CIVIL AVIATION ADVISORY PUBLICATION

CAAP 52

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PBN OPERATIONAL APPROVAL

INFORMATION AND POLICY REGARDING PERFORMANCE BASED NAVIGATION OPERATIONAL APPROVAL

1. PURPOSE

1.1 The purpose of this CAAP is to provide guidance to operators and organisations in the certification process and operations of Performance-based Navigation.

1.2 This guidance and policy material applies to all UAE registered civil aircraft. It identifies the type of equipment that the GCAA has determined to be acceptable means of compliance and contains guidelines to operators for equipping aircraft.

2. STATUS OF THIS CAAP

2.1 This is the first issue of CAAP 52– PBN Operational approval, and will remain current until withdrawn or superseded.

2.2 This CAAP cancels CAAP 01: GPS, CAAP 02: BRNAV, CAAP 03: RNP 5 and CAAP 20: PRNAV.

3. APPLICABILITY

3.1 This guidance material applies to all UAE operators for operations either within UAE territorial airspace. It must be noted that beyond the UAE FIR operators must comply with ICAO ANNEX 2 and other State's regulations when operating within their airspace.

4 REFERENCES

4.1 The following publications were used as reference material:

4.1.1 ICAO

4.1.1.1 Annex 6 – Operations of Aircraft
4.1.1.2 Annex 8 – Airworthiness of Aircraft
4.1.1.3 Annex 10 – Aeronautical Telecommunications
4.1.1.4 Annex 11 – Air Traffic Services
4.1.1.5 Annex 15 – Aeronautical Information Services
4.1.1.6 Doc 9613-AN/937 Performance-based Navigation Manual
4.1.1.7 Doc 4444 PANS ATM - Procedures for Air Navigation Services – Air Traffic Management
4.1.1.8 Doc 8168 VOL I and VOL II – Procedures for Air Navigation Services Aircraft Operations
4.1.1.9 Doc 7030 – Regional Supplementary Procedures
4.1.1.10 Doc 9426 – Air Traffic Services Planning Manual
4.1.1.11 Doc 9689 – Manual on Airspace Planning Methodology for the Determination of Separation Minima

4.1.2 EUROCAE

4.1.2.1 ED 72A – Minimum Operational Performance Specifications for Airborne GPS receiving Equipment used for Supplemental Means of Navigation
4.1.2.2 ED 75B – MASPS Required Navigation Performance for Area Navigation
4.1.2.3 ED 76 – Standards for Processing Aeronautical Data
4.1.2.4 ED 77 – Standards for Aeronautical Information

4.1.3 RTCA

4.1.3.1 DO 208 – Minimum Operational Performance Standards for Airborne Supplemental Navigation Equipment using GPS
4.1.3.2 DO 200A – Standards for Processing Aeronautical Data
4.1.3.3 DO 201A – Standards for Aeronautical Information

4.1.4 ARINC 424 Documents

4.1.5 UAE GCAA PBN Approval Handbook available for download on the GCAA Website www.gcaa.gov.ae under **Downloads → Performance Based Navigation**.

HIGHLIGHTED CHANGE

Effective Pages/paragraph	Brief Description
All	First Edition
Page 63/64	Expansion of the RVFP approval process and responsibilities.

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5 DESCRIPTION OF PERFORMANCE-BASED NAVIGATION

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

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

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

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

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

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

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

6 ON-BOARD PERFORMANCE MONITORING AND ALERTING

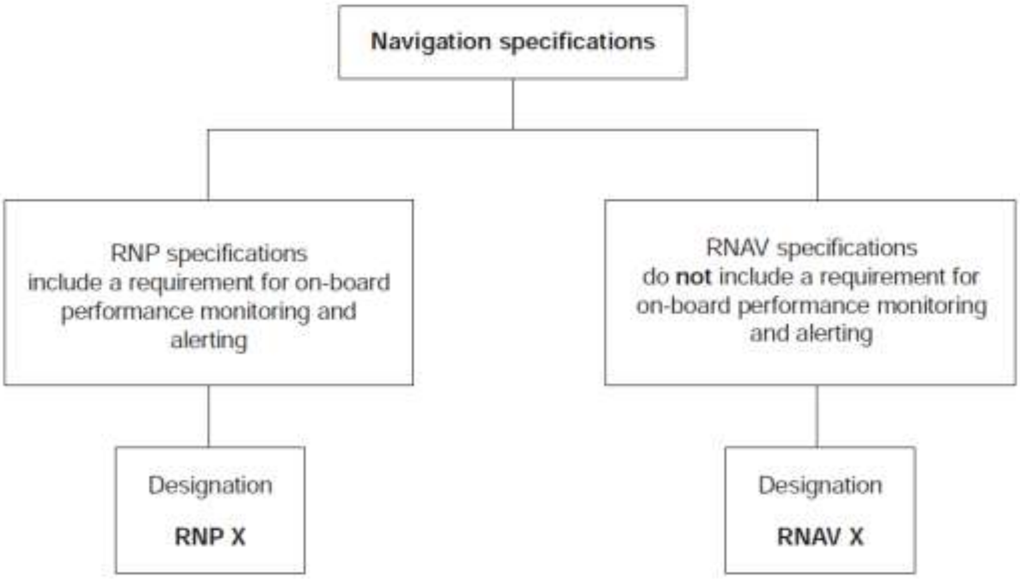
6.1 On-board performance monitoring and alerting is the main element that determines if the navigation system complies with the necessary safety level associated to an RNP application. It relates to both lateral and longitudinal navigation performance and it allows the aircrew to detect that the navigation system is not achieving, or cannot guarantee with 10^{-5} integrity, the navigation performance required for the operation. (A detailed description of onboard performance monitoring and alerting and navigation errors is provided in Doc 9613-AN/937 – PBN Manual Part A of Volume II).

