

KINGDOM OF BAHRAIN
Ministry of Transportation
and Telecommunications



مملكة البحرين
وزارة المواصلات والاتصالات

CIVIL AVIATION PUBLICATION

CAP 11 Volume 2

PBN OPERATIONAL APPROVAL

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CAP 11

PBN

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TPM: __

The following pages have been revised to Revision 01 dated 09 June 2022.

Item	Paragraph number	Page(s)	Reason
1.	1.1	1-2	Introduction of description to RNAV categories
2.	1.3	2	Deletion of irrelevant information
3.	3	10	Clarification to demonstration of on-board performance monitoring & alerting
4.	8	12	Amended to incorporate latest Technology - NAT HLA
5.	9	13	Deletion of irrelevant descriptions.
6.	10.1, 10.16, & 10.18	14,15 & 16	Deletion of irrelevant descriptions
7.	11.2 (d)	19	Deletion of irrelevant descriptions
8.	13.3 & 13.5	22 & 24	Deletion of irrelevant descriptions
9.	14.2	25	Deletion of irrelevant descriptions
10.	14.2.1	25	Amendment to refer DME update requirement.
11.	14.3.3	27	Amendment to refer GNSS update requirement
12.	14.4	27	Deletion of irrelevant descriptions
13.	15.4	36	Deletion of irrelevant descriptions
14.	16.1	36	Deletion of irrelevant descriptions



15.	16.3	39	To introduce reference material
16.	16.5	41	Deletion of irrelevant descriptions
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21.	18.1.2	43	Introduction of DME/DME/IRU or GNSS requirement.
22.	18.2	44	Introduction of RNP specifications / requirement.
23.	18.3	46	Introduction of RNP specifications / operating procedures.
24.	18.6	52	Deletion of irrelevant descriptions
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28.	20.6 (b)	67	Minor requirement correction
29.	20.10	83	Introduction of Flight Crew training requirements
30.	Appendix 1	APP (1-1) & (1-3)	Deletion of irrelevant descriptions and minor amendment to include training requirement



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1. INTRODUCTION

1.1 Purpose

- 1.1.1 The purpose of CAP 11 Volume 2 is to provide guidance material to assist operators and BCAA inspectors in the evaluation of an application for PBN Operational Approval for each of the PBN Navigation Specifications.
- 1.1.2 This guidance and policy material applies to all Bahraini registered civil aircraft and operators. It identifies the type of equipment that the BCAA has determined to be an acceptable means of compliance and contains guidelines to operators for equipping aircraft.
- 1.1.3 CAP 11 Volume 2 contains a statement of the operational requirements for each type of operation and, while it is necessary that the Operational Approval evaluation determines that the proposed operation meets the minimum requirements, it is also necessary that an assessment is made of the operator's capability to meet the operational intent of the particular navigation specification.
- 1.1.4 It should be noted that each of the PBN specifications is contained in the ICAO PBN Manual 9613. Operators and BCAA Inspectors shall ensure those exact specifications are in place for the aircraft equipment as well as the training and procedures for flight crews.
- 1.1.5 This BCAA CAP provides aircraft eligibility and operational guidance for operators to conduct Required Navigation Performance (RNP) operations in Bahrain, in oceanic and remote continental airspace, and in foreign countries which adopt International Civil Aviation Organization (ICAO) standards for RNP operations.
- 1.1.6 The contents of this document do not have the force and effect of law and are not meant to bind the public in any way. This document is intended only to provide clarity to the public regarding existing requirements under the law or agency policies.
- 1.1.7 Guidance is provided for the following:
 - 1.1.8 Required Navigation Performance Approach (RNP APCH) Procedures: Qualification Criteria for Required Navigation Performance Approach (RNP APCH) Operations.
 - 1.1.9 RNP APCH Procedures to LNAV/VNAV Approach Minimums: Use of Barometric Vertical Navigation (baro-VNAV) for Required Navigation Performance Approach (RNP APCH) Operations.
 - 1.1.10 RNP 1 Arrival and Departure Procedures: Qualification Criteria for Required Navigation Performance (RNP) 1 (Terminal) Operations.
 - 1.1.11 RNP 0.3 En Route and Terminal Operations for Rotorcraft: Qualification Criteria for Required Navigation Performance (RNP) 0.3 (Rotorcraft) Operations.
 - 1.1.12 RNP 2 En Route Operations: Qualification Criteria for Required Navigation Performance (RNP) 2 Domestic, Offshore, Oceanic, and Remote Continental Operations.
 - 1.1.13 RNP 4 Operations in Oceanic and Remote Continental Airspace: Qualification Criteria for Required Navigation Performance (RNP) 4 Oceanic and Remote Continental Operations.



- 1.1.14 RNP 10 Operations in Oceanic and Remote Continental Airspace: Qualification Criteria for Required Navigation Performance (RNP) 10 Oceanic and Remote Continental Operations. Note: Area Navigation (RNAV) 10 is designated and authorized as RNP 10. This document uses the designation of RNP 10.
- 1.1.15 Advanced RNP En Route, Terminal, or Approach Operations: Advanced Required Navigation Performance (A-RNP).
- 1.1.16 Additional Capabilities: Note: The contents of this AC reflect and harmonize with ICAO Doc 9613, fourth edition, Performance-Based Navigation (PBN) Manual.

1.2 Applicability

This guidance material applies to all Bahraini operators for operations within the Kingdom of Bahrain territorial airspace. It must be noted that beyond the Bahrain FIR, operators must comply with ICAO Annex 2 and other State's regulations when operating within their airspace.

1.3 Glossary of Terms

The following is an explanation of some of the terms used in PBN procedures. The ICAO definitions have been used



Definitions

Aircraft-based augmentation system (ABAS): A system which augments and/or integrates the information obtained from the other GNSS elements with information available on board the aircraft. The most common form of ABAS is the receiver autonomous integrity monitoring (RAIM).

Area navigation (RNAV): A navigation method that allows aircraft to operate on any desired flight path within the coverage of ground or space-based navigation aids, or within the limits of the capability of self-contained aids, or a combination of both methods.

Flight technical error (FTE): The FTE is the accuracy with which an aircraft is controlled as measured by the indicated aircraft position with respect to the indicated command or desired position. It does not include blunder errors.

Global navigation satellite system (GNSS): A generic term used by the International Civil Aviation Organization (ICAO) to define any global position, speed and time determination system that includes one or more main satellite constellations, such as GPS and the global navigation satellite system (GLONASS), Galileo Europe, EGNOS, BeiDou China, aircraft receivers and several integrity monitoring systems, including aircraft-based augmentation systems (ABAS), satellite-based augmentation systems (SBAS), such as the wide area augmentation systems (WAAS) and, in addition, ground-based augmentation systems (GBAS), such as the local area augmentation system (LAAS).

Global positioning system (GPS): The global positioning system (GPS) of the United States is a satellite-based radio navigation system that uses precise distance measurements to determine the position, speed and time in any part of the world. The GPS is made up by three elements: the spatial, the control and the user elements. The GPS spatial segment nominally consists of, at least, 24 satellites in 6 orbital planes. The control element consists of 5 monitoring stations, 3 ground antennas and one main control station. The user element consists of antennas and receivers that provide the user with position, speed and precise time.

Navigation specifications: Set of aircraft and flight crew requirements needed to support performance-based navigation operations in a defined airspace. There are two kinds of navigation specifications:

Required Navigation Performance (RNP) Specification: Area navigation specification that includes the performance control and alerting requirement, designated by the prefix RNP; e.g. 1,2,4 & 10 RNP APCH, RNP AR APCH.

Area Navigation (RNAV) Specification: Area navigation specification that does not include the performance control and alerting requirement, designated by the prefix RNAV; e.g., RNAV 1,2,5 & 10

Area Navigation Visual Flight Procedure: A procedure that capitalizes on RNAV system technology to promote stabilized visual approaches to a designated runway.



Navigation system error (NSE): The difference between the true position and the estimated position.

Path definition error (PDE): The difference between the defined path and the desired path at a given place and time.

Performance-based navigation (PBN): Performance-based area navigation requirements applicable to aircraft conducting operations on an ATS route, on an instrument approach procedure, or in a designated airspace.

Receiver autonomous integrity monitoring (RAIM): A technique used in a GPS receiver/processor to determine the integrity of its navigation signals, using only GPS signals or GPS signals enhanced with barometric altitude data. This determination is achieved by a consistency check between redundant pseudo-range measurements. At least one additional available satellite is required with respect to the number of satellites that are needed for the navigation solution.

RNP operations: Aircraft operations that use an RNP system for RNP applications.

RNP system: An area navigation system that supports on-board performance control and alerting.

Standard instrument arrival (STAR): A designated instrument flight rules (IFR) arrival route linking a significant point, normally on an air traffic service (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.

Total system error (TSE): The difference between the true position and the desired position. This error is equal to the sum of the vectors of the path definition error (PDE), the flight technical error (FTE) and the navigation system error (NSE).

Note: FTE is also known as path steering error (PSE) and the NSE as position estimation error (PEE).

Way-point (WPT): A specified geographical location used to define an area navigation route or the flight path of an aircraft employing area navigation. Way-points are identified as either:

Fly-by way-point: A way-point which requires turn anticipation to allow tangential interception of the next segment of a route or procedure.

Fly over way-point: A way-point at which a turn is initiated in order to join the next segment of a route or procedure.



Acronyms

ABAS	Aircraft-based augmentation system
AC	Advisory circular (FAA)
AFM	Aircraft flight manual
AIP	Aeronautical information publication
AIRAC	Aeronautical information regulation and control
ANSP	Air navigation service provider
AP	Automatic pilot
APV	Approach procedure with vertical guidance
ARP	Aerodrome reference point
ATC	Air traffic control
ATM	Air traffic management
ATS	Air traffic service
Baro-VNAV	Barometric vertical navigation
CA	Course to an altitude
CDI	Course deviation indicator
CDU	Control and display unit
CF	Course to a fix
Doc	Document
DF	Direct to a fix
DME	Distance-measuring equipment
EASA	European Aviation Safety Agency
EGPWS	Enhanced ground proximity warning system
EHSI	Electronic horizontal situation indicator
FAA	Federal Aviation Administration
(United States) FAF	Final approach fix
FAP	Final approach point
FD	Flight director
FD	Fault detection
FDE	Fault detection and exclusion
FM	Course from a fix to a manual termination
FMS	Flight management system



FOI	Flight Operations Inspector
FOSA	Flight Operational Safety Assessment
FTE	Flight technical error
BCAA	Bahrain CAA
GBAS	Ground-based augmentation system
GNSS	Global navigation satellite system (ICAO)
GLONASS	Global navigation satellite system (Russia)
GPS	Global positioning system (US)
HAL	Horizontal alert limit
HIL	Horizontal integrity limit
HPL	Horizontal Protection Level
HSI	Vertical status indicator
HUGS	Head up guidance system
ICAO	International Civil Aviation Organization
IF	Initial fix
IFR	Instrument flight rules
IMC	Instrument meteorological conditions
LAAS	Local area augmentation system
LNAV	Lateral navigation
LOA	Letter of authorisation/letter of acceptance
LPV	Localizer Performance with Vertical Guidance
MCDU	Multi-function control and display
MEL	Minimum equipment list
MOC	Minimum Obstacle Clearance
NM	Nautical miles
NAVAIDS	Navigation aids
NOTAM	Notice to airmen
NPA	Non-precision approach
NSE	Navigation system error
OM	Operations manual
OEM	Original equipment manufacturer
OPSPEC	Operations specification
PA	Precision approach



PANS-ATM	Procedures for Air Navigation Services - Air Traffic Management
NS-OPS	Procedures for Air Navigation Services - Aircraft operations
PBN	Performance-based navigation
PDE	Path definition error
PEE	Position estimation error
PF	Pilot flying
PNF	Pilot not flying
PM	Pilot monitoring
POH	Pilot operating Handbook
P-RNAV	Precision area navigation
PSE	Path steering error
QAR	Quick access recorder
RAIM	Receiver autonomous integrity monitoring
RNAV	Area navigation
RNP	Required navigation performance
RNP APCH	Required navigation performance approach
RNP AR APCH	Required navigation performance authorisation required approach
RVFP	RNAV Visual Flight Procedure
RTCA	Radio Technical Commission for Aviation
SBAS	Satellite-based augmentation system
SID	Standard instrument departure
STAR	Standard instrument arrival
STC	Supplemental type certificate
TAWS	Terrain awareness system
TF	Track to fix
TSE	Total system error
TSO	Technical standard order
VA	Heading to an altitude
VI	Heading to an intercept
VM	Heading to a manual termination
VMC	Visual meteorological conditions



WAAS	Wide area augmentation system
WGS	World geodetic system
WPR	Waypoint Precision Error
WPT	Waypoint

1.4 References

The following publications were used as reference material:

ICAO

Annex 6 - Operations of Aircraft

Annex 8 - Airworthiness of Aircraft

Annex 10 - Aeronautical Telecommunications

Annex 11 - Air Traffic Services

Annex 15 - Aeronautical Information Services

Doc 9613-AN/937 - Performance-based Navigation Manual

Doc 4444 PANS ATM - Procedures for Air Navigation Services and Air Traffic Management

Doc 8168 VOL I and VOL II- Procedures for Air Navigation Services Aircraft Operations

Doc 7030 - Regional Supplementary Procedures

Doc 9426 - Air Traffic Services Planning Manual

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

EUROCAE

ED 72 - Minimum Operational Performance Specifications for Airborne GPS receiving Equipment used for Supplemental Means of Navigation

ED 758 - MASPS Required Navigation Performance for Area Navigation

ED 76 - Standards for Processing Aeronautical Data

ED 77 - Standards for Aeronautical Information

RTCA

DO 208 - Minimum Operational Performance Standards for Airborne Supplemental



Navigation Equipment using GPS

DO 200A - Standards for Processing Aeronautical Data

DO 201A - Standards for Aeronautical Information

ARINC

ARINC 424 Documents

BCAA

ANTR-OPS 1.243

2. PERFORMANCE BASED NAVIGATION (PBN) CONCEPTS

The performance-based navigation (PBN) concept specifies that aircraft RNAV system performance requirements be defined in terms of accuracy, integrity, availability, continuity and functionality required for the proposed operations in the context of a particular airspace concept, when supported by the appropriate navigation infrastructure. In that context, the PBN concept represents a shift from sensor-based to performance-based navigation. Performance requirements are identified in navigation specifications, which also identify the choice of navigation sensors and equipment that may be used to meet the performance requirements. These navigation specifications provide specific implementation guidance for operators in order to facilitate global harmonization.

Navigation specifications describe, in detail, the requirements placed on the area navigation system for operation along a particular route, procedure or within airspace where approval against the navigation specification is prescribed. These requirements include:

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

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



3. ON-BOARD PERFORMANCE MONITORING AND ALERTING

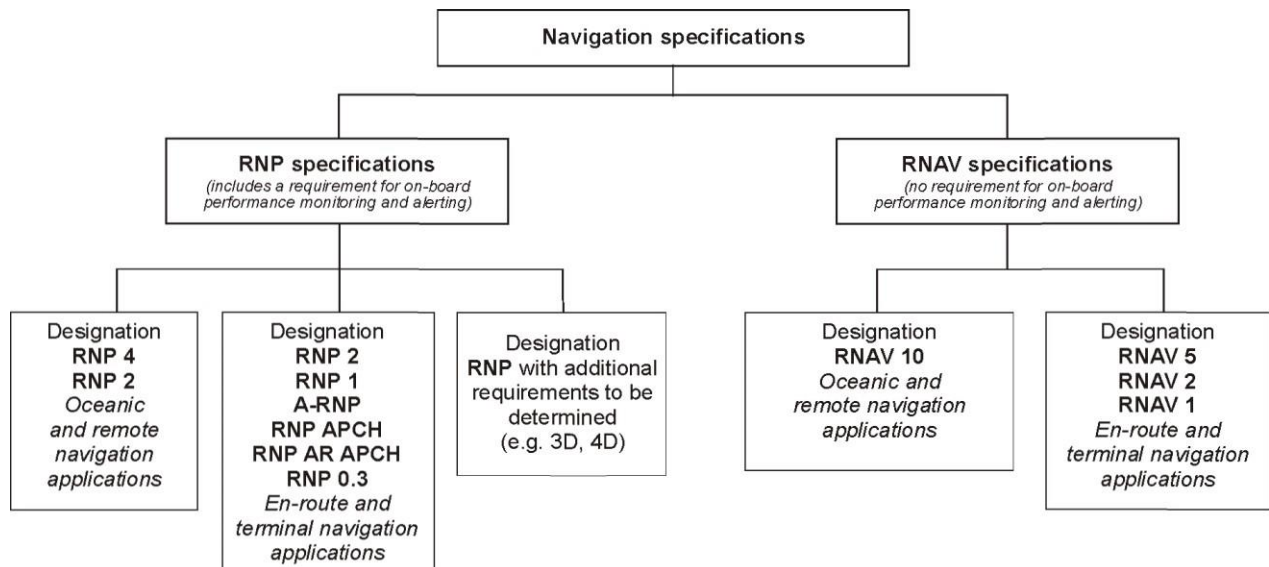
On-board performance monitoring and alerting is the main element that determines if the navigation system complies with the necessary safety level associated with an RNP application. It relates to both lateral and longitudinal navigation performance and it allows the aircrew to detect that the navigation system is not achieving, or cannot guarantee with integrity, the navigation performance required for the operation. (A detailed description of onboard performance monitoring and alerting and navigation errors is provided in CAP 11 Volume 1 and ICAO Doc 9613, Part A, Volume II).

The operator will need to demonstrate that they have robust training and procedures in place to ensure compliance with the particular navigation specification. This will require a demonstration in both the simulator and aircraft. The operator must verify the flight simulator and aircraft have the exact same systems. The BCAA Operations Inspector will observe both the simulator and actual aircraft demonstrations for each PBN authorizations. Specifications may be bundled depending on the aircraft capability and the crew training.

4. DESIGNATION OF RNAV AND RNP SPECIFICATIONS

Two types of navigation specification exist:

- (a) RNAV: A navigation specification which does not require an on-board performance monitoring and alerting function (OPMA).
- (b) RNP: A navigation specification that does require an on-board performance monitoring and alerting function (OPMA).



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



5. APPLICATION OF NAVIGATION SPECIFICATION

Table 5.1 shows that for any particular PBN operation, it is possible that a sequence of RNAV and RNP applications is used. A flight may commence in an airspace using an RNP 1 SID, transit through en-route then oceanic airspace requiring RNAV 2 and RNP 4, respectively, culminating with terminal and approach operations requiring RNAV 1 and RNP APCH.

Table 5.1

Navigation specification	Flight Phase							
	En-route oceanic/ remote	En-route continental	Arrival	Approach				Departure
				Initial	Intermediate	Final	Missed	
RNAV 10	10							
RNAV 5 ^a		5	5					
RNAV 2 ^b		2	2					2
RNAV 1 ^b		1	1	1	1		1 ^c	1
RNP 4	4							
RNP 2	2	2						
Advanced RNP ^d	2 ^e	2 or 1	1	1	1	0.3	1 ^c	1
RNP 1			1 ^f	1	1		1 ^c	1 ^e
RNP 0.3 ^g		0.3	0.3	0.3	0.3	—	0.3	0.3
RNP APCH				1	1	0.3 ^h	1 ^c or 0.3 ⁱ	
RNP AR APCH				1-0.1	1-0.1	0.3-0.1	1-0.1 ^j	

Notes:

- RNAV 5 is an en-route navigation specification which may be used for the initial part of a STAR outside 30 NM and above MSA.
- RNAV 1 and RNAV 2 are issued as a single approval.
- Applies only once 50 m (40 m Cat H) obstacle clearance has been achieved after the start of climb.
- A-RNP also permits a range of scalable RNP lateral navigation accuracies.
- Optional; requires higher continuity.
- Beyond 30 NM from the airport reference point (ARP), the accuracy value for alerting becomes 2 NM.
- The RNP 0.3 specification is primarily intended for helicopter operations.
- The RNP APCH navigation specification is divided into two sections. RNP 0.3 is applicable to RNP APCH Section A (LNAV and LNAV/VNAV). Different angular performance requirements are applicable to RNP APCH Section B (LP and LPV).

- (i) This value applies during the initial straight ahead missed approach segment for RNP APCH Section B (LP and LPV).
- (j) If less than RNP 1 is required in the missed approach, the reliance on inertial to cater for loss of GNSS in final means that accuracy will slowly deteriorate. Therefore, any accuracy value equal to that used in final can be applied only for a limited distance.

6. PBN APPLICATIONS

A navigation application uses a navigation specification and the associated navigation infrastructure to support a particular airspace concept. This is illustrated in Figure 6.1.

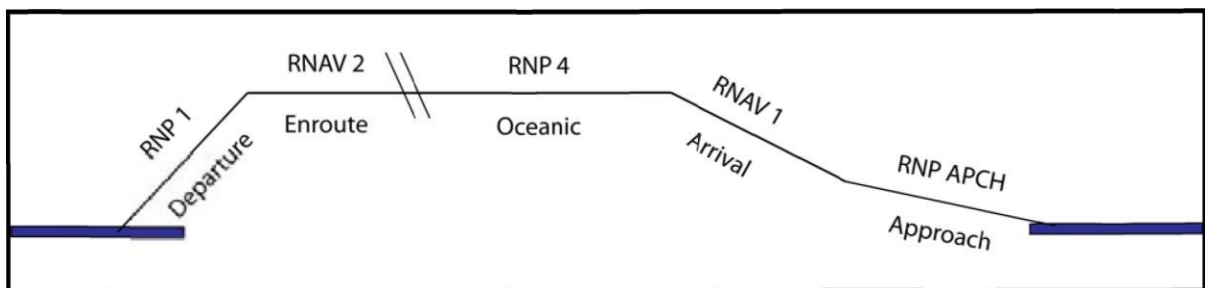


Figure 6.1

7. FLIGHT PLANNING

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

Operators should use the appropriate ICAO flight plan designation specified for the RNP route flown. The letter -Rll 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.

(Flight plan procedures are addressed in ICAO Doc 4444, Procedures for Air Navigation Services - Air Traffic Management).

8. NAT-HLA

Aircraft operating in the North Atlantic High Level Airspace (HLA) airspace are required to meet a minimum navigation performance specification in ICAO Document 007.



9. RESPONSIBILITY FOR OPERATIONAL APPROVAL EVALUATION

Overall responsibility for the evaluation of an operational approval application will be assigned to the Chief Aviation Operations (CAO) Section. He will direct the review and inspection of the proposed operational arrangements and recommend to the Director the grant of operational approval. He will also act as coordinator with the other Sectional Chiefs.

The assigned Aircraft Operations inspector (AOI) should have access to other specialist expertise where required.

The Chief Airworthiness Inspection (CAI) Section is responsible for the review and inspection of the airworthiness requirements and maintenance support arrangements and he will forward the result of review, along with his recommendations, to the Chief Aviation Operations Section.

The Chief Aircraft Permits and Licensing Section is responsible for making the administrative arrangements for the approval.

The Director Aeronautical Licensing signs the Approval letter (ALD/OPS/F100).

It should be recognised that PBN is an operational concept and the primary task is to determine that the applicant's operating practices, procedures and training are adequate. The evaluation of aircraft eligibility and airworthiness is required during the operational approval process, PBN operational approval is a joint responsibility of operations and airworthiness inspectors.

