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17 September 2018

Civil Aviation Authority of Singapore

Advisory Circular

OPERATIONAL APPROVAL FOR REQUIRED NAVIGATION PERFORMANCE APPROACH (RNP 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 guidance to demonstrate compliance with the requirements regarding, and information related to an application for, an approval for specified navigation performance operations in accordance with ANR-98.

Applicability
This AC is applicable to the operator seeking an approval for RNP 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-26.

EFFECTIVE DATE
This AC is effective from 1 October 2018.

OTHER REFERENCES

- ICAO Doc 4444 Procedures for Air Navigation Services – Air Traffic Management
- EASA AMC 20-27 Airworthiness approval and operational criteria for RNP APPROACH (RNP APCH) operations including APV BAROVNAV operations
- EASA AMC 20-28 Airworthiness approval and operational criteria related to Area Navigation for Global Navigation Satellite System approach operation to Localiser Performance with Vertical guidance minima using Satellite Based Augmentation System

1 INTRODUCTION

1.1 RNP APCH procedure is an ICAO designator for PBN approach procedures which are non RNP ARs.

1.2 An RNP APCH procedure requires GNSS as primary navigation support for the initial, intermediate and final segments. However, the missed approach segment may be supported by RNAV or conventional navaids such as, VOR, DME, NDB or even navigation dead reckoning.

2 CHARACTERISTICS OF RNP APCH

2.1 PBN approaches include, but not limited to, such types as RNAV (GNSS), LNAV, LNAV/VNAV and SBAS LPV procedures are types of RNP APCH operations and appended below are some examples:

(a) RNP APCH – LNAV
(b) RNP APCH – LNAV/VNAV (where a vertical guidance system is provided)
(c) RNP APCH – LPV (Localiser Performance with Vertical Guidance)
(d) RNP APCH – LP (SBAS approach where vertical guidance is not available)

2.2 The guidance carried in here is confined to RNP APCH – LNAV operation only and the following are its main characteristics:

(a) Instrument Approach with title of RNAV (GNSS)
(b) Approach path constructed as series of straight segments (T-Y approach)
(c) Descent to an MDA which is published as an LNAV minima
(d) Can be flown with TSO-C129a basic GNSS or RNP 0.3 capable aircraft
(e) Obstacle clearance lateral tolerances not based on RNP value
(f) Vertical flight guidance (e.g. BaroVNAV) may be added

3 SUPPORTING DOCUMENTATION

3.1 Airworthiness documents such as AFM, TC, STC, TCDS or manufacturer's Service Letter attesting to the aircraft system and functional performance capability meeting the standards a set out in TSO-C115b are acceptable for evaluation.

3.2 Aircraft with AFM or manufacturer's specific statement of compliance with such documents as EASA AMC 20-26 (RNP AR) and 20-27 (APV BaroVNAV) or FAA AC 90-101A for RNP SAAAR will be accepted without further Airworthiness compliance evaluation.

4 AIRCRAFT SYSTEM PERFORMANCE MONITORING AND ALERTING CRITERIA

4.1 Accuracy

4.1.1 The lateral and longitudinal TSE (Total System Error) of the onboard navigation system should be equal or better than –

(a) ±1NM for at least 95% of the flight time for the initial, intermediate and RNAV missed approach segments; and
(b) ±0.3NM for at least 95% of the flight time for the final approach segment.

4.1.2 To satisfy the accuracy requirement –

(a) for the initial and intermediate segments and RNAV missed approach of an RNP APCH, the 95% FTE should not exceed 0.5NM;
(b) for the final approach segment of an RNP APCH the 95% FTE should not exceed 0.25NM.

4.2 **Integrity**

4.2.1 Displaying misleading navigational or positional information to the flight crew during the approach is classified as a major condition under airworthiness regulations and the probability should be remote (i.e. $<10^{-5}$ per hour).

4.3 **Continuity**

4.3.1 Loss of function is classified as a minor failure condition if the operator can revert to a different navigation system and proceed to a suitable airport. Procedures containing conventional missed approach should ensure availability of the necessary air and ground based navigation equipment.

4.4 **Performance monitoring and alerting**

4.4.1 During initial, intermediate and missed approach segments the RNP system, (or the RNP system and pilot in combination) the aircraft should be able to provide an alert:
(a) if the accuracy requirement is not met, or
(b) if the probability that the lateral TSE exceeds 2NM is $>10^{-5}$.

