knowledge and Training

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.

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 in the operator's/owner's application for an RNP 4 approval that the operator 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

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).

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.

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

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.

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/ats/ato/rnp.htm>
<http://www.faa.gov/ats/ato/ispacg.htm> (see FANS Operations Manual)
- Civil Aviation Safety Authority (CASA), Australia
<http://www.casa.gov.au/avreg/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 Document Sales Unit, ICAO, 999 University Street, Montreal, 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) – Web site: 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 TMAs with no or limited ATS Surveillance, with low to medium density traffic.

3.1.2. Purpose

This navigation specification provides guidance to States implementing Basic-RNP 1 for arrival and departure procedures.

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 that are required by the appropriate State authority before conducting flights into that airspace.

3.2. ANSP CONSIDERATIONS

3.2.1. Navaid Infrastructure Considerations

GNSS will be the primary navigation system to support the 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 mean it is not practical or cost effective for widespread application.

ANSPs should ensure operators of GNSS-equipped aircraft have access to a means of predicting the availability of fault detection using ABAS (e.g., RAIM). Where applicable, ANSPs should also ensure operators of SBAS-equipped aircraft have access to a means of predicting the availability of 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 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 (5) minutes for any part of the Basic-RNP 1 operation.

Basic-RNP 1 shall not be used in areas of known navigation signal (GNSS) interference.

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 & 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

Detailed guidance on obstacle clearance is provided in PANS-OPS (ICAO Doc 8168, Vol II). The general criteria in Part 1 and Part 3 apply, together with the criteria from Doc 8168, Volume II, Part III, Section 1, Chapter 2 and the chapter in Section 3 for the appropriate phase of flight regarding Basic GNSS.

Route spacing for Basic-RNP 1 depends on the route configuration, air traffic density and intervention capability. Horizontal separation standards are published in Doc 4444 PANS-ATM.

3.2.4. Additional Considerations

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% value.

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 ICAO Annex 15.

All procedures must be based upon WGS 84 coordinates

3.2.6. Controller Training

Air traffic controllers who will provide RNP terminal and approach control services where Basic-RNP 1 is implemented, should have completed training that covers the items listed below.

Core training

- a) How area navigation systems work (in 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 vs. fly-over 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
 - (v) Phraseology

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;
- d) Impact of requesting a change to routeing during a procedure.

3.2.7. Status monitoring

The Navaid infrastructure should be monitored and, where appropriate, maintained by the service provider. Timely warnings of outages (NOTAM) should be issued.

Status information should be provided in accordance with ICAO Annex 11 for navigation facilities or services that may be used to support the operation.

3.2.8. ATS System Monitoring

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

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

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.

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 material must be accepted by the State regulatory authority; and
- e) Operational approval should then be obtained in accordance with national operating rules.

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.

3.3.2.1. Aircraft Eligibility

The aircraft eligibility has to be determined through demonstration of compliance against the relevant airworthiness criteria and the requirements of section 3.3.3. 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, etc.). Aircraft Flight Manual (AFM) entries are not required provided the State accepts manufacturer documentation.

3.3.2.2. Operational Approval

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
- e) Where required, control of navigation database process

The operational approval will likely be documented through the State endorsing the Air Operators Certificate (AOC) through issue of a letter of authorisation, appropriate operations specification (Ops Spec) or amendment to the operations manual.

3.3.2.2.1 Description of aircraft equipment

The operator must have a configuration list detailing pertinent components and equipment to be used for Basic-RNP 1.

3.3.2.2.2 Training documentation

Commercial operators should have a training program 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 program or regimen if RNAV training is already an integrated element of a training program. However, it should be possible to identify what aspects of RNP are covered within a training program.

Private operators should be familiar with the practices and procedures identified in section 3.3.5, Pilot Knowledge/Training.

3.3.2.2.3 Operations manuals and checklists

Operations manuals and checklists for commercial operators must address information/guidance on the standard operating procedures detailed in section 3.3.4 of this chapter. 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.

Private operators should operate using the practices and procedures identified in section 3.3.5, Pilot Knowledge/Training.

3.3.2.2.4 Minimum Equipment List (MEL) considerations

Any minimum equipment list (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
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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% of the total flight time. The along-track error must also be within ± 1 NM for at least 95% of the total flight time.

To satisfy the accuracy requirement, the 95% 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 (ICAO Annex 10, 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 (paragraph 3.3.6) and crew procedures (paragraph 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 it does 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:	<p>Non-numeric lateral deviation display (for example, 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:</p> <ol style="list-style-type: none"> 1) The displays must be visible to the pilot and located in the primary field of view (± 15 degrees from 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.

		<ol style="list-style-type: none"> 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. <p>As an alternate means, a navigation map display should give equivalent functionality to a lateral deviation display as described in section 3.3.3.3.a (i-v), with appropriate map scales (scaling may be set manually by the pilot), and giving equivalent functionality to a lateral deviation display.</p>
b)	The following system functions are required as a minimum within any Basic-RNP 1 equipment:	<ol style="list-style-type: none"> 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 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) Capacity to load from the database into the Basic-RNP 1 system the entire segment of the SID or STAR to be flown. <p><i>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</i></p>

		<i>after the last named waypoint do not have to be loaded from the database. The entire SID will be still be considered an RNP 1 procedure.</i>
c)	The means to display the following items, either in the pilot's primary field of view, or on a readily accessible display page:	<ol style="list-style-type: none"> 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 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 onboard database including the capability to execute fly-over and fly-by turns.	
g)	<p>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.</p> <ul style="list-style-type: none"> • Initial Fix (IF) • Course to Fix (CF) • Direct to Fix (DF) • Track to Fix (TF) 	<p><i>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.</i></p> <p><i>Note 2: Numeric values for courses and tracks must be automatically loaded from the RNP system database.</i></p>
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.

Pre-flight Planning

Operators and pilots intending to conduct operations on Basic-RNP 1 SID's and STAR's should file the appropriate flight plan suffixes.

The onboard 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.

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 SBAS signal is unavailable.

ABAS Availability

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.

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.

In the event of a predicted, continuous loss of appropriate level of fault detection of more than five (5) 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).

RAIM availability prediction software does not guarantee the service, they are rather tools to assess 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.

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.

Note: Pilots must adhere to any AFM limitations or operating procedures required to maintain Basic-RNP 1 performance for the SID or STAR.

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.

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.

Pilots must not fly a Basic-RNP 1 SID or STAR unless it is retrievable by procedure name from the onboard navigation database and conforms to the charted procedure. However, the procedure may subsequently be modified through the insertion or deletion of specific waypoints in response to ATC clearances. The manual entry, or creation of new waypoints, by manual entry of latitude and longitude or rho/theta values is not permitted. Additionally, pilots must not change any SID or STAR database waypoint type from a fly-by to a fly-over or vice versa.