The issues of configuration control, ongoing maintenance, minimum equipment lists, training of maintenance personnel should be assessed by qualified airworthiness inspectors in consultation with the CAO.

10. OPERATIONAL APPROVAL

10.1 General

Approval to operate in PBN airspace will be granted by a Letter of Approval (ALD/OPS/F100) and/or inclusion in the AOC Operations Specifications issued by the BCAA. Each aircraft for which the operator is granted authority will be listed.

This is the responsibility of the Aircraft Operations Section to recommend to the Director that the operational approval be issued.

The Letter of Approval remains valid provided there has been no modification to the navigation equipment installed and the continuation of equipment integrity and navigation accuracy.



OPS SPECs should be annotated as shown Appendix 2 to show the individual PBN operational approvals granted. The remarks as noted should also be included on the OPS SPEC to assist in identifying existing approvals which are equivalent to PBN navigation specifications

The operational approval assessment must take account of the following:

- (a) Aircraft eligibility and airworthiness compliance;
- (b) Operating Procedures for the navigation systems used;
- (c) Control of operating procedures (documented in the OM). The appropriate manuals and checklists should contain navigation operating instructions and contingency procedures, where specified. The operator must submit their manuals and checklists for review as part of the formal application process;
- (d) Flight crew and dispatch training requirements;
- (e) Control of navigation database procedures. Operators need to have documented procedures for the management of navigation databases. These procedures will define the data validation procedures for navigation databases and the installation of new databases into aircraft so that they remain current with the AIRAC cycle; and
- (f) Continuing airworthiness. Operators should have procedures for assessing and incorporating instructions for continued airworthiness and maintenance or inspection information concerning system modifications, software revisions, etc.
- (g) MEL considerations.

← 10.1.1 Aircraft Eligibility

An aircraft is eligible for a particular PBN application provided there is clear statement in:

- (a) the TC; or
- (b) the STC; or
- (c) the associated documentation — AFM or equivalent document; or
- (d) a compliance statement from the manufacturer that has been approved by the State of Design and accepted by the BCAA.

The operator must have a configuration list detailing the pertinent hardware and software components and equipment used for the PBN operation. This must be presented in the formal application.

The TC is the approved standard for the production of a specified type/series of aircraft. The aircraft specification for that type/series, as part of the TC, will include a the specific navigation standards. The aircraft documentation for that type/series will define the system use, operational limitations, equipment fitted and the maintenance practices and procedures. No changes (modifications) are permitted to an aircraft unless the BCAA either approves such changes through a modification approval process, STC or



accepts technical data defining a design change that has been approved by another State.

For recently manufactured aircraft, where the PBN capability is approved under the TC, there shall be a statement in the AFM limitations section identifying the operations for which the aircraft is approved. There is also a statement that the stated approval does not itself constitute an approval for an operator to conduct those operations. Alternate methods of achieving the airworthiness approval of the aircraft for PBN operations is for the aircraft to be issued with an STC for the navigation system installation or a locally approved modification.

One means of modifying an aircraft is the approved SB issued by the aircraft manufacturer. The SB is a document approved by the State of Design to enable changes to the specified aircraft type and the modification then becomes part of the type design of the aircraft. Its applicability will normally be restricted by the airframe serial number. The SB describes the intention of the change and the work to be done to the aircraft. Any deviations from the SB require a design change approval; any deviations not approved will invalidate the SB approval. The State of Registry accepts the application of an SB and changes to the maintenance programme, while the State of the Operator accepts changes to the maintenance programme and approves changes to the MEL, training programmes and Operations specifications. An OEM SB may be obtained for current production or out of production aircraft.

Table 10.1.1 Operational Approval Scenarios

Scenario	Aircraft certification status	Actions by operator/owner
1	Aircraft designed and type certificated for PBN application. Documented in AFM, TC or the STC.	No action required, aircraft eligible for PBN application.
2	Aircraft equipped for PBN application but not certified. No statement in AFM. SB available from the aircraft manufacturer.	Obtain SB (and associated amendment pages to the AFM) from the aircraft manufacturer.
3	Aircraft equipped for PBN application. No statement in AFM. SB not available. Statement of compliance available from the aircraft manufacturer.	Establish whether the statement of compliance is acceptable to the regulatory authority of the State of Registry of the aircraft.
4	Aircraft equipped for PBN application. No statement in AFM. SB not available. Statement of compliance from the aircraft manufacturer not available.	Develop detailed submission to State of Registry showing how the existing aircraft equipment meets the PBN application requirements.
5	Aircraft not equipped for PBN application.	Modify aircraft in accordance with the aircraft manufacturer's SB or develop a major modification in conjunction with an approved design organization in order to obtain an approval from the State of Registry (STC).

10.1.2 Operating Procedures

The SOP must be developed to cover both normal and non-normal (contingency) procedures for the systems used in the PBN operation. The SOP must address:

- (a) preflight planning requirements including the MEL and, where appropriate, RNP/RAIM prediction;
- (b) actions to be taken prior to commencing the PBN operation;



- (c) actions to be taken during the PBN operation; and
- (d) actions to be taken in the event of a contingency, including the reporting of significant incidents.

10.1.3 Control of Operating Procedures

The SOP must be adequately documented in the OM and checklists. The appropriate manuals and checklists should contain navigation operating instructions and contingency procedures, where specified. When required by the BCAA, the operator must submit their manuals and checklists for review as part of the application process

10.1.4 Flight Crew and Dispatch Training

Training shall cover flight crew initial training and continuing competency requirements and dispatch requirements.

A flight crew and dispatch training programme for the PBN operation must cover all the tasks associated with the operation and provide sufficient background to ensure a comprehensive understanding of all aspects of the operation. The operator must have adequate records of course completion for flight crew, flight dispatchers and maintenance personnel.

10.1.5 Control of Navigation Database Procedures

Procedures shall be submitted by the operator in the formal application on the control of navigation database procedures.

Discrepancies that invalidate the route must be reported to the navigation database supplier and the affected route must be prohibited by an operator's notice to its pilots.

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

10.1.6 Continuing airworthiness

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

10.1.7 MEL considerations

Any MEL revisions necessary to address RNP 1,2,4 & 10 and RNAV 1,2,5 & 10 provisions must be approved. Operators must adjust the MEL, or equivalent, and specify the required dispatch conditions.

10.1.8 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.



10.2 Conditions for Removal of PBN Authority

10.2.1 Equipment Tolerances

During the validity of the operational approval, the BCAA will consider any anomaly reports received from the operator or other interested party. Repeated navigation error occurrences attributed to a specific piece of navigation equipment may result in restrictions on use or cancelation of the approval for use of that equipment.

10.2.2 Operator Inaction

The operator should make an effective, timely response to each track keeping error. The BCAA may consider removing PBN operational approval if the operator response to a track keeping error is not effective or timely. The BCAA will also consider the operator's past performance record in determining the action to be taken.

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

If an operator shows a history of operational and/or airworthiness errors, then approval may be removed until the root causes of these errors are shown to be eliminated and PBN programmes and procedures effective. The BCAA will review each situation on a case-by-case basis.

11. APPROVAL PROCESS

11.1 General

Since each operation may differ significantly in complexity and scope, the project manager (FOI) and the operational approval team need considerable latitude in taking decisions and making recommendations during the approval process. The ultimate recommendation by the project manager (FOI) and decision by the BCAA regarding operational approval should be based on the determination of whether or not the applicant:

- (a) meets the requirements established in the ANTRs;
- (b) is adequately equipped; and
- (c) is capable of conducting the proposed operation in a safe and efficient manner.

The on-board PBN systems must be fit for the intended purpose. Operators must ensure that a particular operation is supported by the flight manual or other approved manufacturer's documentation and the operations manual. When approving an operator for any new PBN operation, the BCAA will need to be shown the evidence of airworthiness suitability.

The complexity of the approval process is based on the inspector's assessment of the applicant's proposed operation. For simple approvals, some steps can be condensed or eliminated. Some applicants may lack a basic understanding of what is required for approval. Other applicants may propose a complex operation, but may be well prepared



and knowledgeable. Because of the variety in proposed operations and differences in an applicant's knowledge, the process must be thorough enough and flexible enough to apply to all possibilities.

11.2 Phases of the Approval Process

(a) Step 1: Pre-application phase:

Each individual operator should schedule a pre-application meeting with the BCAA assigned Inspector responsible for its operations. The intent of this meeting is to discuss airworthiness and operational requirements for approval to operate in PBN airspace, including:

- (1) the contents of the operator's application;
- (2) BCAA's review and evaluation of the application;
- (3) limitations (if any) on the approval;
- (4) conditions under which the operational approval may be cancelled by the BCAA; and
- (5) any other operational or airspace requirements that may be established by European or other authorities for the airspace involved.

(b) Step 2: Formal application phase:

An application for the approval for PBN approval must be made by the operator using Form ALD/OPS/F062. The appropriate charges must accompany the application, unless specifically exempted.

(c) Step 3: Document evaluation phase:

The BCAA project manager evaluates the formal, written application for approval to determine whether all the requirements are being met.

The following describes the operational material that an operator should provide to the BCAA for evaluation, preferably at least 60 days before the intended start of PBN operations. The assigned Inspector must refer to the applicable guidance material for specific operational requirements.

(1) Minimum Equipment List.

A minimum equipment list (MEL), adapted from the master minimum equipment list (MMEL), should include items pertinent to operating in PBN airspace.

(2) Navigation Accuracy Records

The operator of an aircraft must be able to produce accuracy records.

(3) Training Programmes and Standard Operating Procedures (SOP's)

All initial training courses must be approved by the BCAA prior to use and the syllabus incorporated in the Operators Manual. Recurrent training is required on an annual basis and the items detailed below should be



incorporated into training programmes and operating procedures. The following general items should also be included in flight crew training programmes of OMD together with any specific airspace or operational requirements:

- (i) knowledge, understanding and compliance of standard ATC phraseology and track messages used in each area of operations;
- (ii) PBN procedures for the applicable airspace
- (iii) Navigation equipment required to be operational for flight in designated PBN airspace, limitations associated with the navigation equipment;
- (iv) Flight planning requirements;
- (v) Entry, in-flight and exit requirements and procedures
- (vi) Contingency procedures for system failures or navigation inaccuracies.

(4) Operations Manuals and Checklists

The appropriate manuals and checklists must be revised to include information/guidance/training on standard operating procedures. Manuals and checklists must be submitted for review and approval by the BCAA as part of the application process.

(d) Step 4: Validation Flight(s):

During a formal inspection by Aircraft Operations Inspector (assisted as necessary by a BCAA team), the operator demonstrates how the requirements are being met.

The operator shall demonstrate the requested PBN specifications in a full flight simulator equipped with the same navigation equipment as their aircraft. During this demonstration the BCAA Inspector will present various scenarios for abnormal. The final step of the approval process shall require a validation flight through the specific airspace by an Aircraft Operations Inspector to verify that all relevant procedures are applied effectively. If the performance is satisfactory, operational approval for the particular airspace may be granted.

(e) Step 5: Approval phase:

The Chief Aviation Operations Section will ensure that the review of the operations documentation is satisfactory and forward the result of review, along with his recommendations regarding operations approval, and the recommendation from the Chief Airworthiness Inspection to the Chief Aircraft Permits and Licensing Section.

The Chief Aircraft Permits and Licensing Section will ensure that he has both recommendations and required fee; then



- (1) Produce the required Letter of Approval (ALD/OPS/F100)
- (2) Present the certificate to the Director for signature;
- (3) Enter the approval details in the PBN data base;
- (4) Provide the operator with the certificate; and
- (5) Copy the certificate to Chief Airworthiness Inspection and Chief Aviation Operations Section.

Note: See Chapter 10, Operational Approval, paragraph 10.1.

12. JOB AIDS (CAP 11 Volume 3)

Job aids have been developed to assist BCAA inspectors in managing the process of PBN operational approvals. The job aids provide both inspectors and operators with guidance on the documentation required to be included in an operator's application and, in addition, the items that must be assessed by the FOI in order for an operational approval to be issued. The job aids also serve as means of recording the documentation process.

The job aids summarise the key elements to be assessed and therefore should be used as a guide to the approval process. However, frequent reference to the CAP 11 Vols. 1 and 2 will be required to identify detailed requirements for approval.

13. RNAV 10 (DESIGNATED AND AUTHORIZED AS RNP 10)

13.1 General

RNAV 10 operations have been, prior to the development of the PBN concept, authorized as RNP 10 operations. An RNAV 10 operational approval does not change any requirement nor does it affect operators that have already obtained an RNP 10 approval.

RNP 10 was developed and implemented at a time when the delineation between RNAV and RNP had not been clearly defined. As the requirements for RNP 10 did not include a requirement for on-board performance monitoring and alerting, it is more correctly described as an RNAV operation and hence the inclusion in CAP 11 as RNAV 10.

Recognising that airspace, routes, airworthiness and operational approvals have been designated as RNP 10, further declaration of airspace, routes, aircraft and operator approvals may continue to use the term RNP 10, while the CAP 11 application will be known as RNAV 10.

RNAV 10 is applicable to operations in oceanic and remote areas and does not require any ground-based navigation infrastructure or assessment.



13.2 ATS Communications and Surveillance

CAP 11 does not address communication or air traffic services (ATS) surveillance requirements that may be specified for operation on a particular route or area. These requirements are specified in other documents, such as the aeronautical information publications (AIP) and ICAO Regional Supplementary Procedures (ICAO Doc 7030). An operational approval conducted in accordance with the requirements of CAP 11 assumes that operators and flight crews take into account all the communication and surveillance requirements related to RNP 10 routes.

13.3 System Requirements

RNAV 10 requires that aircraft operating in oceanic and remote area be equipped with at least two independent and serviceable LRNSs. Commonly available LRNs are:

- (a) INS
- (b) IRS FMS
- (c) GNSS

The most common combinations of dual LRNs are:

- (a) Dual INS
- (b) Dual IRS
- (c) Dual GNSS
- (d) GNSS/IRS (IRS updated by GNSS)

Inertial systems (unless updated by GNSS) are subject to a gradual loss of position accuracy with time (drift rate) and therefore are subject to a maximum time limit in order to meet the RNAV 10 accuracy requirement. The basic time limit is 6.2 hours, but this may be extended by updating or by demonstration of reduced drift rate (<3.7km/2NM per hr).

GNSS position is continuously updated and not subject to any time limit. However, GNSS is subject to some operational limitations that impact on oceanic and remote navigation.

The minimum level of GNSS receiver (TSO C129) is capable of fault detection (FD) but will not provide a navigation solution if a fault is detected. Consequently, no matter how many serviceable satellites are available, the continued availability of GNSS cannot be assured and, therefore, this standard of GNSS is unsuitable for oceanic and remote navigation. In order to be approved for oceanic and remote applications, a GNSS receiver must be capable of excluding a faulty satellite from the solution (Fault detection and Exclusion - FDE) so that continuity of navigation can be provided. FDE is standard for GNSS receivers based on later TSO C145A/146A standards and is available as an option or modification for TSO C129 receivers. Consequently, where a TSO C129 GNSS is used to satisfy the requirement for one or



both of the LRNs, it needs to be determined that the receiver is capable of FDE and approved for oceanic/remote operations.

Despite the GNSS receiver capability for FDE, the satellite constellation may not always be adequate to provide sufficient satellite availability for the redundant navigation solutions to be computed in order to identify and eliminate a faulty satellite from the position solution and, in such situations, FDE is not available. In order to limit the exposure to the potential loss of a navigation solution due to unavailability of FDE, a prediction of satellite availability is required.

Due to the time limitations applicable to INS or IRS, the operator needs to evaluate the route(s) to be flown to determine that RNAV 10 capability can be satisfied.

Accordingly, an RNAV 10 operational approval is not universal for aircraft without GNSS and needs to apply to specific routes or be subject to the operator's procedures for route evaluation.

As inertial position accuracy slowly deteriorates over time since update, for aircraft with INS or IRS only, some attention needs to be placed on radio updating. Aircraft equipped with a Flight Management System normally provide automatic radio updating of inertial position. Automatic updating is normally considered adequate in such circumstances, provided the aircraft is within a reasonable distance of the radio aids at the point at which the last update is expected. If any doubt exists, then the operator should be required to provide any an analysis of the accuracy of the update.

Manual updating is less common and, therefore, the operational approval needs to be based on a more detailed examination of the circumstances.

Approvals for various updating procedures are based upon the baseline for which they have been approved minus the time factors shown below:

- (a) automatic updating using DME/DME = baseline minus 0.3 hours (e.g. an aircraft that has been approved for 6.2 hours can gain 5.9 hours following an automatic DME/DME update);
- (b) automatic updating using DME/DME/VHF omnidirectional radio range (VOR) = baseline minus 0.5 hours; and



13.4 Operating Procedures

13.4.1 Flight Planning

The standard operating procedures adopted by operators flying on oceanic and remote routes should normally be generally consistent with RNAV 10 operations, except that some additional provisions may need to be included to specifically address RNAV 10 operations.

A review of the operator's procedure documentation against the requirements of CAP 11 and the BCAA regulatory requirements should be sufficient to ensure compliance.

The essential elements to be evaluated are that the operator's procedures ensure that:



- (a) RNAV 10 capability is indicated on the flight plan (see Chapter 7).
- (b) Route limitations are defined and observed (e.g. time limits)
- (b) En-route loss of capability is identified and reported
- (d) Procedures for alternative navigation are described

GNSS based operations also require the prediction of FDE availability. Most GNSS service prediction programs are based on a prediction at a destination and do not generally provide predictions over a route or large area. However, for RNAV 10 operations, the probability that the constellation cannot support FDE is remote and this requirement can be met by either a general route analysis or a dispatch prediction of satellite availability. For example, a specified minimum satellite constellation may be sufficient to support all RNAV 10 operations without specific real-time route prediction being required.

13.4.2 Preflight Procedures

To ensure that the aircraft is serviceable for RNAV 10 ops, the following actions should be completed during preflight:

- (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 therequired equipment;
- (b) during the external inspection of an aircraft, if possible check the condition of the navigation antennas and the condition of the fuselage skin in the vicinity of each of these antennas (this check may be accomplished by a qualified and authorized person other than the pilot, e.g. a flight engineer or maintenance person); and
- (c) review the emergency procedures for operations in RNP 10 airspace or on RNP 10 routes. These are no different than normal oceanic emergency procedures with one exception - crews must be able to recognize when the aircraft is no longer able to navigate to its RNP 10 approval capability andATC must be advised.

13.4.3 Enroute Procedures

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

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

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 centre lines, as depicted by on-board lateral deviation indicators and/or flight guidance, during all RNP operations described in this manual unless authorized to deviate by ATC or under emergency conditions. For normal operations, cross-track error/deviation (the difference between the RNAV system computed path and the aircraft position relative to the path) should be limited to $\pm 1/2$ 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 one times the navigation accuracy (i.e. 10 NM), are allowable.

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

13.5 Pilot Knowledge and Training



Where GNSS is used, flight crews must be familiar with GNSS principles related to en-route navigation.

Flight training shall be conducted in a approved full flight simulator.

Guidance on operational training requirements is contained in Chapter 10, paragraph 10.1, Appendix 2 and CAP 11, Volume 1, Chapter 8.

14. RNAV 5

14.1 General

This section replaces CAP 02 B-RNAV.

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. These two documents provide identical functional and operational requirements.

In the context of the terminology adopted by this CAP, B-RNAV and RNP 5 requirements are termed RNAV 5. Therefore, operators previously certified as B-RNAV or RNP 5 compliant will be accepted as RNAV 5 compliant in accordance with this CAP.



RNAV 5 is intended for en-route navigation where there is adequate coverage of ground-based radio navigation aids permitting DME/DME or VOR/DME area navigation operations.

Consequently, an RNAV 5 route is dependent upon an analysis of the supporting navaid infrastructure. However, consideration of navaid coverage is not part of an operational approval as this is the responsibility of the air navigation service provider.

14.2 System Requirements

- (a) A single RNAV system only is required.
- (b) A navigation database is not required. Manual entry of waypoint data is permitted.
- (c) Storage of a minimum of 4 waypoints is required.
- (d) Navigation system alerting is not required.
- (e) Navigation displays in the pilot's forward view must be sufficient to permit track following and maneuvering.
- (f) The maximum cross-track error deviation permitted is 2.5NM
- (g) An RNAV system failure indication is required.

14.2.1 INS or IRS

An INS or IRS system may be used for RNAV 5. If automatic radio updating is not carried out, a time limit of 2 hours applies from the last on ground position update, unless an extended limit has been justified.

DME/DME/IRU with updating in accordance with ETSO C131 (B) or later.

GNSS, approved in accordance with ETSO C129 (A), FAA TSO C129 (A) or later, meets the requirements of RNAV 5.

Stand-alone receivers manufactured to ETSO C129 or FAA TSO C129 are also applicable provided they include pseudo-range step detection and health word checking functions.

GNSS based operations require prediction that a service (with integrity) will be available for the route. Most GNSS availability prediction programs are computed for a specific location (normally the destination airport) and are unable to provide predictions over a route or large area. However, for RNAV 5, the probability of a loss of GNSS integrity is remote and the prediction requirement can normally be met by determining that sufficient satellites are available to provide adequate continuity of service.



14.3 Operating Procedures

14.3.1 General

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

All pilots are expected to maintain route centre lines, as depicted by on-board lateral deviation indicators and/or flight guidance, during all RNAV operations described in this manual, unless authorized to deviate by ATC or under emergency conditions. For normal operations, cross-track error/deviation (the difference between the RNAV system-computed path and the aircraft position relative to the path) should be limited to $\pm\frac{1}{2}$ 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 one times the navigation accuracy (i.e. 5 NM), are allowable.

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

14.3.2 Flight Planning

For most operators normal RNAV operating procedures will meet the requirements of RNAV 5.

However, 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 essential elements to be evaluated are that the operator's procedures ensure that:

- (a) The aircraft is serviceable for RNAV 5;
- (b) RNAV 5 capability is indicated on the flight plan;
- (c) En-route loss of capability is identified and reported; and
- (d) Procedures for alternative navigation are described.

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

If the navigation system does not use a navigation database, manual waypoint entry significantly increases the potential for navigation errors. Operating procedures need to be robust to reduce the incidence of human error, including cross-checking of entry, checking of tracks/distances/bearings against published routes and general situational awareness and checking for reasonableness.



Where navigation data is not extracted from a valid database, operations shall be limited to not below the minimum obstacle clearance altitude.

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 clearance. When the aircraft is not on the published route, the specified accuracy requirement does not apply.

As RNAV 5 operations are typically conducted in areas of adequate navaid coverage, contingency procedures will normally involve reversion to conventional ground-based radio navigation.

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

14.3.3 ABAS availability

If GNSS is used En-route RAIM levels are required for RNAV 5 and can be verified either through NOTAMs (where available) or through prediction services. RNAV 5 can be achieved with only ground based navigation aids or IRU. 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. 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 minutes for any part of the RNAV 5 operation, the flight planning should be revised (i.e. delaying the departure or planning a different departure procedure).

RAIM availability prediction software is a tool used to assess the expected capability of meeting the navigation performance. Due to unplanned failure of some GNSS elements, pilots/ANSP must realize that RAIM or GPS navigation may be lost altogether while airborne, which may require reversion to an alternative means of navigation. Therefore, pilots should assess their capability to navigate (potentially to an alternate destination) in case of failure of GPS navigation.