7 DESIGNATION OF RNAV AND RNP SPECIFICATIONS

7.1 Two TYPES of navigation specification exists:

7.1.1 RNAV: A navigation specification which does not require an on board performance monitoring and alerting function (OPMA)

7.1.2 RNP: A navigation specification that does require an on board performance monitoring and alerting function (OPMA)



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

8 APPLICATION OF NAVIGATION SPECIFICATION

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

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

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

9 FLIGHT PLANNING

9.1 Manual or automated notification of an aircraft's qualification to operate along an ATS route, on a procedure or in an airspace is provided to ATC via the Flight Plan. (Flight Plan procedures are addressed in Doc 4444 Procedures for Air Navigation Services — Air Traffic Management).

10 MINIMUM NAVIGATION PERFORMANCE SPECIFICATION

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

11 RNAV 10

(DESIGNATED AND AUTHORIZED AS RNP 10)

11.1 RNAV 10/RNP 10 is not authorized for use within the UAE airspace.

12 General

12.1 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.

12.2 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 the PBN Manual as RNAV 10.

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

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

13 ATS communications and surveillance

13.1 The PBN Manual 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 the PBN Manual assumes that operators and flight crews take into account all the communication and surveillance requirements related to RNP 10 routes.

14 Summary

14.1 As RNAV 10 is intended for use in oceanic and remote areas the navigation specification is based on the use of Long Range Navigation Systems. A minimum of two LRNs is required for redundancy.

14.2 Commonly available LRNs are:

14.2.1 INS
14.2.2 IRS
14.2.3 GNSS

14.3 The most common combinations of dual LRNs are:

14.3.1 Dual INS
14.3.2 Dual IRS
14.3.3 Dual GNSS
14.3.4 GNSS/IRS (IRS updated by GNSS)

14.4 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 hrs, but this may be extended by updating or by demonstration of reduced drift rate (<3.7km/2NM per hr.)

14.5 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.

14.6 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 is 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.

14.7 Despite the GNSS receiver capability for FDE, the satellite constellation may not always be adequate to provide sufficient satellite 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, and the maximum period during which FDE is predicted to be unavailable is 34 minutes. This time limit is based on the assumption that should a fault occur during a period when FDE is unavailable, then navigation accuracy is reduced (DR).

14.8 For an IRS/GNSS system the same 34 minute time limit is also applied to a loss of FDE.

14.9 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.

14.10 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.

14.11 Manual updating is less common, and the operational approval needs to be based on a more detailed examination of the circumstances. Guidance is provided in the PBN Manual.

15 Operating Procedures

15.1 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.

15.2 A review of the operator's procedure documentation against the requirements of the PBN Manual and the [State] regulatory requirements should be sufficient to ensure compliance.

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

15.3.1 The aircraft is serviceable for RNAV 10 ops

15.3.2 RNAV 10 capability is indicated on the flight plan

15.3.3 Route limitations are defined and observed (e.g. time limits)

15.3.4 En-route loss of capability is identified and reported

15.3.5 Procedures for alternative navigation are described

15.4 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.

16 Pilot Knowledge and Training

16.1 Unless the operator is inexperienced in the use of RNAV, flight crews should possess the necessary skills to conduct RNAV 10 operations with minimal additional training.

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

16.3 Where additional training is required, this can normally be achieved by bulletin, computer based training or classroom briefing. Flight training is not normally required.

16.4 Guidance on operational training requirements is contained in the UAE GCAA PBN Approval Handbook available for download on the GCAA Website www.gcaa.gov.ae

17 RNAV 5

17.1 This section replaces CAAP 02: B RNAV and CAAP 03: RNP 5.

17.2 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.

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

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

17.5 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.

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

17.7 Summary

17.7.1 A single RNAV system only is required.
17.7.2 A navigation database is not required. Manual entry of waypoint data is permitted, but is subject to human error.
17.7.3 Storage of a minimum of 4 waypoints is required
17.7.4 Navigation system alerting is not required.
17.7.5 Navigation displays in the pilot's forward view must be sufficient to permit track following and manoeuvring.
17.7.6 The maximum cross-track error deviation permitted is 2.5NM
17.7.7 An RNAV system failure indication is required.

17.8 INS or IRS

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

17.9 GNSS

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

17.9.2 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.