Flight crews should crosscheck 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° or less may result from equipment manufacturer's application of magnetic variation and are operationally acceptable.

Cross-checking with conventional Nav aids 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.

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).

All pilots are expected to maintain centrelines, as depicted by onboard 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 $\pm \frac{1}{2}$ 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 1 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. As such, pilots of these aircraft may not be able to adhere to the $\pm\frac{1}{2}$ lateral navigation accuracy during turns but are still expected to satisfy the standard during intercepts following turns and on straight segments.

If ATC issues a heading assignment taking the aircraft off 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.

Manually selecting aircraft bank limiting functions may reduce the aircraft's ability to maintain its desired track and are not recommended. Pilots should recognize 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 Airplane Flight Manual procedures; rather, pilots should be encouraged to limit the selection of such functions within accepted procedures.

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.

Basic-RNP 1 SID Specific Requirements

Prior to commencing takeoff, 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 takeoff. A final check of proper runway entry and correct route depiction, shortly before takeoff, is recommended.

Engagement Altitude. The pilot must be able to use Basic-RNP 1 equipment to follow flight guidance for lateral RNAV no later than 500 feet above airport elevation.

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.

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 1nm between 30nm from the ARP and the termination of the Basic-RNP 1 SID.

For aircraft using a lateral deviation display (i.e., navigation map display), the scale must be set appropriate for the Basic-RNP 1 SID, and the flight director or autopilot should be used.

Basic-RNP 1 STAR Specific Requirements

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 fly-over. 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.

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.

Where the contingency procedure requires reversion to a conventional arrival route, necessary preparation must be completed before commencing the Basic-RNP 1 procedure.

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.

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.

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

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 appropriate for the Basic-RNP 1 STAR, and the flight director or autopilot should be used.

Contingency Procedures

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 ATIS 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.

In the event of communications failure, the flight crew should continue with the published lost communication procedure.

3.3.5. Pilot Knowledge and Training

The training program should provide sufficient training (for example, simulator, training device, or aircraft) on the aircraft’s RNP system to the extent that the pilots are familiar with the following:

- a) The information in this chapter.
- b) The meaning and proper use of Aircraft Equipment/Navigation Suffixes.
- c) Procedure characteristics as determined from chart depiction and textual description.
- d) Depiction of waypoint types (fly-over and fly-by) and path terminators (provided in section 3.4.3.4 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 aircraft navigation data.
 - ii) Verify 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 centreline.
- i) R/T phraseology for RNAV/RNP applications
- j) Contingency procedures for RNAV/RNP failures.

3.3.6. Database

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 7.4). 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).

Discrepancies that invalidate a SID or STAR must be reported to the navigation database supplier and affected SID or STAR 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.

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

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.

Information that indicates the potential for repeated errors may require modification of an operator's training program. Information that attributes multiple errors to a particular pilot crew may necessitate remedial training or license 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). Web site: <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) – Web site: www.eurocae.eu

Copies of FAA documents may be obtained from Superintendent of Documents, Government Printing Office, Washington, DC 20402-9325, USA. Web site: <http://www.faa.gov/certification/aircraft/> (Regulation 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). Web site www.rtca.org.

Copies of ARINC documents may be obtained from Aeronautical Radio Inc., 2551 Riva Road, Annapolis, Maryland 24101-7465, USA. Web site: <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 web site, <http://www.jaa.nl> , and on the IHS web sites <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 Document Sales Unit, International Civil Aviation Organization, 999 University Street, Montreal, Quebec, Canada H3C 5H7, (Fax: 1 514 954 6769, or e-mail: sales_unit@icao.org) or through national agencies.

CHAPTER 4

IMPLEMENTING ADVANCED-RNP 1

To be developed

CHAPTER 5

IMPLEMENTING RNP APCH

5.1. INTRODUCTION

5.1.1. Background

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 U.S. 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.

This chapter addresses approach applications based on GNSS which are classified RNP APCH in accordance with the PBN concept.

5.1.2. Purpose

This chapter provides guidance to States implementing RNP APCH operations (excluding RNP AR APCH operations). For the Air Navigation Service Provider, it provides a consistent ICAO recommendation on what to implement. For the operator, it provides a combination of European and U.S. RNAV airworthiness and operational criteria. For existing stand-alone and multi-sensor RNAV systems using GNSS, compliance with both European (EASA AMC 20) and U.S. (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 APCHROACH. 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.

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 guidance material.

5.2. ANSP CONSIDERATIONS

5.2.1. Navaid Infrastructure

GNSS is the primary navigation system to support RNP APCH procedures.

The missed approach segment may be based upon the conventional Navaid (e.g., VOR, DME, NDB).

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 function (e.g. RAIM holes), must be considered by the responsible airspace authority.

5.2.2. Communication & 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

Detailed guidance on obstacle clearance is provided in PANS-OPS (ICAO Doc 8168, Vol II). The general criteria in Part 1 and Part 3 apply, together with the approach criteria from Doc 8168, Volume II, Part III, Section 1, Chapter 2 and Section 3, Chapter 3 regarding Basic GNSS. The criteria in Part 3, Section 1, Chapter 7 shall not be used. If Barometric VNAV is applied (see attachment A), then also PANS-OPS (ICAO DOC 8168, VOL II), Volume II, Section 3, Chapter 4 applies.

Note: Changes in PANS-Ops criteria are anticipated as a result of the consolidation of Basic GNSS and RNP criteria. It is expected that when this occurs, it will only apply from that moment on. Procedures developed consistent with Basic GNSS criteria will not be invalidated or required to change.

Missed approach procedure may be supported by either RNAV or conventional (e.g. based on NDB, VOR, DME) segments.

Procedures design must take account of the absence of a vertical navigation capability on the aircraft.

5.2.4. Additional Considerations

Many aircraft have the capability to execute a holding pattern manoeuvre using their RNP system.

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 ICAO Annex 15 and Annex 4 (as appropriate).

All procedures must be based upon WGS 84 coordinates.

5.2.6. Controller Training

Air traffic controllers, who will provide control services at airports where RNP approaches have been implemented, should have completed training that covers the items listed below.

Core training

- a) How area navigation systems work (in 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 vs. fly-over concept (and different turn performance)
 - b) Flight Plan requirements
-

- c) ATC Procedures
 - (i) ATC contingency procedures
 - (ii) Separation minima
 - (iii) Mixed equipage environment
 - (iv) Transition between different operating environments
 - (v) Phraseology

Training Specific To This Navigation Specification

- a) Related control procedures;
 - (i) Radar Vectoring Techniques (where appropriate);
- b) RNP approach and related procedures:
 - (i) including T and Y approaches;
 - (ii) Approach Minima.
- c) Impact of requesting a change to routeing during a procedure.