14.4 Pilot Knowledge and Training

Where GNSS is used, flight crews must be familiar with GNSS principles related to en-route navigation.

Flight training shall be conducted in an approved full flight simulator.

Guidance on operational training requirements is contained in Appendix 2 and CAP 11, Vols. 1 and 3.

14.5 Operational Approval



The operational approval process for RNAV is made via Operations Specifications.

The AFM will document RNAV 5 capability

15. RNAV 1 AND RNAV 2

15.1 General

The Joint Aviation Authorities (JAA) published airworthiness and operational approval for precision area navigation (P-RNAV) on 1 November 2000 through TGL-10. The Federal Aviation Administration (FAA) published AC 90-100 U.S. terminal and en-route area navigation (RNAV) operations on 7 January 2005. While similar in functional requirements, differences exist between these two documents.

ICAO has therefore harmonized the different criteria of the European Precision RNAV (P-RNAV) and United States RNAV (US-RNAV) into a single RNAV 1 and RNAV 2 specification.

Compliance with ICAO RNAV 1 and RNAV 2 obviates the need for further assessment or AFM documentation. In addition, an operational approval to this specification allows an operator to conduct RNAV 1 and RNAV 2 operations globally.

As there is no difference in the operational approval for RNAV 1 and RNAV 2 and, therefore, only a single RNAV 1 and RNAV 2 approval is issued, an operator with an RNAV 1 and RNAV 2 approval is qualified to operate on both RNAV 1 and RNAV 2 routes. RNAV 2 routes may be promulgated in cases where the navaid infrastructure is unable to meet the accuracy requirements for RNAV 1.

For existing systems, compliance with both P-RNAV (TGL-10) and U.S. RNAV (FAA AC 90-100) assures automatic compliance with this CAP specification.

For operators holding only a P-RNAV approval, or a US-RNAV approval, it is necessary to ensure that any additional requirements for RNAV 1 and RNAV 2 are met. ICAO Doc. 9613, PBN Manual, provides tables identifying these additional requirements. (Part B, Chapter 3 Para 3.3.2.4.4).

The RNAV 1 and RNAV 2 navigation specification applies to:

- (a) All ATS routes, including those established in the en-route domain;
- (b) Standard instrument departures and arrivals (SID/STAR); and
- (c) Instrument approach procedures up to the final approach fix (FAF)/final approach point (FAP).

The RNAV system may be based on:

- (a) DME/DME
- (b) DME/DME/IRU
- (c) GNSS (including GNSS/IRU)

A navigation database is required.



Navigation displays in the pilot's forward view must be sufficient to permit track following and maneuvering.

The maximum cross-track error deviation permitted is $\frac{1}{2}$ navigation accuracy

- (a) 0.5NM for RNAV 1
- (b) 1 NM for RNAV 2

An RNAV system failure indication is required.

As RNAV 1 and RNAV 2 operations can be based on DME/DME or DME/DME IRU, the navaid infrastructure must be assessed to ensure adequate DME coverage. This is the responsibility of the ANSP and is not part of the operational approval.

The aircraft requirements for RNAV 1 and RNAV 2 are identical, while some operating procedures are different.

15.2 System Requirements

RNAV 1 and RNAV 2 operations are based upon the use of RNAV equipment that automatically determines the aircraft position in the horizontal plane using input from the following types of position sensors (no specific priority):

- (a) Global navigation satellite system (GNSS) in accordance with ETSO C129 (A), FAA TSO C129 (A) or later meets the requirements of RNAV 1 and RNAV 2.

Stand-alone receivers manufactured to ETSO C129 or FAA TSO C129 is also applicable provided they include pseudo-range step detection and health word checking functions.

GNSS based operations require prediction that a service (with integrity) will be available for the route. Most GNSS availability prediction programs are computed for a specific location (normally the destination airport) and are unable to provide predictions over a route or large area. However, for RNAV 1 and RNAV 2, the probability of a loss of GNSS integrity is remote and the prediction requirement can normally be met by determining that sufficient satellites are available to provide adequate continuity of service.

CAP 11 makes reference to the possibility of position errors caused by the integration of GNSS data and other positioning data and the potential need for the deselection of other navigation sensors. This method of updating is commonly associated with IRS/GNSS systems and the weighting given to radio updating is such that it is unlikely that any potential reduction in positioning accuracy will be significant in proportion to RNAV 1 and RNAV 2 navigation accuracy.

- (b) DME/DME RNAV equipment complying with required criteria.
- (c) DME/DME/IRU RNAV equipment complying with required criteria.

15.2.1 On-board performance monitoring and alerting:



- (a) Accuracy: During operations in airspace or on routes designated as RNAV 1, the Lateral Total system Error (TSE) must be within ± 1 NM for at least 95 per cent of the total flight time.

The along-track error must also be within ± 1 NM for at least 95 per cent of the total flight time. During operations in airspace or on routes designated as RNAV 2, the lateral total system error must be within ± 2 NM for at least 95 per cent of the total flight time. The along-track error must also be within ± 2 NM for at least 95 per cent of the total flight time.

- (b) Integrity: Malfunction of the aircraft navigation equipment is classified as a major failure condition under airworthiness regulations (i.e. 10^{-5} per hour).
- (c) Continuity: Loss of function is classified as a minor failure condition if the operator can revert to a different navigation system and proceed to a suitable airport.
- (d) 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. 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.

15.2.2 Functionality

For the majority of air transport aircraft equipped with FMS, the required functionalities, with the exception of the provision of a non-numeric lateral deviation display, are normally available. For this category of aircraft lateral deviation is displayed on a map display, usually with a numeric indication of cross-track error in 1/10th NM. In some cases, a numeric indication of cross-track error may be provided outside the primary field of view (e.g. CDU). Acceptable lateral tracking accuracy for both RNAV 1 and RNAV 2 routes is adequate provided the autopilot is engaged or flight director is used.

Aircraft equipped with stand-alone GNSS navigation systems, shall be installed to provide track guidance via a CDI or HSI. A lateral deviation display is often incorporated in the unit, but is commonly neither of sufficient size nor suitable position to allow either pilot to manoeuvre and adequately monitor cross-track deviation.

Caution shall be exercised in regard to the limitations of stand-alone GNSS systems with respect to ARINC 424 path terminators. Path terminators involving an altitude termination are not normally supported due to a lack of integration of the lateral navigation system and the altimetry system. For example, a departure procedure commonly specifies a course after takeoff until reaching a specified altitude (CA path terminator). Using a basic GNSS navigation system it is necessary for the flight crew to manually terminate the leg on reaching the specified altitude and then navigate to the next waypoint, ensuring that the flight path is consistent with the departure procedure. This type of limitation does not preclude operational approval provided the operator's procedures and crew training are adequate to ensure that the intended flight path and other requirements can be met for all SIDs and STAR procedures.



15.3 Operating Procedures

Operators with en-route RNAV experience will generally meet the basic requirements of RNAV 1 and RNAV 2 and the operational approval shall focus on procedures associated with SIDs and STARs.

Particular attention shall be placed on selection of the correct procedure from the database, review of the procedures, connection with the en-route phase of flight and the management of discontinuities. Similarly, an evaluation shall be made of procedures to manage changes, such as a change of runway, and any crew amendments, such as insertion or deletion of waypoints.

As RNAV 1 and RNAV 2 operations are typically conducted in areas of adequate navaid coverage, contingency procedures will normally involve reversion to conventional ground-based radio navigation.

15.3.1 Pre-flight planning requirements.

- (a) Operators and pilots intending to conduct operations on RNAV 1 and RNAV 2 routes should file the appropriate flight plan suffixes.
- (b) The on-board navigation data must be current and appropriate for the region of intended operation and must include the NAVAIDs, waypoints, and relevant coded ATS routes for departure, arrival, and alternate airfields.

Note: Navigation databases are expected to be current for the duration of the flight. If the AIRAC cycle is due to change during flight, operators and pilots should establish procedures to ensure the accuracy of the navigation data, including the suitability of navigation facilities used to define the routes and procedures for flight.

- (c) The availability of the NAVAID infrastructure, required for the intended routes, including any non-RNAV contingencies, must be confirmed for the period of intended operations using all available information. Since GNSS integrity (RAIM or SBAS signal) is required by Annex 10, Volume I, the availability of these should also be determined as appropriate. For aircraft navigating with the SBAS receivers (all TSO-C145/C146), operators should check appropriate GPS RAIM availability in areas where the SBAS signal is unavailable.
- (d) Aircraft-based augmentation system (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 minutes for any part of the RNAV 1 or RNAV 2 operation, the flight plan should be revised (e.g. delaying the departure or planning a different departure procedure).

RAIM availability prediction software does not guarantee a service; such tools assess the RNAV system's ability to meet the navigation performance. Because of unplanned failure of some GNSS elements, pilots/ANSP must realize that RAIM or GPS navigation altogether may be lost while airborne which may require reversion to an alternative means of navigation. Therefore, pilots should assess their capability to navigate (potentially to an alternate destination) in case of failure of GPS navigation.

- (e) Distance measuring equipment (DME) availability: For navigation relying on DME, NOTAMs should be checked to verify the condition of critical DMEs. Pilots should assess their capability to navigate (potentially to an alternate destination) in case of failure of critical DME while airborne.

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

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.

Pilots should cross-check the cleared flight plan by comparing charts or other applicable resources with the navigation system textual display and the aircraft map display, if applicable. If required, the exclusion of specific NAVAIDs should be confirmed.

Note: Pilots may notice a slight difference between the navigation information portrayed on the chart and their primary navigation display. Differences of 3 degrees or less may result from the equipment manufacturer's application of magnetic variation and are operationally acceptable.

During the flight, where feasible, the pilot should use available data from ground-based NAVAIDs 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 as a lateral deviation indicator 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 on-board lateral deviation indicators and/or flight guidance during all RNAV operations described in this manual, unless authorized to deviate by ATC or under emergency conditions. For normal operations, cross-track error/deviation (the difference between the RNAV system computed path and the aircraft position relative to the path, i.e. FTE) should be limited to $\pm 1/2$ 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 one-times the navigation accuracy (i.e. 1.0 NM for RNAV 1, 2.0 NM for RNAV), are allowable.

Note: Some aircraft do not display or compute a path during turns, therefore, pilots of these aircraft may not be able to adhere to the $\pm 1/2$ 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 that manually selectable aircraft bank-limiting functions might reduce their ability to satisfy ATC path expectations, especially when executing large angle turns. This should not be construed as a requirement to deviate from aeroplane flight manual procedures; rather, pilots should be encouraged to limit the selection of such functions within accepted procedures.

15.3.3 RNAV SID specific requirements.

Prior to commencing take-off, the pilot must verify the aircraft's RNAV system is available, operating correctly, and the correct airport and runway data are loaded. Prior to flight, pilots must verify their aircraft navigation system is operating correctly and the correct runway and departure procedure (including any applicable en-route transition) are entered and properly depicted. Pilots who are assigned an RNAV departure procedure and subsequently receive a change of runway, procedure or transition must verify the appropriate changes are entered and available for navigation prior to take-off. A final check of proper runway entry and correct route depiction, shortly before take-off, is recommended.

RNAV engagement altitude. The pilot must be able to use RNAV equipment to follow flight guidance for lateral navigation e.g., LNAV no later than 153 m (500 ft) above the airport elevation. The altitude at which RNAV guidance begins on a given route may be higher (e.g. climb to 304 m (1 000 ft) then direct to ...).

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 304 m (1 000 ft) (0.17 NM) of a known position, at the starting point of the take-off roll. This is usually achieved by the use of an automatic or manual runway update function. A navigation map may also be used to confirm aircraft position, if the pilot procedures and the display resolution allow for compliance with the 304 m (1 000 ft) tolerance requirement.

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

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.

15.3.4 RNAV STAR specific requirements

Prior to the arrival phase, the pilot should verify that the correct terminal route has been loaded. The active flight plan should be checked by comparing the charts with the map display (if applicable) and the MCDU. This includes confirmation of the waypoint sequence, reasonableness of track angles and distances, any altitude or speed constraints, and, where possible, which waypoints are fly-by and which are flyover. If required by a route, a check will need to be made to confirm that updating will exclude a particular NAVAID. A route must not be used if doubt exists as to the validity of the route in the navigation database.

Note: As a minimum, the arrival checks could be a simple inspection of a suitable map display that achieves the objectives of this paragraph.

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

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

Route modifications in the terminal area may take the form of radar headings or -direct toll clearances and the pilot must be capable of reacting in a timely fashion. This may include the insertion of tactical waypoints loaded from the database. Manual entry or modification by the pilot of the loaded route, using temporary waypoints or fixes not provided in the database, is not permitted.

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.

15.3.5 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 ATS as soon as possible. The loss of RNAV capability includes any failure or event causing the aircraft to no longer satisfy the RNAV requirements of the route.

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



15.4 Pilot Knowledge and Training

During the operational approval, particular attention shall be placed on the application of pilot knowledge and training to the conduct of RNAV 1 and RNAV 2 SIDs and STARs. Most crews will already have some experience RNAV operations. Therefore, many of the knowledge and training items will have previously been covered in past training.

Execution of SIDs and STARs, connection with the en-route structure and transition to approach procedures require a thorough understanding of the airborne equipment, its functionality and management.

Particular attention shall be placed on:

- (a) The ability of the airborne equipment to fly the designed flight path. This may involve pilot intervention where the equipment functionality is limited
- (b) Management of changes (procedure, runway, track)
- (c) Turn management (turn indications, airspeed & bank angle, lack of guidance in turns)
- (d) Route modification (insertion/deletion of waypoints, direct to waypoint)
- (e) Intercepting route, radar vectors

Where GNSS is used, flight crews must be trained in GNSS principles related to en-route navigation.

Flight training for RNAV 1 and RNAV 2 shall be conducted in a full flight simulator.

Although not specifically mentioned in RNAV 1 and RNAV 2 navigation specification, where VNAV is used for SIDs and STARs, attention shall be given to the management of VNAV and specifically the potential for altitude constraints to be compromised in cases where the lateral flight path is changed or intercepted.

Guidance on operational training requirements is contained in Appendix 2 and CAP 11, Vols. 1 and 3.

16. RNP 4

16.1 General

RNP 4 is a navigation specification applicable to oceanic and remote airspace. It supports 30NM lateral and 30NM longitudinal separation.

For RNP 4 operational approval:

- (a) Two fully serviceable independent long range navigation systems (LRNSs) are required.
- (b) Two GNSS receivers are required. They can be used as either a stand-alone navigation system or as one of the sensors in a multi-sensor system.



- (c) A navigation database is required.
- (d) Navigation displays in the pilot's forward view must be sufficient to permit track following and manoeuvring.
- (e) The maximum cross-track error deviation permitted is 2NM.

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.



16.2 Aircraft requirements

16.2.1 Global navigation satellite system (GNSS)

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.

GNSS is fundamental to the RNP 4 navigation specification, thereby avoiding any need to impose a time limit on operations. The consequences of a loss of GNSS navigation need to be considered and there are a number of requirements in the navigation specification to address this situation.

Irrespective of the number of GNSS receivers carried, as there is a remote probability that a fault may be detected en-route, a fault detection and exclusion (FDE) function needs to be installed.

This function is not standard on TSO C129a receivers and for oceanic operations a modification is required.

With FDE fitted, integrity monitoring is available provided there are sufficient satellites of a suitable configuration in view. Some reduction in availability of a positioning service with integrity results, as additional satellites are required.

Although for RNP 4 as the alerting requirements are large, it is highly improbable that service will not be available.

The RNP 4 navigation specification does not require a dispatch prediction of the availability of integrity monitoring (with FDE) in the case of a multi-sensor system. In this context a system integrating GNSS and IRS is a suitable multi-sensor system. A prediction of GNSS availability is therefore not considered necessary the multi-sensor system will revert to IRS in the remote possibility that GNSS is unavailable.

Other methods of integrity monitoring, discussed under the heading Aircraft Autonomous Integrity Monitoring (AAIM) in Part 1, utilise hybrid GNSS/IRS monitoring systems which provide increased availability sufficient to not require a



dispatch prediction to be conducted. Examples of these systems are Honeywell HIGH and Litton AIME.

A difficulty is that most availability programs are based on a specific location (normally the destination airport) and are unable to provide predictions over a route or large area. For RNP 4, as the alerting limits are large, provided a minimum number of satellites are available, availability can be assured without the need to carry out a prediction for each flight.

16.2.2 On-board performance monitoring and alerting:

- (a) Accuracy: During operations in airspace or on routes designated as RNP 4, the Lateral Total system Error (TSE) must be within ± 4 NM for at least 95 per cent of the total flight time.
- (b) Integrity: Malfunction of the aircraft navigation equipment is classified as a major failure condition under airworthiness regulations (i.e. 10^{-5} per hour).
- (c) 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).
- (c) On-board 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} .
- (d) 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.

Note: Compliance with the on-board 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 (10.1.5) and crew procedures (10.2.2).

16.2.2 Functionality

For the majority of air transport aircraft equipped with FMS, the required functionalities, with the exception of the provision of a non-numeric lateral deviation display are normally available. For this category lateral deviation is not normally displayed on a CDI or HSI, but is commonly available on a map display, usually with a numeric indication of cross-track error in 1/10th NM. In some cases, a numeric indication of cross-track error may be provided outside the primary field of view (e.g. CDU).



Aircraft equipped with stand-alone GNSS navigation systems, shall be installed to provide track guidance via a CDI or HSI. The CDI/HSI must be coupled to the RNAV route providing a direct indication of lateral position reference the flight planned track. This type of unit in en-route mode (normal outside 30NM from departure and destination airports) defaults to a CDI/HSI full-scale display of 5NM, which is adequate for RNP 4. A lateral deviation display is often incorporated in the unit. The display may therefore be suitable if of sufficient size and position to allow either pilot to manoeuvre and monitor cross-track deviation.

The navigation specification includes some requirements for fly-by transition criteria. The default method for RNAV systems to manage turns at the intersection of –straightll route segments (TF/TF), is to compute, based on groundspeed and assumed angle of bank, a position at which the turn shall commence so that the resulting radius will turn inside the angle created by the two consecutive segments and –fly-byll the intermediate waypoint. For aircraft fitted with a stand-alone GNSS system or an FMS fly-by transitions are a standard function and shall not require specific evaluation. However, a stand-alone GNSS receiver may require a pilot action to initiate the turn. All turns are limited by the physical capability of the aircraft execute a turn of suitable radius. In normal cases where the angle between track is small there is seldom a problem, but operators need to be aware that large angle turns, particularly at high altitude where TAS is high and bank angle is commonly limited, can be outside the aircraft capability. While this condition is rare, flight crews need to be aware of the aircraft and avionics limitations.

16.3 Operating Procedures

The standard operating procedures adopted by operators flying on oceanic and remote routes shall normally be generally consistent with RNP 4 operations, except that some additional provisions may need to be included to specifically address RNP 4 operations. North Atlantic HLA required RNP 4 per ICAO Document 007.

A review of the operator’s procedure documentation against the requirements of CAP 11 and the BCAA regulatory requirements shall be sufficient to ensure compliance.

16.3.1 Pre-flight planning requirements.

Operators should use the appropriate ICAO flight plan designation specified for the RNP route. The letter –Rll should be placed in block 10 of the ICAO flight plan to indicate the pilot has reviewed the planned route of flight and determined the RNP requirements and the aircraft and operator approval for RNP routes. Additional information should be displayed in the remarks section indicating the accuracy capability, such as RNP 4 versus RNP 10. It is important to understand that additional requirements will have to be met for operational authorization in RNP 4 airspace or on RNP 4 routes. Controller-pilot data link communications (CPDLC) and automatic dependent surveillance - contract (ADS-C) systems will also be required when the separation standard is 30 NM lateral and/or longitudinal. The on-board navigation data must be current and include appropriate procedures.

Note: Navigation databases are expected to be current for the duration of the flight. If the AIRAC cycle is due to change during flight, operators and pilots should establish procedures to ensure the accuracy of navigation data, including suitability of navigation facilities used to define the routes and procedures for



flight.

The flight crew shall:

- (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.

16.3.2 Availability of GNSS.

At dispatch or during flight planning, the operator must ensure that adequate navigation capability is available en route to enable the aircraft to navigate to RNP 4 and to include the availability of FDE, if appropriate for the operation.

16.3.3 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 route 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 cause 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. Pilots of aircraft with a lateral deviation indicator must ensure that the lateral deviation indicator scaling (full-scale deflection) is suitable for the navigation accuracy associated with the route (i.e. ± 4 NM). All pilots are expected to maintain route centrelines, as depicted by on-board lateral deviation indicators and/or flight guidance during all RNP operations described in this manual unless authorized to deviate by ATC or under emergency conditions. For normal operations, cross-track error/deviation (the difference between the RNAV system computed path and the aircraft position relative to the path) should be limited to $\pm 1/2$ the navigation accuracy associated with the route (i.e. 2 NM). Brief deviations from this standard (e.g. overshoots or undershoots) during and immediately after route turns, up to a maximum of one-times the navigation accuracy (i.e. 4 NM), are allowable.



16.4 ATS Communications and Surveillance

CAP 11 does not address communication or air traffic services (ATS) surveillance requirements that may be specified for operation on a particular route or area. These requirements are specified in other documents, such as the aeronautical information publications (AIP) and ICAO Regional Supplementary Procedures (Doc. 7030).

An operational approval conducted in accordance with the requirements of CAP 11 assumes that operators and flight crews take into account all the communication and surveillance requirements related to RNP 4 routes (ICAO Annex 6 Part I, Chapter 7 and AC/ALD.GEN/xx/2017).

16.5 Pilot Knowledge and Training

Flight training shall be conducted in a full flight simulator.

Where GNSS is used, flight crews must be familiar with GNSS principles related to en-route navigation.



Guidance on operational training requirements is contained in Appendix 2 and CAP 11, Vols. 1 and 3.

17. RNP 2 General

RNP 2 is based on GNSS positioning. It is intended to support airway and oceanic/remote area operations.

Oceanic/Remote RNP 2 Authorization. An operator with an oceanic/remote RNP 2 authorization will also be granted RNP 4 and RNP 10 navigation authorizations. Authorizations in oceanic and remote continental airspace also depend upon the operator's qualification to meet international surveillance and communication requirements. Those requirements are specified in other documents, such as the Aeronautical Information Publications (AIP) and the International Civil Aviation Organization (ICAO) Doc 7030, Regional Supplementary Procedures (SUPPS)

Operational Approval

- 17.1 Approval Basis. RNP 2 approvals are based on Global Navigation Satellite System (GNSS), including GNSS/Inertial Reference Unit (IRU), due to implementation in remote/oceanic areas. Therefore, distance measuring equipment (DME)/DME/IRU should not be the basis for any RNP 2 approvals.
- 17.2 Qualified Avionics Equipment and Airworthiness Approval. Aircraft with the following avionics equipment and an appropriate airworthiness approval automatically qualify for RNP 2 minima capability without further documentation by virtue of the avionics Technical Standard Order (TSO) and airworthiness approval: 1. Global Positioning System (GPS) stand-alone systems approved in accordance with TSO-C146 operational Class 1, 2, or 3.