17.9.3 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.

17.10 Operating procedures

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

17.10.2 The essential elements to be evaluated are that the operator's procedures ensure that:
17.10.2.1 The aircraft is serviceable for RNAV 5
17.10.2.2 RNAV 5 capability is indicated on the flight plan
17.10.2.3 En-route loss of capability is identified and reported
17.10.2.4 Procedures for alternative navigation are described

17.10.3 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.

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

17.10.5 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.

17.11 Pilot Knowledge and Training

17.11.1 Unless the operator is inexperienced in the use of RNAV, flight crews shall possess the necessary skills to conduct RNAV 5 operations with minimal additional training.

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

17.11.3 Where additional training is required, this can normally be achieved by bulletin, computer based training or classroom briefing. Flight training is not normally required.

17.11.4 Guidance on operational training requirements is contained in the UAE GCAA PBN Approval Handbook available for download on the GCAA Website www.gcaa.gov.ae

17.11.1 Operational Approval

17.12.1 Operational approval will be provided in accordance with the UAE GCAA PBN Approval Handbook available for download on the GCAA Website www.gcaa.gov.ae

17.12.2 The operational approval process for RNAV 5 is generally straightforward, given that most aircraft are equipped with RNAV systems which exceed the minimum requirements for RNAV 5.

17.12.3 In most cases the AFM will document RNAV 5 capability and only occasionally will it be necessary to conduct an evaluation of aircraft capability.

18 RNAV 1 AND RNAV 2

18.1 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 harmonized these different criteria into a single RNAV 1 and RNAV 2 specification.

18.2 For existing systems, compliance with both P-RNAV (TGL-10) and U.S. RNAV (FAA AC 90-100) assures automatic compliance with this CAAP specification. (***Operators with compliance to <u>only</u> TGL-10 <u>or</u> AC 90-100 shall refer to ICAO Doc 9613-AN/937, Part B, Chapter 3, paragraph 3.3.2.7 to confirm whether or not their system gives automatic compliance to this specification***). Compliance with ICAO RNAV 1 and RNAV 2 through either of the above obviates the need for further assessment or AFM documentation. In addition, an operational approval to this specification allows an operator to conduct RNAV 1 and RNAV 2 operations globally. The aircraft requirements for RNAV 1 and RNAV 2 are identical, while some operating procedures are different.

18.3 RNAV 1 and RNAV 2 can be used in en-route, terminal SID and STAR and Instrument Approach Procedures up to the final approach fix.

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

18.5 General

18.5.1 RNAV 1 and RNAV 2 navigation specifications constitute harmonization between European Precision RNAV (P-RNAV) and United States RNAV (US-RNAV) criteria.

18.5.2 The RNAV 1 and RNAV 2 navigation specification applies to:

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

18.5.3 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.

18.5.4 There is no difference in the operational approval for RNAV 1 and RNAV 2, and a single RNAV 1 and RNAV 2 approval only 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.

18.6 Operational Approval

18.6.1 For operators holding either a P-RNAV approval or a US-RNAV approval or both the operational approval is relatively simple and minimal regulatory effort is required.

18.6.2 However, as there are some small differences between the existing European and US specifications, migration to RNAV 1 and RNAV 2 approval is not automatic unless the operator holds both US and European approvals.

18.6.3 Operators holding both P-RNAV and US-RNAV approvals qualify for an ICAO RNAV 1 and RNAV 2 operational approval without further examination.

18.6.4 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. The PBN Manual provides tables identifying these additional requirements. (Part B, Chapter 3 Para 3.3.2.7)

18.6.5 Operators not holding a B-RNAV or US-RNAV approval need to be evaluated to determine that they meet the requirements for RNAV 1and RNAV 2.

18.6.6 Operational approval will be provided in accordance with the UAE GCAA PBN Approval Handbook available for download on the GCAA Website www.gcaa.gov.ae

18.7 Summary

18.7.1 For RNAV 1 and RNAV 2 operational approval a single RNAV system only is required.

18.7.2 The RNAV system may be based on:

18.7.2.1 DME/DME
18.7.2.2 DME/DME/IRU
18.7.2.3 GNSS (including GNSS/IRU)

NOTE: GNSS is required for RNAV 1 and RNAV 2 operations within the UAE airspace as the navaid infrastructure is insufficient to support RNAV 1 and RNAV 2 operations via any other means.

18.7.3 A navigation database is required.

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

18.7.5 The maximum cross-track error deviation permitted is ½ navigation accuracy

18.7.5.1 0.5NM for RNAV 1

18.7.5.2 1 NM for RNAV 2

18.7.6 An RNAV system failure indication is required.

18.8 GNSS

18.8.1 GNSS approved in accordance with ETSO C129 (A), FAA TSO C129 (A) or later meets the requirements of RNAV 1 and RNAV 2.

18.8.2 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.

18.8.3 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.

18.8.4 The PBN Manual makes reference to the possibility of position errors cased by the integration of GNSS data and other positioning data and the potential need for 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.