5.2.7. Status monitoring

The Navaid infrastructure should be monitored and, where appropriate, maintained by the service provider. Timely warnings of outages (NOTAM) should be issued.

Status information should be provided in accordance with ICAO Annex 11 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

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 may require a specific operational approval in some cases. For example, certain operational regulation requires operators to apply to their national authority (State of registry) for operational approval.

This chapter addresses only the lateral part of the navigation system. If the system is approved for APV-
Baro VNAV operation, the installation must be compliant with requirements of Attachment A “Baro VNAV” to this guidance material.

5.3.2. Approval Process

This Navigation Specification does not in itself constitute regulatory guidance material against which either the aircraft or the operator will be assessed and approved. Aircraft are certified by their State of manufacture. Operators are approved in accordance with their National Operating Rules. The Navigation Specification provides the technical and operational criteria, and does not imply a need for recertification.

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.

Following the successful completion of the above steps, a RNP APCH operational approval, letter of authorization or appropriate operations specification (Ops Spec), if required, should then be issued by the State.

5.3.2.1 Aircraft Eligibility

Eligibility airworthiness documents. Relevant documentation acceptable to the State of operation must be available to establish that the aircraft is equipped with an RNAV systems 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 EASA AMC 20 series document. RNP AR APCH Systems are considered qualified for RNP APCH operations without further examination.

5.3.2.2 Operational Approval

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
- e) Where required, control of navigation database process

The operational approval will likely be documented through the State endorsing the Air Operators Certificate (AOC) through issue of a letter of authorisation, appropriate operations specification (Ops Spec) or amendment to the operations manual.

5.3.2.2.1 Description of aircraft equipment

The operator must have a configuration list detailing pertinent components and equipment to be used for RNP APCH operation.

5.3.2.2.2 Training documentation

Commercial operators must have a training program 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 program or regimen if RNAV training is already an integrated element of a training program. However, it should be possible to identify what aspects of RNAV are covered within a training program.

Private operators must be familiar with the practices and procedures identified in paragraph 5.3.5 "Pilot Knowledge/Training" of this chapter.

5.3.2.2.3 Operations manuals and checklists

Operations manuals and checklists for commercial operators must address information/guidance on the standard operating procedures detailed in the "Operating procedures" section of this chapter. 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.

Private operators must operate using the practices and procedures identified in paragraph 5.3.5 "Pilot Knowledge/Training" of this chapter.

5.3.2.2.4 Minimum Equipment List (MEL) considerations

Operators must adjust the MEL, or equivalent, and specify the required dispatch conditions. Any minimum equipment list (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

Accuracy: During operations on the initial, intermediate segment and for the RNAV missed approach of an RNP APCH, the lateral total system error must be within ± 1 NM for at least 95% of the total flight time. The along-track error must also be within ± 1 NM for at least 95% of the total flight time.

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% of the total flight time. The along-track error must also be within ± 0.3 NM for at least 95% of the total flight time.

To satisfy the accuracy requirement, the 95% FTE should not exceed 0.5 NM on the initial, intermediate and for the RNAV missed approach of an RNP APCH. The 95% 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, intermediate and 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).

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. If the missed approach procedure is based on conventional means (e.g. NDB, VOR, DME), related navigation equipment must be installed and be serviceable.

Performance Monitoring and Alerting: During operations on the initial, intermediate segment 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} .

Signal-in-Space: During operations on the initial, intermediate segment 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 (ICAO Annex 10, 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 (ICAO Annex 10, 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 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 (paragraph 5.3.6) and crew procedures (paragraph 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.

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.

- 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 it does 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

Navigation Displays and Required Functions

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.

- a) The displays must be visible to the pilot and located in the primary field of view (± 15 degrees from 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 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), and giving equivalent functionality to a lateral deviation display. 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) Flight director and/or autopilot is not required for this type of operation however if the lateral Total System Error 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.
- 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.

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
 - (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
 - (iv) The active navigation sensor type if there is other sensor in addition to the GNSS one.
- 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 onboard database including the capability to execute fly-over 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 authorise operator to conduct 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

Operators and pilots intending to conduct operations on 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 suitability of navigation facilities used to define the routes and procedures for flight.

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 alternates aerodromes) are selectable from a valid navigation data base (current AIRAC cycle), have been verified by the appropriate process (navigation data base integrity process) and are not prohibited by a company instruction or NOTAM.
- b) Subject to 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.
- d) For missed approach procedures based on conventional means (VOR,NDB) the appropriate airborne equipment required to fly this procedure is installed in the aircraft and is operational. Also, the associated ground-based Navaids are operational.

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 SBAS signal is unavailable.

ABAS Availability

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.

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.

In the event of a predicted, continuous loss of appropriate level of fault detection of more than five (5) 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).

RAIM availability prediction software does not guarantee the service, they are rather tools to assess 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.

5.3.4.2 Prior to Commencing the Procedure

In addition to 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.
- 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.

Crew must also check from the published charts, map display or Control Display Unit (CDU), which waypoints are fly-by and which are fly-over.

For multi-sensor systems, crew must verify during the approach that GNSS sensor is used for position computation.

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.

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.

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.
- 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°.

Note: Direct to clearance to FAF is not acceptable.

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.

5.3.4.3 During the Procedure

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).

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 system (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.

The appropriate displays must be selected so that the following information can be monitored:

- a) The RNAV computed desired path (DTK), and
- b) Aircraft position relative to the path (Cross-track deviation) for FTE monitoring.

The procedure must be discontinued:

- a) If the navigation display is flagged invalid,
- b) Or in case of loss of integrity alerting function,
- c) Or if integrity alerting function is annunciated not available before passing the FAF.

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) Or if FTE is excessive.
-

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,..).
- b) The whole procedure (including the missed approach) is loaded from the navigation data-base.

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 onboard lateral deviation indicators and/or flight guidance during all the 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 $\pm 1/2$ 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 1 times the navigation accuracy (i.e., 1.0 nm for the Initial and Intermediate segments), are allowable.

When Baro-VNAV is used for vertical path guidance during the final approach segment, deviations above and below the Baro-VNAV path must not respectively exceed +100/-50 feet.

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.

5.3.4.4 General Operating Procedures

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.

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

While operating on RNAV segments, pilots are encouraged to use flight director and/or autopilot in lateral navigation mode, if available.

5.3.4.5 Contingency Procedures

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 Air Traffic Service 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 procedure in order to react safely following the loss of the RNP APCH capability during the approach.

