AC 98-2-8(Rev 0)
17 September 2018

Civil Aviation Authority of Singapore

Advisory Circular

REQUIRED NAVIGATION PERFORMANCE AUTHORISATION REQUIRED APPROACH (RNP AR APCH)

GENERAL

Advisory Circulars (ACs) are issued by the Director-General of Civil Aviation (DGCA) from time to time to provide practical guidance or certainty in respect of the statutory requirements for aviation safety. ACs contain information about standards, practices and procedures acceptable to CAAS. An AC may be used, in accordance with section 3C of the Air Navigation Act (Cap. 6) (ANA), to demonstrate compliance with a statutory requirement. The revision number of the AC is indicated in parenthesis in the suffix of the AC number.

PURPOSE

This AC provides to demonstrate compliance with the requirements regarding, and information related to an application for, an approval for a specified navigation performance operation in accordance with ANR-98.

APPLICABILITY

This AC is applicable for the operator seeking an approval for RNP AR APCH operations.

RELATED REGULATIONS

This AC relates specifically to Division 2 in Part 2 of ANR-98.

RELATED ADVISORY CIRCULARS

- AC 98-1-1 Application for an Approval to Conduct a Special Operation

CANCELLATION

This AC supersedes AC AOC-32.

EFFECTIVE DATE
This AC is effective from 1 October 2018.

OTHER REFERENCES
- ICAO Doc 9613 Performance-based navigation (PBN) Manual
- FAA AC 90-101A Approval Guidance for Required Navigation Performance (RNP) Procedures with Authorization Required (AR)
- EASA AMC 20-26 Airworthiness approval and operational criteria for RNP Authorisation Required (RNP AR) operations
- CASA AC 91U-II-C-6(0) Navigation Authorisations – RNP AR Operations
- SRVSOP AC 91-009 Rev1 Aircraft and Operators Approval for RNP Authorisation Required Approach (RNP AR APCH) Operations.

1 EXPLANATION OF TERMS

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

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

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

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

Area navigation (RNAV) – A method of navigation which permits aircraft operation on any desired flight path within the coverage of ground or space-based navigation aids or within the limits of the capability of self-contained aids, or a combination of these.
Note – Area navigation includes Performance-based Navigation as well as other RNAV operations that do not meet the definition of Performance-based Navigation.

ATS surveillance system – A generic term meaning variously, ADS-B, ADS-C, PSR, SSR or any comparable ground-based system that enables the identification of aircraft.

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

Barometric vertical navigation (baro-VNAV) – A function of some RNAV systems that displays an estimated vertical guide to the pilot, referred to as a specific vertical path. The estimated vertical guide is based on barometric altitude information and is commonly estimated as a geometric path between two waypoints or as an angle based on a single waypoint.

Estimated position uncertainty (EPU) – A measure in nautical miles (NM) based on a defined scale that indicates the estimated performance of the current position of the aircraft, also known as navigation performance (ANP) or estimated position error (EPE) in some aircraft. The EPU is not an estimate of the actual error, but a defined statistical indication.

Final approach segment (FAS) – That segment of an instrument approach procedure in which alignment and descent for landing are accomplished.

Global positioning system (GPS) – The US satellite-based global radio navigation system that uses precise distance measurements to determine the position, velocity and time anywhere in the world. The GPS is composed of space, control and user elements. The space element consists of at least 24 satellites in 6 orbiting 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 information.

Global navigation satellite system (GNSS) – Generic term used by ICAO to define any global positioning and timing system made up by one or more main satellite constellations, such as the US GPS (global positioning system) and the Russian GLONASS (global navigation satellite system), aircraft receivers, and several integrity surveillance systems, including aircraft-based augmentation systems (ABAS), satellite-based augmentation systems (SBAS), such as the wide-area augmentation system (WAAS) and ground-based augmentation systems (GBAS), such as the local-area augmentation system (LAAS).

Initial approach fix (IAF) – A fix that marks the beginning of the initial segment and the end of the arrival segment, if applicable. In RNAV applications this fix is normally defined by a fly-by waypoint.

Initial approach segment (IAS) – That segment of an instrument approach procedure between the initial approach fix and the intermediate fix or, where applicable, the final approach fixes or point.

Navaid Infrastructure – NAVAID infrastructure refers to space-based and or ground-based NAVAIDs available to meet the requirements in the navigation specification.

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

(i) RNAV specification – A navigation specification based on area navigation that does not include the requirement for on-board performance monitoring and alerting, designated by the prefix RNAV, e.g. RNAV 5, RNAV 1.

(ii) RNP specification – A navigation specification based on area navigation that includes the requirement for on-board performance monitoring and alerting, designated by the prefix RNP, e.g. RNP 4, RNP 1, RNP APCH.

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

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

Primary field of view – For purposes of this AC, the primary field of view is within 15° of the primary line of sight of the pilot.

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

Radius to fix (RF) leg – An RF leg is defined as any circular path (an arc) with a constant radius around a defined turn centre that starts and ends in a fix.

Receiver autonomous integrity monitoring (RAIM) – A form of ABAS whereby a GNSS receiver processor determines the integrity of the GNSS navigation signals using only GPS signals or GPS signals augmented with altitude (baro-aiding). This determination is achieved by a consistency check among redundant pseudo-range

measurements. At least one additional satellite needs to be available with the correct geometry over and above that needed for the position estimation, for the receiver to perform the RAIM function.

RNAV operations – Aircraft operations using area navigation for RNAV applications. RNAV operations include the use of area navigation for operations which are not developed in accordance with the ICAO PBN manual Doc 9613.

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

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

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

RNP value – The RNP value designates the lateral performance requirement associated with a procedure. Examples of RNP values are: RNP 0.3 and RNP 0.1.

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

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

(i) *Fly-by way-point* – A way-point that requires turn anticipation to allow tangential interception of the next segment of a route or procedure.

(ii) *Flyover way-point* – A way-point at which a turn is initiated in order to join the next segment of a route or procedure.

2 INTRODUCTION

2.1 RNP AR APCH dates back to FAA publication of approval guidance for RNP SAAAR (Special Aircraft and Aircrew Authorisation Required) as private or proprietary AC. The FAA subsequently released the RNP SAAAR AC as AC 90-101A for the public domain. This was followed by publication of several, but essentially similar, guidance documents by other authorities in the form of EASA AMC 20-26, CASA AC 90U-II-C-6(0) as well as ICAO Latin America SRVSOP AC 91-009. Renamed RNP AR APCH under ICAO PBN, the procedure is promulgated as Implementing RNP AR APCH in Chapter 6 of Volume II Part C of ICAO PBN Manual Doc 9613.

2.2 RNP AR APCH procedures enable access into airports with obstacles or other operational constraints as well as improved operational efficiency through application of reduced margins of flight procedure evaluation areas and vertical obstacle clearance surface. Any increased risks and complexities of operations arising from the reduced margins are mitigated through application of more stringent RNP criteria, advanced aircraft capabilities and increased aircrew training coupled with additional levels of scrutiny, control and authorisation.

2.3 This AC covers operational and airworthiness issues regarding RNP AR APCH operational approval that may be granted by CAAS. The operation of an RNP AR APCH procedure may also involve special approval by the State of the Aerodrome. The operator should refer to the AIP (Aeronautical Information Publication) issued by the State of the Aerodrome and the regulations of the State of the Aerodrome on RNP AR APCH operations prior to commencing such operations.

2.4 **Table 1** below provides the maximum, standard and minimum RNP values of each approach segment of a RNP AR APCH procedure as promulgated in ICAO Doc 9905 *Required Navigation Performance Authorisation Required (RNP AR) Procedure Design Manual*:

Table 1

Segment	RNP Values		
	Maximum	**Standard**	**Minimum**
Arrival	2	2	1
Initial	1	1	0.1
Intermediate	1	1	0.1
Final	0.5	0.3	0.1
Missed Approach	1	1	0.1*
* Used only with the provisions for minimum straight final segment.			

3 ASSUMPTIONS AND IMPLEMENTATION CONSIDERATIONS

3.1 The grant of RNP AR APCH Operational Approval to the operator is predicated on the operator's compliance with this AC. However, as the operations of an RNP AR APCH procedure may involve considerations other than just compliance with operational and airworthiness requirements, the operator should verify and satisfy himself that the safety measures listed in this paragraph have been put in place by the responsible airspace and aerodrome authorities as well as the service providers.

3.2 Navaid Infrastructure Considerations –
RNP AR APCH procedures are only authorised based on GNSS as the primary Navaid infrastructure. The use of DME/DME-updating as a reversionary capability (e.g. extraction when on an approach or continuation for departures) is only authorised to the individual air operator where the aerodrome infrastructure supports the required performance. RNP AR APCH operations should not be conducted in areas known to have navigation signal (GNSS) interference.

3.3 Communications and ATS Surveillance Considerations –
RNP AR APCH implementations do not require any specific communications or ATS surveillance considerations.

3.4 Obstacle Clearance and Route Spacing

3.4.1 The ICAO Required Navigation Performance Authorisation (RNP AR) Procedure Design Manual (Doc 9905) contains guidance for the design of RNP AR APCH procedures, and assumes normal operations.

3.4.2 Terrain and obstacle data in the vicinity of the RNP AR APCH procedures are published in accordance with Annex 15 – Aeronautical Information Services. Obstacle clearance must be maintained in accordance with Doc 9905.

3.5 Additional Considerations

3.5.1 Guidance in this AC does not supersede the applicable operational requirements for equipage.

3.5.2 When the aircraft's vertical path is dependent on BAROVNAV, current local barometric pressure settings must be provided to support RNP AR procedures. Failure to set the altimeter subscale with the local QNH may compromise vertical obstacle protection provided by the procedure.

3.5.3 Consistent with CAAS guidance and principles to implement Safety Management System, each RNP AR APCH procedure should be supported by a Flight Operations Safety Assessment (FOSA) specifically developed to address RNP AR APCH operational safety risks. FOSA criteria are provided in Paragraph 5 of this AC for guidance.

3.5.4 Ground and Flight Evaluation

3.5.4.1 As RNP AR procedures do not have a specific underlying navigation facility, there is no requirement for flight inspection of navigation signals by the operator. However, the operator should only use data officially published by the relevant State of the Aerodrome (via AIP etc.) is used.

3.5.4.2 Because of the unique nature of RNP AR APCH procedures, simulator assessment of each procedure should be accomplished during ground validation to evaluate the factors, including basic fly ability, to be considered in the flight validation, to the extent possible, prior to flight validation. To the maximum extent possible, this simulator assessment should evaluate the factors considered in the flight validation, including basic fly ability.

Note – The evaluation of procedure fly ability, and the performance of navigation and flight control systems, including speeds, aircraft weights and other operational variables, is the responsibility of the operator.

3.6 Publication

3.6.1 The AIP published by the State of the Aerodrome would clearly indicate that the navigation application is an RNP AR APCH procedure and specific authorisation is required. If distinct approvals are required for specific RNP AR APCH procedure or aerodrome, this requirement should be clearly identified by the State of the Aerodrome.

3.6.2 The minimum navigation accuracy required during any part of the RNP AR APCH procedure should be clearly published.

3.6.3 The navigation data published in the relevant AIP for the procedures and supporting navaids (if used) must meet the requirements of Annex 15 and Annex 4 – Aeronautical Charts (as appropriate). In particular, the data defining the procedure should be available to the operator in a manner suitable to enable the operator to verify the navigation data.