18.9 Functionality

18.9.1 The PBN Manual lists the functional requirements for RNAV 1 and RNAV 2.

18.9.2 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 both RNAV 1 and RNAV 2 routes is adequate provided the autopilot is engaged or flight director is used.

18.9.3 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.

18.9.4 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 the PBN Manual functional 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 SIDs and STAR procedures.

18.10 Operating procedures

18.10.1 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.

18.10.2 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 manage selection of a new procedures, including change of runway, and any crew amendments such as insertion or deletion of waypoints.

18.10.3 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.

18.11 Pilot Knowledge and Training

18.11.1 During the operational approval, particular attention shall be placed on the application of the 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, and many of the knowledge and training items will have previously been covered in past training.

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

18.11.3 Particular attention shall be placed on:

18.11.3.1 The ability of the airborne equipment to fly the designed flight path. This may involve pilot intervention where the equipment functionality is limited

18.11.3.2 Management of changes (procedure, runway, track)

18.11.3.3 Turn management (turn indications, airspeed & bank angle, lack of guidance in turns)

18.11.3.4 Route modification (insertion/deletion of waypoints, direct to waypoint)

18.11.3.5 Intercepting route, radar vectors

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

18.11.5 Flight training for RNAV 1 and RNAV 2 is not normally required, and the required level of competence can normally be achieved by classroom briefing, computer based training, desktop simulator training, or a combination of these methods. Computer based simulator programs are available from a number of GPS manufacturers which provide a convenient method for familiarity with programming and operation of stand-alone GNSS systems.

18.11.6 Although not specifically mentioned in the PBN Manual 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.

18.11.7 Guidance on operational training requirements is contained in the UAE GCAA PBN Approval Handbook available for download on the GCAA Website www.gcaa.gov.ae

19 RNP 4

19.1 General

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

19.2 Operational Approval

19.2.1 Operators holding an existing RNP 4 operational approval do not need to be re-examined as the PBN Manual requirements are essentially unchanged.

19.3 ATS communications and surveillance

19.3.1 The PBN Manual 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).

19.3.2 An operational approval conducted in accordance with the requirements of the PBN Manual assumes that operators and flight crews take into account all the communication and surveillance requirements related to RNP 4 routes.

19.4 Summary

19.4.1 For RNP 4 operational approval:

19.4.1.1 Two long range navigation systems are required
19.4.1.2 At least one GNSS receiver is required
19.4.1.3 A navigation database is required.
19.4.1.4 Navigation displays in the pilot's forward view must be sufficient to permit track following and manoeuvring
19.4.1.5 The maximum cross-track error deviation permitted is 2NM

19.5 GNSS

19.5.1 GNSS is fundamental to the RNP 4 navigation specification, and carriage avoids 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.

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

19.5.3 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.

19.5.4 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.

19.5.5 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.

19.5.6 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.

19.6 Functionality

19.6.1 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).

19.6.2 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, and may be suitable if of sufficient size and position to allow either pilot to manoeuvre and monitor cross-track deviation.

19.6.3 The navigation specification includes some requirements for fly-by transition criteria. The default method for RNAV systems to manage turns at the intersection of “straight” 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-by” 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.

19.7 Operating Procedures

19.7.1 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.

19.7.2 A review of the operator’s procedure documentation against the requirements of the PBN Manual and the GCAA regulatory requirements shall be sufficient to ensure compliance.

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

19.7.3.1 The aircraft is serviceable for RNP 4 ops
19.7.3.2 RNP 4 capability is indicated on the flight plan
19.7.3.3 En-route loss of capability is identified and reported
19.7.3.4 Procedures for alternative navigation are described

19.7.4 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 RNP 4 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 RNP 4 operations without specific real-time route prediction being required.

19.8 Pilot Knowledge and Training

19.8.1 Unless the operator is inexperienced in the use of RNAV, flight crews shall possess the necessary skills to conduct RNAV 4 operations with minimal additional training.

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

19.8.3 Where additional training is required, this can normally be achieved by bulletin, computer based training or classroom briefing. Flight training is not normally required.

19.8.4 Guidance on operational training requirements is contained in the UAE GCAA PBN Approval Handbook available for download on the GCAA Website www.gcaa.gov.ae

20 Basic RNP 1

20.1 General

20.1.1 Basic RNP 1 is based on GNSS positioning. The navigation specification is intended to support arrival and departure procedures without the dependence on a DME/DME infrastructure.

20.1.2 Other than the requirement for GNSS there is no significant difference between the RNAV 1 and 2 navigation specification and basic RNP 1.

20.2 Operational Approval

20.2.1 Operators of GNSS equipped aircraft holding an RNAV 1 and 2 operational approvals qualify for Basic RNP 1 subject to the following conditions:

20.2.1.1 Manual entry of SID/STAR waypoints is not permitted
20.2.1.2 Pilots of aircraft with RNP input selection capability (typically equipped FMS aircraft) 20.2.1.3 shall select RNP 1 or lower for Basic RNP 1 SIDs and STARs
20.2.1.4 If a Basic 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)
20.2.1.5 If a MAP display is used, scaling must be suitable for Basic RNP 1 and a FD or AP used.