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 program must provide sufficient training (for example, simulator, training device, or aircraft) on the aircraft's RNAV system to the extent that the pilots are not just task oriented.

- 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.

Knowledge regarding depiction of waypoint types (fly-over and fly-by), required path terminators (IF, TF, DF) and any other types used by the operator as well as associated aircraft flight paths.

Knowledge on the required navigation equipment in order to conduct RNP APCH operation (at least one RNP system based on GNSS).

Knowledge of RNP system-specific information:

- a) Levels of automation, mode annunciations, changes, alerts, interactions, reversions, and degradation.
- b) Functional integration with other aircraft systems.
- c) The meaning and appropriateness of route discontinuities as well as related flight crew procedures.
- d) Monitoring procedures for each phase of flight.
- e) Types of navigation sensors utilized by the RNP system and associated system prioritization/weighting/logic.
- f) Turn anticipation with consideration to speed and altitude effects.
- g) Interpretation of electronic displays and symbols.

Knowledge of RNAV equipment operating procedures, as applicable, including how to perform the following actions:

- a) Verify currency of aircraft navigation data.
- b) Verify successful completion of RNP system self-tests.
- c) Initialize RNP system position.
- d) Retrieve and fly an RNP APCH.
- e) Adhere to speed and/or altitude constraints associated with an approach procedure.
- f) Fly interception of an initial or intermediate segment of an approach following ATC notification.
- g) Verify waypoints and flight plan programming.
- h) Fly direct to a waypoint.
- i) Determine cross-track error/deviation.
- j) Insert and delete route discontinuity.
- k) When required by the State aviation authority, perform gross navigation error check using conventional navigation aids.
- l) Change arrival airport and alternate airport.

Knowledge of Operator-recommended levels of automation for phase of flight and workload, including methods to minimize cross-track error to maintain procedure centreline.

Knowledge of Radio Telephony phraseology for RNP applications

Ability to conduct contingency procedures following RNP system failures

5.3.6. Navigation Database

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).

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.

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

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.

Information that indicates the potential for repeated errors may require modification of an operator's training program. Information that attributes multiple errors to a particular pilot crew may necessitate remedial training or license 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). Web site: <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) – Web site: www.eurocae.eu

Copies of FAA documents may be obtained from Superintendent of Documents,

Government Printing Office, Washington, DC 20402-9325, USA. Web site: <http://www.faa.gov/certification/aircraft/> (Regulation 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). Web site www.rtca.org.

Copies of ARINC documents may be obtained from Aeronautical Radio Inc., 2551 Riva Road, Annapolis, Maryland 24101-7465, USA. Web site: <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 web site, <http://www.jaa.nl>, and on the IHS web sites <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 Document Sales Unit, International Civil Aviation Organization, 999 University Street, Montreal, Quebec, Canada H3C 5H7, (Fax: 1 514 954 6769, or e-mail: sales_unit@icao.org) or through national agencies.

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 is developing equivalent guidance.

6.1.2 Purpose

This chapter provides a consistent ICAO recommendation and method of compliance with RNP (AR) instrument approach procedure (IAP) requirements. The goal of this document is to avoid the proliferation of national standards and the need for multiple regional approvals.

This chapter addresses operational and airworthiness issues. It does *not* address all requirements that may be specified for operation on a procedure. 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 that 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 does not exist, avionics and infrastructure variability pose serious challenges to standardization.

6.2.2 Communication & ATS Surveillance Considerations

RNP AR APCHs do not require any unique communication or ATS Surveillance considerations.

6.2.3 Obstacle Clearance and Route Spacing

Guidance for the application of RNP(AR) Approach is provided in the ICAO Manual *Procedure Design for RNP(AR) Approach Procedures*.

Terrain and obstacle data in the vicinity of the approach should be published, in accordance with ICAO Annex 15.

Obstacle clearance must be ensured in accordance with the ICAO Manual *Procedure Design for RNP (AR) Approach Procedures*. A Safety Assessment must be conducted upon determining route spacing.

6.2.4 Additional Considerations

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

Current local pressure setting must be provided to support RNP AR APCHs, where the aircraft's achieved vertical path is dependent on that setting. Failure to report a correct setting can lead to aircraft leaving the obstacle clearance area.

The Safety Assessment items listed in paragraph 6.4 must be considered prior to implementation. The criteria in this Navigation Specification satisfy the criteria of section 6.4 Safety Assessment. As a result, the safety assessment for each procedure need only focus on areas of unique operational risk.

Flight Evaluation

As RNP AR APCHs do not have a specific underlying navigation facility, there is no requirement for flight inspection of navigation signals. However, due to the importance of publishing correct data, it is recommended that flight evaluation be used prior to publication for procedure validation and obstacle validation. Flight evaluation can be accomplished through ground evaluation (e.g, simulator assessment) and actual flight.

Procedure validation includes confirmation of the basic flyability of the procedure in accordance with the procedure design. A thorough flyability assessment is not required prior to publication, since flyability is individually assessed by the operator as part of their database updating and maintenance process due to the unique nature of RNP AR APCHs. The flight evaluation prior to publication should confirm track lengths, bank angles, descent gradients, runway alignment and compatibility with predictive terrain hazard warning functions (e.g., Terrain Awareness and Warning Systems). A truth system is typically not required. Due to variations in aircraft speeds, flight control system design, and navigation system design this flight evaluation does not confirm flyability for all of the various aircraft conducting RNP AR APCHs.

Obstacle validation through flight evaluation may be used to validate the obstacle data used to design the procedure. An obstacle flight evaluation may not be necessary if obstacle validation can be accomplished through ground inspection or validated survey techniques to the appropriate accuracy.

6.2.5 Publication

The AIP should clearly indicate the navigation application is RNP AR APCH and specific authorization is required.

All routes must be based upon WGS 84 coordinates.

The navigation data published in the State AIP for the procedures and supporting navigation aids must meet the requirements of ICAO Annex 15 and Annex 4 (as appropriate). The original data defining the procedure should be available to the operators in a manner suitable to enable the operator to verify their navigation data. 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 will provide control services at airports where RNP approaches have been implemented, should have completed training that covers the items listed below.

Core training

- a) How area navigation systems work (in 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 vs. fly-over concept (and different turn performance)
 - b) Flight Plan requirements
 - c) ATC Procedures
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- (i) ATC contingency procedures
- (ii) Separation minima
- (iii) Mixed equipage environment
- (iv) Transition between different operating environments
- (v) Phraseology

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 routeing during a procedure.

6.2.7 Status monitoring

The Navaid infrastructure should be monitored and, where appropriate, maintained by the service provider. Timely warnings of outages (NOTAM) should be issued.