4 OPERATIONAL APPROVAL AND REQUIREMENTS

4.1 This paragraph provides the operator the technical guidance against which the aircraft and the operator's operating policy and procedures and training programmes for pilots and dispatch personnel are assessed and approved by CAAS for the conduct of RNP AR APCH operations

4.2 Operation Approval is specific to a particular approach; hence, the operator granted an operational approval to conduct instrument approach on one RNP AR APCH procedure will need to seek operational approval from CAAS for another RNP AR APCH procedure.

4.3 Due to the unique requirements of RNP AR APCH operations and the demand for crew procedures that are specific to each particular aircraft and navigation system, operational support documentations from the aircraft manufacturer are needed. The documents should describe the navigation capabilities of the applicant's aircraft to conduct the RNP AR APCH operations for which approval is being sought, and provide all the assumptions, limitations and supporting information necessary for the safe conduct of RNP AR APCH operations. Such documents providing the supporting information should be submitted to CAAS by the operator together with the application for RNP AR APCH operational approval.

4.4 In preparation for an operational approval to conduct RNP AR APCH operations, the operator should also refer to aircraft and avionics manufacturers' recommendations and guidance. Installation of equipment or recognition of aircraft eligibility is not sufficient by itself to obtain operational approval for RNP AR APCH operations.

4.5 Aircraft Eligibility
Aircraft eligibility must be determined through demonstration of compliance against the relevant airworthiness criteria and the requirements in **Appendix A**. The operator should include in his application the approvals granted by the certifying authority (e.g. EASA, FAA) to the respective OEM (Original Equipment Manufacturer) or the holder of installation approval for the aircraft, e.g. STC (Supplementary Type Certificate) holder. Approvals may be presented in the aircraft manufacturer's documentation (e.g. service letters or bulletins). AFM entries are not required, provided appropriate manufacturer's documentation is presented.

4.6 Application for an Operational Approval

4.6.1 Description of aircraft equipment
The operator must have a configuration list and, if necessary, an MEL detailing the required aircraft equipment for RNP AR APCH operations.

4.6.2 Operations Manuals (OMs) and checklists

4.6.2.1 OMs and checklists for the operator holding an AOC must address information/guidance on the SOP detailed in **Appendix B**. The appropriate manuals should contain navigation operating instructions and contingency procedures, where specified. the operator must submit its manuals and checklists for review as part of the application process.

4.6.2.1 The operator of a private aircraft should operate using the practices and procedures identified in **Appendix B**.

4.6.3 Training documentation

4.6.3.1 The operator holding an AOC must have a training programme addressing the operational practices, procedures and training items related to RNP AR APCH operations (e.g. initial, upgrade or recurrent training for pilots, dispatchers or maintenance personnel). This programme must provide sufficient detail on the aircraft's navigation and flight control systems to enable the pilots to identify failures affecting the aircraft's RNP capability and the appropriate abnormal/emergency procedures. Training must include both knowledge and skill assessments of the crew members' and dispatchers' duties. **Appendix C** provide guidance for an acceptable training programme.

Note – The operator need not establish a separate training programme if he already integrates RNAV training as an element of his training programme. However, the operator should be able to identify the aspects of RNP AR APCH operations covered within their training programme.

4.6.3.2 A operator of a private aircraft must be familiar with the practices and procedures identified in **Appendix C**.

4.6.4 MEL considerations

Any MEL revisions necessary to address provisions for RNP AR APCH operations must be approved. The operator must adjust the MEL, or equivalent, and specify the required dispatch conditions.

4.6.5 Continuing airworthiness

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

Note – The operator should confirm with the OEM, or the holder of installation approval for the aircraft, that acceptance of subsequent changes in the aircraft configuration, e.g. SBs, does not invalidate current operational approvals.

4.6.6 Navigation Database considerations

Given the reduced obstacle clearance associated with RNP AR APCH approaches, navigation data is critical to the integrity of every RNP AR APCH procedure. The operator must provide details of its procedures for the validation of navigation data, and its update. **Appendix D** provides guidance for procedures for validating the navigation data associated with RNP AR APCH procedures.

5 GRANT OF THE OPERATIONAL APPROVAL

5.1 Following the successful completion of the above steps, CAAS may grant the operational approval (subject to any conditions or limitations).

5.2 The applicable safety assessment items listed in **Appendix E** should be considered prior to implementation.

5.3 The operational approval (LOA, appropriate Operations specifications, or amendment to the Operations Manual), would be annotated with RNP AR APCH as appropriate.

5.4 The RNP AR APCH approval by CAAS is valid for that specific aerodrome. For operations into other aerodromes with RNP AR APCH requires further approval.

5.5 The approval should identify the type of procedures for which the operator is approved, i.e. the most demanding level of performance permitted, RNP 0.3, RNP 0.1, etc., or additional requirements such as RF turns. Equipment configurations, selected modes and crew procedures must be defined for RNP AR APCH procedures.

6 OVERSIGHT OF OPERATORS

6.1 CAAS may consider any anomaly reports in determining remedial action. Repeated navigation error occurrences attributed to a specific piece of navigation equipment may result in the cancellation of the approval for use of that equipment.

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

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

(a) Total number of RNP AR APCH procedures conducted;

(b) Number of satisfactory approaches by aircraft/system (satisfactory if completed as planned without any navigation or guidance system anomalies;

(c) Reasons for unsatisfactory approaches, such as:
- NABLE REQ NAV PERF, NAV ACCUR DOWNGRAD, or other RNP messages during approaches;
- excessive lateral or vertical deviation;
- TAWS warning;
- autopilot system disconnect;
- navigation data errors; and
- pilot report of any anomaly.

(d) Crew Comments.

APPENDIX A AIRCRAFT REQUIREMENTS

A.1 This appendix describes the aircraft performance and functional criteria for aircraft to qualify for RNP AR APCH. In addition to the specific guidance in this appendix, the aircraft must comply with FAA AC 20-138D, or equivalent.

A.2 On-board performance monitoring and alerting.
This paragraph defines the general performance requirements for aircraft qualification. The requirements for RNP AR APCH are unique due to the reduced obstacle clearance and advanced functionality, therefore the requirements in this paragraph do not use the same structure as for other navigation specifications, e.g. RNP 4, RNP 1 and RNP APCH.

A.2.1 Path definition
Aircraft performance is evaluated around the path defined by the published procedure and RTCA/DO-236B Section 3.2; EUROCAE ED-75B. All vertical paths used in conjunction with the Final Approach Segment (FAS) will be defined by a flight path angle (RTCA/DO 236B, section 3.2.8.4.3) as a straight line emanating to a fix and altitude

A.2.2 Lateral accuracy
All aircraft operating on RNP AR APCH procedures must have a cross-track navigation error no greater than the applicable accuracy value (0.1 NM to 0.3 NM) for 95 per cent of the flight time. This includes positioning error, FTE, PDE and display error. Also, the aircraft along-track positioning error must be no greater than the applicable accuracy value for 95 per cent of the flight time

A.2.3 Vertical accuracy
The vertical system error includes altimetry error (assuming the temperature and lapse rates of the International Standard Atmosphere), the effect of along-track error, system computation error, data resolution error, and FTE.

A.2.4 System monitoring
A critical component of RNP is the ability of the aircraft navigation system to monitor its achieved navigation performance, and to identify, to the pilot, whether the operational requirement is or is not being met during an operation (e.g. “Unable RNP”, “Nav Accur Downgrad”). It should be noted that the monitoring system may not provide warnings of FTE. The management of FTE must be addressed as a pilot procedure.

A.2.5 GNSS updating
A crew alert is required when GNSS updating is lost unless the navigation system provides an alert when the selected RNP no longer meets the requirements for continued navigation.

A.2.6 Airspace containment

A.2.6.1 RNP and BAROVNAV equipped aircraft.
This paragraph provides a detailed acceptable means of compliance for aircraft that use an RNP system based primarily on GNSS, and a VNAV system based on barometric altimetry. Aircraft and operations complying with this navigation specification provide the requisite airspace protection through a variety of monitoring and alerting systems and pilot procedures. Aircraft and operations complying with this navigation specification provide the requisite performance and assurance to satisfy the airspace requirements and safety margins through a variety of monitoring and alerting (e.g. “Unable RNP”, GNSS alert limit, and path deviation monitoring); and

A.2.6.2 Other systems or alternate means of compliance.

For other systems or alternate means of compliance to a), the probability of the aircraft exiting the lateral and vertical extent of the obstacle clearance volume of the procedure must not exceed 107 per approach (including the missed approach). This requirement may be satisfied by an operational safety assessment applying:

(a) appropriate quantitative numerical methods;
(b) qualitative operational and procedural considerations and mitigations; or
(c) an appropriate combination of both quantitative and qualitative methods.

Notes -

(1) This requirement applies to the total probability of excursion outside the obstacle clearance volume, including events caused by latent conditions (integrity) and by detected conditions (continuity) if the aircraft does not remain within the obstacle clearance volume after the failure is annunciated (considering the aircraft wingspan). The monitor limit of the alert, the latency of the alert, the crew reaction time, and the aircraft response should all be considered when ensuring that the aircraft does not exit the obstacle clearance volume. The requirement applies to a single approach, considering the exposure time of the operation and the NAVAID geometry and navigation performance available for each published approach.

(2) This containment requirement is derived from the operational requirement which is notably different than the containment requirement specified in RTCA/DO 236B (EUROCAE ED-75B). The requirement in RTCA/DO-236B (EUROCAE ED-75B) was developed to facilitate airspace design and does not directly equate to obstacle clearance.

A.3 Criteria for specific navigation services

This paragraph identifies unique issues for the navigation sensors within the context of RNP AR APCH operations.

A.3.1 ABAS and other GNSS augmentations based on GPS

A.3.1.1 The sensor must comply with the guidelines in AC 20-138(D). For systems that comply with AC 20-138(D), the following sensor accuracies can be used in the total system accuracy analysis without additional substantiation: GPS (ABAS) sensor lateral accuracy is better than 36 m (119 ft) (95 per cent), and augmented GPS (GBAS or SBAS) sensor lateral accuracy is better than 2 m (7 ft) (95 per cent).

A.3.1.2 In the event of a latent GPS satellite failure and marginal GPS satellite geometry (e.g. HIL) equal to the horizontal alert limit), the probability that the aircraft remains within the obstacle clearance volume used to evaluate the procedure must be greater than 95 per cent (both laterally and vertically).

Notes -

(1) Other GNSS systems meeting or exceeding the accuracy of GPS can use the criteria in a) and b) above.

(2) GNSS-based sensors output a HIL, also known as a HPL (see AC 20-138D, Appendix 1 and RTCA/DO-229C for an explanation of these terms). The HIL is a measure of the position estimation error assuming a latent failure is present. In lieu of a detailed analysis of the effects of latent failures on the TSE, an acceptable means of compliance for GNSS-based systems is to ensure the HIL

remains less than twice the navigation accuracy, minus the 95 per cent of FTE, during the RNP AR APCH operation.

A.3.2 Inertial Reference System (IRS)

An IRS must satisfy the criteria of US 14 CFR part 121, Appendix G, or equivalent. While Appendix G defines the requirement for a 2 NM per hour drift rate (95 per cent) for flights up to 10 hours, this rate may not apply to an RNP system after loss of position updating. Systems that have demonstrated compliance with Part 121, Appendix G, can be assumed to have an initial drift rate of 8 NM/hour for the first 30 minutes (95 per cent) without further substantiation. Aircraft manufacturers and applicants can demonstrate improved inertial performance in accordance with the methods described in Appendix 1 or 2 of FAA Order 8400.12A.

Note – Integrated GPS/INS position solutions reduce the rate of degradation after loss of position updating. For “tightly coupled” GPS/IRUs, RTCA/DO-229C, Appendix R, provides additional guidance.