- 17.3 Navigation Equipment Requirements. Navigation equipage for oceanic/remote RNP 2 operations must require dual independent GPS LRNS where higher continuity is specified. Navigation equipage for all RNP 2 remote and offshore operations areas must have at least a single GPS LRNS.
- 17.4 Specification Basis. The RNP 2 specification is based upon GNSS. Positioning data from other types of navigation sensors may be integrated with the GPS data provided they do not cause position errors exceeding the Total System Error (TSE) budget. Otherwise, means should be provided to deselect the other navigation sensor types.
- 17.5 Knowledge of Operational Requirements. Operators and pilots are required to take account of all operational requirements relating to RNP 2 airspace as required by the appropriate state or regional authority before conducting flights into that airspace.
- 17.6 Fault Detection and Exclusion (FDE) Function. An FDE function must be available when conducting RNP 2 oceanic or remote operations.
- 17.7 GNSS Fault Detection. Operators are required to have the means to predict the availability of GNSS fault detection (e.g., Aircraft-Based Augmentation System (ABAS) receiver autonomous integrity monitoring (RAIM)) to support operations along the RNP 2 ATS route. The onboard RNP system, GNSS avionics, the air navigation service provider (ANSP), or other entities may provide a prediction capability.
- 17.8 Accuracy. The aircraft must comply with Section 2.1.1 of RTCA/DO-236(). During operations in airspace or on routes designated as RNP 2, the lateral TSE must be within ± 2 nautical miles (NM) for at least 95 percent of the total flight time. The along-track (ATRK) error must also be within ± 2 NM for at least 95 percent of the total flight time. To satisfy the 95 percent accuracy requirement, the Flight Technical Error (FTE) should not exceed 1 NM. Note: The use of a lateral deviation indicator with 2 NM full-scale deflection has been found to be an acceptable means of compliance (AMC) integrity. An autopilot (AP) or flight director (FD) may also be used for maintaining TSE, but roll stabilization systems do not qualify.
- 17.9 Integrity. Malfunction of the aircraft navigation equipment that causes the TSE to exceed two times the RNP value is classified as a major failure condition under airworthiness guidance (i.e., 10^{-5} per hour).
- 17.10 System Capabilities. The following system capabilities are required as a minimum within any RNP 2 equipment: 1. The capability to continuously display to the pilot flying (PF), on the primary flight instruments for navigation of the aircraft (primary navigation display), the RNP-computed desired path and aircraft position relative to the path. For operations where the required minimum flight crew is two pilots, a means for the pilot monitoring (PM) 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). 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. 3. The means to display the validity period of the navigation data to the pilot. 4. The means to retrieve and display data stored in the navigation database relating to individual waypoints and navigation aids, to enable the pilot to verify the route to be flown. 5. The capability to load from the database into the RNP system the RNP 2 route to be flown if applicable.



17.11 Aircraft Qualification Documentation. The aircraft or avionics manufacturers should develop aircraft qualification documentation that shows compliance with the applicable criteria, as appropriate. This is not required for aircraft with an AFM or AFMS which explicitly states that the RNP system is approved for instrument flight rules (IFR) operations with RNP values at least as low as RNP 2 and the equipment meets the performance and reliability guidance

17.3 Training

Flight Crews must receive training in a full flight simulator.

Preflight Planning. The following actions should be completed during preflight:

Review maintenance logs and forms to ascertain the condition of equipment.

18. RNP 1

18.1 General

RNP 1 is based on DME/DME/IRU FMS or GNSS positioning. The navigation specification is intended to support arrival and departure procedures. RNP 1 and A-RNP may be used in combination with any type of approach (RNP, instrument landing system (ILS), Ground Based Augmentation System (GBAS) Landing System (GLS)).

18.1.1 Operational Approval

Approval of the Operators with RNP 1 equipped aircraft approvals qualify is subject to the following conditions:

- (a) Manual entry of SID/STAR waypoints is not permitted.
- (b) Pilots of aircraft with RNP input selection capability (typically equipped FMS aircraft) shall select RNP 1 or lower for RNP 1 SIDs and STARs.
- (c) If a RNP 1 SID or STAR extends beyond 30NM from the ARP in some cases the CDI scale may need to be set manually to maintain FTE within limits (see below).
- (d) If a MAP display is used, scaling must be suitable for RNP 1 and a FD or AP used.

18.1.2 Summary

A navigation database is required.

Navigation displays in the pilot's forward view must be sufficient to permit track following and manoeuvring.

DME/DME/IRU or GNSS is required.

MAP display (without CDI) is acceptable provided FD or AP is used.

The maximum cross-track error deviation permitted is 0.5NM.



18.2 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. Qualified Avionics Equipment and Airworthiness Approval. Aircraft with the following avionics equipment and an appropriate airworthiness approval automatically qualify for RNP 1 capability without further documentation by virtue of the avionics Technical Standard Order (TSO) and airworthiness approval: 1. Global Positioning System (GPS) stand-alone systems approved in accordance with TSO-C146() operational Class 1, 2, or 3. 2. A TSO-C115c light management system (FMS) (or later revision) with a TSO-C129() Class B1 or C1, TSO-C145(), or TSO-C196() sensor. Note: TSO-C129a has been cancelled, but equipment with an existing TSO-C129a Technical Standard Order Authorization (TSOA) may still be installed. 3. A TSO-C115b FMS using a TSO-C129() Class B1 or C1, TSO-C145(), or TSO-C196() sensor with documented compliance to the RNP requirements in RTCA, Inc.'s document, RTCA/DO-236 (revision 'B' or later) or RTCA/DO-283A.

18.2.1 On-board performance monitoring and alerting:

- (a) Accuracy: During operations in airspace or on routes designated as RNP 1, the Lateral Total system Error (TSE) must be within ± 1 NM for at least 95 per cent of the total flight time.

The along-track error must also be within ± 1 NM for at least 95 per cent of the total flight time. 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 per cent of the total flight time. The along-track error must also be within ± 1 NM for at least 95 per cent of the total flight time. To satisfy the accuracy requirement, the 95 per cent FTE should not exceed 0.5 NM.

Note: The use of a deviation indicator with 1 NM full-scale deflection has been found to be an acceptable means of compliance. The use of an autopilot or flight director has been found to be an acceptable means of compliance (roll stabilization systems do not qualify).

- (b) Integrity: Malfunction of the aircraft navigation equipment is classified as a major failure condition under airworthiness regulations (i.e. 10^{-5} per hour).
- (c) Continuity: Loss of function is classified as a minor failure condition if the operator can revert to a different navigation system and proceed to a suitable airport.
- (d) On-board performance monitoring and alerting: The 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 1 NM is greater than 1



x 10⁻⁵.

- (e) Signal-in-space: During operations in airspace or on routes designated as RNP 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 2NM exceeds 10⁻⁷ per hour.

Note: Compliance with the on-board performance monitoring and alerting requirements does not imply automatic monitoring of flight technical errors. The on-board monitoring and alerting function should consist at least of a navigation system error (NSE) monitoring and alerting algorithm and a lateral deviation display enabling the crew to monitor the flight technical error (FTE). To the extent operational procedures are used to monitor FTE, the crew procedure, equipment characteristics, and installation are evaluated for their effectiveness and equivalence, as described in the functional requirements and operating procedures. Path definition error (PDE) is considered negligible due to the quality assurance process (10.1.5) and crew procedures (10.2.2).

18.2.2 Functionality

CAP 11 lists the functional requirements for RNP 1 which are identical to RNAV 1 and 2.

For the majority of air transport aircraft equipped with FMS, the required functionalities, with the exception of the provision of a non-numeric lateral deviation display are normally available. For this category of aircraft lateral deviation is displayed on a map display, usually with a numeric indication of cross-track error in 1/10th NM.

In some cases, a numeric indication of cross-track error may be provided outside the primary field of view (e.g. CDU). Acceptable lateral tracking accuracy for RNP 1 routes is adequate provided the autopilot is engaged or flight director is used.

Aircraft equipped, with stand-alone GNSS navigation systems, shall be installed to provide track guidance via a CDI or HSI. A lateral deviation display is often incorporated into the unit and may be suitable if of sufficient size and position to allow either pilot to manoeuvre and monitor cross-track deviation.

Caution shall be exercised in regard to the limitations of stand-alone GNSS systems with respect to ARINC 424 path terminators. Path terminators involving an altitude termination are not normally supported due to a lack of integration of the lateral navigation system and the altimetry system. For example, a departure procedure commonly specifies a course after takeoff until reaching a specified altitude (CA path terminator). Using a basic GNSS navigation system it is necessary for the flight crew to manually terminate the leg on reaching the specified altitude and then navigate to the next waypoint, ensuring that the flight path is consistent with the departure procedure. This type of limitation does not preclude operational approval (as stated in CAP 11 requirements) provided the operator's procedures and crew training are adequate to ensure that the intended flight path and other requirements can be met for all SID and STAR procedures.

18.2.3 Criteria for specific navigation systems: De-selection of Radio Updating



There is a possibility of position errors caused by the integration of GNSS data with other positioning data and the potential need for de-selection of other navigation sensors. While it is unlikely that any reduction in positioning accuracy will be significant in proportion to the required RNP 1 navigation accuracy, this should be confirmed. Otherwise, a means to deselect other sensors should be provided and the operating procedures should reflect this.

Note: For RNP procedures, the RNP system may only use DME updating when authorized by the State. The manufacturer should identify any operating constraints (e.g., manual inhibit of DME) in order for a given aircraft to comply with this requirement. This is in recognition of States where a DME infrastructure and capable equipped aircraft are available. Those States may establish a basis for aircraft qualification and operational approval to enable use of DME. It is not intended to imply a requirement for implementation of DME infrastructure or the addition of RNP capability using DME for RNP operations. This requirement does not imply an equipment capability must exist providing a direct means of inhibiting DME updating. A procedural means for the pilot to inhibit DME updating or executing a missed approach if reverting to DME updating may meet this requirement.

18.3 Operating Procedures

Special Characteristics of RNP 1 Operations. C.4.1 Operation on RNP ODPs, SIDs, STARs. DME/DME/IRU and/or GNSS are the primary navigation systems supporting RNP 1 operations. Refer to AC 20-138(), Chapter 6, Sections 6-4, 6-6, and 6-8 for additional aircraft and system qualification criteria when using DME/DME/IRU. Pilots are not required to monitor ground-based navigation facilities used in position updating unless required by the AFM. C.4.2 Navigation Infrastructure. The BCAA will monitor the navigation infrastructure and issue timely warnings of outages and facilities designated out of service. Source data contains the navigation performance needed to fly each RNP procedure and must be clearly designated on all appropriate charts. C.4.4 DME/DME/IRU. If DME/DME/IRU is used, the available DME navigation infrastructure supporting the design of a procedure will be assessed and validated by the service provider.

Operators with en-route RNAV experience will generally meet the basic requirements of RNP 1 and the operational approval shall focus on procedures associated with SIDs and STARs.

Multisensor Systems with RNP 1 Approval. For multisensor systems with RNP 1 approval based on DME/DME, pilots must confirm the availability of critical DME for ODPs, SIDs, and STARs. Note: Procedures with (GPS) in the title and with a GPS required are not evaluated for critical DMEs. C.7.3 Radius to Fix (RF) Legs. For RNP 1 operations employing RF legs, confirmation of RF leg aircraft eligibility must be confirmed during preflight planning., Additional Capabilities, for aircraft RF leg eligibility requirements.

Particular attention shall be placed on selection of the correct procedure from the database, review of the procedures, connection with the en-route phase of flight and the management of discontinuities. Similarly, an evaluation shall be made of procedures to manage changes, such as change of runway and any crew amendments, such as insertion or deletion of waypoints.



18.3.1 Pre-flight planning requirements.

- (a) Operators and pilots intending to conduct operations on RNP 1 SIDs and STARs should file the appropriate flight plan suffixes.
- (b) The on-board navigation data must be current and include appropriate procedures.

Note: Navigation databases are expected to be current for the duration of the flight. If the AIRAC cycle is due to change during flight, operators and pilots should establish procedures to ensure the accuracy of the navigation data, including the suitability of navigation facilities used to define the routes and procedures for flight.

- (c) The availability of the NAVAID infrastructure, required for the intended routes, including any non-RNAV contingencies, must be confirmed for the period of intended operations using all available information. Since GNSS integrity (RAIM or SBAS signal) is required by Annex 10, Volume I, the availability of these should also be determined as appropriate. For aircraft navigating with the SBAS receivers (all TSO-C145/C146), operators should check appropriate GPS RAIM availability in areas where the SBAS signal is unavailable.
- (d) Aircraft-based augmentation system (ABAS) availability: RAIM levels required for RNP 1 can be verified either through NOTAMs (where available) or through prediction services. The operating authority may provide specific guidance on how to comply with this requirement (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 minutes for any part of the RNP 1 operation, the flight plan should be revised (e.g. delaying the departure or planning a different departure procedure).

RAIM availability prediction software does not guarantee a service; such tools assess the RNAV system's ability to meet the navigation performance. Because of unplanned failure of some GNSS elements, pilots/ANSP must realize that RAIM or GPS navigation altogether may be lost while airborne which may require reversion to an alternative means of navigation. Therefore, pilots should assess their capability to navigate (potentially to an alternate destination) in case of failure of GPS navigation.

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

Pilots should cross-check the cleared flight plan by comparing charts or other applicable resources with the navigation system textual display and the aircraft map display, if applicable. If required, the exclusion of specific NAVAIDs should be confirmed.

Note: Pilots may notice a slight difference between the navigation information portrayed on the chart and their primary navigation display. Differences of 3 degrees or less may result from the equipment manufacturer's application of magnetic variation and are operationally acceptable.

Cross-checking with conventional NAVAIDs is not required, as the absence of integrity alert is considered sufficient to meet the integrity requirements. However, monitoring of navigation reasonableness is suggested, and any loss of RNP capability shall be reported to ATC.

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

Pilots of aircraft with a lateral deviation display must ensure that lateral deviation scaling is suitable for the navigation accuracy associated with the route/procedure (e.g. full-scale deflection: ± 1 NM for RNP 1).

All pilots are expected to maintain route centrelines, as depicted by on-board lateral deviation indicators and/or flight guidance during all RNAV operations described in this manual, unless authorized to deviate by ATC or under emergency conditions. For normal operations, cross-track error/deviation (the difference between the RNAV system computed path and the aircraft position relative to the path, i.e. FTE) should be limited to $\pm 1/2$ the navigation accuracy associated with the procedure or route (i.e. 0.5 NM for RNP 1). Brief deviations from this standard (e.g. overshoots or undershoots) during and immediately after procedure/route turns, up to a maximum of one-times the navigation accuracy (i.e. 1.0 NM for RNP 1), are allowable.



Note: Some aircraft do not display or compute a path during turns, therefore, pilots of these aircraft may not be able to adhere to the $\pm 1/2$ 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 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 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 that manually selectable aircraft bank-limiting functions might reduce their ability to satisfy ATC path expectations, especially when executing large angle turns. This should not be construed as a requirement to deviate from aeroplane flight manual procedures; rather, pilots should be encouraged to limit the selection of such functions within accepted procedures.

18.3.3 RNP 1 SID specific requirements.

Prior to commencing take-off, the pilot must verify the aircraft's 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 RNP departure procedure and subsequently receive a change of runway, procedure or transition must verify the appropriate changes are entered and available for navigation prior to take-off. A final check of proper runway entry and correct route depiction, shortly before take-off, is recommended.

RNP 1 engagement altitude. The pilot must be able to use RNP1 equipment to follow flight guidance for lateral navigation e.g., LNAV no later than 153 m (500 ft) above the 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 RNP 1.

GNSS aircraft. When using GNSS, the signal must be acquired before the take-off roll commences. For aircraft using TSO-C129a avionics, the departure airport must be loaded into the flight plan in order to achieve the appropriate navigation system monitoring and sensitivity. For aircraft using TSO-C145()/C146() avionics, if the departure begins at a runway waypoint, then the departure airport does not need to be in the flight plan to obtain appropriate monitoring and sensitivity. If the RNP 1 SID extends beyond 30 NM from the ARP and a lateral deviation indicator is used, its full-scale sensitivity must be selected to not greater than 1 NM between 30 NM from the ARP and the termination of the RNP 1 SID (see 18.4 below).

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



18.3.4 RNP 1 STAR specific requirements

Prior to the arrival phase, the pilot should verify that the correct terminal route has been loaded. The active flight plan should be checked by comparing the charts with the map display (if applicable) and the MCDU. This includes confirmation of the waypoint sequence, reasonableness of track angles and distances, any altitude or speed constraints, and, where possible, which waypoints are fly-by and which are flyover. If required by a route, a check will need to be made to confirm that updating will exclude a particular NAVAID. A route must not be used if doubt exists as to the validity of the route in the navigation database.

Note: As a minimum, the arrival checks could be a simple inspection of a suitable map display that achieves the objectives of this paragraph.

The creation of new waypoints by manual entry into the RNP 1 system by the pilot would invalidate the route and is not permitted.

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

Procedure modifications in the terminal area may take the form of radar headings or -direct to|| clearances and the pilot must be capable of reacting in a timely fashion. This may include the insertion of tactical waypoints loaded from the database. Manual entry or modification by the pilot of the loaded route, using temporary waypoints or fixes not provided in the database, is not permitted.

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 RNP 1 STAR begins beyond 30 NM from the ARP and a lateral deviation indicator is used, then full scale sensitivity should be manually selected to not greater than 1 NM prior to commencing the STAR. For aircraft using a lateral deviation display (i.e. navigation map display), the scale must be set for the RNP 1 STAR, and the flight director or autopilot should be used (see 18.4 below).

18.3.5 FMS Systems

Aircraft equipped with a flight management system, normally integrate positioning from a number of sources (radio nav aids, GNSS) often using a multi-mode receiver (MMR) with IRS.

In such systems, the navigation capability, alerting and other functions are based upon an RNP capability. The RNP for a particular operation may be a default value, a pilot selected value or a value extracted from the navigation database.

There is normally no automatic mode switching (as in the case of a stand-alone receiver), although the default RNP may vary with the phase of flight.



For this type of operation, it is necessary for the flight crew to select either RNP 1 or accept a lesser default value before commencement of a RNP 1 SID or STAR.

18.3.6 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 RNP 1 SID or STAR for any reason, pilots must advise ATS as soon as possible. The loss of RNP capability includes any failure or event causing the aircraft to no longer satisfy the RNP 1 requirements of the route.

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

18.4 Maintaining 1 NM scaling

18.4.1 Stand-alone GNSS Systems

The most basic qualifying system is a stand-alone GNSS receiver (TSO C129(a)) which shall be coupled to a CDI or HSI display providing course guidance and cross-track deviation indications. This type of system may also be integrated with a map display, however, primary guidance is provided by the CDI/HSI. The receiver normally incorporates a self-contained control and display unit, but the interface may also be provided by a separate CDU.

In this arrangement, RNP 1 capability is provided when in terminal mode. In terminal mode:

- (a) CDI scaling is automatically set at ± 1 NM full scale deflection
- (b) HAL is automatically set to 1 NM (RAIM alert limit)

In the default mode (en-route) CDI scaling increases to ± 5 NM and HAL increases to 2NM. Terminal mode cannot be manually selected but will be system selected provided certain conditions exist.

For departure, provided the current flight plan includes the departure airport (usually the ARP), terminal mode will be active and annunciated. (An annunciator panel shall be installed in accordance with the manufacturer's recommendations and BCAA's airworthiness regulations). In the general case, terminal mode will automatically switch to en-route mode at 30NM from the departure ARP. If the RNP 1 SID extends past 30NM, the CDI scaling will no longer be adequate to support the required FTE limit (± 0.5 NM). Flight crew action is necessary to manually select ± 1 NM CDI scaling.

On arrival, provided the current flight plan route includes the destination airport (ARP) the receiver will automatically switch from en-route to terminal mode at 30NM from the ARP. If the STAR commences at a distance greater than 30NM radius from the destination, then en-route CDI scaling of ± 5 NM is inadequate for RNP 1 and must be manually selected to ± 1 NM.



Note 1: Manual selection of \pm INM CDI scale (terminal scaling) does not change the mode. En- route RAIM alert limits apply.

Note 2: If manual selection of \pm 1 NM is not available, crew procedures to maintain FTE at \pm 0.5 NM may be considered an acceptable means of compliance.

18.5 Integrity Availability

GNSS based operations require prediction that a service (with integrity) will be available for the route. Most GNSS availability prediction programs are computed for a specific location (normally the destination airport) and are unable to provide predictions over a route or large area. However, for RNP 1, the probability of a loss of GNSS integrity is remote and the prediction requirement can normally be met by determining that sufficient satellites are available to provide adequate continuity of service.

18.6 Pilot Knowledge and Training

During the operational approval, particular attention shall be placed on the application of the pilot knowledge and training to the conduct of RNP 1 SIDs and STARs. Most crews will already have some experience RNAV operations as many of the knowledge and training items will have previously been covered in past training.

Execution of SIDs and STARs, connection with the en-route structure and transition to approach procedures require a thorough understanding of the airborne equipment, its functionality and management.

Particular attention shall be placed on:

- (a) The ability of the airborne equipment to fly the designed flight path. This may involve pilot intervention where the equipment functionality is limited
- (b) Management of changes (procedure, runway, track)
- (c) Turn management (turn indications, airspeed & bank angle, lack of guidance in turns)
- (d) Route modification (insertion/deletion of waypoints, direct to waypoint)
- (e) Intercepting route, radar vectors

Where GNSS is used, flight crews must be trained in GNSS principles related to en-route navigation.



Flight training for RNP 1 is required in a full flight simulator. Although not specifically mentioned in CAP 11, RNP 1 navigation specification, where VNAV is used for SIDs and STARs, attention shall be given to the management of VNAV and specifically the potential for altitude constraints to be compromised in cases where the lateral flight path is changed or intercepted.

Guidance on operational training requirements is contained in Appendix 2 and CAP 11, Vols. 1 and 3.



19. ADVANCED RNP (A-RNP)

Advanced Required Navigation Performance (A-RNP).

In order to be A-RNP qualified for Advanced Required Navigation Performance (A-RNP), operators must be operationally and functionally qualified to perform the following three required functions:

1. Scalability,
2. Radius to Fix (RF),
3. Parallel offset.

Note: Higher continuity may be required for oceanic and remote airspace. Currently, fixed radius transition (FRT) and Time of Arrival Control (TOAC) are optional. For each applicable OpSpec, MSpec, or LOA, A-RNP functions are added to the bundled hierarchy of PBN authorizations.

Performance and Functional Requirements. This appendix provides guidance on the performance and functional requirements for the A-RNP operational implementation and related operations of:

- Required Navigation Performance (RNP) 2 (domestic or offshore en route),
- RNP 1 instrument departure procedures (DP),
- RNP 1 (RNP Obstacle Departure Procedures (ODP), and Standard Instrument Departures (SID)), and
- RNP 1 Standard Terminal Arrival Routes (STAR).

Qualification. A-RNP qualification.

Airworthiness Approval of Positioning and Navigation Systems, means the aircraft navigation system performs all six A-RNP functions (RF legs, parallel offsets, Area Navigation (RNAV) holding, Scalable RNP, FRTs, and TOAC)

20. RNP APCH

20.1 General

Introduction. This section provides guidance on the performance and functional requirements for systems used to conduct RNP APCH operations as Area Navigation (RNAV) Global Positioning System (GPS) or GPS and categorized as RNP APCH by the International Civil Aviation Organization (ICAO). Localizer performance without vertical guidance (LP) and localizer performance with vertical guidance (LPV) operations. Guidance for Localizer Performance with Vertical Guidance and Localizer Performance without Vertical Guidance Approach Operations. The barometric vertical navigation (baro-VNAV) aspects of RNP APCHs are specified in use of Barometric Vertical Navigation (baro-VNAV) for Required Navigation Performance Approach (RNP APCH) Operations. Baro-VNAV systems are optional capabilities that are not a minimum requirement to fly RNAV (GPS) or GPS approaches using the lateral navigation (LNAV) line of minima. The requirements for Radius to Fix (RF) legs are specified in additional capabilities.

