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Airworthiness EAC 91-16 and Operational Approval of P-RNAV Systems for use in designated airspace where P-RNAV is implemented

PREAMBLE

As a further development of the concept of area navigation within the European region, Precision Area Navigation (P-RNAV) is to be implemented in terminal airspace as an interim step to obtain increased operating capacity together with environmental benefits arising from route flexibility.

In accordance with the EUROCONTROL Navigation Strategy, the carriage of RNAV equipment capable of precision navigation will be optional enabling the initial application of P-RNAV in terminal airspace for suitably equipped aircraft. The P-RNAV application addresses a navigation performance for track keeping accuracy but does not satisfy all aspects of the Required Navigation Performance (RNP) concept promulgated by ICAO in documents 9613 and 9650. P-RNAV is expected to be progressively replaced by RNPRNAV operations from about 2005.

This Advisory Circular provides guidance material for the airworthiness approval of area navigation systems and their use for P-RNAV operations. The guidance is consistent with EUROCONTROL publications dealing with related operational and functional requirements, and with the design of terminal airspace procedures for DME/DME and GNSS based area navigation.

1. PURPOSE

The guidance material of this Advisory Circular does not constitute a regulation but, when followed in its entirety, does establish an acceptable means that can be used to obtain airworthiness approval of a P-RNAV system, and to obtain the necessary operational approval for its use in designated European airspace. An applicant may elect to use an alternative means of compliance. However, that means of compliance must meet the objectives of this Advisory Circular and be acceptable to the responsible authority. Compliance with this Advisory Circular is not mandatory hence use of the terms *shall* and *must* apply only to an applicant who elects to comply with this Advisory Circular as the means to obtain airworthiness and operational approval.

This Advisory Circular may be amended periodically and will be replaced in due course by appropriate ECAR Requirements, Advisory or Interpretative and Explanatory Material.

2. SCOPE

2.1 The guidance material includes airworthiness and operational approval criteria related to P-RNAV systems intended to be used under Instrument Flight Rules, including Instrument Meteorological Conditions, in designated European airspace. It addresses general certification considerations including functional requirements, accuracy, integrity, continuity of function, and system limitations together with operational considerations.

2.2 The guidance material is applicable to P-RNAV operations in terminal airspace and, where implemented by states, to en-route navigation. For the purposes of this Advisory Circular, PRNAV procedures are expected to apply to operations including departures, arrivals, and approaches up to the point of the Final Approach Waypoint (FAWP). For the immediate future, holding patterns are expected to be flown with conventional procedures. For PRNAV operations in terminal airspace, obstacle clearance protection, up to the FAWP, will assume that aircraft comply with the P-RNAV accuracy requirements. It should be noted, however, that the navigational accuracy required for the final flight phase of the intermediate segment will be influenced by the transition to, and requirements of the subsequent flight phase.

2.3 The final approach, i.e. from the FAWP down to the runway threshold, together with the associated missed approach, will be addressed in a future Advisory Circular.

Similarly, a future Advisory Circular will address the application of the concepts of RNP-RNAV.

2.4 The P-RNAV application addresses a navigation performance for track keeping accuracy but does not satisfy all aspects of the Required Navigation Performance concept
promulgated by ICAO in documents 9613 and 9650.

2.5 This Advisory Circular discusses operational aspects of vertical navigation but does not give certification criteria for such systems as vertical navigation capability is not mandated for PRNAV.

2.6 Section 3.2 of this Advisory Circular refers to documents which contribute to the understanding of the P-RNAV concept and which may support an application for approval. However, it is important that an applicant evaluates his aircraft system and proposed operational procedures against the criteria of this Advisory Circular. Unless stated to the contrary in this Advisory Circular, systems and procedures previously approved as compliant with earlier area navigation guidance material will need to be re-evaluated to identify where additional approval effort , if any, is needed.

2.7 Compliance with this Advisory Circular provides a basis for, but by itself does not constitute, an operational approval to conduct P-RNAV operations. Aircraft operators should apply to ECAA for such an approval.

2.8 A glossary of terms and acronyms used in this Advisory Circular is given in Appendix A.

3. REFERENCE DOCUMENTS

3.1 Related Requirements

ECAR 91.709

3.2 Related Guidance Material

3.2.1 ICAO

ICAO Doc 8168-OPS/611 Aircraft Operations (PANS OPS).

ICAO documents 9613 and 9650.