A.3.3 Distance Measuring Equipment (DME)

GNSS-updating is the basis for initiating all RNP AR APCH procedures. When authorized by the State, the aircraft may use DME/DME-updating as a reversionary navigation mode during an approach or during the missed approach when the navigation system continues to comply with the required navigation accuracy. The aircraft manufacturer should identify any requirements for the DME infrastructure or any necessary operational procedures and limitations when conducting a procedure through use of DME/DME updating of the aircraft's position.

A.3.4 VHF omnidirectional range (VOR) station

The aircraft's RNP system may not use VOR-updating when conducting RNP AR APCH procedures. The aircraft manufacturer should identify any pilot procedures or techniques for an aircraft to comply with this requirement.

Note: This does not imply a requirement for a direct means of inhibiting VOR updating. An operational procedure requiring the pilot to inhibit VOR updating or a procedure requiring the pilot to execute a missed approach when the navigation system reverts to VOR-updating may satisfy this requirement.

A.3.5 For multi-sensor systems, there must be automatic reversion to an alternate area navigation sensor if the primary area navigation sensor fails. Automatic reversion from one multi-sensor system to another multi-sensor system is not required.

A.3.6 The 99.7 per cent aircraft ASE for each aircraft (assuming the temperature and lapse rates of the International Standard Atmosphere) must be less than or equal to the following with the aircraft in the approach configuration:

$$ASE = - 8.8 \times 10^{-8} \times H2 + 6.5 \times 10^{-3} \times H + 50(ft)$$

where H is the true altitude of the aircraft.

A.3.7 Temperature compensation systems

Systems that provide temperature-based corrections to the barometric VNAV guidance must comply with RTCA/DO-236B, Appendix H.2. This applies to the FAS. Manufacturers should document compliance to this standard to allow the operator to conduct RNP approaches when the actual temperature is below or above the published procedure design limit. Appendix H also provides guidance on operational issues associated with temperature compensated systems, such as intercepting the compensated path from uncompensated procedure altitudes.

A.4 Functional requirements

Note – Additional guidance and information concerning many of the required functions are provided in EUROCAE ED-75A/ RTCA DO-236B.

A.4.1 General

A.4.1.1 Path definition and flight planning

A.4.1.1.1 Maintaining track and leg transitions

The aircraft must have the capability to execute leg transitions and maintain tracks consistent with the following paths:

(a) a geodesic line between two fixes;
(b) a direct path to a fix;
(c) a specified track to a fix, defined by a course; and
(d) a specified track to an altitude.

Notes -

(1) Industry standards for these paths can be found in EUROCAE ED-75A/ RTCA DO-236B and ARINC 424, which refer to them as TF, DF, CF, and FA path terminators. Also, certain procedures require RF legs. EUROCAE ED-75A/RTCA DO-236B and ED-77/ DO-201A describe the application of these paths in more detail.

(2) The navigation system may accommodate other ARINC 424 path terminators (e.g. heading to manual terminator (VM)), and the missed approach procedure may use these types of paths when there is no requirement for RNP containment.

A.4.1.1.2 Fly-by and fly-over fixes

The aircraft must have the capability to execute fly-by and fly-over fixes. For fly-by turns, the navigation system must limit the path definition within the theoretical transition area defined in EUROCAE ED-75B/ RTCA DO-236B and under the wind conditions identified in Doc 9905. The fly-over turn is not compatible with RNP flight tracks and will only be used when there is no requirement for repeatable paths.

A.4.1.1.3 Waypoint resolution error

The navigation database must provide sufficient data resolution to ensure the navigation system achieves the required accuracy. The waypoint resolution error must be less than or equal to 60 ft, including both the data storage resolution and the RNP system computational resolution used internally for construction of flight plan waypoints. The navigation database must contain vertical angles (flight path angles) stored to a resolution of hundredths of a degree, with computational resolution such that the system-defined path is within 1.5 m (5 ft) of the published path.

A.4.1.1.4 Capability for a “direct-to” function

The navigation system must have a “direct-to” function that the pilot can activate at any time. This function must be available to any fix. The navigation system must also be capable of generating a geodesic path to the designated “To” fix, without “S-turning” and without undue delay.

A.4.1.1.5 Capability to define a vertical path

The navigation system must be capable of defining a vertical path by a flight path angle to a fix. The system must also be capable of specifying a vertical path between altitude constraints at two fixes in the flight plan. Fix altitude constraints must be defined as one of the following:

(a) an “AT” or “ABOVE” altitude constraint (e.g. 2400A may be appropriate for situations where bounding the vertical path is not required);
(b) an “AT” or “BELOW” altitude constraint (e.g. 4800B may be appropriate for situations where bounding the vertical path is not required);
(c) an “AT” altitude constraint (e.g. 5200); or
(d) a “WINDOW” constraint (e.g. 2400A, 3400B).

Note – For RNP AR APCH procedures, any segment with a published vertical path will define that path based on an angle to the fix and altitude.

A.4.1.1.6 Altitudes and/or speeds associated with published terminal procedures must be extracted from the navigation database.

A.4.1.1.7 The system must be able to construct a path to provide guidance from the current position to a vertically constrained fix.

A.4.1.1.8 Capability to load procedures from the navigation database

The navigation system must have the capability to load the entire procedure(s) to be flown into the RNP system from the on-board navigation database. This includes the approach (including vertical angle), the missed approach and the approach transitions for the selected airport and runway.

A.4.1.1.9 Means to retrieve and display navigation data

The navigation system must provide the ability for the pilot to verify the procedure to be flown through review of the data stored in the on-board navigation database. This includes the ability to review the data for individual waypoints and for NAVAIDs.

A.4.1.1.10 Magnetic variation

For paths defined by a course (CF and FA path terminators), the navigation system must use the magnetic variation value for the procedure in the navigation database.

A.4.1.1.11 Changes in navigation accuracy

RNP changes to lower navigation accuracy must be completed by the fix in the navigation system. Any operational procedures necessary to accomplish this must be identified.

A.4.1.1.12 Automatic leg sequencing

The navigation system must provide the capability to automatically sequence to the next leg and display the sequencing to the pilot in a readily visible manner.

A.4.1.1.13 A display of the altitude restrictions associated with flight plan fixes must be available to the pilot. If there is a specified navigation database procedure with a flight path angle associated with any flight plan leg, the equipment must display the flight path angle for that leg.

A.4.1.2 Demonstration of path steering performance

The demonstration of path steering performance must be completed in a variety of operational conditions, i.e. rare-normal conditions and non-normal conditions (e.g. see FAA AC 120-29A, 5.19.2.2 and 5.19.3.1). Realistic and representative procedures should be used (e.g. number of waypoints, placement of waypoints, segment geometry, leg types, etc.). The non-normal assessment should consider the following:

(a) Criteria for assessing probable failures during the aircraft qualification will demonstrate that the aircraft trajectory is maintained within a 1 × RNP corridor, and 22 m (75ft) vertical. Proper documentation of this demonstration in the AFM, AFM extension, or appropriate aircraft operational support document, alleviates the operational evaluations;

(b) RNP-significant improbable failure cases should be assessed to show that, under these conditions, the aircraft can be safely extracted from the procedure. Failure cases might include dual system resets, flight control surface runaway and complete loss of flight guidance function; and

(c) The aircraft performance demonstration during the operational evaluations can be based on a mix of analyses and flight technical evaluations using expert judgment. Recommended operating procedures (relevant to sections 10.4 and 10.5) resulting from the above demonstration (e.g. one engine inoperative performance) should be documented in the AFM, AFM extension, or appropriate aircraft operational support documents.

A.4.1.3 Displays

A.4.1.3.1 Continuous display of deviation

The navigation system must provide the capability to continuously display to the pilot flying, on the primary flight instruments for navigation of the aircraft, the aircraft position relative to the RNP defined path (both lateral and vertical deviation). The display must allow the pilot to readily distinguish if the cross-track deviation exceeds the lateral navigation accuracy (e.g. 1 × RNP) or a smaller value, and if the vertical deviation exceeds 22 m (75ft) (or a smaller value) during RNP AR APCH operations.

Note – The aircraft manufacturer may allocate a lateral deviation limit smaller than 1 × RNP to ensure lateral containment during RNP AR APCH operations. Likewise, the manufacturer may require a vertical deviation limit smaller than 22 m (75 ft) to ensure compliance with the vertical error budget in the procedure design.

It is recommended that an appropriately scaled non-numeric deviation display (i.e. lateral deviation indicator and vertical deviation indicator) be located in the pilot's primary optimum field of view. A fixed-scale CDI is acceptable as long as the CDI demonstrates appropriate scaling and sensitivity for the intended navigation accuracy and operation. With a scalable CDI, the scale should be derived from the selection of the lateral navigation accuracy, and not require the separate selection of a CDI scale. Alerting and annunciation limits must also match the scaling values. If the equipment uses default navigation accuracy to describe the operational mode (e.g. en route, terminal area and approach), then displaying the operational mode is an acceptable means from which the pilot may derive the CDI scale sensitivity.

Numeric display of deviation or graphic depiction on a map display, without an appropriately scaled deviation indicator, is generally not considered acceptable for monitoring deviation. The use of a numeric display or a map display may be feasible depending on the pilot workload, the display characteristics, and the pilot procedures

and training. Additional initial and recurrent pilot training (or line experience) may be necessary.

A.4.1.3.2 Identification of the active (To) waypoint

The navigation system must provide a display identifying the active waypoint either in the pilot's primary optimum field of view, or on a readily accessible and visible display to the pilot.

A.4.1.3.3 Display of distance and bearing

The navigation system must provide a display of distance and bearing to the active (To) waypoint in the pilot's primary optimum field of view. Where not viable, a readily accessible page on a control display unit, readily visible to the pilot, may display the data.

A.4.1.3.4 Display of ground speed and time to the active (To) waypoint

The navigation system must provide the display of ground speed and time to the active (To) waypoint in the pilot's primary optimum field of view. Where not viable, a readily accessible page on a control display unit, readily visible to the pilot, may display the data.

A.4.1.3.5 Display of 'To' the active fix

The navigation system must provide a 'To' display in the pilot's primary optimum field of view.

A.4.1.3.6 Desired track display

The navigation system must have the capability to continuously display to the pilot flying the desired aircraft track. This display must be on the primary flight instruments for navigation of the aircraft.

A.4.1.3.7 Display of aircraft track

The navigation system must provide a display of the actual aircraft track (or track angle error) either in the pilot's primary optimum field of view, or on a readily accessible and visible display to the pilot

A.4.1.3.8 Failure annunciation

The aircraft must provide a means to annunciate failures of any aircraft component of the RNP system, including navigation sensors. The annunciation must be visible to the pilot and located in the primary optimum field of view.

A.4.1.3.9 Slaved course selector

The navigation system must provide a course selector automatically slaved to the RNP computed path.

A.4.1.3.10 RNP path display

The navigation system must provide a readily visible means for the pilot monitoring to verify the aircraft's RNP-defined path and the aircraft position relative to the defined path.

A.4.1.3.11 Display of distance to go

The navigation system must provide the ability to display distance to go to any waypoint selected by the pilot.

A.4.1.3.12 Display of distance between flight plan waypoints

The navigation system must provide the ability to display the distance between flight plan waypoints.

A.4.1.3.13 Display of deviation

The navigation system must provide a numeric display of the vertical and lateral deviation. Vertical deviation must have a resolution of 3 m (10 ft) or less for RNP AR APCH operations. Lateral deviation resolution must be:

(a) 0.1NM or less for RNP operations not less than 0.3; or

(b) 0.01NM or less for RNP operations below 0.3.

A.4.1.3.14 Display of barometric altitude

The aircraft must display barometric altitude from two independent altimetry sources, one in each of the pilot's primary optimum field of view.