RNP APCH is the general ICAO designator for PBN approach procedures that are not authorization required operations.



As GNSS fulfills the basic requirement of RNP for on-board performance and monitoring, both RNAV (GNSS) and SBAS LPV procedures are types of RNP APCH operations.

RNP APCH procedures will be identified as:

- (a) RNP APCH LNAV - lateral positioning with GNSS (basic constellation);
- (b) RNP APCH LNAV/VNAV - lateral positioning with GNSS, vertical positioning with barometric inputs;
- (c) RNP APCH LPV - lateral and vertical positioning with SBAS;
- (d) RNP APCH LP - SBAS approach where vertical guidance is not available.

The published RNP APCH OCA/H are treated as:

- (a) MDA/H for LNAV and LP minima;
- (b) DA/H for LNAV/VNAV and LPV minima.

Note: The current version of CAP 11, Volume 2, addresses only LNAV and LNAV/VNAV procedures; the next version will include LP and LPV procedures.

20.2 Characteristics

The main characteristics of RNP APCH LNAV operations are:

- (a) Instrument Approach Chart titled RNAV (GNSS)
- (b) Approach path constructed as series of straight segments
- (c) Descent to an MDA which is published as an LNAV minima
- (d) Can be flown using basic GNSS (TSOC129a) equipment or RNP 0.3 capable aircraft
- (e) Obstacle clearance lateral tolerances not based on RNP value
- (f) Vertical flight guidance (e.g. Baro-VNAV) may be added

20.3 Flight Procedure Design

Although RNAV (GNSS) approach procedures are designated in the PBN concept as RNP APCH LNAV procedures, there has been no change to the method of procedure design which is in accordance with PANS-OPS RNAV(GNSS) design criteria.

Instrument approach charts continue to include RNAV (GNSS) in the title and descent is made to a minimum descent altitude which is shown as an LNAV minimum or LNAV/VNAV where vertical guidance is available.

RNAV (GNSS) procedure design criteria are not currently based on an RNP requirement but on the performance capability of a basic TSO C129a GPS receiver.



However, it is considered that an aircraft with RNP 0.3 capability has at least equivalent performance and a number of States have authorised RNAV (GNSS) operations based on RNP 0.3 capability.

The RNAV (GNSS) Approach plate shown in Fig. 20.1 is an example of an RNP APCH LNAV/VNAV procedure. Although there is no specific notation on the chart, this type of approach can be flown by aircraft equipped with either a stand-alone GNSS receiver or an FMS equipped aircraft with RNP 0.3 capability.

When flown as an LNAV operation, the altitude limitation at C02LS (660') applies, and descent is to an MOA of 580'. The missed approach point for this procedure is located at the runway threshold (RW 02L) and pilot action is required at this point to initiate flight plan sequencing for navigation past the MAPt for stand-alone GNSS receivers.

Note: In this example, as there is no missed approach turning or holding fix and a pilot-interpreted heading is flown, no track guidance is provided after the MAPt.

In this case, the 3° VPA and the on-slope altitude at C02LS are advisory only (although recommended). Therefore, the flight crew responsibility is to ensure descent not lower than 660ft until passing C02LS.

If flown as an LNAV/VNAV approach, the fix and altitude limitation at C02LS is not relevant and, from the FAF at C02LF, the approach is flown as a VNAV approach to the OA (530'). The MAPt in this case is not relevant.

Caution: Different coding is required for approaches flown using stand-alone GNSS equipment and FMS equipped aircraft, as stand-alone receivers require specific identification of certain waypoints (FAF and MAPt) in order to initiate automatic CDI scaling, alerting levels and waypoint sequencing. FMS equipped aircraft do not require such coding. Incorrect coding can lead to some FMS equipped aircraft interpreting a MAPt, located prior to the threshold, as the origin of the VPA. Undershooting can therefore occur.



Figure 20.1 RNAV (GNSS) Approach Chart with LNAV and LNAV/VNAV Minima



20.4 System Requirements

Aircraft and System Requirements. A.2.1 Approval for RNAV (GPS) or GPS Approaches. Aircraft with approval to conduct RNAV (GPS) or GPS approaches meet the performance and functional requirements in this CAP for RNP APCH instrument approaches without RF legs.

Statement of Compliance (SOC). Aircraft with a SOC with the criteria in this AC in their Airplane Flight Manual (AFM), Airplane Flight Manual Supplement (AFMS), pilot's operating handbook (POH), or the operating manual for their avionics meet the performance and functional requirements.

Statement from the Manufacturer. Aircraft with a statement from the manufacturer documenting compliance with the criteria in AC 20-138(), Airworthiness Approval of Positioning and Navigation Systems, meet the performance and functional requirements.

Manufacturer documentation can include Service Bulletins (SB) or Service Letters (SL). These statements should include the airworthiness basis for compliance. AFM/Rotorcraft Flight Manual (RFM).

Qualified Avionics Equipment and Airworthiness Approval. Aircraft with the following avionics equipment and an appropriate airworthiness approval automatically qualify for RNP APCH to LNAV minima capability without further documentation by virtue of the avionics Technical Standard Order (TSO) and airworthiness approval: 1. GPS stand-alone systems approved in accordance with TSO-C129(), Class A1, or TSO-C146 operational Class 1, 2, or 3.3/7/16 Aircraft with a TSO-C115c or later flight management system (FMS) with a TSO-C129() (Class B1, C1, B3, C3), TSO-C145(), or TSO-C196() sensors. 3. Aircraft with a TSO-C115b FMS using a TSO-C129() Class B1/C1, TSO-C145(), or TSO-C196() sensor with documented compliance to the RNP requirements in RTCA, Inc.'s document, RTCA/DO-236 (revision 'B' or later) or RTCA/DO-283 (revision 'A' or later) as part of the approval basis.

GPS-Equipped Multisensor Systems. Multisensor systems using GPS should be approved in accordance with TSO-C115b or later and meet the functionality requirements. Multisensor systems that use distance measuring equipment (DME)/DME or DME/DME/Inertial Reference Unit (IRU) as the only means of Required Navigation Performance (RNP) compliance are not authorized to conduct RNP APCHs.

Accuracy. The aircraft must comply with Section 2.1.1 of RTCA/DO-236C. During operations on the initial and intermediate segments and for the missed approach of an RNP APCH procedure, the lateral Total System Error (TSE) must be within ± 1 nautical mile (NM) for at least 95 percent of the total flight time. The along-track (ATRK) error must also be within ± 1 NM for at least 95 percent of the total flight time.

The RNP APCH system requirements are as follows:

- (a) a dual area navigation system;
- (b) GNSS sensor only - receivers must be approved in accordance with ETSO-C129(a), TSO-C129(a) or later;
- (c) a navigation database containing the approach procedures;
- (d) continuous indication of aircraft position relative to track to be displayed to the pilot flying (and the pilot not flying) on a navigation display situated in the primary



field of view;

- (e) identification of active waypoint;
- (f) display of distance and bearing to the active (To) waypoint;
- (g) display of ground speed or time to the active (To) waypoint;
- (h) lateral deviation display must have scaling and FSD suitable for RNP APCH - the maximum FTE permitted is:
 - (1) 0.5 NM for initial, intermediate and missed approach;
 - (2) 0.25 NM for final approach;

Note: Angular display systems may be considered.

- (i) automatic leg sequencing and fly-by or flyover turn functionality;
- j) execution of leg transitions and maintenance of tracks consistent with ARINC 424:
 - (1) CA/FA;
 - (2) CF;
 - (3) DF;
 - (4) HM;
 - (5) IF;
 - (6) TF;
- (k) area navigation system failure indication;
- (l) indication when NSE alert limit is exceeded.

20.4.1 Navigation Systems (RNP APCH LNAV systems)

In general, the navigation systems available for RNP APCH LNAV operations fall into two distinct categories:

- (a) Stand-alone GNSS receivers
- (b) RNP capable FMS equipped aircraft

Although both types of navigation systems have similar capability, there are significant differences in functionality, cockpit displays and flight crew procedures.

(a) Stand-alone Systems

This type of system is commonly represented by a panel-mounted self-contained unit comprising a GNSS receiver incorporating a control unit, a lateral deviation indicator and an annunciator panel. In some cases the unit may also include a map display.

For IFR approach operations, the installation must provide a lateral deviation displayed on a CDI or HSI in the pilot's primary field of view. This is normally done by either



connecting the GNSS receiver output to a dedicated CDI or by enabling the selection of the navigation source to the primary HSI/CDI to be selected. (The in-built CDI provided on most stand-alone GNSS receivers is generally not considered adequate, even if the unit is installed in the pilot's primary field of view).

An annunciator panel is standard equipment for approach operations and must be located in a suitable position on the instrument panel. Navigation mode annunciation in the terminal mode - -approach armed \parallel and -approach active \parallel - are required.

In this type of installation, mode switching from en-route, to terminal and to approach is automatic, provided a suitable flight plan is loaded which enables the receiver to identify the destination airport. CDI scaling automatically reduces from ± 5 NM en-route mode scaling to ± 1 NM terminal mode scaling at 30 NM from the ARP. The RAIM alert limit reduces similarly from 2 NM en-route mode to 1 NM terminal mode.

At 2NM from the FAF, the receiver checks that approach RAIM will be available and, provided the aircraft is on or close to track, the receiver will ARM and the CDI scaling will gradually reduce to ± 0.3 NM. Any off-track deviation, as the FAF is approached, will be exaggerated as CDI scaling changes. The flight crew can be misled if the aircraft is not flown accurately or if the effect of scale change is not understood.

An -APPROACH \parallel annunciation must be observed before crossing the FAF and continuing with the approach. If -APPROACH \parallel is not annunciated, the approach must be discontinued.

During the approach, distance to run is given to the -Next WPT \parallel in the flight plan and not to the runway. Minimum altitudes are commonly specified at a WPT or at a distance from a waypoint. Situational awareness can be difficult, and it is not uncommon for pilots to confuse the current segment and descend prematurely.

Cross-track deviation shall be limited to $\frac{1}{2}$ scale deflection (0.5NM) on initial/intermediate/missed approach segments and 0.25NM on final. A missed approach shall be conducted if these limits are exceeded.

Note: Although the design of RNP APCH – LNAV procedures is not based on the RNP level, they may be flown by aircraft capable of RNP 0.3. For aircraft operations based on RNP capability, normal operating practice requires a go-round at 1 x RNP. For stand-alone systems, therefore, a go-round must be conducted at full-scale deflection (0.3NM).

At the MAPt, which is commonly located at the runway threshold, waypoint sequencing is inhibited, on the assumption that the aircraft is landing. If a missed approach is conducted, pilot action is normally required to sequence to the missed approach. Depending on the procedure design, track guidance in the missed approach may not be provided. Flight crews need to understand the navigation indications that are provided and the appropriate technique for managing the missed approach.

On sequencing to the missed approach, the receiver automatically reverts to terminal mode.

Close attention needs to be placed on the human factors associated with approaches flown using this type of equipment.



(b) Flight Management Systems

RNP APCH LNAV operations conducted in aircraft equipped with an FMS and GNSS are managed very differently to stand-alone systems.

As discussed above, RNP APCH procedures are designed using RNAV (GNSS) criteria which were developed on the basis of GNSS performance rather than an RNP requirement. However, it can be shown that an aircraft capable of RNP 0.3 approach operations meets or exceeds the navigation tolerance requirements for RNAV (GNSS) approach procedure design. FMS equipped aircraft therefore are able to fly RNP APCH LNAV procedures provided RNP 1.0 is selected for the initial, intermediate and missed approach segments and RNP 0.3 for the final approach segment.

Positioning data, including GNSS, is commonly combined with IRS and radio position to compute an FMS position. The GNSS receiver, which may be separate or part of a multi-mode receiver, provides position data input but does not drive automatic mode switching or CDI scaling. Navigation system integrity may be based on RAIM, but more commonly is provided by a hybrid IRS/GNSS system, which can provide significantly improved integrity protection and availability.

Most FMS aircraft are not equipped with a CDI type, non-numerical lateral deviation indicator, although some manufacturers offer a lateral deviation indicator as an option. Where a lateral deviation indicator is provided, the scaling is determined by the manufacturer and may be either a fixed scale or a non-scaled system. Lateral deviation scales may only be available (either automatic or selectable) for certain phases of flight. Automatic scaling similar to stand-alone systems is not provided.

Lateral deviation in this type of system is commonly displayed as a digital cross-track deviation on a map display. Digital cross-track deviation is normally displayed in 1/10th of an NM, although 1/100th of an NM is often available as an option. Digital cross-track deviation may also be subject to rounding. For example, where the display threshold is set at 0.15NM on a display capable of only 1 decimal place, the first digital indication of cross-track deviation is displayed as 0.2NM. In the same example, as cross-track deviation is reduced, the lowest value displayed is 0.1NM rounded down when the actual deviation reaches 0.15NM.

Monitoring of deviations within the limits of the navigation specification (0.15NM on final approach) using digital cross-track indications alone can be difficult in some cases. In the example in the previous paragraph the first digital indication of cross-track error is displayed at 0.2NM (although this indication is initiated at 0.15). However, a relative or graphical indication of cross-track error can be derived from the relative position of the aircraft symbol to the flight plan track on the navigation display. For this method to be satisfactory, the size and resolution of the map display needs to be sufficient and a suitable map scale must be selected.

A go-round shall be conducted if the cross-track error reaches 1 x RNP (0.3NM) unless the pilot has in sight the visual references required to continue the approach.

Modern large screen (10inch) multi-function displays at 10NM range are generally satisfactory and small deviations can be estimated sufficiently accurately to provide good initial indication of track divergence. Older and smaller displays, including LCD



type displays can be less effective and subject to variation (jumping) in displayed position.

Additional cross-track deviation information may also be available on the CDU/MCDU which, although outside the normal field of view, can be monitored by the PNF/PM. In such cases, the evaluation of cockpit displays must also take into consideration crew operation procedures and callouts, etc.

As turns for RNP APCH LNAV approaches are TF/TF transitions and initiation is based on turn anticipation logic, track guidance during turns is not provided. Also, cross-track deviation indications are not provided with respect to a defined turning path. The lack of a defined path is accommodated in the design of the approach procedure; however, it is necessary for the turn to be initiated and correctly executed so that there is no significant under or over- shooting of the subsequent leg.

In the evaluation cross-track deviation monitoring, track adherence using autopilot or flight director for normal operations is generally very good and little or no cross-track deviation is observed. The evaluation shall therefore concentrate on determining that, in the unlikely event of a deviation, the crew has sufficient indications to detect and manage any deviation. Deviations can also occur due to delayed or incorrect NAV selection, delay in autopilot connection, autopilot inadvertent disconnection, turbulence, excessive adverse wind, OEI operations and other rare normal or non-normal events.

Navigation system alerting varies between aircraft systems and, unlike stand-alone systems, it is determined by OEM logic. Although the operational approval will not normally need to consider the methodology used, the basics of the alerting system must be understood. The approval needs to determine that the operator's flight crew procedures and training is consistent with the particular aircraft system.

The appropriate RNP for the initial and intermediate segment is RNP 1.0, in the final approach segment RNP 0.3 and RNP 1.0 for the missed approach. The most common method used to manage RNP is to select RNP 0.3 prior to the IAF and retain that selection throughout the approach and missed approach. In some cases, a default RNP for approaches may apply. The crew therefore needs only to confirm that the correct RNP is available. In other cases, crew selection of RNP 0.3 prior to commencement of the approach is necessary. Changing the RNP after passing the IAF is not recommended as it increases crew workload, introduces the opportunity for error (forgetting to change the RNP) and provides little or no operational advantage. For RNP 0.3 operations, availability is normally close to 100% and, although RNP 0.3 may not be required for the majority of the approach (initial/intermediate segments), the probability of an alert due to the selection of a lower than necessary RNP is extremely low, especially as prediction for RNP 0.3 availability is required to conduct an approach.

Less commonly, some systems allow the RNP to be automatically extracted from the navigation database.

20.4.2 Using VNAV Advisory Information

Barometric VNAV (baro-VNAV) is commonly available on modern jet air transport category aircraft equipped with FMS. Other VNAV systems are also available (e.g. SBAS) although few aircraft in this category are fitted.



Aircraft in the general aviation, commuter and light airline categories are generally not equipped with an integrated lateral and vertical navigation (LNAV/VNAV) system, (typically stand-alone GNSS systems) although, increasingly, business jets are fitted with capable VNAV systems.

RNP APCH LNAV approach procedures are not dependent upon VNAV and normal non-precision approach principles apply in which obstacle clearance is dependent upon minimum altitudes.

However, most RNP APCH LNAV approach procedures are published to indicate an optimum approach gradient (normally 3°) above all minimum obstacle clearance altitudes. Despite there being no change to the underlying non-precision approach obstacle clearance requirements, it is recommended that VNAV is used where available to manage the approach and assist in flying a stabilised constant angle flight path. Navigation database coding normally supports a flight path angle where identified on the instrument approach chart.

It must be clearly understood that VNAV used in this way does not relieve the crew from the responsibility to ensure obstacle clearance is maintained by strict adherence to minimum altitudes by use of the pressure altimeter. Descent is made to the LNAV minima which is an MDA. An acceptable alternative method is to add a margin to the LNAV minimum altitude (typically 50-100ft) and to treat the higher MDA as a DA, on the basis that any height loss during the go-around will result in descent not lower than the published MDA.

The operational approval needs to carefully examine the aircraft capability, VNAV functionality, mode selection and annunciation, mode reversion, operating procedures and crew knowledge and training. Because the flight path guidance provided by a barometric VNAV system is directly affected by the barometric pressure subscale setting, particular attention needs to be paid to pressure setting procedures and associated aircraft systems.

Normally an approach will be designed so that the vertical path clears all minimum altitudes in the final approach segment by a convenient margin (50-100ft). This allows for some tolerance in the VNAV system and avoids any tendency to level off in order to observe any hard altitude limitations. Where a suitable tolerance is not provided consideration shall be given to revising the design of the procedure to be more VNAV friendly.

20.4.3 VNAV Approach Guidance

Where an LNAV/VNAV minimum is published, the procedure has been designed as a vertically guided approach and obstacle clearance in the final approach segment is dependent upon the use of an approved VNAV system. Descent in this case is made to the LNAV/VNAV minimum which is a DA. Minimum altitude in the FAS therefore do not apply.

RNP APCH LNAV/VNAV procedures are currently based upon the use of barometric VNAV, although satellite based vertical guidance may also be applicable.

The design of the vertical flight path is based upon a fixed minimum obstacle clearance (MOC) of 75m/246ft beneath the nominal vertical flight path. The MOC is assumed to



contain all errors associated with the determination of the VNAV path, including vertical FTE. Separate allowance is made for the effect of any along-track error in the determination of the vertical path (horizontal coupling effect).

As barometric VNAV is based on air density, the actual vertical flight path angle varies with temperature and low temperature results in a reduced flight path angle lowering the approach path and reducing obstacle clearance. In order to compensate for this effect an allowance is made for low temperature such that the designed vertical flight path angle clears all obstacles by the MOC (75m/246ft) plus an allowance for low temperature.

A low temperature limit may be published to ensure obstacle clearance is maintained at the lowest operating temperature. Temperature compensated VNAV systems are available which enable the design vertical flight path to be flown irrespective of temperature, although compensation is not commonly fitted to jet transport category aircraft.

Extension of the coded vertical path as far as the IF shall also be considered in order to better manage interception of the VNAV path.

When conducting an LNAV/VNAV approach, the primary means of obstacle clearance is provided by the VNAV system rather than the altimeter. Therefore, adherence to the vertical flight path within reasonable tolerance is required.

Note: ICAO Doc 8168 PANS-OPS Volume 1 provides operational guidance on the conduct of approach with barometric VNAV guidance. Vertical deviations from the defined path shall be limited to +100/-50ft.

20.4.4 Altimeter Setting Procedures

As the flight path guidance provided by a barometric VNAV system is directly affected by the barometric pressure subscale setting, particular attention needs to be placed to pressure setting procedures and associated aircraft systems.

20.4.5 Vertical Navigation Systems

Most commercial jet transport aircraft are equipped with a Baro-VNAV system that is compliant with FAA AC 20-129 which has been in existence for many years.

It can be difficult to reconcile the specified minimum barometric VNAV system performance requirements in CAP 11 Vol. 1, Chapter 6 (which are derived from FAA AC 20-129) with actual VNAV operating practice. However, the actual performance of installed VNAV systems has been demonstrated to provide accurate vertical guidance which meets the standard necessary for RNP APCH.

FAA AC 20-129 makes the assumption that altimetry system error (ASE) will be compensated and, consequently, no allowance is made for altimetry errors in the estimation of vertical TSE. In practice a residual error does exist in most aircraft and manufacturers are generally able to provide data. As a guide, ASE is typically less than 60ft.

The FTE standard in CAP 11 Vol. 1 (and FAA AC 20-129) is larger than is normally observed during approach operations. For example, the FTE requirement applicable to



most approach operations is 200ft, compared to observed values which are commonly less than 60ft (3σ).

Potential errors associated with waypoint resolution, vertical path angle definition and ATIS errors are not included.

Although a statistical analysis of VNAV component errors is not required for basic Baro-VNAV operations, it may be helpful to assess the typical VNAV errors, in a similar manner to that applied to Baro-VNAV for RNP AR APCH operations.

Note: Horizontal coupling error or ANPE is considered separately in PANS-OPS and does not need to be included.

This value is slightly higher than the figure given for the CAP 11 Vol. 1 value (224ft) but less than the 246ft MOC used in design.

Given that the commonly observed VNAV errors, including FTE (with autopilot) are significantly less than the values used in this example, the performance of a VNAV system compliant with FAA AC 20-129 can be expected to be consistent with the assumption of a 246ft fixed MOC.

Additional mitigation is also provided by the operational requirement to monitor the vertical FTE and conduct a go-round if the deviation below the vertical path exceeds 50ft (or 75ft if amended).

For aircraft approved for RVSM operations the ASE and VNAV errors can be expected to be small. If any doubt exists as to the suitability of a particular VNAV system, additional data on actual in-service performance shall be sought.

20.4.6 GNSS Availability Prediction.

As the current GPS constellation is unable to provide 100% availability at all levels of service, there a period, depending upon a number of factors, when an RNP approach cannot be conducted. Consequently, a prediction of availability is conducted to enable the flight crew and dispatchers (where applicable) to take into consideration the availability of GNSS capability to be expected at any particular location.

Availability of RNP APCH operations is normally limited by the approach HPL which is set to 0.3NM by default for stand-alone GNSS receivers. At this level of service, the periods when an RNP service is unavailable are short. A delay in departure or en-route is therefore often sufficient to schedule an arrival when the service is predicted to be available.

An operation is not available, or shall be discontinued when an alert is displayed to the flight crew. Consequently, availability is determined by the means used to generate an alert, which as discussed previously, varies between aircraft. In order to be most accurate and effective a prediction of availability needs to be based on the same parameters that are used in the particular aircraft systems, rather than a general prediction of a parameter such as HPL.