4.4.2 During the final approach segment, the RNP system, (or the RNP system and pilot in combination) the aircraft should be able to provide an alert:
(a) if the accuracy requirement is not met, or
(b) if the probability that the lateral TSE exceeds 0.6NM is $>10^{-5}$.

4.5 **Signal-in-space**

4.5.1 The aircraft navigation system should be able to provide an alert if the probability of signal-in-space errors causing a lateral position error greater than –
(a) 2 NM exceeds 10^{-7} per hour for the initial and intermediate segments and for the RNAV missed approach, or
(b) 0.6NM exceeds 10^{-7} per hour for the final approach segment.

Note 1: There are no RNP APCH requirements for a missed approach based on conventional means (VOR, DME, NDB) or on dead reckoning.

Note 2: Compliance with the performance monitoring and alerting requirement does not imply automatic monitoring of a flight technical error. The on-board monitoring and alerting function should consist of at least a navigation system error (NSE) monitoring and alerting algorithm and a lateral deviation display enabling the crew to monitor the flight technical error (FTE). To this extent operational procedures are used to monitor FTE, the crew procedure, equipment characteristics, and installation are evaluated for their effectiveness and equivalence as described in the functional requirements and operating procedures. Path definition error (PDE) is considered negligible due to the quality assurance process and crew procedures

Note 3: The following systems meet the requirements for accuracy, integrity and continuity:

(a) GNSS standalone systems approved in accordance with:
(i) ETSO-C129a Class A1 or
(ii) ETSO-C146 () / TSO-C146 () Class Gamma, operational class 1, 2 or 3.

(b) GNSS sensors used in multi-sensor system (e.g. FMS) approved in accordance with:
(1) TSO-C129 () / ETSO-C129 () Class B1, C1, B3, C3 or
(2) ETSO-C145 () / TSO-C145 () class 1, 2 or 3.
(c) Multi-sensor systems using GNSS approved in accordance with TSO-C115b, having been demonstrated for RNP capability.

Note 4: For GNSS receivers approved in accordance with ETSO-129 () / TSO-129 () capability for FDE (satellite detection and exclusion) functions are recommended.

5 FUNCTIONAL REQUIREMENTS

5.1 The table below itemises the required functions for RNP APCH.

Item	Required Function
5.1.1	Navigation data, including a to/from indication, and a failure indication, should be displayed on a lateral deviation display (CDI, (E) HSI) and/or a navigation map display. These should be used as primary flight instruments for the navigation of the aircraft, for manoeuvre anticipation and for failure/status/integrity indication: (a) the displays should be visible to the pilot and located in the primary field of view (±15 degrees from the pilot's normal line of sight) when looking forward along the flight path; (b) the lateral deviation display scaling should agree with any alerting and annunciation limits; (c) the lateral deviation display should also have a full-scale deflection suitable for the current phase of flight and is based on the TSE requirement. scaling is (i) ±1NM for the initial and intermediate segments and (ii) ±0.3NM for the final segment; (d) the display scaling may be set automatically by default logic or set to a value obtained from a navigation database. The full-scale deflection value should be known or should be available for display to the pilot commensurate with approach values; (e) as an alternate means, a navigation map display should give equivalent functionality to a lateral deviation display with appropriate map scales (scaling may be set manually by the pilot). To be approved, the navigation map display has to meet the TSE requirements; (f) it is highly recommended that the course selector of the deviation display is automatically slaved to the RNAV computed path; Note: This does not apply for installations where an electronic map display contains a graphical display of the flight path and path deviation. (g) a flight director and/or autopilot is not required for this type of operation, however, if the lateral TSE cannot be demonstrated without these systems, it becomes mandatory. In this case, coupling to the flight director and/or automatic pilot from the RNAV system should be clearly indicated at the cockpit level; and (h) enhanced navigation display (e.g. electronic map display or enhanced EHSI) to improve lateral situational awareness, navigation monitoring and approach verification (flight plan verification) could become mandatory if the RNAV installation doesn't support the display of information necessary for the accomplishment of these crew tasks.