20.2.2 Operators of GNSS equipped aircraft holding both P-RNAV and US RNAV approvals also meet the requirements for RNAV 1 and 2 and therefore also qualify for Basic RNP 1 subject to the additional conditions listed in the previous paragraph.

20.2.3 Applicants without previous relevant approvals will need to be assessed against the requirements of the Basic RNP 1 navigation specification.

20.3 Summary

20.3.1 A single RNAV system only is required.

20.3.2 GNSS is required.

20.3.3 A navigation database is required.

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

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

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

20.4 Stand-alone GNSS systems

20.4.1 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.

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

20.4.2.1 CDI scaling is automatically set at +/- 1NM full scale deflection

20.4.2.2 HAL is automatically set to 1 NM (RAIM alert limit)

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

20.4.4 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 State airworthiness regulations). In the general case terminal mode will automatically switch to en-route mode at 30NM from the departure ARP. If the Basic RNP 1 SID extends past 30NM, the CDI scaling will no longer be adequate to support the required FTE limit (+/-0.5NM), and flight crew action is necessary to manually select +/-1NM CDI scaling.

20.4.5 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 +/-5NM is inadequate for Basic RNP 1 and must be manually selected to +/-1NM.

Note: Manual selection of +/- 1NM CDI scale (terminal scaling) does not change the mode, and en-route RAIM alert limits apply.

20.5 RNP Systems

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

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

20.5.3 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.

20.5.4 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 Basic RNP 1 SID or STAR.

20.6 Integrity availability

20.6.1 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 Basic 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.

20.7 De-selection of radio updating

20.7.1 The PBN Manual makes reference to the possibility of position errors cased by the integration of GNSS data and other positioning data and the potential need for de-selection 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 Basic RNP 1 navigation accuracy.

20.8 Functionality

20.8.1 The PBN MANUAL lists the functional requirements for Basic RNP 1 which are identical to RNAV 1 and 2.

20.8.2 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 Basic RNP 1 routes is adequate provided the autopilot is engaged or flight director is used.

20.8.3 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, and may be suitable if of sufficient size and position to allow either pilot to manoeuvre and monitor cross-track deviation.

20.8.4 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 the PBN MANUAL functional 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.

20.9 Operating procedures

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

20.9.2 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 manage selection of a new procedures, including change of runway, and any crew amendments such as insertion or deletion of waypoints.

20.10 Pilot Knowledge and Training

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

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

20.10.3 Particular attention shall be placed on:

20.10.4 The ability of the airborne equipment to fly the designed flight path. This may involve pilot intervention where the equipment functionality is limited

20.10.5 Management of changes (procedure, runway, track)

20.10.6 Turn management (turn indications, airspeed & bank angle, lack of guidance in turns)

20.10.7 Route modification (insertion/deletion of waypoints, direct to waypoint)
20.10.8 Intercepting route, radar vectors

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

20.10.10 Flight training for Basic RNP 1 is not normally required, and the required level of competence can normally be achieved by classroom briefing, computer based training, desktop simulator training, or a combination of these methods. Computer based simulator programs are available from a number of GPS manufacturers which provide a convenient method for familiarity with programming and operation of stand-alone systems.

20.10.11 Although not specifically mentioned in the PBN MANUAL Basic 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.

20.10.12 Guidance on operational training requirements is contained in the UAE GCAA PBN Approval Handbook available for download on the GCAA Website www.gcaa.gov.ae

21 RNP APCH

21.1 General

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

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

21.1.3 RNP APCH procedures will be identified as:

21.1.3.1 RNP APCH – LNAV
21.1.3.2 RNP APCH – LNAV/VNAV (where a vertical guidance system is used)
21.1.3.3 RNP APCH – LPV (Localiser Performance with Vertical Guidance)
21.1.3.4 RNP APCH – LP (SBAS approach where vertical guidance is not available)

21.2 Characteristics

21.2.1 The main characteristics of RNP APCH LNAV operations are:

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

21.3 Flight procedure design

21.3.1 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.

21.3.2 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.

21.3.3 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.

21.3.4 The RNAV (GNSS) Approach 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.

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 to 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 and undershooting can occur.

21.4 Operational approval

21.4.1 Operators currently approved to conduct RNAV (GNSS) approaches qualify for RNP APCH – LNAV without further examination.

21.5 Navigation systems

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

21.5.1.1 Stand-alone GNSS receivers
21.5.1.2 RNP capable FMS equipped aircraft

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

21.6 Stand-alone systems

21.6.1 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. Units may also be installed with a separate CDU, or a separate map display.

21.6.2 Commonly installed in general aviation aircraft, this type of system is also frequently installed in commuter airline aircraft and occasionally in older jet air transport category aircraft.

21.6.3 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 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.)

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

21.6.5 In this type of installation, mode switching from en-route, terminal, to approach is automatic, provided certain conditions exist. Provided a suitable flight plan is loaded which enables the receiver to identify the destination airport, the unit will automatically switch to terminal mode at 30NM from destination ARP. CDI scaling automatically reduces from +/- 5NM en-route mode scaling to +/-1NM terminal mode scaling and the RAIM alert limit reduces to 1NM.