Notes -

(1) This display supports an operational cross-check (comparator monitor) of altitude sources. If the aircraft altitude sources are automatically compared, the output of the independent altimetry sources, including independent aircraft static air pressure systems, is expected to be analysed to ensure that they can provide an alert in the pilot's primary optimum field of view when deviations between the sources exceed 30 m (±100 ft). This comparator monitor function should be documented as it may eliminate the need for an operational mitigation.

(2) When barometric vertical guidance is used, the altimeter setting input is expected to be used simultaneously by the aircraft altimetry system and by the RNP system. A single input is necessary to prevent possible crew error. Separate altimeter settings for the RNP system are prohibited.

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A.4.1.3.15 Display of active sensors

The aircraft must either display the current navigation sensor(s) in use or indicate sensor loss/degradation in navigation system performance. It is recommended that this display be provided in the primary optimum field of view.

Note – This display is used to support operational contingency procedures. If such a display is not in the primary optimum field of view, pilot procedures may mitigate the requirement provided the workload is acceptable.

A.4.1.4 Design assurance

A.4.1.4.1 The system design assurance must be consistent with at least a major failure condition for the display of misleading lateral or vertical guidance on an RNP AR APCH procedure.

Note: The display of misleading lateral or vertical RNP guidance is considered a hazardous (severe-major) failure condition for RNP AR APCHs with a navigation accuracy less than RNP-0.3. Systems designed consistent with this effect should be documented as it may eliminate the need for some operational mitigations for the aircraft

A.4.1.4.1 The system design assurance must be consistent with at least a major failure condition for the loss of lateral guidance and a minor failure condition for loss of vertical guidance on an RNP AR APCH procedure.

Note: Loss of vertical guidance is considered a minor failure condition because the pilot can take action to stop descending or climb when guidance is lost.

A.4.1.5 Navigation database

The aircraft navigation system must use an on-board navigation database which can receive updates in accordance with the AIRAC cycle and allow retrieval and loading of RNP AR APCH procedures into the RNP system. The RNP system must not allow the pilot to modify the data stored in the on-board navigation database.

Note – When a procedure is loaded from the on-board navigation database, the RNP system is expected to execute the procedure as published. This does not preclude the pilot from having the means to modify a procedure already loaded into the navigation system.

A.4.1.6 The aircraft must have the capacity to execute leg transitions and maintain tracks consistent with an RF leg between two fixes.

A.4.2 Requirements for RNP AR with RF legs

A.4.2.1 The navigation system must have the capability to execute leg transitions and maintain tracks consistent with an RF leg between two fixes.

A.4.2.2 The aircraft must have an electronic map display of the selected procedure.

A.4.2.3 The RNP system, the flight director system and autopilot must be capable of commanding a bank angle up to 25 degrees above 121 m (400 ft) AGL and up to 8 degrees below 121 m (400 ft) AGL.

A.4.2.4 Upon initiating a go-around or missed approach (through activation of TOGA or other means), the flight guidance mode should remain in lateral navigation to enable continuous track guidance during an RF leg.

A.4.2.5 When evaluating an FTE on RF legs, the effect of rolling into and out of the turn should be considered. The procedure is designed to provide a 5-degree manoeuvrability margin, to enable the aircraft to get back on the desired track after a slight overshoot at the start of the turn.

A.4.3 Requirements for RNP AR approaches to less than RNP 0.3

A.4.3.1 No single point of failure

No single point of failure can cause the loss of guidance compliant with the navigation accuracy associated with the approach. Typically, the aircraft must have at least the following equipment: dual GNSS sensors, dual FMS, dual air data systems, dual autopilots, and a single IRU.

Note – For RNP AR APCH operations requiring less than 0.3 to avoid obstacles or terrain, the loss of the display of lateral guidance is considered a hazardous (severe-major) failure condition. The AFM should document systems designed consistent with this effect. This documentation should describe the specific aircraft configuration or mode of operation that achieves navigation accuracy less than 0.3. Meeting this requirement can substitute for the general requirement for dual equipment described above.

A.4.3.2 Design assurance

The system design assurance must be consistent with at least a major failure condition for the loss of lateral or vertical guidance on an RNP AR APCH where RNP less than 0.3 is required to avoid obstacles or terrain while executing the procedure.

A.4.3.3 Go-around guidance

Upon initiating a go-around or missed approach (through activation of TOGA or other means), the flight guidance mode should remain in lateral navigation to enable continuous track guidance during an RF leg. If the aircraft does not provide this capability, the following requirements apply:

(a) If the aircraft supports RF legs, the lateral path after initiating a go-around (TOGA), (given a minimum 50-second straight segment between the RF end point and the DA), must be within 1 degree of the track defined by the straight segment through the DA point. The prior turn can be of arbitrary angular extent and radius as small as 1 NM, with speeds commensurate with the approach environment and the radius of the turn.

(b) The pilot must be able to couple the autopilot or flight director to the RNP system (engage lateral navigation) by 121m (400 ft) AGL.

A.4.3.4 Loss of GNSS

After initiating a go-around, or missed approach following loss of GNSS, the aircraft must automatically revert to another means of navigation that complies with the navigation accuracy.

A.4.4 Requirements for approaches with missed approach less than RNP 1.0

A.4.4.1 Single point of failure

No single point of failure can cause the loss of guidance compliant with the navigation accuracy associated with a missed approach procedure. Typically, the aircraft must have at least the following equipment: dual GNSS sensors, dual FMS, dual air data systems, dual autopilots, and a single IRU.

A.4.4.2 Design assurance

The system design assurance must be consistent with at least a major failure condition for the loss of lateral or vertical guidance on an RNP AR APCH where RNP less than 1.0 is required to avoid obstacles or terrain while executing a missed approach.

Note – For RNP AR APCH missed approach operations requiring less than 1.0 to avoid obstacles or terrain, the loss of the display of lateral guidance is considered a hazardous (severe-major) failure condition. The AFM should document systems designed consistent with this effect. This documentation should describe the specific aircraft configuration or mode of operation that achieves navigation accuracy less than 1.0. Meeting this requirement can substitute for the general requirement for dual equipment described above.

A.4.4.3 Go-around guidance

Upon initiating a go-around or missed approach (through activation of TOGA or other means), the flight guidance mode should remain in lateral navigation to enable continuous track guidance during an RF leg. If the aircraft does not provide this capability, the following requirements apply:

(a) If the aircraft supports RF legs, the lateral path after initiating a go-around (TOGA) (given a minimum 50-second straight segment between the RF end point and the DA) must be within 1 degree of the track defined by the straight segment through the DA point. The prior turn can be of arbitrary angular extent and the radius as small as 1 NM, with speeds commensurate with the approach environment and the radius of the turn.

(b) The pilot must be able to couple the autopilot or flight director to the RNP system (engage lateral navigation) by 121m (400ft) AGL.

A.4.4.4 Loss of GNSS

After initiating a go-around or missed approach following loss of GNSS, the aircraft must automatically revert to another means of navigation that complies with the navigation accuracy.

APPENDIX B OPERATING PROCEDURES

B.1 Pre-flight considerations

B.1.1 MEL

The operator's MEL should be developed/revised to address the equipment requirements for RNP AR instrument procedures. Guidance for these equipment requirements is available from the aircraft manufacturer. The required equipment may depend on the intended navigation accuracy and whether the missed approach requires an RNP less than 1.0. For example, GNSS and autopilot are typically required for high navigation accuracy. Dual equipment is typically required for approaches when using a line of minima less than RNP 0.3 and/or where the missed approach has an RNP less than 1.0. An operable Class A TAWS is required for all RNP AR APCH procedures. It is recommended that the TAWS use an altitude that compensates for local pressure and temperature effects (e.g. corrected barometric and GNSS altitude), and includes significant terrain and obstacle data. The TAWS must not utilize the captain's altimeter subscale setting as the sole reference to help militate against a dual QNH setting error by the pilot. The pilot must be cognizant of the required equipment

B.1.2 Autopilot and flight director

RNP AR APCH procedures with a lateral navigation accuracy of less than RNP 0.3 or with RF legs require the use of an autopilot or flight director driven by the RNP system in all cases. Thus, the autopilot/flight director must be operable and able to track the lateral and vertical paths defined by the procedure. When the dispatch of a flight is predicated on flying an RNP AR APCH procedure requiring the autopilot at the destination and/or alternate, the dispatcher must determine that the autopilot is operational

B.1.3 Dispatch RNP availability prediction

The operator must have a predictive performance capability which can forecast whether or not the specified RNP will be available at the time and location of a desired RNP AR APCH procedure. This capability can be a ground service and need not be resident in the aircraft's avionics equipment. The operator must establish procedures requiring use of this capability as both a preflight dispatch tool and as a flight-following tool in the event of reported failures. The RNP assessment must consider the specific combination of the aircraft capability (sensors and integration) and the following:

(a) RNP assessment when GNSS updating. This predictive capability must account for known and predicted outages of GNSS satellites or other impacts on the navigation system's sensors. The prediction programme should not use a mask angle below 5 degrees, as operational experience indicates that satellite signals at low elevations are not reliable. The prediction must use the actual GNSS constellation with the integrity monitoring algorithm (RAIM, AAIM, etc.) identical to that used in the actual equipment. For RNP AR APCH operations with high terrain, use a mask angle appropriate to the terrain; and

(b) RNP AR APCH operations must have GNSS updating available prior to the commencement of the procedure.

B.1.4 NAVAID exclusion

The operator must establish procedures to exclude NAVAID facilities in accordance with NOTAMs (e.g. DMEs, VORs, localizers)

B.1.5 Navigation database currency

During system initialization, the pilot of aircraft equipped with an RNP capable system, must confirm that the navigation database is current. Navigation databases are expected to be current for the duration of the flight. If the AIRAC cycle changes during flight, the operator and his pilots must establish procedures to ensure the accuracy of the navigation data, including the suitability of the navigation facilities used to define the routes and procedures for the flight. An outdated database must not be used to conduct the RNP AR APCH operation unless it has been established that any amendments to the database have no material impact on the procedure. If an amended chart is published for the procedure, the database must not be used to conduct the operation

B.2 In-flight considerations

B.2.1 Modification of the flight plan

The pilot is not authorized to fly a published RNP AR APCH procedure unless it is retrievable by the procedure name from the aircraft navigation database and conforms to the charted procedure. The lateral path must not be modified, with the exception of;

(a) accepting a clearance to go direct to a fix in the approach procedure that is at or before the FAF and that does not immediately precede an RF leg; or

(b) changing the altitude and/or airspeed waypoint constraints on the initial, intermediate, or missed approach segments of an approach (e.g. to apply cold temperature corrections or comply with an ATC clearance/instruction).

B.2.2 Required list of equipment

The pilot must have a required list of equipment for conducting RNP AR APCH operations or alternate methods to address in-flight equipment failures prohibiting RNP AR APCH procedures (e.g. a quick reference handbook).

B.2.3 RNP management

The pilot's operating procedures must ensure the navigation system uses the appropriate navigation accuracy throughout the approach. If multiple lines of minima associated with different navigation accuracy are shown on the approach chart, the crew must confirm that the desired navigation accuracy is entered in the RNP system. If the navigation system does not extract and set the navigation accuracy from the on-board navigation database for each leg of the procedure, then the pilot's operating procedures must ensure that the smallest navigation accuracy required to complete the approach or missed approach is selected before initiating the procedure (e.g. before the IAF and before take-off roll). Different segments may have different navigation accuracy, which are annotated on the approach chart.