Status information should be provided in accordance with ICAO Annex 11 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 Air Traffic Service (ATS) facilities and aircraft track-keeping capabilities are analyzed. 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.

6.3 NAVIGATION SPECIFICATION

6.3.1 Background

This chapter 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

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.

Any operator with an appropriate operational approval may conduct RNP (AR) instrument approach procedures, in a similar manner that operators with the proper authorization may conduct CAT II and CAT III ILS operations.

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 document should describe the navigation capabilities of 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 to support operational approval by the appropriate Regulatory Authorities.

Operators should use the manufacturer recommendations when developing their procedures and application for approval. Installation of equipment is not sufficient by itself to obtain approval for use on RNP AR APCHs.

The following steps must be completed before conducting RNP AR APCH operations:

6.3.2.1 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 manufacturer documentation. Aircraft equipment eligibility must include:

- a) Aircraft qualification
- b) Established maintenance procedures
- c) MEL revision

6.3.2.2 Operational Approval

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) Operating procedures for the navigation systems to be used and the operator navigation database process must include:
 - i) Navigation database validation program (see paragraph 6.3.6 for additional information)
 - ii) Operational procedure requirements
 - iii) RNP monitoring program (see paragraph 6.3.7 for additional information)
 - iv) Dispatch/flight following procedures
- c) Control of those procedures through acceptable entries in the Operations Manual
- d) Identification of flight crew training requirements
- e) Where required, control of navigation database process
- f) Flight crew and dispatch training based upon the operating procedures must be documented;

The operational approval will likely be documented through the State endorsing the Air Operators Certificate (AOC) through issue of a letter of authorisation, appropriate operations specification (Ops Spec) or amendment to the operations manual.

6.3.2.2.1 Description of aircraft equipment

The operator must have a configuration list detailing pertinent components and equipment to be used for RNP AR APCH.

6.3.2.2.2 Training documentation

Commercial operators should have a training program 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 program or regimen if these items are already an integrated element of a training program. The operator should identify which aspects of RNP are covered within a training program.

Private operators should be familiar with the practices and procedures identified in section 6.3.5, Pilot Knowledge/Training.

6.3.2.2.3 Operations manuals and checklists

Operations manuals and checklists for commercial operators must address information/guidance on the standard operating procedures detailed in section 6.3.4 of this chapter. 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.

Private operators should operate using the practices and procedures identified in section 6.3.5, Pilot Knowledge/Training.

6.3.2.2.4 Minimum Equipment List (MEL) considerations

Any minimum equipment list (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.

6.3.2.3 Approval Submittal

Following the successful completion of the above steps, the above material must be accepted by the State regulatory authority; for operational approval (subject to any conditions or limitations) to be obtained in accordance with national operating rules.

The Safety Assessment items listed in paragraph 6.4 should be considered prior to implementation.

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.

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.

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

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, so the requirements in this paragraph do not use the same structure as RNP-4, Basic-RNP 1 and RNP APCH.

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.

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.

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% of system error in the vertical direction must be less than the following (in feet):

$$\sqrt{\left((6076.115)(1.225)\text{RNP} \cdot \tan \theta\right)^2 + (60 \tan \theta)^2 + 75^2 + \left((-8.8 \cdot 10^{-8})(h + \Delta h)\right)^2 + \left(6.5 \cdot 10^{-3}(h + \Delta h) + 50\right)^2}$$

where θ is the vertical navigation (VNAV) path angle, h is the height of the local altimetry reporting station and Δh is the height of the aircraft above the reporting station.

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').

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, 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 ICAO Manual *Procedure Design for RNP(AR) Approach Procedures*) must not exceed 10^{-7} per approach, including the approach and missed approach. This requirement may be satisfied by an operational safety assessment applying (a) appropriate quantitative numerical methods, (b) qualitative operational and procedural considerations and mitigations, or (c) 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 derives from the operational requirement. This requirement 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

This section identifies unique issues for the navigation sensors within the context of RNP AR APCHs.

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 meters (95%), and augmented GPS (GBAS or SBAS) sensor accuracy is better than 2 meters (95%).
- 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% (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% of FTE, during the RNP AR APCH operation.

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%) 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%) 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.

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.

VHF Omni-directional Range station (VOR). 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.

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.

The 99.7% 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:

$$ASE = -8.8 \cdot 10^{-8} \cdot H^2 + 6.5 \cdot 10^{-3} \cdot H + 50 \text{ (ft)}$$

Where H is the true altitude of the aircraft.

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 is provided in EUROCAE ED-75A/ RTCA DO-236B.

General Requirements

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 Fly-Over Fixes. The aircraft must have the capability to execute fly-by and fly-over fixes. For fly-by turns, the navigation system must limit the path definition within the theoretical transition area defined in EUROCAE ED-75B/ RTCA DO-236B under the wind conditions identified in the ICAO Manual *Procedure Design for RNP(AR) Approach Procedures*. The fly-over 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. Waypoint resolution error must be less than or equal to 60 feet, 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 5 ft of the published path.
- d) Capability for a "Direct-To" Function. The navigation system must have a "Direct-To" function the flight crew can activate at any time. This function must be available to any fix. The navigation system must also be capable of generating a geodesic path to the designated "To" fix, without "S-turning" and without undue delay.
- 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 (for example, 2400A, may be appropriate for situations where bounding the vertical path is not required);
 - ii) An "AT or BELOW" altitude constraint (for example, 4800B, may be appropriate for situations where bounding the vertical path is not required);
 - iii) An "AT" altitude constraint (for example, 5200); or
 - iv) A "WINDOW" constraint (for example, 2400A3400B).

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 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 onboard 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 onboard 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 (CF and FA path terminators), the navigation system must use the magnetic variation value for the procedure in the navigation database.
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- k) Changes in Navigation accuracy. RNP changes to lower navigation accuracy must be complete 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.

Demonstration of Path Steering Performance. The demonstration of path steering performance (flight technical error) must be completed in a variety of operational conditions, rare-normal conditions and non-normal conditions (e.g., see FAA AC 120-29A, paragraphs 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) An acceptable criteria to be used for assessing probable failures and engine failure during the aircraft qualification is to demonstrate that the aircraft trajectory is maintained within a 1xRNP corridor, and 75 feet 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 analysis and flight technical evaluation using expert judgement.