5.1.2	The capability to continuously display to the pilot flying, on the primary flight instruments for navigation of the aircraft (primary navigation display), the RNAV computed desired path and aircraft position relative to the path. Note: Where the minimum flight crew is two pilots, the means for the pilot monitoring to verify the desired path and the aircraft position relative to the path has to be provided.
5.1.3	A navigation database, containing current navigation data officially promulgated for civil aviation, (a) which can be updated in accordance with the AIRAC cycle and (b) from which approach procedures can be retrieved in their entirety and loaded into the RNAV system. The stored resolution of the data has to be sufficient to achieve the required track-keeping accuracy. The database has to be protected against pilot modification of the stored data. Note: When a procedure is loaded from the database, the RNAV system is required to fly it as published. This does not preclude the flight crew from having the means to modify a procedure or route already loaded into the RNAV/GNSS system as permitted by paragraph 10. However, the procedure stored in the database should not be modified and has to remain intact within the database for future use and reference.
5.1.4	The means to display the validity period of the navigation data to the flight crew.
5.1.5	The means to retrieve and display data stored in the navigation database relating to individual waypoints and navigation aids, to enable the pilot to verify the procedure to be flown.
5.1.6	Capacity to load from the database into the RNAV system the whole approach to be flown.
5.1.7	The means to display the either in the pilot's FOV or on a readily accessible display page on the RNAV CDU, readily visible to the flight crew: (a) the identification of the active (To) waypoint; (b) the distance and bearing to the active (To) waypoint; and (c) the ground speed or time to the active (To) waypoint.
5.1.8	The means to display the following items on a readily accessible display page: (a) the display of distance between flight waypoints; (b) the display of distance to go; (c) the display of along-track distances; and (d) the active navigation sensor type if there is another sensor in addition to the GNSS sensor.
5.1.9	Capability to execute a "Direct to" function.
5.1.10	Capability for automatic leg sequencing with display of sequencing to the flight crew.
5.1.11	Capability to execute database procedures including: (a) Fly over and (b) Fly by turns
5.1.12	Capability to automatically execute leg transitions and maintain tracks consistent with the following ARINC 424 path terminators, or their equivalent: (a) ARINC 424 path terminators (b) Initial fix (IF) (c) Track to fix (TF) (d) Direct to fix (DF) Note: Path terminators are defined in ARINC Specification 424, and their application is described in more detail in RTCA DO-236B / EUROCAE ED-75(B) and RTCA DO-201A / EUROCAE ED-77, and EUROCONTROL Document NAV.ET1.ST10.

5.1.13	Capability to display an indication of the RNAV system failure, including the associated sensors, in the pilot's primary field of view.
5.1.14	Capability to indicate to the flight crew when NSE alert limit in exceeded (alert provided by the "on-board performance monitoring and alerting function").

6 OPERATING PROCEDURES

6.1 Pre-flight planning

6.1.1 The operator has to ensure that the flight crew conducting RNP APCH procedures files the appropriate flight plan suffixes and that the on-board nav data are current and include appropriate procedures.

Note: The operator should have a procedure to cope with such in-flight navdata change due to AIRAC cycle.

6.1.2 In addition to the normal pre-flight planning checks, the operator has to ensure the following:

(a) the flight crew uses only approach procedure selected from a valid navigation database not prohibited by the operator or NOTAM;

(b) the flight crew are trained and have sufficient means to navigate and land at the destination or at an alternate aerodrome in the case of loss of RNP APCH airborne capability;

(c) the flight crew takes into account of any NOTAMs or operator briefing material that could adversely affect the aircraft system operation, or the availability or suitability of the procedures at the airport of landing, or any alternate airport; and

(d) for missed approach procedures based on conventional means (VOR, NDB), the flight crew checks that the appropriate airborne equipment required for this procedure is installed in the aircraft and is operational and that the associated ground-based nav aids are operational.

6.1.3 The availability of the nav aid infrastructure, required for the intended routes, including any non-RNAV contingencies, has to be confirmed for the period of intended operations using all available information. Since GNSS integrity (RAIM or SBAS signal) is required by Annex 10, Volume I, the availability of these should also be determined as appropriate. For aircraft navigating with SBAS receivers (all TSO-C145(b) / C146(b)), the operator should check appropriate GPS RAIM availability in areas where the SBAS signal is unavailable.

6.2 ABAS availability

6.2.1 RAIM availability prediction should take into account the latest GPS constellation NOTAMs and avionics model (when available). The service may be provided by the ANSP, avionics manufacturer, and other entities, or through an airborne receiver RAIM prediction capability. The operator should ensure that the flight crew are familiar with the RAIM availability prediction information for the intended route.

6.2.2 The operator should provide clear instruction that in the event of a predicted, continuous loss of appropriate level of fault detection of more than five minutes for any part of the RNP APCH operation, the flight planning should be revised (e.g. delaying the departure or planning a different departure procedure).