4. ASSUMPTIONS

Applicants should note that this guidance material is based on the following assumptions concerning the measures taken by the responsible airspace authorities to safeguard PRNAV operations in the European region:

(a) All terminal P-RNAV procedures:

(1) Are consistent with the relevant parts of ICAO Doc 8168 PANS OPS ;

(2)Are designed following the guidelines of EUROCONTROL document NAV.ET1.ST10 ‘Guidance Material for the Design of Procedures for DME/DME and GNSS Area Navigation’, as amended, or equivalent material;

(3) Take account of the functional and performance capabilities of RNAV systems and their safety levels as detailed in this Advisory Circular;

Note: Particular attention should be given to the constraints implied by the certification objectives of paragraph 6.

(4) Take account of the lack of a mandate for vertical navigation by ensuring that traditional means of vertical navigation can continue to be used; and

(5) support integrity checking by the flight crew by including, on the charts, fix data (e.g. range and bearing to navigational aids) from selected waypoints.

(b) All routes/procedures are based upon WGS 84 co-ordinates.

(c) The design of a procedure and the supporting navigation infrastructure (including consideration for the need of redundant aids) have been assessed and validated to the satisfaction of the responsible airspace authority demonstrating aircraft compatibility and adequate performance for the entire procedure. This assessment includes flight checking where appropriate.

(d) If the procedure allows a choice of navigation infrastructure, e.g. DME/DME, VOR/DME or GNSS, the obstacle clearance assessment has been based upon the infrastructure giving the poorest precision.

(e) The required navigation aids critical to the operation of a specific procedure, if any, i.e. those which must be available for the required performance, are identified in the AIP and on the relevant charts. Navigation aids that must be excluded from the operation of a specific procedure, if any, are identified in the AIP and on the relevant charts.

Note: This may include required VOR/DME beacons.

(f) Barometric altitude compensation for temperature effects is accounted for in accordance with current approved operating practices. (Temperature compensation is not addressed as a special P-RNAV consideration in this Advisory Circular).

(g) The supporting navigation infrastructure, including the GNSS space segment, is monitored and maintained and timely warnings (NOTAM) are issued for non-availability of a P-RNAV procedure, if navigational aids, identified in the AIP as critical for a specific P-RNAV procedure, are not available.

(h) For procedures which allow aircraft to rely only on GNSS, (see paragraph 5.1), the acceptability of the risk of loss of P-RNAV capability for multiple aircraft due to satellite failure or RAIM holes, has been considered by the responsible airspace authority. Similarly, the risk is considered where a single DME supports multiple P-RNAV procedures.

(i) The particular hazards of a terminal area and the feasibility of contingency procedures following loss of P-RNAV capability are assessed and, where considered necessary, a requirement for the carriage of dual P-RNAV systems is identified in the AIP for specific terminal P-RNAV procedures, e.g. procedures effective below the applicable minimum obstacle clearance altitude, or where radar performance is inadequate for the purposes of supporting P-RNAV.

Note: Airspace authorities may need to amend their national legal code to establish the power to require that P-RNAV or dual P-RNAV systems be carried in airspace notified for the purposes of these requirements.

(j) Where reliance is placed on the use of radar to assist contingency procedures, its performance has been shown to be adequate for that purpose, and the requirement for a radar service is identified in the AIP.

(k) RT phraseology appropriate to P-RNAV operations has been promulgated.

(l) Navigation aids, including TACAN, not compliant with ICAO Appendix 10, are excluded from the AIP.

5. SYSTEM DESCRIPTION

5.1 Lateral Navigation

5.1.1 For lateral navigation, the RNAV equipment enables the aircraft to be navigated in accordance with appropriate routing instructions along a path defined by waypoints held in an on-board navigation database.

5.1.2 For the purposes of this Advisory Circular, P-RNAV operations are based upon the use of RNAV equipment that automatically determines aircraft position in the horizontal plane using inputs from the following types of positioning sensor (in no specific order of priority):

(a) Distance Measuring Equipment giving measurements from two or more groundstations (DME/DME).

(b) Very high frequency Omni-directional Radio range with a co-located DME (VOR/DME) where it is identified as meeting the requirements of the procedure.

(c) Global Navigation Satellite System (GNSS).

(d) Inertial Navigation System (INS) or Inertial Reference System (IRS), with automatic updating from suitable radio based navigation equipment.

Notes:

(1) LORAN-C is not an acceptable navigation sensor for terminal airspace operations.