21.6.6 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 +/- 0.3NM. Any off track deviation as the FAF is approached will be exaggerated as CDI scaling changes, and the flight crew can be mislead if the aircraft is not flown accurately or if the effect of scale change is not understood.

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

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

21.6.9 Cross-track deviation shall be limited to ½ scale deflection i.e. 0.5NM on initial/intermediate/missed approach segments and 0.15NM 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).

21.6.10 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 (coding) defined track guidance in the missed approach may not be provided, and crews need to understand the navigation indications that are provided and the appropriate technique for managing the missed approach.

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

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

21.7 Flight Management Systems

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

21.7.2 As discussed above, RNP APCH procedures are designed using RNAV (GNSS) criteria which were not 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.

21.7.3 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.

21.7.4 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.

21.7.5 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 NM, although 1/100th 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.

21.7.6 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.

21.7.7 A go-round shall be conducted if the cross-track error reaches 1 x RNP (0.3NM).

21.7.8 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.

21.7.9 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 the crew operation procedures, callouts etc.

21.7.10 As turns for RNP APCH LNAV approaches are TF/TF transitions and initiation is based turn anticipation logic, track guidance during turns is not provided, and 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.

21.7.11 In the evaluation cross-track deviation monitoring, it needs to be recognised that track adherence using autopilot or flight director for normal operations is generally very good and little of no cross-track deviation is observed. The evaluation shall therefore concentrate on determining that in the unlikely event of a deviation that 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 no-normal events.

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

21.7.13 The appropriate RNP for the initial and intermediate segment is RNP 1.0, in the FAS RNP 0.3NM, and RNP 1 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, and it is sufficient that the crew confirms 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.

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

21.8 Using VNAV advisory information

21.8.1 Barometric 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.

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

21.8.3 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.

21.8.4 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.

21.8.5 While the use of VNAV for this purpose is recommended, 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.

21.8.6 It must be clearly understood that VNAV used in this way does not resolve the crew from the responsibility to ensure obstacle clearance is maintained by strict adherence to minimum attitudes 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 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-round will result in descent not lower than the published MDA.

21.8.7 During the operational approval due attention shall be placed to vertical navigation at all stages of the approach. Although an approach angle is normally only published for the FAS extension of the coded angle to the IF shall be considered in order to provide additional protection and avoid potential problems with intercepting the vertical path. Operators will normally need to make a special request to the navigation database supplier for the extension of the vertical path angle coding.

21.8.8 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.

21.9 VNAV approach guidance

21.9.1 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 and minimum altitudes in the FAS do not apply.

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

21.9.3 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).

21.9.4 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.

21.9.5 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.

21.9.6 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.

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

21.9.8 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.

21.9.9 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.

21.10 Altimeter setting procedures

21.10.1 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.

21.11 Vertical Navigation Systems

21.11.1 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.

21.11.2 It can be difficult to reconcile the specified minimum barometric VNAV system performance requirements in the Attachment to the PBN Manual (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.

21.11.3 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.

21.11.4 The FTE standard in the PBN Manual (and 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 (3 σ).

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

21.11.6 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.

21.11.7 This value is slightly higher than the figure given in the PBN Manual RSS value (224ft) but less than the 246ft MOC used in design.

21.11.8 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.

21.11.9 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.)

21.11.10 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.

21.12 GNSS Availability Prediction.

21.12.1 As the current GPS constellation is unable to provide 100% availability at all levels of service, there a 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 availability of GNSS capability to be expected at any particular location.

21.12.2 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, and a delay in departure or en-route, is often sufficient to schedule an arrival when the service is predicted to be available.

21.12.3 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.

21.12.4 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 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.

21.12.5 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.

21.13 Radio updating.

21.13.1 The PBN Manual 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.

21.13.2 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.

21.13.3 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.

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

21.13.5 However, it can be difficult to obtain conformation 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.

21.14 Operating Procedures

21.14.1 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.

21.15 Procedure selection and review

21.15.1 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, and the evaluation will need to recognise that new techniques may be appropriate to RNP approach operations.

21.15.2 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. Care needs to be taken that flight crew procedures take into account these limitations and that the correct procedure is selected and then checked.

21.15.3 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.

21.16 Use of autopilot and flight director

21.16.1 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.

21.17 GNSS updating

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

21.17.2 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.

21.17.3 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.

21.17.4 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.

21.17.5 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.

21.18 Flight crew knowledge and training

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

21.18.2 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.

21.18.3 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 provide as a guide.

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

21.18.5 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 commonly sufficient.

21.18.6 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. Where necessary initial training shall be supplemented by operational experience in VMC or under supervision.

21.18.7 Guidance on operational training requirements is contained in the UAE GCAA PBN Approval Handbook available for download on the GCAA Website www.gcaa.gov.ae

21.19 Navigation Database

21.19.1 RNP APCH operations are critically dependent on valid data. The PBN Manual includes the basic requirements associated with the use and management of navigation databases.