The operator needs to make arrangements for prediction service to be available that replicates the monitoring system on the aircraft. Prediction services are readily available from a number of commercial sources. The prediction shall be based on the



latest satellite health data, which is readily available and, in addition, take into account other factors such as high terrain. On board prediction programs are generally unsatisfactory in that they are unable to take account of satellite NOTAMS and terrain masking.

While satellite prediction services are normally accurate and reliable it shall be noted that an unpredicted loss of service can occur at any time. However, safety is not compromised (provided adequate fuel reserves are carried) and on-board monitoring assures that the crew will be alerted, and the approach can be discounted, delayed or an alternative approach conducted.

20.4.7 Radio Updating.

PBN navigation specification permits the integration of other navigation sensor information with GNSS provided the TSE is not exceeded. Where the effect of radio updating cannot be established, inhibiting of radio updating is required.

The computed aircraft position is normally a mix of IRS/GPS and in some cases also DME and VOR combined using a Kalman filter. The manufacturer's stated RNP capability shall take into account the method used to compute position and any weighting of navigation sources.

In the typical case, IRS position is updated continually by GNSS and radio aid updating is either inhibited or weighted so as to have little or no effect on the computed position. When a source of updating is lost, the position will be determined in accordance with a reversionary mode. If GNSS updating is lost, IRS position is normally updated by DME if available and VOR if insufficient DME stations are in view. As DME and, particularly, VOR updating is much less accurate than GNSS, there is some potential for degradation in the position accuracy.

If it can be determined that radio updating has no detrimental effect on the accuracy of the computed position, then no action is required.

However, it can be difficult to obtain confirmation of the effect of radio updating and, where this cannot be determined, radio updating shall be selected OFF. Most systems provide for a means for de-selection of radio updating, either manually or by a pin selection option. Manual de-selection can be an inconvenient additional crew procedure, although on at least one aircraft type, a single button push de-selection is available. Where possible, a default option, where radio updating is normally OFF, is preferred, with the option of crew selection to ON in the unlikely event of a loss of GNSS updating.

20.5 Operating Procedures

In recent years, most manufacturers have developed recommendations for RNAV (GPS)/RNAV (GNSS) procedures. Although the manufacturer recommendations shall be followed, the operational approval shall include an independent evaluation of the operators' proposed procedures. RNP APCH operating procedures shall be consistent with the operator's normal procedures where possible in order to minimise any human factors elements associated with the introduction RNP operations.

Airworthiness certification alone does not authorize operator to conduct RNP APCH



operations. Operational approval is also required to confirm the adequacy of the operator's normal and contingency procedures for the particular equipment installation.

20.5.1 Procedure Selection and Review

Operating procedures need to address the selection of the approach from the navigation database and the verification and review of the displayed data. Commonly, some changes to an operator's normal practice will be involved. The evaluation will therefore need to recognise that new techniques may be appropriate to RNP approach operations.

In most cases the instrument approach chart will contain RNAV (GNSS) in the title and the clearance issued will refer to RNAV, the runway and, usually, a suffix letter e.g. RNAV (GNSS) RWY 20 X. Due to avionics limitations, the available approaches may be displayed in an abbreviated format e.g. RNVX. In some cases, the suffix letters (X, Y and Z) may not be supported. Flight crew procedures must take into account these limitations to ensure that the correct procedure is selected and then checked.

It shall be recognised that the approach chart assumes less importance for an RNP APCH procedure once the procedure is loaded in the FMS and checked. During the approach only limited reference to the approach chart is normally required.

20.5.2 Use of the Autopilot and Flight Director

The manufacturer's guidance will normally provide recommendations on the use of auto-pilot and/or flight director. In general, RNP APCH procedures shall be flown with autopilot coupled if the aircraft is equipped, enabling the crew to place greater attention to monitoring the approach and taking advantage of the reduced FTE normally available. This policy shall not preclude the use of flight director (consistent with manufacturer procedures) when autopilot is not available or in other circumstances (e.g. OEI operations).

Note: The FTE used by the aircraft manufacturer to demonstrate RNP capability may be dependent upon the use of a coupled auto-pilot or flight director. A lesser RNP capability may be applicable to procedures flown manually using a map display.

20.5.3 GNSS Updating

RNP APCH procedures are dependent on GNSS positioning. Therefore, the availability of GNSS, (as well as the available level of RNP) shall be checked prior to commencement of an approach.

The failure of a GNSS receiver (i.e. an equipment failure) is commonly annunciated, but in the normal case where duplicated GNSS receivers are installed, the approach can continue normally using the serviceable receiver.

A loss of GNSS updating due to a loss of signal may occur at any time, but an alert will not normally be generated immediately. Where position integrity can be maintained following the loss of GNSS a valid position continues to be displayed.

When the required performance cannot be sustained an alert will be generated and the



normal procedure is to conduct a go-round, unless the approach can be conducted visually.

Inspectors shall be familiar with the alerting system applicable to the specific aircraft under consideration to ensure that operating procedures and crew knowledge and training is consistent with the system functionality.

20.6 Flight Crew Knowledge and Training

Successful RNP APCH LNAV and LNAV/VNAV approach operations depend heavily on sound flight crew knowledge and training.

The type of navigation system has a significant effect on the conduct of this type of procedure and flight training must take this factor into account.

Crews operating aircraft equipped with basic stand-alone systems typically require significantly more flight training than crews operating FMS equipped aircraft. The amount of training will vary depending on the flight crew's previous RNAV experience. However, the following is provided as a guide:

(a) Ground training:

Ground training including computer-based training and classroom briefings, will normally require a minimum of one day.

(b) Simulator training. For FMS systems operated by crews with experience in the use of the FMS for the conduct of conventional approach procedures, a pre-flight briefing session and one 2 to 4 hours simulator session per crew is required.

For operators of stand-alone systems, simulator or flight training may require 2 or more training sessions. Proficiency may be achieved in normal uncomplicated operations in a short period of time; however additional flight time needs to be scheduled to ensure competency in the management of approach changes, go-round, holding and other functions, including due consideration of human factors. Necessary initial training shall be supplemented by operational experience in VMC or under supervision.

Guidance on operational training requirements is contained Appendix 2 and CAP 11, Vols. 1 and 2.

20.7 Navigation Database

RNP APCH operations are critically dependent on valid data. CAP 11 includes the basic requirements associated with the use and management of navigation databases.

Although the navigation database shall be obtained from a qualified source, operators must also have in place sound procedures for the management of data. Experienced RNAV operators who understand the importance of reliable data will normally have such procedures established. However, less experienced operators may not fully understand the need for comprehensive management procedures and may need to develop or improve existing procedures.



It shall be noted that, despite the requirement for the database supplier to comply with RTCA D0200A/EUR0CAE document ED 76, data errors will still occur and dependence on quality management alone is not sufficient.

Cyclic Data Updates: There is no specific requirement in the PBN navigation specification to implement checks of RNP APCH approach data at each update. Despite this, operators shall be encouraged to implement an electronic means of ensuring that the data loaded onto the aircraft remains valid. Although the operating tolerances for RNP APCH provide a level of conservatism and GNSS-driven approach procedures are inherently extremely accurate, electronic data errors are not in any way related to these factors and gross errors can occur just as easily as minor ones.

A cyclic comparison of new versus old data must be designed to identify changes that have not been ordered prior to the effective date for each database cycle. Action can then be taken to rectify the problem before the effective date, or issue corrective action such as notices to flight crew, withdrawal of procedures etc.

In cases where an effective electronic cyclic data validation process is not available, it may be necessary to conduct re-validation of procedures at each cycle. This is a time-consuming and complex procedure which shall be avoided wherever possible.

21. RNP AR APCH

21.1 General

RNP AR APCH operations permit additional safety and efficiency to be achieved by the capability of advanced navigation equipment, aircraft systems and procedures design.

A large number of RNP AR approach and departure procedures have been developed by the industry commonly sponsored by airlines and designed using commercially developed design criteria. These operations have been approved in a number of States following evaluation on a case-by-case basis, normally for a specific aircraft type and individual operator.

The RNP AR APCH navigation specification has been developed to provide ICAO guidance for similar RNP approach procedures that can be applied generally and to a range of qualified aircraft types.

Procedure design criteria have now been published in ICAO Doc 9905 RNP AR Procedure Design Manual.

21.2 Authorisation Required

All operations involve some form of authorisation, either specific or implied. Consequently, questions are often raised with regard to the use of the term authorisation required in the context of RNP AR APCH operations.



Early development work on RNP approach procedures was carried out in the United States. Under the US Federal Aviation Regulations, all instrument approach procedures that are in the public domain are developed under FAR Part 97. Where approach procedures (for whatever reason) do not comply with FAR Part 97, the FAA can approve an operation (for a specific operator) as a Special Airworthiness and Aircrew Authorisation Required (SAAAR) procedure.

Accordingly, as at the time (1995) the initial work on RNP approach development was undertaken there was no provision in FAR Part 97 for this type of operation, the FAA approved RNP approach operations as procedures with SAAAR.

Subsequently the FAA developed procedure design rules (FAA Order 8260.52) and airworthiness and operational rules (FAA AC90-101) to support FAA Part 97 RNP SAAAR operations, referred to Public RNP SAAAR.

In 2005, when the then Obstacle Clearance Panel (now Instrument Flight Procedures Panel) in ICAO decided to harmonise ICAO procedure design rules with FAA Order 8260.52, it was recognised that there was no equivalent process in ICAO which related to non-conforming or special procedures. Consequently, it was decided to abbreviate the term to Authorisation required or AR for ICAO application.

The implication (whether SAAAR or AR) is that improvements in operational safety and efficiency gained by the utilisation of the capability of advanced navigation capability are matched by an appropriate level of detailed evaluation of aircraft, operations and procedure design.

AR therefore requires the operator to conduct a full evaluation of all aspects of the operation before the BCAA will issue an approval. Therefore, only qualified operators are permitted to conduct RNP operations which are identified as Authorisation Required.

An operator which is approved for RNP AR Approach operations in accordance with this CAP is authorized to conduct RNP AR Approach operations at all airports where RNP AR Approach procedures are published in the Bahrain AIP.

Note that whilst this CAP provides for a blanket RNP AR Approach operational approval, operators are to ensure that they comply with any additional published requirements at specific airports and specific RNP AR Approach procedure requirements where applicable.

21.3 Characteristics

There are a number of characteristics of RNP AR APCH operations that combine to improve the capability of this type of operation, including:

- (a) Support for RNP less than 0.3 (RNP 0.1 is the lowest currently available)
- (b) Obstacle clearance lateral tolerance 2 x RNP
- (c) Final approach vertical obstacle clearance provided by a vertical error budget



(d) Radius to fix (RF) legs enabling circular flight paths to be flown

It shall be noted that while RNP AR APCH procedures support low RNP types, that this is only one characteristic and that many RNP AR APCH operations do not require RNP less than 0.3. An RNP 0.3 RNP AR APCH operation shall not be confused with an RNP APCH which also uses RNP 0.3 capabilities.

21.4 Procedure Design

RNP AR APCH procedures are designed in accordance with ICAO Doc 9905 - Required Navigation Performance Authorization Required (RNP AR) Procedure Design Manual.

The design criteria for RNP AR APCH procedures has been derived from operational experience in a number of States which have generally been applied to individual operators, specific aircraft types and industry developed design criteria. The ICAO RNP AR Procedure Design Manual provides guidance to States on the early implementation of generic RNP AR approach procedures that can be applied to any appropriately capable aircraft and qualified operating crew.

21.5 Operational Approval

RNP AR APCH procedures depend upon the integration of aircraft, operations and procedure design to deliver a safe and efficient outcome. Conventional navigation systems which have been in common usage for many years depend on aircraft equipment & avionics, operating procedures and procedure design that have benefited from many years of common usage and we are generally able to consider each element in isolation. For example, ILS receivers are manufactured by many different companies, the operation and crew interface is standard. A pilot qualified to fly ILS can therefore do so on any aircraft with minimum of cross-training. ILS operating procedures are common, and it is not necessary to apply different procedures for differing aircraft or avionics. Similarly, the procedure designer develops ILS approaches without reference to specific avionics capabilities or operating procedures. All of these aspects are common, well understood and standardised throughout the industry.

The same cannot be said of RNP AR APCH operations. In most cases, aircraft avionics were installed before the concept of RNP approaches was developed and equipment has been adapted to provide RNP AR APCH capability. Consequently, there is no common standard yet available for RNP AR APCH avionics, cockpit displays, alerting and other functions. In some cases, modification or upgrade of aircraft systems may be available, in other cases evaluation may be required for systems which cannot be upgraded.

Operating procedures also need to be matched to the aircraft, avionics, cockpit displays, etc., and, therefore, they will vary considerably between aircraft types, models and configurations. Both operating procedures and aircraft equipment/capability need to be evaluated against the basis upon which RNP AR



APCH procedures are designed, and therefore consideration of the basic procedure design principles needs to be included in the operational approval process.

21.6 Evaluation Team

A team approach shall be used in the conduct of an RNP AR APCH evaluation. As the first such operational experience will be a learning experience for all concerned it can be very useful to involve all parties, including the applicant, in a consultative approach to the approval process.

A project lead shall be appointed to co-ordinate the combined efforts of the project team. As the outcome is an operational approval the project lead shall be a person experienced in flight operations assisted by experts in other specialist fields as required. The project lead and other participants on the team shall be encouraged to learn as much as possible about areas outside their immediate area of expertise. A vital part of a successful approval process is the synergy between all aspects of the operation that leads to a successful safety outcome.

21.7 Operator's Application

An important contributor to a successful RNP AR APCH implementation project is a well-developed and comprehensive application. However, it needs to be realised that the operator is likely to be inexperienced in this type of operation and will be developing their knowledge and expertise during the authorisation process, so some allowance will need to be made. The applicant shall be encouraged to present, as clearly as possible, the details of how the operation is to be conducted. He must therefore be prepared to discuss the proposal with the BCAA so that a satisfactory outcome is achieved.

It needs to be recognised that while the assistance of a competent operational approvals consultant can be very helpful, at the end of the operational approval process both the applicant and the approving authority need to ensure that they have comprehensive understanding of all aspects of the operation. Leaving it to a consultant to prepare a conforming application and, then, just -ticking the boxes|| does little to validate the Authorisation Required process.

21.8 System Requirements

20.8.1 Aircraft Eligibility

As the airworthiness requirements for RNP AR APCH operations are relatively recent (e.g. FAA AC 90-101 published December 2005) few aircraft have yet to be specifically approved for RNP AR APCH operations. Commonly the eligibility for an aircraft to conduct RNP AR APCH operations needs to be established during the operational approval process.

Some AFMs will contain a statement of RNP capability (AR may not be mentioned) which may have been approved or accepted by the regulatory authority in the State of manufacture. However, such statements need to be considered against the circumstances existing at the time of manufacture. Most RNP capability statements



were made at a time when there was no international guidance and the basis for the capability statements were commonly developed by the manufacturer. They were therefore accepted by the regulatory authority at the time as being reasonable, but of no specific relevance to operations being conducted at that time.

Some manufacturers have applied for RNP AR APCH approval by their respective aviation authority and, where such documentation is available, the issue of aircraft eligibility is very much simpler to determine.

However, there remain a significant number of aircraft that are RNP AR APCH capable but which do not have an RNP AR APCH airworthiness approval that is consistent with the requirements of RNP AR APCH navigation specification. The reasons are varied and may include a lack of operator demand leading the manufacturer to apply for approval, a disagreement between the manufacturers and approving authority, an inability to meet one or more specific requirements, or a lack of supporting data.

The absence of an RNP AR APCH airworthiness approval does not mean that the aircraft is not suitable for RNP AR APCH operations, but that this capability has not been demonstrated against available airworthiness guidelines. In many cases an operational procedure or mitigation is required to overcome the inability to obtain an airworthiness approval. In fact, many operational approvals have been issued for aircraft that do not have an RNP AR APCH airworthiness approval.

Where the eligibility needs to be established by operational approval, the normal process is to obtain supporting data from the aircraft manufacturer. Leading manufacturers are increasingly coming under pressure from customers to provide support for RNP AR operations and the amount and detail for information available is increasing steadily.

States with limited resources may be able to request advice and assistance from States that have previously issued operational approvals in respect of specific aircraft. Care shall be taken to identify the specific basis of such approvals as there are many variations in aircraft equipment, software, displays, options and other relevant features that vary between aircraft of the same type and model.

21.8.2 Flight Technical Error

The manufacturer will normally use flight technical error data obtained during flight trials to establish the RNP capability depending upon the phase of flight and the method of control. Typically, the lowest FTE and therefore the lowest RNP is obtained with auto-pilot coupled. However, other values may be applicable to the use of flight director or map mode.

If there is any concern over the FTE data, then the operator can be required to gather additional in-service data. This can be achieved during initial operations, which shall be limited to a conservative RNP (e.g. RNP 0.3). FTE data can be captured via on-board engineering monitoring systems or the Quick Access Recorder (QAR). The standard deviation of FTE observed can then be used to calculate the RNP capability based on the formula in CAP 11 Vol. 1.



Despite the values used for FTE, a further consideration is the monitoring of FTE performance in flight. To illustrate this point, an aircraft may demonstrate very low FTE values and therefore the calculated RNP capability could be low, but no cockpit display is available to permit the monitoring of this performance in real time. The aircraft, while able to meet RNP performance requirements would not qualify for RNP AR APCH because it could not meet the requirement for on board performance and monitoring of the FTE. As the standard of cockpit display varies and, therefore, the ability for the flight crew to monitor FTE also varies, this has a bearing on the RNP capability.

The preferred standard of display of lateral FTE is therefore:

- (a) A lateral deviation indicator; and
- (b) A numeric display of .01NM

However, in many cases, particularly for older aircraft, this level of display is not available. The question then arises as to the eligibility and if so the RNP capability.

The purpose of the lateral display of deviation is (as stated above) to allow the pilot to readily distinguish if the cross-track deviation exceeds the navigation accuracy (or a similar value).

Where the specified standard of display is not provided, an operational evaluation needs to be conducted to determine if the display of information is adequate to support RNP AR APCH operations. The evaluation may determine, for example, that cross-track deviations of 0.3NM can be adequately monitored, but that less than that value the displays are considered inadequate. An operational approval might be given in these circumstances for RNP AR APCH operations limited to not less than RNP 0.3.

21.8.3 Demonstration of Path Steering Performance

CAP 11 includes a requirement that path steering performance (i.e. FTE) is evaluated under a number of conditions, including non-normal conditions.

It shall be noted that differences exist amongst regulatory authorities on the means of assessment of the management of FTE in non-normal conditions. European authorities take the view that the aircraft system shall be capable of managing non-normal events, while the FAA considers that operational mitigations are acceptable.

The method(s) is used to demonstrate FTE performance must be taken into account when evaluating crew procedures.

21.8.4 Navigation System Monitoring and Alerting

In order to qualify for RNP operations of any kind the navigation system must incorporate a system to monitor the performance of the navigation system and provide



an alert to the flight crew when the system no longer meets the specified performance requirements.

Two elements of navigation system performance are normally monitored, accuracy and integrity.

Depending upon the manufacturer, the parameters used, and the alerting levels will vary. However, the method used is not normally an issue with regard to aircraft eligibility, although there can be implications in operating procedures. Information shall be obtained on the parameters that are monitored, the relevant alert limits and the method of annunciation of the alert.

Navigation system accuracy is commonly represented by Horizontal Figure of Merit (HFOM) or Estimated Position Error (EPE). These parameters represent an estimate of the position solution assuming that the satellite system is operating within its specific performance. An alert is normally generated when HFOM or EPE equals or exceeds a limit, normally 1 x RNP.

Integrity is commonly monitored by Horizontal Protection Level (HPL), sometimes called Horizontal Integrity Limit (HIL). An alert is provided when HPL equals or exceeds a limit relative to the selected RNP.

In at least one case the manufacturer derives a value for accuracy as a function of HPL. As both accuracy and integrity are dependent upon the same satellite constellation there is a relationship between derived parameters such as HFOM, EPE and HPL (HIL). Although each of these parameters measures different performance characteristics, each can be shown to be a function of another, within specified bounds.

Normally NSE integrity is monitored, but some systems monitor both accuracy and integrity and separate alerting limits are set for each parameter. In some (less common) cases HFOM is used and there may be no alert directly related to integrity. Such cases warrant further examination to ensure that integrity is adequately monitored, and it may be necessary to implement supplementary procedures (e.g. ground monitoring) to ensure that integrity is available for all operations.

21.8.5 GNSS Latent Failure Protection

GNSS systems must provide protection from latent GPS satellite failure. Protection is provided by an integrity monitoring system.

For RNP AR APCH operations, when $HIL = HAL$, the probability that the aircraft will remain within the obstacle clearance volume used to evaluate the procedure must be greater than 95 percent - both laterally and vertically. Normally the manufacturer will provide documentation that this condition is met.

21.9 Operating Procedures

In recent years most manufacturers have developed recommendations for RNP AR APCH operating procedures. Although the manufacturer recommendations shall be



followed, the operational approval shall include an independent evaluation of the operators' proposed procedures. RNP AR APCH operating procedures shall be consistent with the operator's normal procedures where possible in order to minimise any human factors elements associated with the introduction of RNP AR APCH operations.

Vectoring. A procedure may be intercepted at a position inside the IAF but no later than the VIP when vectored by ATS. Descent on an approach procedure below the minimum vectoring altitude is not permitted until the aircraft is established within the vertical and lateral tolerances of the procedure and the appropriate navigation mode(s) is engaged.

21.9.1 RNP Availability Prediction.

As the current GPS constellation is unable to provide 100% availability of RNP at all levels of service, there are periods, depending upon a number of factors, when an RNP approach cannot be conducted. Consequently, a prediction of availability is conducted to enable the flight crew and dispatchers (where applicable) to take into consideration the level of RNP capability that can be expected at any particular location.

Commonly, even for low RNP levels, the periods when an RNP service is unavailable are short. A delay in departure or en-route is therefore often sufficient to schedule an arrival when the service is predicted to be available.

An operation is not available, or shall be discontinued when an alert is displayed to the flight crew. Consequently, availability is determined by the means used to generate an alert, which as discussed previously, varies between aircraft. In order to be most accurate and effective a prediction of availability needs to be based on the same parameters that are used in the particular aircraft systems, rather than a general prediction of a parameter such as HPL.

The operator needs to make arrangements for prediction service to be available that replicates the monitoring system on the aircraft. Prediction services are readily available from a number of commercial sources. The prediction shall be based on the latest satellite health data, which is readily available and, in addition, take into account other factors such as high terrain. On board prediction programs are generally unsatisfactory in that they are unable to take account of satellite NOTAM and terrain masking.

While satellite prediction services are normally accurate and reliable it shall be noted that an unpredicted unavailability can occur at any time. However, safety is not compromised (provided adequate fuel reserves are carried) and on-board monitoring assures that the crew will be alerted, and the approach can be discounted, delayed or an alternative approach conducted.

21.9.2 Radio Updating.

The operational approval needs to consider the method used to determine the computed aircraft position.



The computed aircraft position is normally a mix of IRS/GPS and in some cases also DME and VOR combined using a Kalman filter. The manufacturer's stated RNP capability shall take into account the method used to compute position and any weighting of navigation sources.