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 75 feet (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 derive 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, the flight crew procedures and training. Additional initial and recurrent flight crew training (or line experience) is necessary, so such a solution increase flight crew workload during the approach and imposes 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.
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- c) Display of Distance and Bearing. The navigation system must provide a display of distance and bearing to the active (To) waypoint in the pilot's primary optimum field of view. Where not viable, a readily accessible page on a control display unit, readily visible to the flight crew, may display the data.
- d) Display of Groundspeed and Time. The navigation system must provide the display of groundspeed and time to the active (To) waypoint in the pilot's primary optimum field of view. Where not viable, a readily accessible page on a control display unit, readily visible to the flight crew, may display the data.
- e) 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 aircraft desired 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 10 feet 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 pilots' 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 analyzed to ensure that they can provide an alert in the pilot's primary optimum field of view when deviations between the sources exceed ± 100 feet. Such 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 setting 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.

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 an 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.

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 onboard navigation database must be protected against flight crew modification 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.

The aircraft must provide a means to display the validity period for the onboard navigation database to the flight crew.

Requirements for RNP (AR) Approaches with RF Legs

The navigation system must have the capability to execute leg transitions and maintain tracks consistent with an RF leg between two fixes.

The aircraft must have an electronic map display of the selected procedure.

The FMC, the flight director system and autopilot must be capable of commanding a bank angle up to 25 degrees above 400 feet AGL and up to 8 degrees below 400 feet AGL.

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.

When evaluating 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 5 degrees of manoeuvrability margin, to enable the aircraft to get back on the desired track after a slight overshoot at the start of the turn.

Requirements for RNP (AR) Approaches to less than RNP-0.3

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).

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

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 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 400 feet AGL.

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.

Requirements for Approaches with Missed Approach less than RNP 1.0

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).

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

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 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 400 feet AGL.

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

Pre-flight Considerations

Minimum Equipment List. Operators minimum equipment list 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 or not the missed approach requires 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 altitude that is compensated for local pressure and temperature effects (e.g., corrected barometric and GNSS altitude), and include significant terrain and obstacle data. The flight crew must be cognizant of the required equipment.

Autopilot and Flight Director. RNP AR APCH procedures with navigation accuracy less than RNP-0.3 or with RF legs require the use of 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.

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 program 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.

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.

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 navigation data, including suitability of navigation facilities used to define the routes and procedures for 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.

In-Flight Considerations

Modification of 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 to the loaded procedure is to change 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).

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. quick reference handbook).

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 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 IAF's may have different navigation accuracy, which are annotated on the approach chart.

GNSS Updating. Initially all RNP AR APCH instrument approach procedures require GNSS updating of the navigation position solution. The flight crew must verify 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.

Radio Updating. 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. VOR updating is not authorized at this time. The flight crew must comply with the operator's procedures for inhibiting specific facilities.

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 validity of the navigation database is in doubt. A navigation system textual display or navigation map display must be used.

Track Deviation Monitoring. Pilots must use a lateral deviation indicator, flight director and/or autopilot in lateral navigation mode on RNP AR APCH approach 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 approach procedure. All pilots are expected to maintain procedure centrelines, as depicted by onboard 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 $\pm 1/2$ 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 1 times the navigation accuracy of the procedure segment, are allowable.

The vertical deviation must be within 75 feet 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.

Pilots must execute a Missed Approach if the lateral deviation exceeds $1 \times \text{RNP}$ or the vertical deviation exceeds 75 feet, 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 demonstration of the procedure with a number of trained crews and inclusion of this monitoring procedure in the recurrent RNP AR APCH training program.
- 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 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).

System Crosscheck. For approaches with 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 provided by an independent means.

Note: This crosscheck 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 (see paragraph on Design Assurance) and if the normal system performance supports airspace containment.

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 or not 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 0-1 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 DA may require the segment speed for that segment be maintained.

Table 0-1: 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 & Intermediate (IAF to FAF)	150	180	240	250	250
Final (FAF to DA)	100	130	160	185	As Specified
Missed Approach (DA to MAHP)	110	150	240	265	As Specified
Airspeed Restriction*	As specified				

*Airspeed restrictions may be used to reduce turn radius regardless of aircraft category.

Temperature Compensation. For aircraft with temperature compensation capability, 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.

Altimeter Setting. Due to the reduced obstruction clearance inherent in RNP AR APCH instrument approach procedures, the flight crew must verify 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.

Altimeter Crosscheck. The flight crew must complete an altimetry crosscheck ensuring both pilots' altimeters agree within ± 100 feet prior to the final approach fix (FAF) but no earlier than the IAF. If the altimetry crosscheck 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 also address actions to take if a comparator warning for the pilots' altimeters occurs while conducting an RNP AR APCH procedure.

Note: This operational crosscheck is not necessary if the aircraft automatically compares the altitudes to within 100 feet (see also paragraph 6.3.3.4, *Displays, (n) Display of Barometric Altitude*).

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 final approach fix) is considered operationally acceptable, and desirable, to ensure 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 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.

Non-Standard Climb Gradient. When the operator plans to use the DA associated with a non-standard missed approach climb gradient, he 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 personnel that determine if their aircraft can comply with published climb gradients, information should be provided to the pilots indicating the climb gradient they can expect to achieve.

Engine-Out Procedures. Aircraft may demonstrate acceptable flight technical error with one engine inoperative to conduct RNP AR APCHs. Otherwise, flight crews are expected to take appropriate action in event of engine failure during an approach so that no specific aircraft qualification is required. The aircraft qualification should identify any performance limits in event of engine failure to support definition of appropriate flight crew procedures. Particular attention should be given to procedures with published non-standard climb gradients.

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. To be approved to conduct these approaches, equipment and procedures must meet criteria in paragraph 6.3.3.4 (Requirements for Approaches with Missed Approach less than RNP 1.0).

In many aircraft when executing a go-around or missed approach activating Take-off/Go-around (TOGA) may cause a change in lateral navigation. In many aircraft, activating TOGA disengages the autopilot and flight director from LNAV guidance, and the flight director reverts to track-hold derived from the inertial system. LNAV guidance to the autopilot and flight director should be re-engaged as quickly as possible.

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 issued a different clearance by ATC. 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.

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.

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 paragraph 6.3.4, Preflight Considerations (Dispatch RNP Assessment), the flight crew also must be able to assess the impact of changes in the GNSS constellation and take appropriate action.

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 crewmembers 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 program 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. Required training must include both knowledge and skill assessments of the crewmembers and dispatchers duties.

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
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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 flying activities. Many operators may train for RNP AR APCH procedures under the established training standards and provisions for Advanced Qualification Programs (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 mediums 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 programs in a 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 program 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 program relies on previous training (e.g., Special RNP IAP's) must receive specific authorization from their Principal Operations Inspector/Flight Operations Inspector. In addition to the current RNP training program the air carrier will need to provide differences training between existing training program and the RNP AR APCH training requirements.
- f) Training for flight dispatchers must include: the explanation of 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 manual's 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.