B.2.4 GNSS updating

All RNP AR instrument procedures require GNSS updating of the navigation position solution. The pilot must verify that GNSS updating is available prior to commencing the RNP AR procedure. During an approach, if at any time GNSS updating is lost and the navigation system does not have the performance to continue the approach, the pilot must abandon the RNP AR APCH unless the pilot has in sight the visual references required to continue the approach.

B.2.5 Radio updating

Initiation of all RNP AR APCH procedures is based on the availability of GNSS updating. Except where specifically designated on a procedure as "Not Authorized", DME/DME updating can be used as a reversionary mode during the approach or missed approach when the system complies with the navigation accuracy. VOR

updating is not authorized at this time. The pilot must comply with the operator's procedures for inhibiting specific facilities.

B.2.6 Procedure confirmation

The pilot must confirm that the correct procedure has been selected. This process includes confirmation of the waypoint sequence, reasonableness of track angles and distances, and any other parameters that can be altered by the pilot, such as altitude or speed constraints. A procedure must not be used if the validity of the navigation database is in doubt. A navigation system textual display or navigation map display must be used.

B.2.7 Track deviation monitoring

The pilot must use a lateral deviation indicator and/or flight director in lateral navigation mode in RNP AR APCH procedures. The pilot of an aircraft with a lateral deviation indicator must ensure that lateral deviation indicator scaling (full-scale deflection) is suitable for the navigation accuracy associated with the various segments of the RNP AR APCH procedure. The pilot is expected to maintain procedure centre lines, as depicted by on-board lateral deviation indicators and/or flight guidance during all RNP operations described in this manual, unless authorized to deviate by ATC or under emergency conditions. For normal operations, cross-track error/deviation (the difference between the RNP system computed path and the aircraft position relative to the path) should be limited to ±½ the navigation accuracy associated with the procedure segment. Brief lateral deviations from this standard (e.g. overshoots or undershoots) during and immediately after turns, up to a maximum of one-times the navigation accuracy of the procedure segment are tolerable.

B.2.8 Vertical deviation

The vertical deviation must be within 22m (75ft) during the FAS noting that transients in excess of 75ft above the vertical path are acceptable (e.g. configuration changes or energy management actions). Vertical deviation should be monitored above and below the vertical path; while being above the vertical path provides margin against obstacles on the final approach, continued intentional flight above the vertical path can result in a go-around decision closer to the runway and reduce the margin against obstacles in the missed approach.

B.2.9 Lateral/Vertical deviation exceedance

The pilot must execute a missed approach if the lateral deviation exceeds 1 × RNP or the vertical deviation exceeds –22 m (–75 ft), unless the pilot has in sight the visual references required to continue the approach.

Some aircraft navigation displays do not incorporate lateral and vertical deviations scaled for each RNP AR APCH operation in the primary optimum field of view. Where a moving map, low-resolution vertical deviation indicator (VDI), or numeric display of deviations are to be used, pilot training and procedures must ensure the effectiveness of these displays. Typically, this involves the demonstration of the procedure with a number of trained crews and inclusion of this monitoring procedure in the recurrent RNP AR APCH training programme.

For installations that use a CDI for lateral path tracking, the AFM or aircraft qualification guidance should state which navigation accuracy and operations the aircraft supports and the operational effects on the CDI scale. The pilot must know the CDI full-scale deflection value. The avionics may automatically set the CDI scale (dependent on the phase of flight) or the pilot may manually set the scale. If the pilot manually selects the CDI scale, the operator must have procedures and training in place to assure the

selected CDI scale is appropriate for the intended RNP operation. The deviation limit must be readily apparent given the scale (e.g. full-scale deflection).

B.2.10 System cross-check

For approaches with a navigation accuracy less than RNP 0.3, the pilot must monitor the lateral and vertical guidance provided by the navigation system by ensuring it is consistent with other available data and displays that are provided by independent means.

Note: This cross-check may not be necessary if the lateral and vertical guidance systems have been developed consistent with a hazardous (severe-major) failure condition for misleading information and if the normal system performance supports airspace containment.

B.2.11 Procedures with RF legs

An RNP AR APCH procedure may require the ability to execute an RF leg to avoid terrain or obstacles. This requirement will be noted on the chart. As not all aircraft have this capability, the pilot must be aware of whether or not they can conduct these procedures. When flying an RF leg, the pilot must not exceed the maximum airspeeds shown in **Table 2** throughout the RF leg segment. For example, a Category C A320 must slow to 160 KIAS at the FAF or may fly as fast as 185 KIAS if using Category D minima. A missed approach prior to DA may require the segment speed for that segment be maintained.

Table 2

Indicated airspeed (knots)						
Segment	Indicated airspeed by aircraft category					
	Cat H	Cat A	Cat B	Cat C	Cat D	Cat E
Initial and intermediate (IAF to FAF)	120	150	180	240	250	250
Final (FAF to DA)	90	100	130	160	185	As specified
Missed approach (DA to MAHF)	90	110	150	240	265	As specified
Airspeed restriction*	As specified					

* RNP AR APCH procedure design may use airspeed restrictions to reduce the RF turn radius regardless of aircraft category. Operators therefore need to ensure they comply with the limiting speed for planned RNP AR APCH operations under all operating configurations and conditions,

B.2.12 Temperature compensation

For aircraft with temperature compensation capabilities, approved operating procedures may allow the pilot to disregard the temperature limits on RNP AR APCH procedures if the operator provides pilot training on the use of the temperature compensation function. Temperature compensation by the system is applicable to the baro-VNAV guidance and is not a substitute for the pilot compensating for the cold temperature effects on minimum altitudes or the DA. The pilot should be familiar with the effects of the temperature compensation on intercepting the compensated path described in EUROCAE ED-75B/ RTCA DO-236B Appendix H.

Note – When using GNSS vertical guidance on RNP AR operations (e.g. SBAS or GBAS), the temperature limits for the procedure do not apply. However, the pilot may still need to compensate for the cold temperature effects on minimum altitudes or the DA.

B.2.13 Altimeter setting

RNP AR APCH IAPs use barometric data to derive vertical guidance. The pilot must ensure that the current local QNH is set prior to the FAF. Remote altimeter settings are not permitted.

B.2.14 Altimeter cross-check

The pilot must complete an altimetry cross-check ensuring both pilots' altimeters agree within 30 m (±100 ft) prior to the FAF but no earlier than the IAF on approach. If the altimetry cross-check fails then the procedure must not be continued. If the avionics systems provide a comparator warning system for the pilots' altimeters, the pilot procedures should address actions to take if a comparator warning for the pilots' altimeters occurs while conducting an RNP AR APCH procedure.

Note: This operational cross-check is not necessary if the aircraft automatically compares the altitudes to within 30m (100ft) (see also paragraph A.4.1.3.14 "Display of barometric altitude" of **Appendix A**). This operational check is not necessary when the aircraft uses GNSS vertical guidance (e.g. SBAS or GBAS)

B.2.15 VNAV altitude transitions

The aircraft barometric VNAV system provides fly-by vertical guidance, and may result in a path that starts to intercept the vertical path of the procedure prior to the FAF. The small vertical displacement which may occur at a vertical constraint (e.g. the FAF is considered operationally acceptable, providing a smooth transition to the next flight path vertical segment. This momentary deviation below the published minimum procedure altitude is acceptable provided the deviation is limited to no more than 30m (100ft) and is a result of a normal VNAV capture. This applies to both "level off" and "altitude acquire" segments following a climb or descent, or vertical climb or descent segment initiation, or joining of climb or descent paths with different gradients.

B.2.16 Non-standard climb gradient

When an approach procedure specifies a non-standard climb gradient, the operator must ensure the aircraft is capable of complying with the published climb gradient at the aircraft landing weight under ambient atmospheric conditions.

B.2.17 Go-around or missed approach

Where possible, the missed approach will require a navigation accuracy of RNP 1.0. The missed approach portion of these procedures is similar to a missed approach of an RNP APCH approach. Where necessary, navigation accuracy less than RNP 1.0 will be used in the missed approach. Approval to conduct these approaches, equipage and procedures must meet criteria in paragraph A.4.4 "Requirements for approaches with missed approach less than RNP 1.0" of **Appendix A**.

B.2.18 TOGA activation during the initiation of a go-around or missed approach

In some aircraft, activating TOGA during the initiation of a go-around or missed approach may cause a change in lateral navigation mode or functionality, (i.e. TOGA disengages the autopilot and flight director from lateral navigation guidance) and track guidance may revert to track-hold derived from the inertial system. In such cases,

lateral navigation guidance to the autopilot and flight director should be re-engaged as quickly as possible.

B.2.19 Pilot procedures when initiating a go-around while the aircraft is in a turn

The pilot procedures and training must address the impact on navigation capability and flight guidance if the pilot initiates a go-around while the aircraft is in a turn. When initiating an early go-around, the pilot must ensure adherence to the published track unless ATC has issued a different clearance. The pilot should also be aware that RF legs are designed for a maximum ground speed. Initiating an early go-around at speeds higher that those considered in the design, may cause the aircraft to diverge throughout the turn and require pilot intervention to maintain the path.

B.2.20 Contingency procedures – failure while en route

The aircraft RNP capability is dependent on operational aircraft equipment and GNSS. The pilot must be able to assess the impact of equipment failure on the anticipated RNP AR APCH procedure and take appropriate action. As described in para B.1.3(b) “Dispatch RNP availability prediction”, the pilot also must be able to assess the impact of changes in the GNSS constellation and take appropriate action.

B.2.21 Contingency procedures – failure on approach

The operator’s contingency procedures need to address the following conditions: Failure of the RNP system components, including those affecting lateral and vertical deviation performance (e.g. failures of a GPS sensor, the flight director or automatic pilot); and loss of navigation SIS (loss or degradation of external signal).

APPENDIX C PILOT / DISPATCH / OPERATOR KNOWLEDGE AND TRAINING

C.1 The operator must provide training for key personnel (e.g. pilots and dispatchers) in the use and application of RNP AR APCH procedures. A thorough understanding of the operational procedures and best practices is critical to the safe operation of aircraft during RNP AR APCH operations. This programme must provide sufficient detail on the aircraft's navigation and flight control systems to enable the pilots to identify failures affecting the aircraft's RNP capability and the appropriate abnormal/emergency procedures. Training must include both knowledge and skill assessments of the crew members' and dispatchers' duties.

C.2 Operator's responsibilities

C.2.1 The operator is responsible for the training of pilots for the specific RNP AR APCH operations exercised by the operator. The operator must include training on the different types of RNP AR APCH procedures and required equipment. Training must include discussion of RNP AR APCH regulatory requirements. The operator must include these requirements and procedures in their flight operations and training manuals (as applicable). This material must cover all aspects of the operator's RNP AR APCH operations including the applicable operational authorisation. An individual must have completed the appropriate ground and or flight training segment before engaging in RNP AR APCH operations.

C.2.2 Flight training segments must include training and checking modules representative of the type of RNP AR APCH procedures the operator conducts during line-oriented flying activities. The operator may train for RNP AR APCH procedures under the established training standards and provisions for advanced qualification programmes. He may conduct evaluations in LOFT scenarios, selected event training scenarios or in a combination of both. The operator may conduct required flight training modules in flight training devices, aircraft simulators, and other enhanced training devices as long as these training devices accurately replicate the operator's equipment and RNP AR APCH operations. For purpose of this subparagraph (b), the flight simulator to be used should be one that has been qualified by CAAS to ICAO Type VII or Level II, meets the aircraft requirements in paragraph 4.2 and CAAS' Functionality and Qualification for RNP AR APCH checklist.