In the typical case IRS position is updated continually by GNSS and radio aid updating is either inhibited or weighted so as to have little effect or none on the computed position. When a source of updating is lost the position will be determined in accordance with a reversionary mode. If GNSS updating is lost, IRS position is normally updated by DME if available and VOR if insufficient DME stations are in view. As DME and particular VOR updating is much less accurate than GNSS there is some potential for degradation in the position accuracy.

If it can be determined that radio updating has no detrimental effect on the accuracy of the computed position, then no action is required.

However, it can be difficult to obtain confirmation of the effect of radio updating and, where this cannot be determined, radio updating shall be selected OFF. Most systems provide for a means for de-selection of radio updating, either manually or by a pin selection option. Manual de-selection can be an inconvenient additional crew procedure, although on at least one aircraft type a single button push selection is available. Where possible a default option where radio updating is normally OFF is preferred, with the option of crew selection to ON in the unlikely event of a loss of GNSS updating.

At least one manufacturer has identified that, where reversion to updating from a single VOR is possible, significant position degradation may occur. It therefore recommends that radio updating is selected OFF for all RNP AR APCH operations.

21.9.3 Procedure Selection and Review

Operating procedures need to address the selection of the approach from the navigation database and the verification and review of the displayed data. Commonly, some changes to an operator's normal practice will be involved. The BCAA's evaluation will therefore need to recognise that new techniques may be appropriate to RNP approach operations.

In most cases the instrument approach chart will contain RNAV (RNP) in the title and the clearance issued will refer to RNAV, the runway and, usually, a suffix letter e.g. RNAV (RNP) RWY 20 X. Due to avionics limitations the available approaches may be displayed in an abbreviated format e.g. for RNVX. In some cases, the suffix letters (X, Y and Z etc.) may not be supported. Care needs to be taken that flight crew procedures take into account these limitations and that the correct procedure is selected and then checked.

The procedures normally applied to the review and briefing for a conventional approach are typically not suitable for RNP AR APCH operations. Approach procedures can be complex, with numerous legs, tracks distances, fixes, altitude and



speed constraints etc, which can result in a long, complex and ineffective briefing process.

Many of the parameters normally checked on a conventional procedure are contained within the navigational database which is subjected to a rigorous quality control process. Detailed checking of numerous individual data elements delivers no safety benefit and attention needs to be placed on the more important aspects of the approach. Of greater importance is the verification that the correct procedure is selected, and this can be achieved by a review of the waypoint sequence.

Other key elements are:

- (a) Minimum altitudes
- (b) Location of VIP and FAF
- (c) Speed limitations

It shall be recognised that the approach chart assumes less importance for an RNP AR APCH procedure once the procedure is loaded in the FMS and checked. During the approach the only limited reference to the chart is normally required.

21.9.4 Required List of Equipment.

Separate from the MEL, RNP AR APCH brings in the idea of required equipment. This list, which shall be readily available to the crew, identifies the operator's policy in regard to items of equipment that must be serviceable prior to commencement of an RNP AR APCH. This list shall be consistent with the requirements for conduct of the particular approach and the operator's Safety Risk Assessment, which will identify and assess the risks associated with equipment failure during an approach.

For example, for RNP AR APCH where RNP is less than 0.3, there shall be no single point of failure. Many operators will specify redundant equipment for approaches irrespective of the RNP, particularly where terrain is an issue.

21.9.5 Use of Autopilot and Flight Director

The manufacturer's guidance will normally provide recommendations on the use of auto-pilot and/or flight director. Irrespective of this guidance, the underlying philosophy of RNP AR APCH is that maximum use is made of the aircraft systems and auto-coupled approaches shall be regarded as standard practice. This shall not preclude the use of flight director (consistent with manufacturer procedures) when autopilot is not available or in other circumstances (e.g. OEI operations).

Note: The FTE used by the aircraft manufacturer to demonstrate RNP capability may be dependent upon the use of a coupled auto-pilot. A lesser RNP capability may be applicable to procedures flown using flight director.



21.9.6 RNP Selection.

The RNP for an approach or segment of an approach can be set by a number of means, including a default value (commonly RNP 0.3), automatic extraction from the navigation database or pilot selection.

In all cases a crew procedure is necessary to check that the required RNP is selected prior to commencement of the procedure.

It is common for more than one line of minima to be published with lower RNP associated with lower DAs. Standard practice is to select the highest RNP consistent with the operational requirement. For example, if the RNP 0.3 DA is likely to permit a successful approach then a lower RNP would not be selected, as lowering RNP tightens the alerting limits and increases the possibility of an alert message.

21.9.7 GNSS Updating

RNP AR APCH procedures are dependent on GNSS positioning. The availability of GNSS, (as well as the available level of RNP) shall therefore be checked prior to commencement of an approach.

The failure of a GNSS receiver (i.e. an equipment failure) is commonly annunciated, but in the normal case where duplicated GNSS receivers are installed, the approach can continue normally using the serviceable receiver.

A loss of GNSS updating due to a loss of signal may occur at any time, but an alert will not normally be generated immediately. Where position integrity can be maintained following the loss of GNSS a valid position continues to be displayed.

When the required performance cannot be sustained an alert will be generated. The normal procedure is to conduct a go-round, unless the approach can be conducted visually.

During the operational approval attention must be placed on determining the alerting protocol associated with both loss of a receiver and loss of signal and the operating procedures evaluated accordingly.

21.9.8 Track Deviation Monitoring.

A basic principle of RNP is performance monitoring and alerting. In most cases the monitoring of FTE is a flight crew responsibility and is not provided by an automated system.

The acceptable tolerance for normal operations is $\frac{1}{2}$ the navigation accuracy. In practice FTE, normally managed by the autopilot, is very small for both straight and turning flight. An observed cross-track standard deviation of less than .01NM is typical and while the flight crew must understand their responsibility in regard to monitoring of FTE, there is normally no action required at all.



Deviation from track is most likely to occur due to a loss of AP guidance (disconnection or failure to connect), inadvertent limitation of bank angle, incorrect or delayed mode selection and, in rare cases, excessive wind during turns. In the event of an excursion from the flight planned path, immediate action shall be taken to regain track, or a go-around conducted if the cross-track error reaches $1 \times \text{RNP}$. The lateral navigation mode must be engaged (or re-engaged) during the go-around and accurate tracking regained.

Note that while the allowable tolerance is relative to RNP the actual FTE is independent of the selected RNP.

FTE monitoring and management is of greater interest in regard to non-normal events. Attention shall be placed on OEI operations, autopilot disconnect, loss of lateral navigation guidance, go-around and similar events. FTE limits can also be exceeded in turns if bank angle is not maintained, airspeed is excessive, or winds are stronger than designed.

Sound procedures need to be in place to recognise any deviation, including crew callouts and appropriate recovery or go-around actions.

Automation induced complacency given the accuracy and reliability of track adherence in normal operations is a concern and attention shall be placed on awareness of potential factors that might lead to a FTE increase, rather than simple reliance upon crew monitoring.

The evaluation of cockpit displays (refer aircraft eligibility) shall also be considered against the background that in normal circumstances track adherence is excellent and recognise that the primary function of cross-track error display is to provide adequate indication to the flight crew shall a deviation occur.

21.9.9 Vertical Navigation

At the present time RNP AR APCH uses barometric VNAV which is currently available on most aircraft otherwise capable of RNP AR APCH operations. Other VNAV systems will become available (e.g. SBAS) but only Baro-VNAV is discussed in this section.

Most commercial jet transport aircraft are equipped with a Baro VNAV system that is compliant with FAA AC 20-129 which has been in existence for many years. The vertical performance parameters contained in AC 20-129 were developed at a time when the use of Baro-VNAV for RNP AR APCH operations had not been envisioned and do not match the requirements for RNP AR APCH.

However, the actual performance of installed VNAV systems has been demonstrated to provide accurate vertical guidance which meets the standard necessary for RNP AR APCH.

It is therefore necessary to obtain data to substantiate the VNAV performance. The basis of the procedure design is the VEB which is comprised of the following elements:



- (a) Altimetry System Error (ASE)
- (b) Flight Technical Error (FTE)
- (c) Horizontal coupling or Actual Navigation Performance Error (ANPE)
- (d) Waypoint resolution error (WPR)
- (e) Vertical angle error (VAE)
- (f) ATIS Error

ASE shall be determined by the manufacturer and documentation provided to show that the aircraft meets the minimum requirement.

The 99.7% altimetry system error for each aircraft (assuming the temperature and lapse rates of the ISA) shall be less or equal to than the following with the aircraft in the approach configuration:

- (a) $ASE = -8.8 \times 10^{-8} \times H^2 + 6.5 \times 10^{-3} \times H + 50$ (ft)
- (b) Where H is the true altitude of the aircraft.

This information may be obtained from the manufacturers in most cases, or from other regulatory authorities that have conducted an operational approval for the particular aircraft.

Where insufficient data exists, in-service data can be collected using on-board engineering or QAR data collection, during the initial implementation period.

Aircraft which are RVSM compliant shall have no difficulty in meeting the ASE requirement.

The value for FTE used in the calculation of VEB is 23m (75ft)/ 99.7% (3σ) and it needs to be established that the aircraft can meet this requirement. Most manufacturers will provide a statement that the FTE/99.7% is less than this value and performance is typically of the order of 50 to 60 ft. Where the manufacturer supplied data is unavailable, insufficient or inconclusive, the FTE values can be substantiated during initial operations by collecting on-board data from the engineering monitoring system or QAR. Operations may need to be limited to a high minima or visual conditions during the data collection periods.

Vertical angle error (VAE) is a value normally set by the FMS manufacturer and, therefore, it shall be equal or less than 0.01° . As many FMSs were designed when there was no requirement for such as accurate definition of vertical flight path angle, the value could be as high as 0.1° . This of itself does not mean that the aircraft is unable to qualify as the VEB is a sum of all the contributing errors. An analysis of the sum of all the errors, including a high value of VAE shall demonstrate that the VEB remains within the design limit.



21.9.10 Vertical Deviation Monitoring.

Although variations in FTE are accommodated in the VEB, it is a flight crew responsibility to monitor FTE and limit any excursions above and below the vertical flight path.

Most aircraft do not have a system for automatic monitoring and/or alerting of deviation from the vertical flight path and this function is a crew responsibility. The maximum acceptable deviation below the flight path is set at 23m (75ft). Crew procedures must detail the callouts required when a deviation is observed and, in addition, mandate a go-round if the deviation exceeds the maximum. Deviations above the flight path do not compromise obstacle clearance in the final approach, but can result in the aircraft arriving above the flight path, leading to destabilisation of the approach, a long landing, energy management issues and other effects. Sustained deviation above the flight path shall be limited to less than 75ft.

During the evaluation of the aircraft systems attention shall be placed on the vertical flight path and deviation displays which need to be adequate to allow flight crew monitoring of flight path deviations.

Although the design of an RNP AR APCH procedure uses the VEB obstacle clearance only in the final approach segment, it is operationally convenient to nominate a point prior to the FAF at which the aircraft is to be established on the lateral and vertical flight path, with the appropriate flight mode engaged (e.g. VNAV PATH or FINAL APP) in a suitable approach configuration and in stable flight. Although various terms have been used for this point, Vertical Intercept Point (VIP) is becoming accepted in common use. This is also useful to indicate to ATC the latest point at which the approach can be joined if it is necessary to take the aircraft off-track after the IAF.

21.9.11 Maximum Airspeeds

As the ability for an aircraft to remain on track during an RF leg is limited by angle of bank and groundspeed, it is important that the operational approval addresses both the aircraft capability and the flight crew responsibilities associated with this common manoeuvre.

Bank angle authority is subject to a number of factors including crew selection, airspeed, altitude, ground proximity, loss of systems (e.g. RADALT) and can result in an unplanned reduction of commanded bank angle leading to a deviation from track.

The minimum radius for an RF legs is determined by the assumed maximum bank angle (25°/ 8° above/below 121m (400ft) respectively) at the maximum design groundspeed. The maximum groundspeed is a function of the assumed maximum true airspeed, (which is affected by altitude and temperature) and an assumed rare normal tailwind component. In normal operations, as flight is well within the maximum limits (i.e. light winds), observed bank angles are low. However, should design rare normal tailwind conditions exist and/or the maximum design airspeed is reached or exceeded, then the aircraft will command up to the maximum bank angle in order to stay on the



flight path. If the maximum bank angle is reached, any further increase in groundspeed will result in a deviation from the flight path.

It is necessary that flight crews understand the effect of airspeed on track keeping in RF turns and limit speeds to the maximum used in design. The design airspeeds used for various phases of flight and aircraft category are published in CAP 11. Maximum airspeeds may also be programmed in the navigation database enabling less reliance on flight crew memory to manage airspeed.

Although not a mandatory function for RNP AR APCH the capability to fly an RF leg is commonly required for RNP AR APCH procedures. Consequently, it is unusual for an operational approval to not cover operations with RF legs.

21.9.11 Limiting Temperature

Obstacle clearance in the final approach segment is adjusted to allow for the change in flight path with temperature. In temperatures below ISA the actual vertical flight path is flatter than the nominal designed gradient and obstacle clearance is reduced. The procedure designer, in order to maintain minimum clearance from obstacles beneath the final approach path, may need to limit the operating temperature. Consequently, a minimum temperature is published on the approach chart.

Some aircraft systems incorporate a temperature compensation system which allows the design flight path gradient to be flown, removing the requirement to protect the final approach path from the effect of temperature. However, the majority of air transport aircraft do not have temperature compensation installed.

Note: Some operations also incorporate provision for non-normal operations, and temperature limits may also be predicated on OEI climb performance.

21.9.12 Altimeter Setting Procedures

As the flight path guidance provided by a barometric VNAV system is directly affected by the barometric pressure subscale setting, particular attention needs to be placed to pressure setting procedures and associated aircraft systems.

21.9.13 TOGA Navigation Functionality

The Take-off Go Around (TOGA) function in most existing aircraft installations was designed to assist in the conduct of a missed approach in circumstances where the general requirement is to maintain the approach track during the missed approach. For RNP AR APCH operations this typical functionality is no longer an appropriate solution and the requirement is that missed approach guidance is provided such that continual lateral navigation guidance is provided in the go-round. The terms TOGA to LNAV or TOGA to NAV describe this functionality in common usage.

This feature is becoming standard on production aircraft and is available as an upgrade on many later model aircraft. Where the function is not available, special crew procedures and training may be developed to overcome this limitation. Normally



it will be necessary to over-ride the normal TOGA track hold function and manually maintain the RNP track until the normal RNP navigation can be re-engaged.

21.10 Flight Crew Training

Properly conducted RNP AR APCH operations are perhaps the simplest yet most efficient approach operation available. The fact that normal operations, routinely conducted using the aircraft auto-flight system, provide excellent repeatable and very accurate flight path guidance can mislead operators into a false sense of security.

It must be recognised that the improvements in operational capability and efficiency need to be matched by an enhanced awareness and sound operating procedures. One of the subtle risks to RNP AR APCH operations is the reduced levels of alertness that may occur simply due to the confidence that crews have in the operation.

Thorough flight crew training is essential to ensure that crews are fully conversant with the aircraft systems and operations and are able to manage all normal and non-normal operations with confidence. Training needs to emphasise the role of the flight crew to monitor the aircraft systems and a thorough understanding of aircraft systems management.

Training requirements will vary significantly depending on the operator's previous experience. Operators familiar with the conduct of RNP APCH (RNAV GNSS) operations will find the transition to RNP AR APCH less demanding. Operators without relevant experience would be well advised to progress slowly and introduce RNP AR APCH operations under a phased implementation program.

As a guide, crews with previous relevant RNAV approach experience will typically require a minimum of one day ground briefing on RNP AR APCH principles, systems and operating procedures.

Flight crews will receive at least 4 hours of training on RNP AR APPCH in a full flight simulator. Additionally, recurrent training will be required on RNP AR APPCH.

Guidance on operational training requirements is contained in Appendix 2 and CAP 11, Vols. 1 and 2.

21.11 Navigation Database

CAP 11 includes a number of requirements associated with the navigation database as follows:

- (a) *Data management process:* Operators who are experienced in RNAV operations are likely to have sound procedures in place for the management of data. Less experienced operators may not fully understand the need for comprehensive management procedures and may need to develop or improve existing procedures.
- (b) *Data Suppliers:* The requirement for a data supplier to have an approval in accordance with RTCA DO200A/Eurocae ED76 is now common practice. It is common for States to recognise a LoA issued by the State where the data base supplier is located. It shall be noted that despite the requirement for a



LoA that data errors may still occur and dependence on quality management alone is not sufficient.

- (c) *Initial Data Validation:* The procedure designer is required conduct an initial flight validation in an RNP capable aircraft. Experience has been that, despite the validity of the data originating in the design office, errors can occur downstream in data packing, reading and interpreting of data, data execution and functionality. It is therefore necessary for each operator to conduct an initial data validation to ensure correct operation in the particular type/model of aircraft to be flown.

While this requirement is necessary it can present problems in practice. If the validation is to be done in a simulator, then the simulator shall accurately replicate the aircraft. In many cases this is not possible as simulators tend to lag behind aircraft in terms of upgrades. Consideration may need to be made for the simulator compatibility, complexity of the procedure, past experience and other factors. If a suitable simulator is not available, then validation may need to be conducted in the aircraft. This can be achieved with safety in visual conditions during normal revenue operations without incurring additional unnecessary expense.

- (d) *Cyclic Data Validation:* This is an important consideration in the management of navigation data as each update provides a subtle opportunity for data errors to occur. Various methods are used in an attempt to ensure that data remains valid, but the most reliable method involves an electronic comparison of the new database against a database of known validity. For this process to be successful, source data in electronic form is necessary, although most States have yet to implement facilities to enable the export of procedures in an electronic file.
- (e) *Data Updates:* Changes are routinely made to all approach procedures and unless there is a significant change to the flight path, either laterally or vertically, re-validation shall not be necessary. The cyclic comparison of new versus old data must be designed to identify changes that have not been ordered prior to the effective date for each database cycle. Action can then be taken to rectify the problem before the effective date, or issue corrective action such as notices to flight crew, withdrawal of procedures etc.

In cases where an effective electronic cyclic data validation process is not available, it may be necessary to conduct re-validation of procedures at each cycle. This is a time-consuming and complex procedure which shall be avoided wherever possible.

21.12 Flight Operational Safety Risk Assessment

NOTE: The Flight Operational Safety Risk Assessment is in principal equated to the ICAO FOSA as specified in ICAO DOC 9613.

The improved capability of RNP AR APCH operations enables approach procedures to be designed to low decision altitudes at locations where conventional approach



procedures are not possible. The ability to deliver an aircraft to a DA as low as 75m/250ft in close proximity to terrain brings with its increased exposure to risk in the event of a critical systems failure.

The safety of normal RNP AR APCH operations is not in question. Compliance with the requirements of the RNP AR APCH navigation specification is regarded as sufficient to meet the required level of safety. The Safety Risk Assessment is intended to provide assurance that the level of safety is maintained in the event of a non-normal event.

ICAO instrument approach procedure design criteria do not make provision for non-normal events and, consequently, approach procedures are designed without regard to the consequences of failures. An aircraft could therefore be placed in a situation where there is increased exposure to risk in the event of a system failure.

While there are elements of an approach procedure that are associated with the air navigation service provider, the aircraft manufacturer and the procedure designer, the fundamental responsibility for the Safety Risk Assessment rests with the operator.

The method used to conduct the Safety Risk Assessment is of less importance than the fact that an assessment of the hazards is conducted. There are generally accepted practices for risk assessment adopted by a number of industries which can be applied to the Safety Risk Assessment.

The following hazard conditions are examples of some of the more significant hazards and mitigations addressed by the specific aircraft and operational and procedural criteria of this navigation specification.

(a) Aircraft failures:

- (1) Failure of a navigation system, FGS, flight instrument system for the approach or missed approach (e.g. loss of GNSS updating, receiver failure, autopilot disconnect, FMS failure) may be addressed through aircraft design or operational procedure to cross-check guidance (e.g. dual equipage for lateral errors, use of TAWS).
- (2) Crew procedure cross-check between two independent systems mitigates the malfunction of the air data system or altimetry.

(b) Aircraft performance:

- (1) The aircraft qualification and operational procedures ensure that the performance is adequate on each approach. Consideration should be given to the impact of aircraft configuration during approach and any configuration changes associated with a go-around (e.g. flap retraction).

(c) Navigation services:

- (1) Aircraft requirements and operational procedures must be developed to address the risk that a NAVAID is used outside of designated coverage or while it is in test mode.



- (2) IFPs must be validated through flight validation specific to the operator and aircraft. The operator is therefore required to have a process defined to maintain validated data through updates to the navigation database.
- (d) ATC operations:
- (1) Operators are responsible for declining clearances for procedures assigned to non-approved aircraft.
 - (2) ATC training and procedures must ensure that obstacle clearance is maintained until the aircraft is established on the procedure. ATC should not vector aircraft to intercept on, or just prior to, the curved segments of the procedure.
- (e) Flight crew operations:
- (1) Pilot entry and cross-check procedures are required to mitigate the risk of erroneous barometric altimeter setting.
 - (2) Pilots must verify that the loaded procedure matches the published procedure using the map display in order to mitigate the risk that an incorrect procedure is selected or loaded.
 - (3) Pilot training must emphasize the importance of flight control modes and the need for independent procedures to monitor for excessive path deviation.
 - (4) Pilots must verify that the RNP loaded in system matches the published value.
 - (5) Pilot training must include balked landing or rejected landing at or below DA/H.
- (f) Infrastructure:
- (1) GNSS satellite failure is evaluated during aircraft qualification to ensure obstacle clearance can be maintained, considering the low likelihood of this failure occurring.
 - (2) Relevant independent equipage (e.g. IRU) is required to address the loss of GNSS signals for RNP AR APCH procedures with RF legs, a lateral navigation accuracy less than RNP 0.3 and/or a lateral navigation accuracy for the missed approach less than RNP 1.0. For other approaches, operational contingency procedures can be used to approximate the published track and climb above obstacles.
 - (3) Aircraft and operational procedures are required to detect and mitigate the effects of any testing of ground NAVAIDs in the vicinity of the approach.
- (g) Operating conditions:
- (1) Excessive speed, due to tailwind conditions, on RF legs will result in the inability to maintain track. This is addressed through aircraft requirements on the limits of command guidance, inclusion of 5 degrees of bank



manoeuvrability margin, consideration of speed effect and crew procedure to maintain speeds below the maximum authorized.

- (2) Nominal FTE is evaluated under a variety of wind conditions. The crew procedure is therefore to monitor and limit deviations to ensure safe operation.
- (3) The effect of extreme temperature (e.g. extreme cold temperatures, known local atmospheric or weather phenomena, high winds, severe turbulence) on barometric altitude errors 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 DA is addressed in an equivalent manner to all other approach operations.

Note: This list shall not be regarded as exhaustive.

The probability of a hazard event occurring shall be assessed. For example, probability may be assessed as:

Almost certain
Likely
Possible
Unlikely
Rare
Extremely Rare

Assess the consequences of each event, for example:

Minor
Moderate
Major
Severe
Catastrophic

Identify risk mitigators (including documentation)

Evaluate the overall risk

At the end of this process all risk outcomes shall be assessed as low or –as low as reasonably practicall.