21.19.2 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.

21.19.3 It shall be noted that despite the requirement for the database supplier to comply with RTCA DO200A/EUROCAE document ED 76 that data errors may still occur and dependence on quality management alone is not sufficient.

21.19.4 Cyclic Data Updates: There is no specific requirement in the PBN Manual navigation specification to implement checks of RNP APCH approach data at each update. Despite these 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.

21.19.5 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.

21.19.6 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.

22 RNP AR APCH

22.1 General

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

22.1.2 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.

22.1.3 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.

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

22.2 Authorisation Required

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

22.2.2 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.

22.2.3 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.

22.2.4 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.

22.2.5 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.

22.2.6 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.

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

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

Note that whilst this CAAP 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.

22.3 Characteristics

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

22.3.1.1 Support for RNP less than 0.3 (RNP 0.1 is the lowest currently available)
22.3.1.2 Obstacle clearance lateral tolerance 2 x RNP
22.3.1.3 Final approach vertical obstacle clearance provided by a vertical error budget
22.3.1.4 Radius to fix (RF) legs enabling circular flight paths to be flown

22.3.2 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.

22.4 Procedure Design

22.4.1 RNP AR APCH procedures are designed in accordance with ICAO Doc 9905 REQUIRED NAVIGATION PERFORMANCE AUTHORIZATION REQUIRED (RNP AR) PROCEDURE DESIGN MANUAL.

22.4.2 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.

22.5 Operational Approval

22.5.1 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, and a pilot qualified to fly ILS can 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.

22.5.2 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 of upgrade of aircraft systems may be available, in other cases evaluation may be required for systems which cannot be upgraded.

22.5.3 Operating procedures also need to be matched to the aircraft, avionics, cockpit displays, etc., and 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.

22.6 Evaluation Team

22.6.1 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.

22.6.2 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.

22.7 Operator's Application

22.7.1 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, and be prepared to discuss the proposal with the regulator so that a satisfactory outcome is achieved.

22.7.2 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.

22.8 Aircraft Eligibility

22.8.1 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.

22.8.2 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 are commonly developed by the manufacturer, and were accepted by the regulatory authority at the time as being reasonable, but of no specific relevance to operations being conducted at that time in history.

22.8.3 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.

22.8.4 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 the PBN Manual 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.

22.8.5 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.

22.8.6 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.

22.8.7 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.

22.9 Flight Technical Error

22.9.1 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.

22.9.2 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 Part 1 of UAE GCAA PBN Approval Handbook available for download on the GCAA Website www.gcaa.gov.ae

22.9.3 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 the ability for the flight crew to monitor FTE also varies, this has a bearing on the RNP capability.

22.9.4 The preferred standard of display of lateral FTE is therefore:

22.9.4.1 A lateral deviation indicator; and
22.9.4.2 A numeric display of .01NM

22.9.5 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.

22.9.6 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).”

22.9.7 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.

22.10 Demonstration of Path Steering Performance

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

22.10.2 It shall be noted that differences exists 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.

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

22.11 Navigation System Monitoring and Alerting

22.11.1 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.

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

22.11.3 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.

22.11.4 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.

22.11.5 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.

22.11.6 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.

22.11.7 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.

22.12 GNSS latent failure protection

22.12.1 GNSS systems must provide protection from latent GPS satellite failure. Protection is provided by an integrity monitoring system and the principles of integrity monitoring are discussed in the UAE PBN Approval Handbook available for download on the GCAA Website www.gcaa.gov.ae

22.12.2 For RNP AR APCH operations the PBN Manual (Para 6.3.3.2.2 (b)) includes a requirement that when HIL = HAL that the probability that the aircraft remains 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.

22.13 Operating Procedures

22.13.1 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.

22.13.2 *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.

22.14 RNP Availability Prediction.

22.14.1 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.

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

22.14.3 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.

22.14.4 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 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.

22.14.5 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.

22.15 Radio updating.

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

22.15.2 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.

22.15.3 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.

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

22.15.5 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.

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

22.16 Procedure selection and review

22.16.1 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, and the regulator’s evaluation will need to recognise that new techniques may be appropriate to RNP approach operations.

22.16.2 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 limitation and that the correct procedure is selected and then checked.

22.16.3 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.

22.16.4 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 is can be achieved by a review of the waypoint sequence.

22.16.5 Other key elements are:

22.16.5.1 Minimum altitudes
22.16.5.2 Location of VIP and FAF
22.16.5.3 Speed limitations

22.16.6 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.

22.17 Required list of equipment.

22.17.1 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 asses the risks associated with equipment failure during an approach.

22.17.2 The PBN manual, for example, requires that for RNP AR APCH where RNP is less than 0.3 that 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.

22.18 Use of autopilot and flight director

22.18.1 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.

22.19 RNP selection.

22.19.1 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.

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

22.19.3 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.

22.20 GNSS updating

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

22.20.2 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.

22.20.3 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.

22.20.4 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.

22.20.5 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.

22.21 Track deviation monitoring.

22.21.1 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.