C.2.3 The operator must address initial RNP AR APCH training and qualifications during initial, transition, upgrade, recurrent, differences, or stand-alone training and qualification programmes in the respective qualification category. The qualification standards assess each pilot's ability to properly understand and use RNP AR procedures (RNP AR APCH initial evaluation). The operator must also develop recurrent qualification standards to ensure their pilots maintain appropriate RNP AR APCH operations knowledge and skills (RNP AR APCH recurrent qualification)

C.2.4 The operator may address RNP AR APCH operation topics separately or integrate them with other curriculum elements. For example, an RNP AR APCH pilot qualification may focus on a specific aircraft during transition, upgrade, or differences courses. General training may also address RNP AR APCH qualification, e.g. during recurrent training or checking events such as recurrent proficiency check/proficiency training, line-oriented evaluation or special purpose operational training. A separate, independent RNP AR APCH operations qualification programme may also address RNP AR APCH training, e.g. by completion of an applicable RNP AR APCH curriculum at the operator's training centre or at designated crew bases.

C.2.5 The operator intending to receive credit for RNP training, when his proposed programme relies on previous training (e.g. special RNP IAPs), must receive specific authorisation from CAAS (via his principal operations inspector/flight operations inspector). In addition to the current RNP training programme, the air carrier will need to provide differences training between existing training programme and the RNP AR APCH training requirements.

C.2.6 Training for flight dispatchers must include: the explanation of the different types of RNP AR APCH procedures, the importance of specific navigation equipment and other equipment during RNP AR APCH operations and the RNP AR APCH regulatory requirements and procedures. Dispatcher procedure and training manuals must include these requirements (as applicable). This material must cover all aspects of the operator's RNP AR operations including the applicable authorisations (e.g. Operations specifications, Operations Manual, or LOA). An individual must have completed the appropriate training course before engaging in RNP AR APCH operations. Additionally, the dispatchers' training must address how to determine: RNP AR APCH availability (considering aircraft equipment capabilities), MEL requirements, aircraft performance, and navigation signal availability (e.g. GPS RAIM/predictive RNP capability tool) for destination and alternate airports.

C.3 Ground training segments contents

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

C.3.1 General concepts of RNP AR APCH operation.

RNP AR APCH training must cover RNP AR APCH systems theory to the extent appropriate to ensure proper operational use. The pilot must understand basic concepts of RNP AR APCH systems operation, classifications, and limitations. The training must include general knowledge and operational application of RNP AR procedures. This training module must address the following specific elements:

(a) definition of RNP AR APCH;

(b) the differences between RNAV and RNP;

(c) the types of RNP AR APCH procedures and familiarity with the charting of these procedures;

(d) the programming and displaying of RNP and aircraft specific displays (e.g. actual navigation performance (ANP display));

(e) how to enable and disable the navigation updating modes related to RNP;

(f) the navigation accuracy appropriate for different phases of flight and RNP AR APCH procedures and how to select the navigation accuracy, if required;

(g) the use of GPS RAIM (or equivalent) forecasts and the effects of RAIM availability on RNP AR APCH procedures (pilot and dispatchers);

(h) when and how to terminate RNP navigation and transfer to traditional navigation due to loss of RNP and/or required equipment;

(i) how to determine database currency and whether it contains the navigational data required for use of GNSS waypoints;

(j) explanation of the different components that contribute to the TSE and their characteristics (e.g. effect of temperature on baro-VNAV and drift characteristics when using IRU with no radio updating); and

(k) temperature compensation – pilots operating avionics systems with compensation for altimetry errors introduced by deviations from ISA may disregard the temperature limits on RNP AR APCH procedures, if pilot training on the use of the temperature compensation function is provided by the operator and the compensation function is utilized by the crew. However, the training must also recognize the temperature compensation by the system is applicable to the VNAV guidance and is not a substitute for the pilot compensating for the cold temperature effects on minimum altitudes or the DA.

C.3.2 ATC communications and coordination for use of RNP AR APCH.
Ground training must instruct the pilots on proper flight plan classifications and any ATC procedures applicable to RNP AR APCH operations. The pilots must receive instructions on the need to advise ATC immediately when the performance of the aircraft's navigation system is no longer suitable to support continuation of an RNP AR APCH procedure. Pilots must also know what navigation sensors form the basis for their RNP AR APCH compliance, and they must be able to assess the impact of a failure of any avionics or a known loss of ground systems on the remainder of the flight plan.

C.3.3 RNP AR APCH equipment components, controls, displays, and alerts.
Academic training must include a discussion of RNP terminology, symbology, operation, optional controls, and display features including any items unique to the operator's implementation or systems. The training must address applicable failure alerts and equipment limitations. The pilots and dispatchers should achieve a thorough understanding of the equipment used in RNP operations and any limitations on the use of the equipment during those operations.

C.3.4 The AFM or other aircraft eligibility evidence must address normal and abnormal flight crew operating procedures, responses to failure alerts, and any equipment limitations, including related information on RNP modes of operation. Training must also address contingency procedures for loss or degradation of RNP capability. The flight operations manuals approved for use by the pilots (e.g. FOM or POH) should contain this information

C.3.5 MEL operating provisions.
Pilots must have a thorough understanding of the MEL requirements supporting RNP AR APCH operations

C.4 Flight training segments — contents
Training programmes must cover the proper execution of RNP AR APCH procedures in concert with the OEM's documentation. The operational training must include: RNP AR APCH procedures and limitations; standardization of the set-up of the cockpit's electronic displays during an RNP AR APCH procedure; recognition of the aural advisories, alerts and other annunciations that can impact compliance with an RNP AR APCH procedure; and the timely and correct responses to loss of RNP AR APCH capability in a variety of scenarios, embracing the scope of the RNP AR APCH procedures which the operator plans to complete. Such training may also use

approved flight training devices or simulators. This training must address the following specific elements:

(a) Procedures for verifying that each pilot's altimeter has the current setting before beginning the final approach of an RNP AR APCH procedure, including any operational limitations associated with the source(s) for the altimeter setting and the latency of checking and setting the altimeters approaching the FAF;

(b) The use of aircraft radar, TAWS, GPWS, or other avionics systems to support the pilot's track monitoring and weather and obstacle avoidance;

(c) The effect of wind on aircraft performance during RNP AR APCH procedures and the need to remain within RNP containment area, including any operational wind limitation and aircraft configuration essential to safely complete an RNP AR procedure;

(d) The effect of ground speed on compliance with RNP AR APCH procedures and bank angle restrictions impacting the ability to remain on the course centre line. For RNP AR APCH procedures, aircraft are expected to maintain the standard speeds associated with the applicable category;

(e) The relationship between RNP and the appropriate approach minima line on an approved published RNP AR APCH procedure and any operational limitations noted on the chart, e.g. temperature limits, RF leg requirements or loss of GNSS updating on approach;

(f) Concise and complete pilot briefings for all RNP AR APCH procedures and the important role CRM plays in successfully completing an RNP AR APCH procedure;

(g) Alerts from the loading and use of improper navigation accuracy data for a desired segment of an RNP AR procedure;

(h) The performance requirement to couple the autopilot/flight director to the navigation system's lateral and vertical guidance on RNP AR APCH procedures requiring an RNP of less than RNP 0.3;

(i) The importance of aircraft configuration to ensure the aircraft maintains any required speeds during RNP AR procedures;

(j) The events triggering a missed approach when using the aircraft's RNP capability;

(k) Any bank angle restrictions or limitations on RNP AR APCH procedures;

(l) The potentially detrimental effect on the ability to comply with an RNP AR APCH procedure when reducing the flap setting, reducing the bank angle or increasing airspeed;

(m) Pilot knowledge and skills necessary to properly conduct RNP AR APCH operations;

(n) Programming and operating the FMC, autopilot, auto throttles, radar, GPS, INS, EFIS (including the moving map), and TAWS in support of RNP AR APCH procedures;

(o) The effect of activating TOGA while in a turn;

(p) FTE monitoring and impact on go-around decision and operation;

(q) Loss of GNSS during a procedure;

(r) Performance issues associated with reversion to radio updating and limitations on the use of DME and VOR updating; and

(s) Flight crew contingency procedures for a loss of RNP capability during a missed approach. Due to the lack of navigation guidance, the training should emphasize the flight crew contingency actions that achieve separation from terrain and obstacles. The operator should tailor these contingency procedures to their specific RNP AR APCH procedures.

C.5 Evaluation module

C.5.1 Initial evaluation of RNP AR APCH operations knowledge and procedures.
The operator must evaluate each individual pilot's knowledge of RNP AR APCH procedures prior to employing RNP AR APCH procedures as appropriate. As a minimum, the review must include a thorough evaluation of pilot procedures and specific aircraft performance requirements for RNP AR APCH operations. An acceptable means for this initial assessment includes one of the following:

(a) an evaluation by an authorized instructor/evaluator or check-airman using an approved simulator or training device;

(b) an evaluation by an authorized instructor/evaluator or check-airman during line operations, training flights, proficiency checks, practical tests events, operating experience, route checks, and/or line checks; or

(c) LOFT/LOE programmes using an approved simulator that incorporates RNP operations that employ the unique RNP AR APCH characteristics (i.e. RF legs, RNP missed approach) of the operator's approved procedures.

C.5.2 Evaluation content.
Specific elements that must be addressed in this evaluation module are:

(a) demonstrate the use of any RNP limits that may impact various RNP AR APCH procedures;

(b) demonstrate the application of radio-updating procedures, such as enabling and disabling ground-based radio updating of the FMC (i.e. DME/DME and VOR/DME updating) and knowledge of when to use this feature. If the aircraft's avionics do not include the capability to disable radio updating, then the training must ensure the pilot is able to accomplish the operational actions that mitigate the lack of this feature;

(c) demonstrate the ability to monitor the actual lateral and vertical flight paths relative to the programmed flight path and complete the appropriate flight crew procedures when exceeding a lateral or vertical FTE limit;

(d) demonstrate the ability to read and adapt to a RAIM (or equivalent) forecast, including forecasts predicting a lack of RAIM availability;

(e) demonstrate the proper set-up of the FMC, the weather radar, TAWS, and moving map for the various RNP AR APCH operations and scenarios the operator plans to implement;

(f) demonstrate the use of pilot briefings and checklists for RNP AR APCH operations, as appropriate, with emphasis on CRM;

(g) demonstrate knowledge of and ability to perform an RNP AR APCH missed approach procedure in a variety of operational scenarios (e.g. loss of navigation or failure to acquire visual conditions);

(h) demonstrate speed control during segments requiring speed restrictions to ensure compliance with an RNP AR APCH procedures;

(i) demonstrate competent use of RNP AR APCH procedure plates, briefing cards, and checklists;

(j) demonstrate the ability to complete a stable RNP AR APCH operation including bank angle, speed control, and remain on the procedure's centre line; and

(k) knowledge of the operational limit for deviation below the desired flight path on an RNP AR APCH procedure and how to accurately monitor the aircraft's position relative to the vertical flight path.

C.6 Recurrent training

C.6.1 The operator should incorporate recurrent RNP training that employs the unique AR characteristics of the operator's approved procedures as part of the overall programme.

C.6.2 A minimum of two RNP AR APCHs, as applicable, must be flown by each pilot for each duty position (pilot flying and pilot monitoring), with one culminating in a landing and one culminating in a missed approach, and may be substituted for any required "precision-like" approach.

APPENDIX D NAVIGATION DATABASE

D.1 The procedure stored in the navigation database defines the lateral and vertical path. Navigation database updates occur every 28 days, and the navigation data in every update are critical to the integrity of every RNP AR APCH procedure. Given the reduced obstacle clearance associated with these procedures, validation of navigation data warrants special consideration. This section provides guidance for the operator's procedures for validating the navigation data associated with RNP AR APCH procedures.