(2) TACAN beacons may be included in the on-board navigation database and used to supplement DME provided they meet ICAO Appendix 10 Standards and are listed in the AIP.

(3) The term GNSS refers to the US Department of Defence Global Positioning System (GPS) with barometric altitude augmentation and Receiver Autonomous Integrity Monitoring (RAIM), or to a GPS with Aircraft Based Augmentation System (ABAS), or Space Based Augmentation System (SBAS), e.g. EGNOS. See also, Appendix A, paragraphs 2.4 and 2.5.

(4) Limitations for the use of inertial data, as the means of determining aircraft position during short periods of loss of radio updating, are discussed in further detail in paragraph 8.4.

5.1.3 Navigation parameters, such as distance and bearing to a waypoint, are computed from the aircraft position and the location of the waypoint. Guidance, referenced to the path between two waypoints, is then output to navigation displays and guidance systems to enable the desired path to be followed.

5.2 Vertical Navigation

Although this Advisory Circular does not set criteria for the approval of vertical navigation systems, a brief description is included in Appendix D to aid understanding of the overall navigation function and the relationship of VNAV to this guidance material.

6. AIRWORTHINESS CERTIFICATION OBJECTIVES FOR P-RNAV SYSTEMS

The following performance certification criteria are defined for the airborne systems on the basis that the Assumptions of Section 4 are valid.

6.1 Accuracy

During operations on routes or in areas notified exclusively for P-RNAV equipped aircraft, the lateral track keeping accuracy of the on-board P-RNAV system shall be equal to or better than +/- 1 NM for 95% of the flight time.

Notes:

(1) The track keeping accuracy is dependent on the navigation system error (a combination of path definition error, position estimation error and display error) and Flight Technical Error (FTE). It corresponds to the accuracy component of RNP-1 and RNP-1 RNAV.

(2) For the purposes of obstacle clearance, a FTE of ± 0.5NM is assumed for the departure (except at the departure end of the runway where, in accordance with PANS-OPS Doc 8168, Volume II, Part II, 7.3.2 and 8.1, a value of ±0.1NM is assumed), ±1NM for the initial and intermediate segments, and 2NM for en-route.

(3) The objective behind this chosen level of performance is to enable RNAV systems based on DME/DME, as currently installed in many aircraft, to be used in terminal airspace on P-RNAV procedures designed according to the published criteria without further evaluation of system accuracy.

(4) Provided that the assumption of paragraph 4(c) has been shown to be valid in respect of typical DME performance, then, for RNAV systems that have been declared (e.g. in the Aircraft Flight Manual) to be compliant with the 2D navigation accuracy criteria of FAA AC 90-45A, AC 20- 130(), FAA TSO-C115(), or JAA JTSO-2C115(), the intent of this paragraph is considered as satisfied and no further accuracy demonstration is required. However, such a Flight Manual statement, by itself, does not constitute an airworthiness approval for P-RNAV and compliance with all other criteria of this Advisory Circular will need to be shown.

6.2 Integrity

With respect to the airborne system, the probability of displaying hazardously misleading navigational or positional information simultaneously to both pilots shall be Remote.

Notes:

(1) In the context of P-RNAV operations in the terminal area, *hazardous* should be interpreted as involving misleading information without a timely warning and which, in the absence of other cues, is unlikely to be detected by the flight crew.

(2) A safety objective of *Extremely Remote* will continue to be applicable to a precision approach on the final segment i.e. from the FAWP down to the runway.

(3) Systems approved for RNP operations have capabilities exceeding that required for PRNAV operations. These systems provide higher navigation integrity through implementation of containment and by giving the flight crew better awareness of accuracy through the availability of estimated position uncertainty.

6.3 Continuity of Function

With respect to the airborne systems, it shall be shown that:

(a) The probability of loss of all navigation information is Remote.

(b)The probability of non-restorable loss of all navigation and communication functions is Extremely Improbable.