6.2.3 The operator should be fully aware that RAIM or GPS navigation may altogether be lost while airborne which may require reversion to an alternative means of navigation and should therefore ensure that the flight crew have the capability to navigate (potentially to an alternate destination) in case of failure of GPS navigation.

6.3 Prior to commencing the procedure

6.3.1 The operator has to ensure in the procedure that before the IAF and in compatibility with crew workload, the flight crew verifies the correct navdata procedure is displayed by comparison with the approach charts. The checks include –

(a) the waypoint sequence; and

(b) reasonableness of the tracks and distances of the approach legs, and the accuracy of the inbound course and length of the final approach segment.

6.3.2 The crew have to also check using the published charts, the map display or control display unit (CDU), to determine which waypoints are fly-by and which are flyover.

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

6.3.4 For an RNP system with ABAS requiring barometric corrected altitude, the current airport barometric altimeter setting should be input at the appropriate time and location, consistent with the performance of the flight operation.

6.3.5 When the operation is predicated on the availability of ABAS, the flight crew should perform a new RAIM availability check if ETA is more than 15 minutes different from the ETA used during the pre-flight planning. This check is also processed automatically 2 NM before the FAF for an E/TSO-C129a Class A1 receiver.

6.3.6 The operator has to ensure that the flight crew are fully aware of the limitations of the RNP system with regard to “Direct to” tactical intervention clearance by ATC that –

(a) the manual entry of coordinates into the RNAV system by the flight crew for operation within the terminal area is not permitted; and

(b) “Direct to” clearances may be accepted to the intermediate fix (IF) provided that the resulting track changes at the IF does not exceed 45 degrees.

(c) “Direct to” clearance to FAF is not acceptable.

6.3.7 The operator has to ensure that the flight crew does not revise the lateral definition of the flight path between the FAF and the missed approach point (MAPt).

6.4 During the procedure

6.4.1 The aircraft has to be established on the final approach course no later than the FAF before starting the descent (to ensure terrain and obstacle clearance).

6.4.2 The operator has to ensure that the flight crew check the approach mode annunciator (or equivalent) is properly indicating approach mode integrity within 2 NM before the FAF.

Note: This will not apply for certain RNP systems (e.g. aircraft already approved with demonstrated RNP capability). For such systems, other means are available including electronic map displays, flight guidance mode indications, etc., which clearly indicate to the crew that the approach mode is activated.

6.4.3 The flight crew have to select the appropriate displays so that the following information can be monitored:
(a) the RNAV-computed desired path (DTK); and
(b) the aircraft position relative to the path (cross-track deviation) for FTE monitoring.

6.4.4 The procedure has to be discontinued –
(a) if the navigation display is flagged invalid; or
(b) in case of loss of integrity alerting function; or
(c) before passing FAF the integrity alerting function annunciation is not available; or
(d) if FTE is excessive.

Note: For multi-sensor system that includes demonstrated RNP capability without GNSS, it may not be necessary to discontinue the procedure. The manufacturer's documentation should be referred to in order to determine the extent the system may be used in such configuration.

6.4.5 The missed approach has to be flown in accordance with the published procedure. Use of the RNAV system during the missed approach is acceptable, provided that –
(a) the RNAV system is operational (e.g no loss of function, no NSE alert, no failure indication); and
(b) the whole procedure (including the missed approach) is loaded from the navigation database.

6.4.6 The operator has to endure that during the RNP APCH procedure, the flight crew uses a lateral deviation indicator, flight director and/or autopilot in lateral navigation mode and checks that lateral deviation indicator (CDI) scaling (full-scale deflection) is suitable for the navigation accuracy associated with the various segments of the procedure i.e.:
(a) The operator has to ensure that during the RNP APCH procedure, the flight crew uses a lateral deviation indicator, flight director and/or autopilot in lateral navigation mode and checks that lateral deviation indicator (CDI) scaling (full-scale deflection) is suitable for the navigation accuracy associated with the various segments of the procedure i.e.
(i) ±1.0 NM for the initial and intermediate segments,
(ii) ±0.3 NM for the final approach segment, and
(iii) ±1.0 NM for the missed approach segment.
(b) Unless authorised by ATC to deviate or under emergency conditions, the flight crew has to maintain procedure centrelines as depicted by on-board lateral deviation indicators and/or flight guidance during the whole approach procedure.
(c) For normal operations, cross-track error/deviation (the difference between the RNAV system computed path and the aircraft position relative to the path) should be limited to ±½ the navigation accuracy associated with the procedure (i.e. 0.5 NM for the initial and intermediate segments, 0.15 nm for the final approach segment, and 0.5 NM for the missed approach segment). Brief deviations from this standard (e.g. overshoots or undershoots) during and immediately after turns, up to a maximum of one-times the navigation accuracy (i.e. 1.0 NM for the initial and intermediate segments), are allowable.