D.2 Data process

D.2.1 The operator must identify the responsible manager for the data updating process within their procedures.

D.2.2 The operator must document a process for accepting, verifying and loading navigation data into the aircraft.

D.2.3 The operator must place their documented data process under configuration control.

D.2.4 Initial data validation

The operator must validate every RNP AR procedure before flying the procedure in instrument meteorological conditions (IMC) to ensure compatibility with their aircraft and to ensure the resulting path matches the published procedure. As a minimum, the operator must:

(a) compare the navigation data for the procedure(s) to be loaded into the RNP system with the published procedure;

(b) validate the loaded navigation data for the procedure, either in a simulator or in the actual aircraft in visual meteorological conditions (VMC). The depicted procedure on the map display must be compared to the published procedure. The entire procedure must be flown to ensure the path does not have any apparent lateral or vertical path disconnects, and is consistent with the published procedure; and

(c) once the procedure is validated, retain and maintain a copy of the validated navigation data for comparison to subsequent data updates.

D.2.5 Data updates

Upon receipt of each navigation data update, and before using the navigation data in the aircraft, the operator must compare the update to the validated procedure. This comparison must identify and resolve any discrepancies in the navigation data. If there are significant changes (any change affecting the approach path or performance) to any portion of a procedure and source data verifies the changes, the operator must validate the amended procedure in accordance with initial data validation.

D.2.6 Data suppliers

Data suppliers must have an LOA for processing navigation data (e.g. FAA AC 20 153, EASA Conditions for the issuance of Letters of Acceptance for navigation database Suppliers by the Agency, or equivalent). An LOA recognizes the data supplier as one whose data quality, integrity and quality management practices are consistent with the criteria of DO-200A/ED-76. The operator's supplier (e.g. the FMS company) must have a Type 2 LOA, and their respective suppliers must have a Type 1 or 2 LOA.

D.2.7 Aircraft modifications

If an aircraft system required for RNP AR APCH operations is modified (e.g. software change), the operator is responsible for validating of RNP AR APCH procedures using the navigation database and the modified system. This may be accomplished without any direct evaluation if the manufacturer verifies that the modification has no effect on the navigation database or path computation. If no such assurance from the manufacturer is available, the operator must conduct an initial data validation using the modified system noting that flight control computers, FMS OPS and display software changes are particularly critical.

APPENDIX E FLIGHT OPERATIONS SAFETY ASSESSMENT (FOSA)

E.1 Introduction

E.1.1 Traditionally safety is based on the TLS or Target Level of Safety of mono-pulse SSR (Secondary Surveillance Radar) and specified as a risk of collision of 10^{-7} per approach.

E.1.2 RNP AR APCH procedure uses a different methodology known as a Flight Operations Safety Assessment (FOSA) to provide flight safety level that is equivalent to the SSR TLS.

E.1.3 FOSA operational safety objective takes into consideration beyond aircraft navigation system. It combines quantitative and qualitative analyses and assessments of hazards for:

(a) navigation systems;
(b) aircraft systems;
(c) operational procedures;
(d) failure mitigations;
(e) operational environment.

E.2 FOSA relies on detailed criteria; **aircraft qualification**, **operator approval** and **instrument procedure design** are used to address the majority of general technical, procedural and processing factors. Additionally, technical and operational expertise and experience are inducted into the conduct and conclusion of FOSA.

E.3 ICAO Doc 9613 states: "A FOSA should be conducted where aircraft specific characteristics, operational environment, obstacle environment, etc., not already accounted for by the navigation specification and procedure design criteria (Doc 9905) warrant an additional review to ensure operational safety objectives are still achieved. The assessment should give proper attention to the interdependence of the elements of design, aircraft capability, crew procedures and operating environment."

E.4 Notwithstanding paragraph E.3 above, for added operational safety safeguard and to ensure adequate review of each RNP AR APCH procedure, a dedicated FOSA should be carried out for each RNP AR APCH procedure prior to commencing operations.

E.5 **Figure 1** below shows the various elements that contribute to the conduct and conclusion of a FOSA while **Figure 2** depicts the sequential steps in a FOSA process.

Figure 1

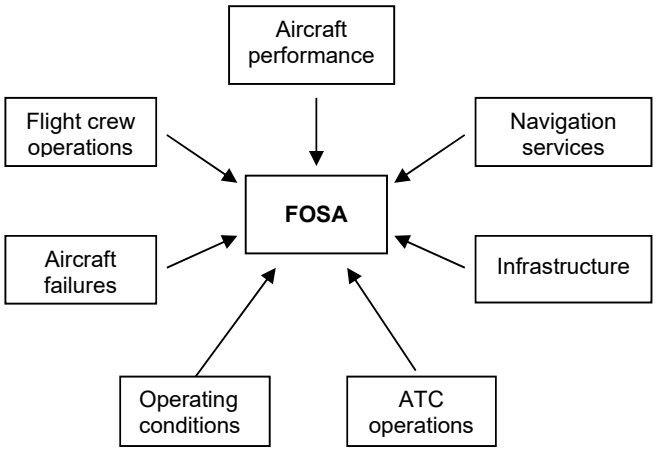
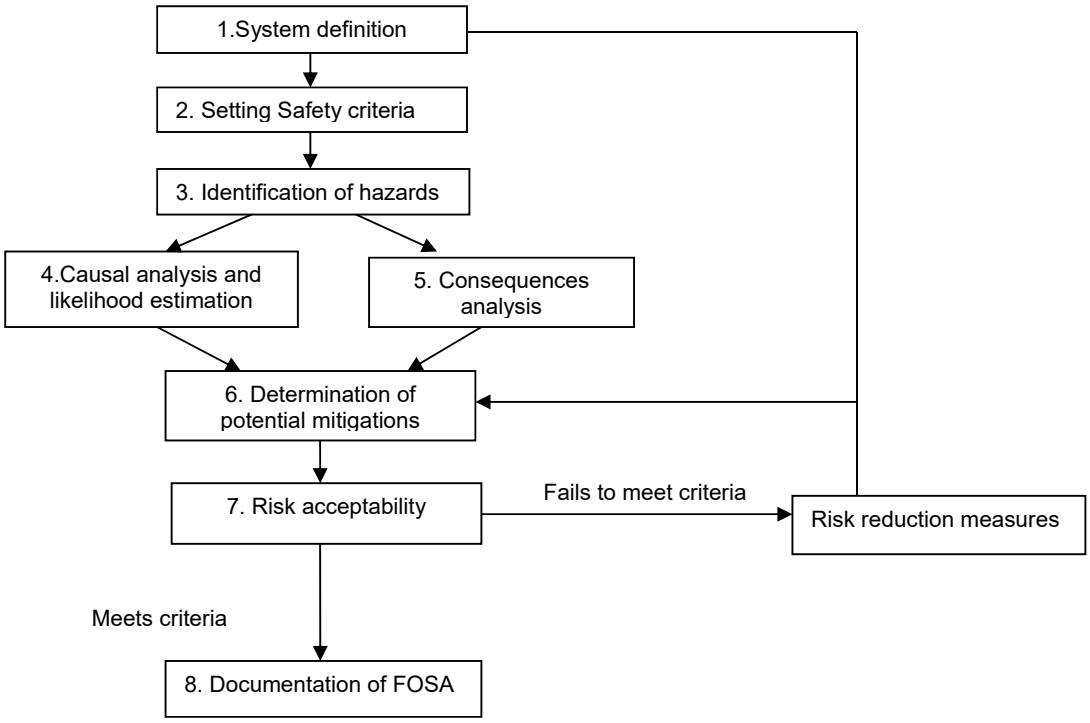


Figure 2



E.6 As safety of an RNP AR operation rests solely with the operator, the operator is also solely responsible for ensuring verification and implementation of the FOSA elements and process depicted in **Figure 1** and **Figure 2** in paragraph E.5 above.

E.7 To assist the operator in applying the FOSA criteria, a sample overview of the hazards and mitigations is provided below.

E.7.1 Hazard conditions

E.7.1.1 The following hazard conditions are examples of some of the more significant hazards and mitigations addressed by the specific aircraft and operational and procedural criteria of this navigation specification. Where operational requirements result in a change or adjustment to the RNP AR APCH procedure criteria, aircraft requirements or crew procedures, a unique FOSA should be conducted.

E.7.1.2 To facilitate the discussion of hazard conditions, it is necessary to first differentiate between normal and rare-normal or abnormal performance. In this context, the following paragraphs apply

E.7.1.3 Normal performance: Lateral and vertical performance are addressed in the aircraft requirements: aircraft and systems normally operate in standard configurations and operating modes, and individual error components are monitored/truncated through system design or crew procedure.

E.7.1.4 Rare-normal and abnormal performance: Lateral and vertical accuracy are evaluated for aircraft failures as part of the determination of aircraft qualification. Additionally, other rare-normal and abnormal failures and conditions for ATC operations, crew procedures, NAVAID infrastructure and operating environment are also assessed.

Where the failure or condition results are not acceptable for continued operation, mitigations are developed or limitations established for the aircraft, crew and/or operation.

E.7.2 Aircraft failures

E.7.2.1 Failure of a navigation system, FGS, flight instrument system for the approach or missed approach (e.g. loss of GNSS updating, receiver failure, autopilot disconnect, FMS failure) may be addressed through aircraft design or operational procedure to cross-check guidance (e.g. dual equipage for lateral errors, use of TAWS)

E.7.2.2 Crew procedure cross-check between two independent systems mitigates the malfunction of the air data system or altimetry

E.7.3 Aircraft performance

E.7.3.1 The aircraft qualification and operational procedures ensure that the performance is adequate on each approach. Consideration should be given to the impact of aircraft configuration during approach and any configuration changes associated with a go-around (e.g. flap retraction)

E.7.4 Navigation services

E.7.4.1 Aircraft requirements and operational procedures must be developed to address the risk that a NAVAID is used outside of designated coverage or while it is in test mode.

E.7.4.2 IFPs must be validated through flight validation specific to the operator and aircraft, and the operator is required to have a process defined to maintain validated data through updates to the navigation database

E.7.5 ATC operations

E.7.5.1 The operator is responsible for declining clearances for procedures assigned to non-approved aircraft.

E.7.5.2 The operator should satisfy himself that the ATC procedures are able to ensure obstacle clearance until the aircraft is established on the procedure and that the aircraft is not vectored to intercept on, or just prior to, the curved segments of the procedure.

E.7.6 Flight crew operations

E.7.6.1 Pilot entry and cross-check procedures are required to mitigate the risk of erroneous barometric altimeter setting

E.7.6.2 The pilot must verify that the loaded procedure matches the published procedure using the map display in order to mitigate the risk that an incorrect procedure is selected or loaded

E.7.6.3 Pilot training must emphasize the importance of flight control modes and the need for independent procedures to monitor for excessive path deviation.

E.7.6.4 The pilot must verify that the RNP loaded in system matches the published value

E.7.6.5 Pilot training must include balked landing or rejected landing at or below DA/H.

E.7.7 Infrastructure

E.7.7.1 GNSS satellite failure is evaluated during aircraft qualification to ensure obstacle clearance can be maintained, considering the low likelihood of this failure occurring

E.7.7.2 Relevant independent equipage (e.g. IRU) is required to address the loss of GNSS signals for RNP AR APCH procedures with RF legs, a lateral navigation accuracy less than RNP 0.3 and/or a lateral navigation accuracy for the missed approach less than RNP 1.0. For other approaches, operational contingency procedures can be used to approximate the published track and climb above obstacles

E.7.7.3 Aircraft and operational procedures are required to detect and mitigate the effects of any testing of ground NAVAIDs in the vicinity of the approach.