For example:

Risk: Loss of integrity during an approach with RF legs

Probability: Rare

Consequences: Minor (Go-round, IRS nav available)

Risk mitigators: Availability prediction, TOGA to LNAV available, crew training

Risk Assessment: Low



22. RNAV VISUAL FLIGHT PROCEDURES

22.1 General

Reports indicate flight crews sometimes descend at excessive rates on approach, resulting in un-stabilized approaches. Many of these reports come from flight crew conducting visual approaches to runways not served by vertically guided approach procedures. However, the events can also occur at airports with vertically guided approach procedures when visual approach operations impose altitude restrictions that interfere with the flight crew's ability to establish a stabilized approach. Many of the aircraft involved in these events are equipped with RNAV systems capable of providing lateral, vertical and airspeed guidance/reference. Procedures such as RVFP, which capitalize on the capabilities of these RNAV systems, are beneficial because they promote flight path repeatability, may reduce air traffic communications and enhance safety.

The design and implementation of RVFP differ from that of charted visual flight procedures in a number of regards. First, RVFP developed under this guidance are for use only by pilots of aircraft equipped with instrument flight rules approved RNAV systems. Second, if these procedures are not published in the State's AIP, a separate operational approval is required.

22.2 Weather Requirements

The ceiling and visibility values required to conduct these procedures must equal or exceed the requirements for visual approach operations.

22.3 Operational Approval

The operator must ensure that the aircraft is equipped in accordance with the functional requirements of the RVFP.

The operator must ensure the appropriate operating procedures.

The operator must ensure that the appropriate training has been conducted and that an RVFP training program is in place.

The operator must also validate fly ability of the procedure in a simulator approved for each make, model and series of aircraft intended for use of the RVFP.

Once the Authority is satisfied with the operator's aircraft equipage, procedures and training program, the operator is approved to fly RVFP commensurate with their PBN Operational Approval.



22.4 Roles and Responsibilities.

Operators must train their pilots on RVFP. This training must include RVFP phraseology and procedures.

The RVFP must be coded in the aircraft RNAV system database and retrievable by name (i.e. line-selectable). Pilots are not authorized to build these procedures manually.

Pilots must request the RVFP on initial contact with the controlling agency, unless previously coordinated.

Pilots must report the airport or preceding traffic in sight to receive clearance for an RVFP.

Pilots must fly the published RVFP route and, unless otherwise cleared by ATC, comply with charted mandatory altitudes and speeds.

By accepting an RVFP clearance, pilots also accept the requirements and responsibilities associated with a visual approach clearance, e.g., visibility minimums and cloud clearances.

Controllers must receive training on these procedures, including RVFP phraseology, Intervention policies and procedures, and, in addition, actions to be taken if a pilot has not reported the airport or preceding traffic in sight by the beginning of the procedure.

Controllers may allow an aircraft to join the procedure at other than the initial fix. However, ATC may not vector an aircraft to the initial fix of an RF leg, nor to any intermediate location on the RF leg.

The controlling facility must radar monitor aircraft operating on any portion of an RVFP.



Appendix 1

FLIGHT CREW TRAINING

1.1 General

The amount and type of training required for flight crews varies significantly depending upon a number of factors including;

- Previous training and experience
- Complexity of operations
- Aircraft equipment

Consequently, it is not possible to specify for each of the navigation specifications the particular training that will be required. Therefore, some judgement is required in determining the content and structure of flight crew training. The navigation specifications cover a wide range of operations, from basic to complex and that training needs to be appropriate to the particular circumstances.

Each navigation specification includes guidance on flight crew training although it should be noted that the training specified for each operation is generally considered independently. It should be recognised that CAP 11 is a compilation of guidance material, some of which has been in existence in other forms for some number of years. The training requirements may therefore not be entirely consistent across the range of navigation specifications.

For en-route operations with RNP 2 or 4 simulator training is required.

Arrival and departure operations and particularly approach operations normally will always require flight simulator training, in addition to ground training and briefings.

Consideration should also be placed upon the need for flight crews to demonstrate that competency standards are achieved and the means of documentation of qualification.

1.2 Knowledge requirements

For all PBN operations the following areas of knowledge will need to be included, with varying content and complexity depending upon the particular operations.

Area navigation principles. Area navigation is the basis for all PBN operations. The same general knowledge is therefore applicable to all navigation specifications. Note that pilots with previous experience may not be familiar with some more advanced features such as Radius to Fix legs (RF) and the application of vertical navigation.



Navigation system principles. Flight crews should have a sound knowledge of the navigation system to be used. The relevance of the navigation system to particular PBN navigation specifications should be clearly established. For example, knowledge of inertial navigation and updating is relevant to requirements for some oceanic and remote navigation specifications, as is knowledge of GNSS is necessary for RNP AR APCH operations.

Equipment operation and functionality. Considerable variation exists in the operation of navigation equipment, cockpit controls, displays and functionality. Crews with experience on one type of installation or aircraft may require additional training on another type of equipment. Special attention should be placed on the differences between stand-alone GNSS equipment and Flight Management Systems with GNSS updating.

Flight planning. Knowledge of the relevant aspects of each of the navigation specifications that relate to flight planning is required.

Operating procedures. The complexity of operating procedures varies considerably between PBN operations. RNP APCH and RNP AR APCH require a detailed knowledge of standard operating procedures for both normal and non-normal operations.

Monitoring and alerting. Flight crew responsibilities for performance monitoring and alerting provided by the navigation system or other means (crew procedures) must be understood.

Limitations. Operating limitations (e.g. time limits, minimum equipment) vary both between and within the PBN navigation specifications and flight crews need to be able to recognise and plan accordingly.

Contingencies. Alternative means of navigation or other contingency procedures must be included.

Air Traffic Control procedures. Flight crews need to be aware of ATC procedures that may be applicable to PBN operations.

1.3 Flight Training requirements

Approach and departure operations and, in some cases, arrivals require flight training and the demonstration of flight crew competency.

The amount of flight training required varies with the PBN operation, previous flight crew training and experience and other factors. In the course of operational approval all relevant circumstances need to be considered and the training evaluated for completeness and effectiveness. Ongoing and recurrent training should also be considered.

Despite the variation in training requirements, some general guidelines may be helpful in evaluating the extent of training that might be required. Some examples of "average" cases are included below. These examples assume that flight crews have previous relevant experience and have completed a knowledge training curriculum.



En-Route: In general, flight training is not required except for RNP 2 and 4 which will require Simulator training.

Arrival & Departure: As departure and arrival operations require strict adherence to track during periods of higher workload and, in addition, are associated with reduced clearance from terrain and increased traffic, crews need to be fully conversant with the operation of the navigation system. Consequently, simulator or flight training must be provided. Particular care should be taken in the evaluation of this type of operation conducted with stand-alone GNSS equipment where functional limitations require crew intervention.

RNP APCH: Training for RNP APCH conducted using stand-alone GNSS equipment, particularly in a single-pilot aircraft normally requires multiple in-flight exercises each with pre-flight and post-flight briefing. Considerable attention needs to be given to programming and management of the navigation system, including in-flight re-programming, holding, multiple approaches, mode selection and recognitions, human factors and the navigation system functionality.

Approaches conducted in FMS equipped aircraft, are generally much easier to manage and aircraft are generally fitted with good map displays assisting situational awareness. Normal operations are generally quite simple, and competency can be achieved with one or two approaches. Additional training should be provided to achieve familiarity and competency in operations which involve changes to the planned approach, system alerting and missed approach requirement. Attention also needs to be placed on the method of vertical navigation, using standard non-precision approach procedures (LNAV) or barometric VNAV (LNAV/VNAV). As a guide initial training for crews with previous relevant GNSS & RNAV experience typically can achieve competency during one full flight simulator training session with associated pre-flight and post flight briefing.

RNP AR APCH: RNP AR APCH operations are able to deliver improvements in safety and efficiency which are enabled by the Authorisation Required process which ensures that all areas of the operating are carefully examined, and appropriate attention placed on all aspects of the operation including training. Accordingly training for RNP AR APCH operations should be thorough and ensure that crews are able to manage operations safely within the additional demands placed on procedure design, aircraft and crew procedures.

As a guide, crews without previous relevant experience (e.g. RNP APCH with Baro VNAV), may require a course of ground training (1 - 2 days) plus simulator flight training (4hrs or more) in order to achieve competency.



Appendix 2

EXAMPLE OPERATIONS SPECIFICATION (OPS SPEC) ENTRIES

OPERATIONS SPECIFICATIONS (subject to the approved conditions in the operations manual)				
ISSUING AUTHORITY CONTACT DETAILS ¹				
Telephone: _____		Fax: _____		Email: _____
AOC# ² : _____		Operator name ³ : _____		Date ⁴ : _____ Signature: _____
Dba (Doing Business as) trading name: ____				
Aircraft model ⁵ :				
Types of operation: Commercial air transportation <input type="checkbox"/> Passengers <input type="checkbox"/> Cargo <input type="checkbox"/> Other ⁶ : _____				
Area(s) of operation ⁷ :				
Special limitations ⁸ :				
SPECIAL AUTHORIZATIONS	YES	NO	SPECIFIC APPROVALS ⁹	REMARKS
Dangerous goods	<input type="checkbox"/>	<input type="checkbox"/>		
Low visibility operations				
Approach and landing	<input type="checkbox"/>	<input type="checkbox"/>	CAT ¹⁰ : _____ RVR: _____ m DH: _____ ft	
Take-off	<input type="checkbox"/>	<input type="checkbox"/>	RVR ¹¹ : _____ m	
RVSM ¹² <input type="checkbox"/> N/A	<input type="checkbox"/>	<input type="checkbox"/>		
EDTO ¹³ <input type="checkbox"/> N/A	<input type="checkbox"/>	<input type="checkbox"/>	Threshold time ¹⁴ : minutes Maximum diversion time ¹⁴ : minutes	
Navigation specifications for PBN operations ¹⁵	<input type="checkbox"/>	<input type="checkbox"/>		16
Continuing airworthiness	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>		
Other ¹⁸	<input type="checkbox"/>	<input type="checkbox"/>		



Notes:

1. Telephone and fax contact details of the authority, including the country code. Email to be provided if available.
2. Insert the associated AOC number.
3. Insert the operator's registered name and the operator's trading name, if different. Insert -dball before the trading name (for -doing business as||).
4. Issuance date of the operations specifications (dd-mm-yyyy) and signature of the authority representative.
5. Insert the Commercial Aviation Safety Team (CAST)/ICAO designation of the aircraft make, model and series, or master series, if a series has been designated (e.g. Boeing-737-3K2 or Boeing-777-232). The CAST/ICAO taxonomy is available at <http://www.intlaviationstandards.org/>.
6. Other type of transportation to be specified (e.g. emergency medical service).
7. List the geographical area(s) of authorized operation (by geographical coordinates or specific routes, flight information region or national or regional boundaries).
8. List the applicable special limitations (e.g. VFR only, day only).
9. List in this column the most permissive criteria for each approval or the approval type (with appropriate criteria).
10. Insert the applicable precision approach category (CAT I, II, IIIA, IIIB or IIIC). Insert the minimum RVR in metres and decision height in feet. One line is used per listed approach category.
11. Insert the approved minimum take-off RVR in metres. One line per approval may be used if different approvals are granted.
12. Not applicable (N/A)|| box may be checked only if the aircraft maximum ceiling is below FL 290.
13. If extended diversion time operations (EDTO) approval does not apply based on the provisions in Annex 6, Part I, Chapter 4, 4.7, select -N/A||. Otherwise a threshold time and maximum diversion time must be specified.
14. The threshold time and maximum diversion time may also be listed in distance (NM), as well as the engine type.
15. Performance-based navigation (PBN): one line is used for each PBN specification authorization (e.g. RNAV 10, RNAV 1, RNP 4), with appropriate limitations or conditions listed in the -Specific Approvals|| and/or -Remarks|| columns.



16. Limitations, conditions and regulatory basis for operational approval associated with the performance-based navigation specifications (e.g. GNSS, DME/DME/IRU). Information on performance-based navigation and guidance concerning the implementation and operational approval process, are contained in the Performance-based Navigation (PBN) Manual (Doc 9613).
17. Insert the name of the person/organization responsible for ensuring that the continuing airworthiness of the aircraft is maintained and the regulation that requires the work, i.e. within the AOC regulation or a specific approval (e.g. EC2042/2003, Part M, Subpart G).
18. Other authorizations or data can be entered here, using one line (or one multi-line block) per authorization (e.g. special approach authorization, MNPS, approved navigation performance).

Example entries are illustrated below

<i>Special Authorizations</i>	<i>Yes</i>	<i>No</i>	<i>Specific Approvals</i>	<i>Remarks</i>
Navigation specifications for PBN operations			RNAV 10	Primary sensor GNSS.
			RNAV 5	Also valid for B-RNAV routes. Approval based upon GNSS and DME/DME.
			RNAV 1 and 2	Also valid for P-RNAV routes/procedures.
			RNP 1	Authorized for RF legs.
			RNP APCH (LPV)	Approval based upon SBAS. Authorized for approaches to LPV, LNAV/VNAV or LNAV minima.
			RNP AR APCH	RNP 0.15 Authorized for RF legs. RNP 0.2 in missed approach. AP required. Dual FMS/IRS required.



Appendix 3

ACCEPTABLE METHODS FOR FLIGHT TECHNICAL ERROR (FTE) ASSESSMENT

This appendix outlines criteria for assessment of "Flight Technical Error" (FTE) related to RNP capability and other navigation applications (e.g. instrument approach capability, etc.). These criteria are available for use for FMS/EFIS based applications, RNP applications, or other navigation applications related to this CAP or as otherwise determined to be acceptable by the BCAA. It may be used in lieu of FTE assumptions referenced in other publications.

1 Background

For RNP of 0.3 NM or greater, industry standard default values for FTE e.g. RTCA DO-208, AC20-130, etc. are used and present a convenience to an operator or applicant in enabling a quick determination of what combinations of systems, capabilities, features and performance are allowable for the conduct of operations. However, the default value is the dominant error as RNP values are reduced below 0.3 NM. As a result, use of the standard defaults limit the extent that a system may be utilised, i.e. for RNP 0.15 an FTE of 0.125 NM is assumed when coupled to an autopilot. For RNP less than 0.15 NM, the standard FTE values are insufficient such that an aircraft may not be used even with a precision source such as GNSS, until there is a reduction in FTE. FTE estimates or assumptions are typically added to navigation system error characteristics to permit specification of "protected airspace" for obstacle clearance or aircraft to aircraft separation (using various mathematical statistical methods such as "Root Sum Squared"). Protected airspace may pertain to procedure obstacle clearance surfaces, establishing route or airway widths, setting oceanic track separation values, definition of ICAO Obstacle Clearance Limits, or other similar applications.

Previous FTE assessments were based on very limited samples of normal performance of a population of aircraft that included "worst case aircraft types and least capable systems" and is not representative of modern, advanced aircraft. This penalises, or does not appropriately credit, modern systems which have resulted in improved FTE performance. Further, some assessments of FTE usually consider only "normal performance", and do not appropriately assess path displacements for "rare normal performance" (e.g. strong winds), or "non-normal performance" (e.g. flight path performance related to failures engine failure while on RF turn, extraction, etc).

2 Objectives

A major element of aircraft and navigation system performance assessment is the proper characterisation of FTE. This appendix provides uniform criteria for assessing FTE to be used in conjunction with AC120-29A, and other relevant regulatory and industry references.



This FTE method:

- (a) Establishes FTE for modern aircraft in a way that provides improved pilot situation information over that provided in previous generation aircraft,
- (b) Comprehensively considers the factors which affect FTE,
- (c) Establishes a means to provide credit to an aircraft and navigation system design which includes features which provide for significantly reduced FTE,
- (d) Permits improved partitioning of the application and use of FTE between airworthiness assessment, operational authorisation, and procedure development and implementation (e.g. for definition of RNP routes, use of PANSOPS or TERPS applications etc.),
- (e) Provides operational incentives, and consequential design incentives for good FTE performance,
- (f) Allows proactive rather than reactive applications (e.g. eliminate the need for lengthy and costly in service data collection)
- (g) Properly addresses "real" safety factors related to functional hazard assessments,
- (h) Establishes consistent application with the desired navigation evolution to RNP, 4D, MASPS, etc.
- (i) Permits the eventual introduction of new methods of risk assessment (i.e. performance based design) as alternatives to the traditional, conservative methods such as "Collision Risk Model (CRM)", and
- (j) Facilitates the transition to GPS, GNSS, and other modern navigation techniques.

3 Criteria

The criteria in the following sections provide a means for applicants to demonstrate improved FTE performance which may be used in lieu of previous standard FTE assumptions that may not be appropriate for certain modern aircraft and systems. Items in section 4 address FTE demonstration criteria. Items in section 5 address acceptable methods for data collection and presentation of results.

4 FTE Demonstration Criteria

- (a) Use of Realistic Tasks

Tasks selected should address relevant flight phases applicable to the FTE measurements sought (e.g. takeoff, climb, cruise, descent, approach, landing, and missed approach.). Tasks should be realistic in providing appropriate lateral, vertical, and longitudinal elements, even though capability in only one or several dimensions is being assessed. Realistic and representative procedures should be



used (e.g., number of waypoints, placement of waypoints, segment geometry, leg types, etc.).

(b) Representative Test Methods and Test Subjects

(1) Test Methods

An acceptable combination of analysis, simulation, and flight verification should be used to establish alternative FTE performance. A plan acceptable to the BCAA should be provided by the applicant prior to testing.

(2) Test Subjects

Test crews should represent an appropriate mix of flight experience, currency, and qualification (Captain, F/O, etc.).

(c) Performance Assessment

Normal performance (straight and turning flight), Rare Normal Performance (e.g. strong winds and wind gradient effects), and Non-Normal Performance (e.g. engine failure, remote and extremely remote effects) should each be considered. Functional hazard assessments should be the basis for deciding how to assess non-normal performance. Characterisation of performance should address "95%" and "limit performance" for a suitable sample size. Emphasis should be on practical and realistic flight scenarios rather than on rigorous statistical demonstrations that may not be representative of "in service" conditions. Successful demonstration of procedures intended for terminal area applications (e.g. approach, missed approach) may generally be considered to also cover enroute applications.

The demonstration of Flight Technical Error must be completed in a variety of operational conditions; rare normal conditions and non-normal conditions. This should be documented in the appropriate aircraft operational support document. Realistic and representative procedures should be used (e.g. Number of waypoints, placement of waypoints, segment geometry, leg types, wind etc.). The non-normal assessment should consider the following:

- (1) 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 laterally and 75 feet vertically.
- (2) Acceptable criteria to be used for assessing remote failures during the aircraft qualification is to demonstrate that the aircraft trajectory is maintained within a 2xRNP corridor laterally and 75 feet vertically.
- (3) Extremely remote 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 while in NAV.

- (4) The aircraft performance demonstration during the operational evaluations can be based on a mix of analysis and flight technical evaluation using expert judgment. RNP AR procedures with navigation accuracy less than RNP 0.3 or with RF legs require the use of autopilot or flight director driven by the RNAV 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 approach procedure.

(d) Reference Path Selection

For FTE assessments a nominal path may be used (magenta line) that does not include consideration of specific navigation sensor/system anomalies (e.g. DME updating anomaly characteristics etc.). The applicant should, however, indicate how any FTE effects related to navigation system anomalies, if any, should be operationally addressed.

5 Parameters to be Measured and Presentation of Results

(a) FTE Assessment Parameter Measurement

Parameters measured should include:

- (1) Pertinent lateral and vertical path displacements,
- (2) Longitudinal performance as applicable (speed errors, ETA/RTA errors, etc.),
- (3) Other parameters as necessary to assure realistic operational performance (bank angles, pitch attitudes, thrust changes, track/heading variation, G loading, etc.).

(b) FTE Assessment Methods

Unless otherwise agreed by the regulator, demonstrations should be based on appropriate simulations, and be verified by flight trials.

(c) FTE Assessment Result Presentation

Data may be presented in various AFM provisions related to demonstrated performance for levels of "RNP", instrument approach and landing capability, etc.

6 Examples of Regulatory Responsibility for Assessment of FTE and Use of FTE Evaluation Results

The BCAA will:



- (a) typically conduct assessments of FTE in conjunction with Type Certification/Supplemental Type Certification (TC/STC) projects, when a TC/STC applicant has made such a request. Special circumstances may exist where assessments acceptable to the CAA will be conducted by other organisations (FAA, etc.),
- (b) participate in FTE assessments in conjunction with aircraft certification projects, and assure that appropriate flight standardisation provisions are identified,
- (c) assure proper application of FTE as specified in AFMs for particular applications (e.g. RNP authorisations),
- (d) address crew qualification requirements necessary to achieve the intended FTE performance.

7 FTE ASSESSMENT PROCESS

Applicants apply through normal channels to the CAA. The CAA will evaluate the application for applicable criteria and specific evaluation plans.



Appendix 4

FLIGHT OPERATION SAFETY ASSESSMENTS (FOSA)

1 Safety Assessment

The safety objective for RNP AR 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 approaches a flight operational safety assessment (FOSA) methodology may be 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 these criteria. Safety of RNP AR approach operations rests with the operator and the air navigation service provider as described in this chapter.

A FOSA should be conducted for each RNP AR approach procedure where more stringent aspects of the nominal procedure design criteria are applied (e.g. RNP 0.1 missed approach, RF legs, and RNP missed approaches less than 1.0) or where the application of the default procedure design criteria is in an operating environment with special challenges or demands to ensure that for each specific set of operating conditions, aircraft, and environment that all failure conditions are assessed and where necessary mitigations implemented to meet the operational safety objective. The assessment should give proper attention to the interdependence 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 in the aircraft, operational and procedure criteria:

Normal performance: Lateral and vertical accuracy 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, 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.

2 Aircraft Failures

- (a) System Failure: Failure of a navigation system, flight guidance system, flight instrument system for the approach, or missed approach (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 crosscheck guidance (e.g. dual equipment for lateral errors, use of terrain awareness and warning system).
- (b) Malfunction of air data system or altimetry: Crew procedure crosscheck between two independent systems mitigates this risk.

3 Aircraft Performance

- (a) 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, reengagement of LNAV mode).
- (b) Loss of engine: Loss of an engine while on an RNP AR 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.

4 Navigation Services

- (a) 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.
- (b) 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.

5 ATC Operations

- (a) Procedure assigned to incapable aircraft: Operators are responsible for declining the clearance.
- (b) 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 a curved segment of the procedure.



6 Flight Crew Operations

- (a) Erroneous barometric altimeter setting: Crew entry and crosscheck procedures mitigate this risk.
- (b) Incorrect procedure selection or loading: crew procedure to verify loaded procedure matches published procedure, aircraft requirement for map display.
- (c) Incorrect flight control mode selected: training on importance of flight control mode, independent procedure to monitor for excessive path deviation.
- (d) Incorrect RNP entry: crew procedure to verify RNP loaded in system matches the published value.
- (e) Go-Around/Missed Approach: Balked landing or rejected landing at or below DA (H).
- (f) Poor meteorological conditions: Loss or significant reduction of visual reference that may result in or require a go-around.

7 Infrastructure

- (a) 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.
- (b) Loss of GNSS signals: Relevant independent equipment (e.g. IRU) is required for RNP AR 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.
- (c) Testing of ground Navaid in the vicinity of the approach: Aircraft and operational procedures are required to detect and mitigate this event.

8 Operating Conditions

- (a) 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 authorised.
- (b) Wind conditions and effect on flight technical error: nominal flight technical error is evaluated under a variety of wind conditions, and crew procedures to monitor and limit deviations ensure safe operation.
- (c) 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.