7. FUNCTIONAL CRITERIA

7.1 Required Functions

The following are the minimum system functions required for P-RNAV operations:

7.1.1- Display elements, e.g. CDI, (E)HSI, each with a lateral deviation display, To/From flag, and failure indicator, for use as primary flight instruments for navigation of the aircraft, for manoeuvre anticipation, and for failure/status/integrity indication, visible to the pilot and

located in the primary field of view when looking forward along the flight path. The course selector of the deviation display shall be automatically slaved to the RNAV computed path. The deviation display shall have a full-scale deflection suitable for the phase of flight and based on the required track keeping accuracy. Scaling may be set automatically by default logic or to a value obtained from a navigation database. The full-scale deflection value must be known or made available for display to the flight crew. For PRNAV operations, a value of ±1 NM is acceptable. An acceptable alternative is a navigation map display, readily visible to the flight crew, with appropriate map scales and giving equivalent functionality to the lateral deviation display, except that scaling may be set manually by the pilot.

Note: JAA JTSO-C129a, for GPS equipment, prescribes scaling values of 5.0 NM for enroute,

1.0 NM for terminal airspace, and 0.3 NM for a non-precision approach.

7.1.2- Capability to continuously display to the pilot flying, on the primary flight instruments for navigation of the aircraft, the RNAV computed desired path (DTK) and aircraft position relative to the path.

7.1.3- Where the minimum flight crew is two pilots, means for the pilot not flying to verify the desired path and the aircraft position relative to the path.

7.1.4- A navigation database, containing current navigation data officially promulgated for civil aviation, which can be updated in accordance with the AIRAC cycle and from which terminal airspace procedures can be retrieved and loaded into the RNAV system.

The resolution to which the data is stored must be sufficient to achieve the required track keeping accuracy.

The database must be protected against flight crew 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 system as permitted by Section 10.

However, the procedure stored in the database must not be modified and must remain intact within the database for future use and reference.

7.1.5-Means to display the validity period of the navigation database to the flight crew.

7.1.6- Means to retrieve and display data stored in the navigation database relating to individual

waypoints and navigation aids, to enable the flight crew to verify the procedure to be flown.

7.1.7- Capacity to load from the database into the RNAV system the whole terminal procedure(s) to be flown.
7.1.8- Display of the active navigation sensor type, either in the pilot's primary field of view, or
on a readily accessible page on an MCDU together with a means of determining navigation system performance.
7.1.9- Display of the identification of the active (To) waypoint, either in the pilot's primary field of view, or on a readily accessible page on an MCDU, readily visible to the flight crew.
7.1.10- Display of distance and bearing to the active (To) waypoint in the pilot's primary field of
view. Where impracticable, the data may be displayed on a readily accessible page on an MCDU, readily visible to the flight crew.
7.1.11- Display of ground speed or time to the active (To) waypoint, either in the pilot's primary
field of view, or on a readily accessible page on a MCDU, readily visible to the flight crew.
7.1.12- Where the MCDU is to be used to support the accuracy checks of Section 10, display of lateral deviation with a resolution of 0.1NM.
7.1.13- Automatic tuning of VOR and DME navigation aids used for position updating together with the capability to inhibit individual navigation aids from the automatic selection process. Note: Further guidance may be found in ED-75A/DO-236A, Section 3.7.3.1.
7.1.14- Capability for the P-RNAV system to perform automatic selection (or de-selection) of navigation sources, a reasonableness check, an integrity check, and a manual override or deselect. Further guidance may be found in ED-75A/DO-236A, Section 3.7.3.1.
7.1.15- Capability for the "Direct to" function.
7.1.16- Capability for automatic leg sequencing with display of sequencing to the flight crew.
7.1.17- Capability to execute database procedures including fly-over and fly-by turns.
7.1.18- Capability to execute leg transitions and maintain tracks consistent with the following
ARINC 424 path terminators, or their equivalent:

- Initial Fix (IF),
- Track between Two Fixes (TF),
- Course to a Fix (CF)
- Course from a Fix to an Altitude (FA),
- Direct to a Fix (DF)

7.1.19- Indication of the RNAV system failure, including the associated sensors, in the pilot's
primary field of view.
7.1.20- For multi-sensor systems, automatic reversion to an alternate RNAV sensor if the primary RNAV sensor fails.
Note: This does not preclude means for manual navigation source selection.
7.1.21- Alternative means of displaying navigation information, sufficient to perform the checking procedures of Section 10.

7.2 Recommended Functions

The following are the system functions recommended for P-RNAV operations:
7.2.1- Capability to fly a path parallel to, but offset left or right from, the original active route.
The system should provide for entry of an offset distance of at least 20 NM in increments
of 1 NM. Operation in offset mode should be clearly indicated to the flight crew. When in offset mode, the system should provide reference parameters (e.g. cross-track deviation,distance-to-go) relative to the offset path and offset reference points. An offset

should not be propagated through route discontinuities, unreasonable path geometry, or beyond the initial approach waypoint. Prior to the end of the offset path, indication should be provided to the flight crew, to allow sufficient time to return to the original active route.