Ground training segments content

Ground training segments must address the following subjects as training modules in approved RNP AR APCH academic training during the initial introduction of a crewmember to RNP AR APCH systems and operations. For recurrent programs, the curriculum need only review initial curriculum requirements and address new, revised, or emphasized items.

General Concepts of RNP (AR) Approach 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) 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 display of RNP and aircraft specific displays (e.g., Actual Navigation Performance).
- e) How to enable and disable the navigation updating modes related to RNP.
- f) Navigation accuracy appropriate for different phases of flight and RNP AR APCH procedures and how to select (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 required navigational data for use of GPS 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, 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 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.

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 instruction 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 failure of any avionics or a known loss of ground systems on the remainder of the flight plan.

RNP AR APCH Equipment Components, Controls, Displays, and Alerts. Academic training must include 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 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.

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 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.

MEL Operating Provisions. Flight crews must have a thorough understanding of the MEL requirements supporting RNP AR APCH operations.

Flight Training Segments - Content

Training programs 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 breadth of the RNP AR APCH procedures 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) 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 groundspeed 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 applicable category.
 - e) 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 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 of reducing the flap setting, reducing the bank angle or increasing airspeeds on the ability to comply with an RNP AR APCH procedure.
 - 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) 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.
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- 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, RNP missed). One procedure must culminate in a transition to landing and one procedure must culminate in execution of an RNP missed approach procedure.

Evaluation Module

Initial Evaluation of RNP AR APCH Knowledge and Procedures. The operator must evaluate each individual flight crewmember on their 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, PC/PT events, operating experience, route checks, and/or line checks.
- c) Line Oriented Flight Training (LOFT)/Line Oriented Evaluation (LOE). LOFT/LOE programs using an approved simulator that incorporates RNP operations that employ the unique RNP AR APCH characteristics (i.e., RF legs, RNP missed) of the operator's approved procedures.

Evaluation Content. Specific elements that must be addressed in this evaluation module are:

- a) Demonstrate the use of any RNP limits/minimums 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 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 setup 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) 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.
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- k) Know 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 vertical flight path.

Recurrent Training

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 program.

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 is 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 paragraph provides guidance for the operator's procedures for validating the navigation data associated with RNP AR APCHs.

Data Process

The operator must identify the responsible manager for the data updating process within their procedures.

The operator must document a process for accepting, verifying and loading navigation data into the aircraft.

The operator must place their documented data process under configuration control.

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 is flyable, does not have any apparent lateral or vertical path disconnects, and is consistent with the published procedure.
- c) Once the procedure is validated, retain and maintain a copy of the validated navigation data for comparison to subsequent data updates.

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.

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.

Aircraft Modifications. If an aircraft system required for RNP AR APCH is modified (e.g., software change), the operator is responsible for validation of RNP AR APCH procedures with 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 initial data validation with the modified system.

6.3.7 Oversight of Operators

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 cancellation of the approval for use of that equipment.

Information that indicates the potential for repeated errors may require modification of an operator's training program. Information that attributes multiple errors to a particular pilot crew may necessitate remedial training or license review.

The operator must have an RNP monitoring program to ensure continued compliance with the guidance of this chapter and to identify any negative trends in performance. At a minimum, this program must address the following information. During the interim approval, the operator must submit the following information every 30 days to the authority granting their authorization. Thereafter, the operator must continue to collect and periodically review this data to identify potential safety concerns, and maintain summaries of this data.

- a) Total number of RNP (AR) 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) Nav data errors.
 - (vi) Pilot report of any anomaly.
- d) Crew comments.

6.4 SAFETY ASSESSMENT

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 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, procedure and process factors. Additionally, technical and operational expertise and experience are essential to the conduct and conclusion of the FOSA.

An overview of the hazards and mitigations is provided to assist States in applying this criteria. Safety of RNP AR APCH operations rests with the operator and the air navigation service provider as described in this chapter.

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 inter-dependence of the elements of design, aircraft capability, crew procedures and operating environment.

The following hazard conditions are examples of some of the more significant hazards and mitigations addressed by the specific aircraft, operational and procedure 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.

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.

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.

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 system).
2. Malfunction of air data system or altimetry: Crew procedure cross-check between two independent systems mitigates this risk.

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.

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.

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 aircraft is established on the procedure, and ATC should not intercept on or just prior to curved segments of the procedure.

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.
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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.

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 (eg 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.

Operating Conditions

1. Tailwind conditions: Excessive speed on RF legs will result in 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) – Web site: 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. Web site: <http://www.faa.gov/certification/aircraft/> (Regulation and Guidance Library)

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- 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). Web site 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 Document Sales Unit, International Civil Aviation Organization, 999 University Street, Montreal, Quebec, Canada H3C 5H7, (Fax: 1 514 954 6769, or e-mail: sales_unit@icao.org) or through national agencies.

ATTACHMENTS

Attachment A

BAROMETRIC VNAV

1.1. INTRODUCTION

1.1.1. 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 provides vertical path information that can be defined by vertical angles or altitudes at fixes in the procedure.

1.1.2. Purpose

This specification provides guidance to States implementing instrument flight procedures where Baro-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 approvals for existing Baro-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 Baro-VNAV operations globally.

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.

1.2. ANSP CONSIDERATIONS

1.2.1. Application of BARO-VNAV

Baro-VNAV is intended to be applied where vertical guidance and information is 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 1).

1.2.2. 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 Part 1 and Part 3 apply, together with the approach criteria from Doc 8168, Volume II, Part III, Section 1, Chapter 2 and Section 3, Chapter 4. The PANS-OPS criteria does not provide specific guidance for design of a Baro-VNAV overlay to a conventional non-precision procedure. In such cases, many other considerations must be made to ensure continued obstacle clearance, flyability, charting consistency and compatibility with airborne systems.

1.3. GENERAL CONSIDERATIONS FOR DEVELOPMENT OF BARO-VNAV SPECIFICATION

1.3.1. Navaid Infrastructure Considerations

The procedure design does not have unique infrastructure requirements. This criteria is 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.

1.3.2. Publication Considerations

Charting should follow the standards of Annex 4 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 (for example if the lateral procedure is predicated on GNSS, the charting will indicate RNAV_(GNSS)).

1.3.3. 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.

1.3.4. Navigation Error Reports

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.

Information that indicates the potential for repeated errors may require modification of an operator's training program. Information that attributes multiple errors to a particular pilot crew may necessitate remedial training or license review.

1.3.5. Service Provider Assumptions

It is expected that air navigation service provision will include data and information to enable correct and accurate altimeter setting on-board the aircraft, as well as local temperature. This data must be from measurement equipment at the airport where the approach is to take place. The specific medium for transmission of this 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.