22.21.2 The acceptable tolerance for normal operations is ½ 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.

22.21.3 Deviation from track is most likely to occur due to a loss of AP guidance (disconnection of 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-round conducted if the cross-track error reaches 1 x RNP. The lateral navigation mode must be engaged (or re-engaged) during the go-round and accurate tracking regained.

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

22.21.4 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-round 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.

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

22.21.6 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.

22.21.7 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.

22.22 Vertical Navigation

22.22.1 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.

22.22.2 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.

22.22.3 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.

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

22.22.4.1 Altimetry System Error (ASE)
22.22.4.2 Flight Technical Error (FTE)
22.22.4.3 Horizontal coupling or Actual Navigation Performance Error (ANPE)

22.22.4.4 Waypoint resolution error (WPR)
22.22.4.5 Vertical angle error (VAE)
22.22.4.6 ATIS Error

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

22.22.6 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:

22.22.6.1 ASE = -8.8 x 10-8 x H2 + 6.5 x10-3 x H + 50 (ft)
22.22.6.2 Where H is the true altitude of the aircraft.

22.22.7 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.

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

22.22.9 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 – 60 ft. Where the manufacturer supplied data is unavailable, insufficient on 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.

22.22.10 Vertical angle error (VAE) is a value normally set by the FMS manufacturer, and 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.

22.23 Vertical deviation monitoring.

22.23.1 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.

22.23.2 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 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.

22.23.3 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.

22.23.4 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.

22.24 Maximum airspeeds

22.24.1 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.

22.24.2 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.

22.24.3 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 ground speed. 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 shall 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 stay on the flight path. If the bank angle is reached, any further increase in groundspeed will result in a deviation from the flight path.

22.24.4 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 the PBN Manual. Maximum airspeeds may also be programmed in the navigation database enabling less reliance on flight crew memory to manage airspeed.

22.24.5 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.

22.25 Limiting temperature

22.25.1 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, and a minimum temperature is published on the approach chart.

22.25.2 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.

22.26 Altimeter setting procedures

22.26.1 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.

22.27 TOGA Navigation Functionality

22.27.1 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 PBN Manual 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.

22.27.2 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.

22.28 Navigation Database

22.28.1 The PBN Manual includes a number of requirements associated with the navigation database as follows:

22.28.2 *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.

22.28.3 *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.

22.28.4 *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, and it is necessary for each operator to conduct an initial data validation to ensure correct operation in the particular type/model of aircraft to be flown.

22.28.5 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.

22.28.6 *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.

22.28.7 *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.

22.28.8 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.

22.29 Flight crew training

22.29.1 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.

22.29.2 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.

22.29.3 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.

22.29.4 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.

22.29.5 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, and one or more 4hr simulator training sessions (per crew).

22.29.6 Guidance on operational training requirements is contained in the UAE GCAA PBN Approval Handbook available for download on the GCAA Website www.gcaa.gov.ae

22.30 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.

22.30.1 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 it increased exposure to risk in the event of a critical systems failure.

22.30.2 The safety of normal RNP AR APCH operations is not in question, and 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.

22.30.3 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, and could therefore place an aircraft in a situation where there is increased exposure to risk in the event of a system failure.

22.30.4 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.

22.31

22.31.1 The method used to conduct the Safety Risk Assessment is of less importance that 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.

22.31.2 Each of the hazards shall be identified. Guidance on typical hazards is provided in the PBN Manual, but this list shall not be regarded as exhaustive.

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

22.30.7.1 Almost certain
22.30.7.2 Likely
22.30.7.3 Possible
22.30.7.4 Unlikely
22.30.7.5 Rare
22.30.7.6 Extremely Rare

22.31.4 Assess the consequences of each event, for example:

22.30.8.1 Minor
22.30.8.2 Moderate
22.30.8.3 Major
22.30.8.4 Severe
22.30.8.5 Catastrophic

22.31.5 Identify risk mitigators (including documentation)

22.31.6 Evaluate the overall risk

22.31.7 At the end of this process all risk outcomes shall be assessed as low or “as low as reasonably practical”.

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

References: OPS Manual Section 5 Ch 2 RNP availability program

Fight crew operations manual Part II Section 3 Para 7.4.3.1

Flight crew training Manual Section4 Chapter 1 Para 1.9.3

Risk Assessment: Low

23 RNAV VISUAL FLIGHT PROCEDURES

23.1 General

23.1.1 Reports indicate flight crew 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.

23.1.2 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 States AIP, a separate operational approval is required.

23.2 Weather Requirements

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

23.3 Operational Approval

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

23.3.2 The operator must ensure the appropriate operating procedures.

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

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

23.3.5 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.

23.4 Roles and Responsibilities.

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

23.4.2 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.

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

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

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

23.4.6 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.

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

23.4.8 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.

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

24 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), 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 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.,* RNP 4, 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 5, RNAV 2, RNAV 1.

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 area 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.

25 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
GCAA	*Refer to UAE GCAA*
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
PANS-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
UAE GCAA	United Arab Emirates General Civil Aviation Authority
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