Once a parallel offset is activated, it should remain active for all route segments of the flight plan until either it is removed automatically, until the flight crew enter a Direct-To routing, or until flight crew (manual) cancellation.

Note: The purpose of this function is to enable offsets for tactical operations authorised by ATC (e.g. weather avoidance). It is not intended to be used for strategic offsets which will be promulgated and coded in the navigation database as separate parallel routes.

7.2.2- Coupling to the flight director and /or automatic pilot from the RNAV system with unambiguous mode indication. (See also paragraph 8.1.1 (e)).

7.2.3- Capability for vertical navigation based upon barometric inputs. (See Appendix D).

7.2.4- For an RNAV system using DME/DME updating, supported by IRS, means for automatic runway position update at the start of the take-off run including means to enter a distance offset for situations where the published threshold and the actual start of the take of run differ (i.e. take-off shift).

7.2.5- Display of the navigation mode in the pilot's primary field of view.

7.2.6- Capability to execute leg transitions and maintain tracks consistent with the following:

- ARINC 424 path terminators, or equivalent:
- Holding Pattern to a Manual Termination (HM)
- Holding Pattern to an Altitude (HA)
- Holding Pattern to a Fix (HF)
- Constant Radius to a Fix (RF).

8. ACCEPTABLE MEANS OF AIRWORTHINESS COMPLIANCE

8.1 General

Where practicable, to get a concurrent process that ensures the operational evaluation rationale is based on the certification rationale for the particular equipment installation, the airworthiness assessment of this Section should be performed in conjunction with the operational evaluation of Section 10, taking account of the proposed normal and contingency procedures. The following compliance guidelines assume that the aircraft is equipped in accordance with ECAR Part 91& Part 121 for IFR flight, or equivalent.

8.1.1 New or Modified Installations

In demonstrating compliance with this Advisory Circular, the following specific points should be noted:

(a) The applicant will need to submit to ECAA , a compliance statement which shows how the criteria of this Advisory Circular have been satisfied. The statement should be based on a plan, agreed by ECAA at an early stage of the implementation programme. The plan should identify the certification data to be submitted which should include, as appropriate, a system description together with evidence resulting from the activities defined in the following paragraphs.

(b) Compliance with the airworthiness requirements for intended function and safety may be demonstrated by equipment qualification, system safety analysis, confirmation of appropriate software design assurance level (i.e. consistent with paragraph 6.2), performance analyses, and a combination of ground and flight tests. To support the approval application, design data will need to be submitted showing that the objectives and criteria of Sections 6 and 7 of this Advisory Circular have been satisfied.

(c) Use of the RNAV systems and the manner of presentation of lateral and vertical guidance information on the flight deck must be evaluated to show that the risk of flight crew error has been minimised. In particular, during the transition to the final approach, the display of ILS information simultaneously with RNAV information to a flight crew member will need careful consideration.

(d) Equipment failure scenarios involving conventional navigation sensors and the RNAV system(s) must be evaluated to demonstrate that adequate alternative means of navigation are available following failure of the RNAV system, and that reversionary switching arrangements, e.g. VOR#2 on HSI#1, do not lead to misleading or unsafe display configurations. The evaluation must consider also the probability of failures within the switching arrangements.

(e) The coupling arrangements for the RNAV system to flight director/automatic pilot must be evaluated to show compatibility and that operating modes, including RNAV system failures modes, are clearly and unambiguously indicated to the flight crew.

(f) To comply with Section 7, Table 1, item 18, and Table 7.2, item 6 (if applicable), the execution of all leg types (in particular when intercepting a CF leg) must be shown to be possible without the need for manual intervention, i.e. without disengaging the RNAV mode, and then a manual course selection. This does not preclude means for manual intervention when needed.

8.1.2 Existing Installations

The applicant will need to submit, to the responsible authority, a compliance statement which shows how the criteria of this Advisory Circular have been satisfied for existing installations.

Compliance may be established by inspection of the installed system to confirm the availability of required features and functionality. The performance and integrity criteria of Section 6 may be confirmed by reference to statements in the Aircraft Flight Manual or to other applicable approvals and supporting certification data. In the absence of such evidence, supplementary analyses and/or tests may be required. Paragraph 9.3 addresses Aircraft Flight Manual changes that might be necessary.