E.7.8 Operating conditions

E.7.8.1 Excessive speed, due to tailwind conditions, on RF legs will result in the inability to maintain track. This is addressed through aircraft requirements on the limits of command guidance, inclusion of 5 degrees of bank manoeuvrability margin, consideration of speed effect, and crew procedure to maintain speeds below the maximum authorized.

E.7.8.2 Nominal FTE is evaluated under a variety of wind conditions, and the crew procedure is to monitor and limit deviations to ensure safe operation.

E.7.8.3 The effect of extreme temperature (e.g. extreme cold temperatures, known local atmospheric or weather phenomena, high winds, significant turbulence) on barometric altitude errors on the vertical path is mitigated through the procedure design and crew procedures, with an allowance for aircraft that compensate for this effect to conduct procedures regardless of the published temperature limit. The effect of this error on minimum segment altitudes and the DA is addressed in an equivalent manner to all other approach operations.

E.8 FOSA uses the following safety assessment methodology (as per **Figure 2** Flowchart) for management of risk to ALARP (as low as reasonable possible) level and for achieving the TLS (target level of safety):

(a) System analysis and safety criteria definition
(b) Hazards identification
(c) Estimation of the hazard(s) consequences severity
(d) Estimation of the hazard(s) occurrence likelihood
(e) Risk estimation
(f) Risk acceptability/mitigation
(g) Safety assessment documentation

E.8.1 Tables below provide classification for Hazard Severity and Probability of Occurrence classification in conformity with accepted industry norm:

E.8.1.1 Hazard Severity

S/n	Severity	Description of consequences
(1)	Negligible	Failure Conditions that would have little or no effect on safety; for example, Failure Conditions that would not affect the operational capability of the airplane or increase crew workload.
(2)	Minor	Failure Conditions which would not significantly reduce airplane safety, and which involve crew actions that are well within their capabilities. Minor Failure Conditions may include, for example, a slight reduction in safety margins or functional capabilities, a slight increase in crew workload, such as routine flight plan changes, or some physical discomfort to passengers or cabin crew.
(3)	Major	Failure Conditions which would reduce the capability of the airplane or the ability of the crew to cope with adverse operating conditions to the extent that there would be, for example, a significant reduction in safety margins or functional capabilities, a significant increase in crew workload or in conditions impairing crew efficiency, or discomfort to the flight crew, or physical distress to passengers or cabin crew, possibly including injuries.
(4)	Hazardous	Failure Conditions, which would reduce the capability of the airplane or the ability of the crew to cope with adverse operating, conditions to the extent that there would be: A large reduction in safety margins or functional capabilities Physical distress or excessive workload such that the flight crew cannot be relied upon to perform their tasks accurately or completely; or Serious or fatal injury to a relatively small number of the occupants other than the flight crew.
(5)	Catastrophic	Failure Conditions, which would result in multiple fatalities, usually with loss of the airplane.

E.8.1.2 Probability of Occurrence

S/n	Frequency	Description of qualitative probability	Quantitative average per flight
(1)	Frequent	Failure Conditions are likely to occur many times or has occurred frequently.	Probability $<10^{-3}$
(2)	Probable	Failure Conditions are those anticipated to occur one or more times during the entire operational life of each airplane.	Probability $>10^{-3}$ $<10^{-5}$
(3)	Remote	Failure Conditions are those unlikely to occur to each airplane during its total life, but which may occur several times when considering the total operational life of a number of airplanes of the type.	Probability $>10^{-7}$ $<10^{-5}$
(4)	Extremely Remote	Failure Conditions are those not anticipated to occur to each airplane during its total life but which may occur a few times when considering the total operational life of all airplanes of the type.	Probability $>10^{-7}<10^{-9}$
(5)	Extremely Improbable	Failure Conditions are those so unlikely that they are not anticipated to occur during the entire operational life of all airplanes of one type.	Probability $<10^{-9}$

E.9 FOSA preparation

E.9.1 Step 1

Identification of hazards – The hazard elements identified in this AC are consistent with ICAO Doc 9613 Volume II Part C:

(1) Aircraft failures para E.7.2 / ICAO Doc 9613 para 6.4.2.5)
(2) Aircraft performance para E.7.3 (ICAO Doc 9613 para 6.4.2.6)
(3) Navigation services para E.7.4 (ICAO Doc 9613 para 6.4.2.7)
(4) ATC operations para E.7.5 (ICAO Doc 9613 para 6.4.2.8)
(5) Flight crew operations para E.7.6 (ICAO Doc 9613 para 6.4.2.9)
(6) Infrastructure para E.7.7 (ICAO Doc 9613 para 6.4.2.10)
(7) Operating conditions para E.7.8 (ICAO Doc 9613 para 6.4.2.11)

E.9.2 Step 2

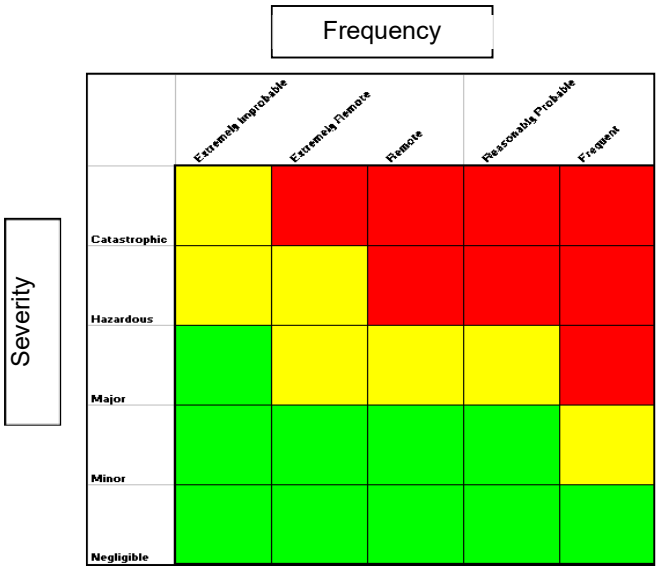
Estimation of severity of hazards – The hazard severity of is assessed in accordance with the definitions above and recorded.

E.9.3 Step 3

Estimation of frequency of hazard occurrence – Hazard frequency was then assessed according to the definitions above and recorded in the same table

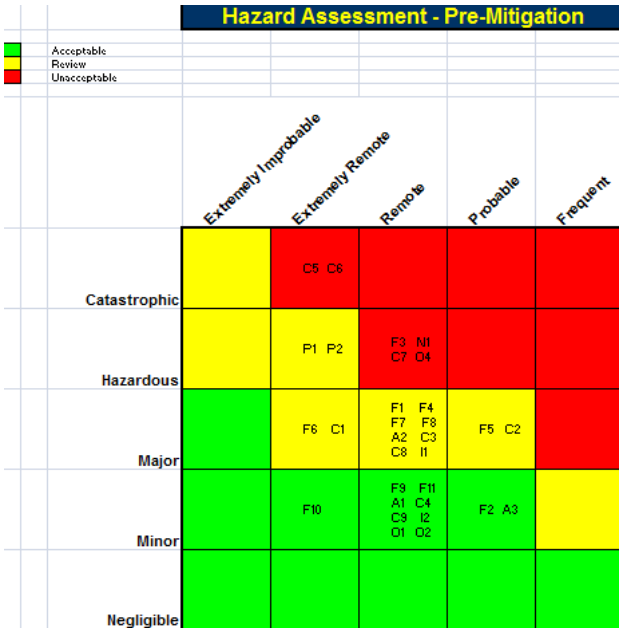
E.9.4 Step 4

Evaluation of the Risks (Before any mitigation actions taken) – Each hazard was evaluated in terms of severity and probability of occurrence, labelled, then charted in a 2-dimensional green, yellow, and red diagram according as a risk. Frequency is the horizontal axis and Severity is the vertical axis.



E.9.5 Step 5

Hazard categorization – Hazards in the green boxes are acceptable, yellow boxes require review and/or mitigation actions and red are unacceptable risks and require mitigation.

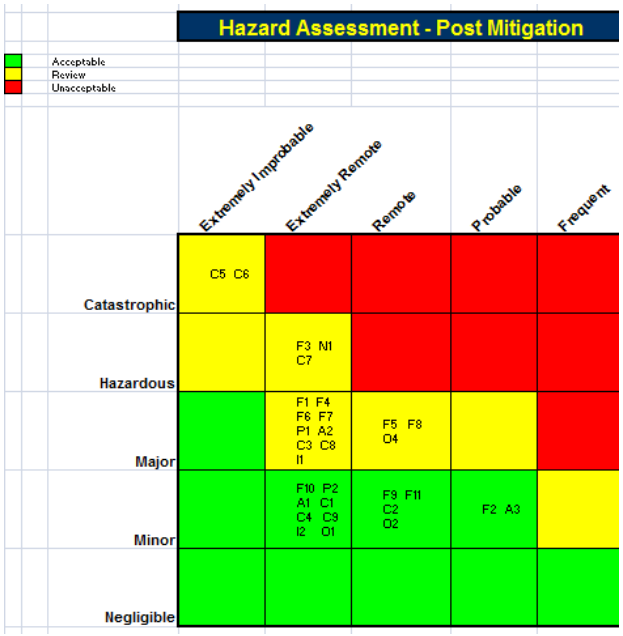


E.9.6 Step 6

Mitigation of Risk – For each risk identified, the mitigations so devised and accepted shall incorporated into operational procedures.

E.9.7 Step 7

Re-evaluation of Risks with Mitigation actions in place – Once mitigation actions are identified for a risk, the risk shall be re-graded under the assumption that the mitigation is in place and re-charted. The same convention for grading shall be applied in post-mitigation assessment and is displayed below.



E.8.8 Step 8

Sample of summary and report

The following FOSA worksheet summarizes and reports the results of the estimation of hazard severity and likelihood for an RNP operations at XXX airport. The hazards considered are addressed using the above defined convention. The left section of the table summarizes the results of the initial estimation of hazard severity and likelihood while the right section of the table sums up the final results and record the for RNP operations

Sample FOSA worksheet

Hazard Ident	AC 98-2-8 reference	ID	Hazard	Consequences	Severity	Probability	Mitigation	Post mitigation severity	Post mitigation severity	Follow-up Action	Monitoring and periodic Review
Aircraft failure	Para E.7.2	F1	Air Data / Altimetry system failure – display error	Increased CFIT risk	Major	Remote	1. Install dual system 2. System comparator 3. Crew procedure	Major	Extremely remote	Train crew in recognition and escape procedure	
	Para E.7.2	F2	Auto-pilot disconnect	1. Increased crew workload 2. Potential impact to FTE	Minor	Probable	1. AFM demo manual flt with NPS LNAV + FD to RNP0.10 2. Ops with A/P only 3. Crew training	Minor	Probable	Crew Training on escape procedure	
	Para E.7.2	F3	Dual FMC/CDU fail in IMC	Loss of position fixing	Hazardous	Remote	1. EGPWS TAWS 2. Pilot perform TAWS maneuver to MSA 3. Wx RDR in Terrain mode 4. Crew training / awareness	Hazardous	Extremely remote	Crew Training/ awareness/ escape maneuver exercise	
Aircraft Performance	Para E.7.3	P1	Engine failure								
	Para E.7.3	P2	Flaps asymmetry/ extension failure								
	Para E.7.3	P3									
Navigation Services	Para E.7.4	N1									
	Para E.7.4	N2									
ATC Operations	Para E.7.5	A1									
	Para E.7.5	A2									
Flt crew Operations	Para E.7.6	C1									
	Para E.7.6	C2									
Infrastructure	Para E.7.7	I1									
	Para E.7.7	I2									
Operating conditions	Para E.7.8	O1									
	Para E.7.8	O2									