6.4.7 When BaroVNAV is used for vertical path guidance during the final approach segment, deviations above and below the BaroVNAV path should not exceed +30 m / –15 m (+100 ft /–50 ft), respectively.

6.4.8 Unless positive visual references are acquired to continue the approach, the flight crew have to execute a missed approach if the lateral deviations or vertical deviations exceed the above criteria.

6.5 General operating procedures

6.5.1 Unless operational approval to for RNP APCH is obtained from the CAAS, the operator has to ensure that the flight crew do not request or engage in RNP APCH operations.

6.5.2 The operator has to ensure the flight crew comply with any instructions or procedures identified by the manufacturer as necessary for safe operation.

6.5.3 Unless specifically approved by CAAS the operator has to ensure that the RNP APCH approach is flown with flight director and autopilot systems.

6.6 Contingency procedures

6.6.1 The operator has to develop contingency procedures to cope with loss of the RNP APCH capability during the approach. This procedure shall require the flight crew to notify the ATC of loss of RNP APCH capability as well as the procedural course of action

6.6.2 The contingency procedure should contain instruction to the flight crew during communications failure to continue with the RNP APCH in accordance with the published loss of communication procedure.

7 PILOT KNOWLEDGE AND TRAINING

7.1 The list below describes the scope of training necessary for proficiency of RNP APCH operations. Subject to CAAS's discretion, an operator who is RNAV experienced may submit a truncated version for approval.

(a) the concept of PBN operation and contents of this BaroVNAV Attachment;
(b) the meaning and proper use RNP systems;
(c) ICAO Doc 8168 Vol 1 Chapter 1 Table I-4-1-2 Speeds for procedures calculations.
(d) procedure characteristics, as determined from chart depiction and textual description
(e) knowledge regarding depiction of waypoint types (flyover and fly-by) and path terminators (IF, TF, DF) used by the operator) as well as associated aircraft flight paths;
(f) knowledge of the required navigation equipment in order to conduct RNP APCH operations;
(g) Knowledge of RNP system specific information:
    (i) levels of automation, mode annunciations, changes, alerts, interactions, reversions, and degradation;
    (ii) functional integration with other aircraft systems;
    (iii) the meaning and appropriateness of route discontinuities as well as related flight crew procedures;
    (iv) monitoring procedures for each phase of flight;
    (v) types of navigation sensors utilised by the RNP system and associated system prioritisation/weighting/logic;
    (vi) turn anticipation with consideration to speed and altitude effects; and
    (vii) interpretation of electronic displays and symbols.

(h) knowledge of RNAV equipment operating procedures including how to perform the following actions:
    (i) verify the currency of the aircraft data;
    (ii) verify the successful completion of RNP system self-tests;
    (iii) initialise RNP system position;
    (iv) retrieve and fly an RNP APCH;
    (v) adhere to speed and/or altitude constraints associated with an approach procedure;
    (vi) fly interception of an initial or intermediate segment of an approach following ATC notification;
    (vii) verify waypoints and flight plan programming;
    (viii) fly direct to a waypoint;
    (ix) determine cross-track error/deviation;
    (x) insert and delete route discontinuity;
    (xi) perform gross navigation error check using conventional navigation aids in accordance with approved procedures; and
    (xii) change arrival airport and alternate airport;
(i) knowledge of operator-recommended levels of automation for phase of flight and workload, including methods to minimise cross-track error to maintain procedure centreline;
(j) knowledge of radio telephony phraseology for RNP applications; and
(k) ability to conduct contingency procedures following RNP system failures.

8 NAVIGATION DATABASE INTEGRITY

8.1 The navigation database integrity should comply with RTCA DO-200A / EUROCAE ED-76 standards. The operator has to ensure that the navigation database supplier or vendor to the operator hold valid Type LOA (Letter of Approval issued in accordance with FAA AC 20–153B or EASA Part DAT.

8.2 The operator should also conduct additional nav data check of any new or changed procedure. Reports of navigation error must be acted upon promptly. Repeated navigation error occurrences attributed to a specific piece of navigation equipment may result in cancellation of the approval for use of that equipment.