1.3.6. ATC Coordination

It is expected that ATC will be familiar with aircraft VNAV capability, as well as issues associated with altimeter setting and temperature data required by the aircraft.

1.4. NAVIGATION SPECIFICATION

1.4.1. 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 to aircraft flight and operations manuals. Compliance with the operational requirements herein should be addressed through national operational regulations, and may require a specific operational approval in some cases. For example, certain operational regulation requires operators to apply to their national authority (State of registry) for operational approval.

1.4.2. Approval Process

The following steps must be completed before the use of BARO-VNAV in the conduct of basic RNP approach 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.
-

Following the successful completion of the above steps, operational approval for the use of VNAV, letter of authorization or appropriate operations specification (Ops Spec), or amendment to the Operations Manual, if required, should then be issued by the State.

1.4.3. Aircraft Requirements

1.4.3.1. Aircraft Eligibility

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. as with 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 program addressing the operational practices, procedures and training items 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 program or regimen if RNAV and VNAV training is already an integrated element of a training program. However, it should be possible to identify what aspects of VNAV are covered within a training program. Private operators should be familiar with the practices and procedures identified in paragraph 1.4.6, Pilot Knowledge/Training.

- c) Operations manuals and checklists. Operations manuals and checklists for commercial operators must address information/guidance on the standard operating procedures detailed in section 1.2.1 of this chapter. 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.

Private operators should operate using the practices and procedures identified in section 1.4.6, Pilot Knowledge/Training.

1.4.3.2. Minimum Equipment List (MEL) Considerations

Any unique minimum equipment list (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.

1.4.4. Aircraft System Requirements

1.4.4.1. 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.
- 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 feet per 100 KIAS. Altimetry systems meeting such a requirement will satisfy the Altimetry System Error (ASE) requirements for Baro-VNAV. No further demonstration or compliance is necessary

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 percent probability basis:

	Level Flight Segments and Climb/Descent Intercept Altitude Region of Specified Altitudes (ft)	Climb/Descent Along Specified Vertical Profile (angle) (ft)
At or below 5,000 ft	50	100
5,000 ft to 10,000 ft	50	150
Above 10,000 ft	50	220

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 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. 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. *Note: The vertical error component of along track positioning error is bounded by the following equipment qualification requirements for Baro-VNAV, and is directly reflected in the along track tolerance offset used in Baro-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 and
 - Serviceable VNAV equipment and
 - VNAV system certified for Baro-VNAV approach operations and
 - Equipped with integrated LNAV/VNAV system with accurate source of barometric altitude and
 - VNAV altitudes and procedure information from 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 (ft)	Climb/Descent Along Specified Vertical Profile (angle) (ft)
At or below 5,000 ft	150	200
5,000 ft to 10,000 ft	240	300
Above 10,000 ft	240	300

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 (ft)	Climb/Descent Along Specified Vertical Profile (angle) (ft)
At or below 5,000 ft	158	224
5,000 ft to 10,000 ft	245	335
Above 10,000 ft	245	372

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.

Continuity of function

For operations predicated on the use of barometric VNAV capability, at least one RNAV system is required.

1.4.4.2. Vertical Navigation Functions

Path Definition

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.

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 (for example, 2400A, may be appropriate for situations where bounding the vertical path is not required);
- b) An “AT or BELOW” altitude constraint (for example, 4800B, may be appropriate for situations where bounding the vertical path is not required);
- c) An “AT” altitude constraint (for example, 5200); or
- d) A “WINDOW” constraint (for example, 2400A3400B).
- e) 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.

Vertical Constraints

Altitudes and/or speeds associated with published procedures must be automatically extracted from the navigation database upon selecting the approach procedure.

Path Construction

The system must be able to construct a path to provide guidance from current position to a vertically constrained fix.

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 instruction, into the RNAV system from the onboard 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.

Temperature Limits.

For aircraft using barometric vertical navigation 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 glidepath angle while high temperatures increase the actual glidepath angle. Aircraft using barometric vertical navigation with temperature compensation or aircraft using an alternate means for vertical guidance (e.g., SBAS) may disregard the temperature restrictions.

1.4.4.3. 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.

1.4.4.4. User Interface

Displays and Control

The display readout and entry resolution for vertical navigation information should be as follows:

Parameter	Display Resolution	Entry Resolution
Altitude	Flight level or 1 foot	Flight level or 1 foot
Vertical Path Deviation	10 feet	Not Applicable
Flight Path Angle	0.1 degree	0.1 degree
Temperature	1 degree	1 degree

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 +100/-50 feet. 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 feet. 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.*

Barometric Altitude

The aircraft must display barometric altitude from two independent altimetry sources, one in each pilots' primary optimum field of view. Operator procedures should ensure current altimeter settings for the selected instrument procedure and runway.

1.4.5. Operating Procedures

Airworthiness certification alone does not authorize operator 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.

1.4.5.1. 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.

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."

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 Baro-VNAV capability. If the airborne system contains a temperature compensation capability, manufacturer instructions should be followed for use of the Baro-VNAV function.

1.4.5.2. Contingency Procedures

Where the contingency procedure requires reversion to a conventional procedure, necessary preparation should be completed before commencing the RNAV procedure, consistent with operator practices.

1.4.6. Pilot Knowledge and Training

The training program should provide sufficient training (for example, simulator, training device, or aircraft) on the aircraft's VNAV capability to the extent that the pilots are not just task oriented.

- 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 (fly-over 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 (for example, monitor “PROGRESS” or “LEGS” page).
 - vii) Turn anticipation with consideration to speed and altitude effects.
 - viii) Interpretation of electronic displays and symbols.

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 for crew requirements for comparisons to primary altimeter information, altitude crosschecks (e.g. altimetry comparisons of 100 feet), temperature limitations for instrument procedures using VNAV, and procedures for altimeter settings for approach.
- 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

Additional operations guidance related to the considerations reflected in the procedure design are included in PANS-Ops Vol I.

1.4.7. Database

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 LOA's.

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.

Aircraft operators should consider the need to conduct periodic checks of the operational navigation databases in order to meet existing quality system requirements.

1.5. REFERENCES

Copies of EUROCAE documents may be purchased from EUROCAE, 102 rue Etienne Dolet – 92240 Malakoff – France (FAX: +33 1 46 55 62 65) – Web site: 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. Web site: <http://www.faa.gov/certification/aircraft/> (Regulation 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). Web site www.rtca.org.

- RTCA/DO-200A, Standards for Processing Aeronautical Data.
- RTCA/DO-201A, User Recommendations for Aeronautical Information Services.

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