8.2 Database Integrity

The navigation database updating process shall comply with EUROCAE ED-76 / RTCA DO--200A, or equivalent approved procedures (see paragraph10.6).

8.3 Use of GPS Equipment

8.3.1 The use of GPS to perform P-RNAV operations is limited to equipment approved under FAA TSO-C145 and TSO-146, and JTSO-C129a/ TSO-C129 (), in the equipment classes: A1, B1, C1, B3 and C3, and which support the minimum required system functions specified in Section 7, Table 1 of this Advisory Circular. Receiver Autonomous Integrity Monitoring (RAIM), or an equivalent means of integrity monitoring as part of a multi-sensor navigation system, must be provided.

8.3.2 To complete the compliance statement of paragraph 8.1.1(a) for JTSO-C129a/TSOC129() equipment, the criteria of JAA Guidance Advisory Circular No.3, revision 1, paragraph 5.4, needs to be taken into consideration when stand-alone GPS equipment is the only installed means of meeting the P-RNAV criteria.

8.3.3 GPS with the capability for satellite Fault Detection and Exclusion (FDE) is recommended to improve Continuity of Function.

8.4 Use of Inertial Data

In the event of unavailability or loss of radio sensor derived automatic position updating, it is permissible to use, for a short period of time, data from an inertial system as the only means of positioning. For such operations, in the absence of a position integrity indication, the applicant must establish how long the aircraft can maintain the required accuracy using only inertial data. Both take-off and terminal area operations will need to be considered and may need to be addressed in the contingency procedures. The limits may be based on an acceptable drift rate model as agreed by the responsible aircraft operations authority .

8.5 Intermixing of Equipment

Installation of area navigation systems with different crew interfaces can be very confusing and can lead to problems when they have conflicting methods of operation and conflicting display formats. There can be problems even when intermixing different versions of the same equipment. For approach operations, intermixing of RNAV equipment is not permitted. As a minimum, consideration must be given to the following potential incompatibilities particularly where the flight deck architecture

includes cross coupling capabilities (e.g. GNSS-2 switched to drive the number 1 displays).

(a) Data entry: The two systems must have consistent methods of data entry, and similar pilot procedures for accomplishing common tasks. Any differences should be evaluated for pilot workload. If the wrong procedures are used, (for example, the data entry procedures for the offside system are used by mistake for the onside), there must be no misleading information and it must be easy to identify and recover from the mistake.

(b) CDI scaling: Sensitivity must be consistent or annunciated.

(c) Display symbology and mode annunciation: There must be no conflicting symbols or annunciation (e.g., a common symbol used for two different purposes), and differences should be specifically evaluated to evaluate the potential confusion they may cause.

(d) Mode logic: The modes internal to the equipment and their interface to the rest of the aircraft must be consistent.

(e) Equipment failure: The effect of failure of one unit must not result in misleading information.

(f) Displayed data: The display of primary navigation parameters must use consistent units and a consistent notation. Any inconsistency in the display of the primary information will not be approved.

(g) Database differences: Due to the inherent data conflict, differences in the area navigation database will not be permitted.

9. AIRCRAFT FLIGHT MANUAL

9.1 For new or modified aircraft, the Aircraft Flight Manual (AFM) or the Pilot's Operating Handbook (POH), whichever is applicable, should provide at least the following information.

This limited set assumes that a detailed description of the installed system and related operating instructions and procedures are available in other approved operating or training manuals.

(a) A statement which identifies the equipment and aircraft build or modification standard certificated for P-RNAV operations or having RNP-1 or better capability.

9.2 In the absence of suitable material in other approved operating or training manuals, appropriate amendments or supplements to cover P-RNAV operations will need to be provided for the following sections of the Flight Manual, or the Pilot's Operating Handbook, whichever is applicable:

- Limitations
- Normal Procedures
- Abnormal Procedures
- Emergency Procedures
- Performance

9.3 For existing aircraft already equipped with an RNAV system but where the Flight Manual or Pilot's Operating Handbook does not define, or is unclear about, the system capability, the aircraft operator may adopt, as an alternative to Change Sheets or Supplements produced by the aircraft constructor, one of the following options, subject to agreement of the responsible authority:

(a) Submit a compliance statement as discussed in 8.1.2 together with a proposed Supplement, devised by the operator, in accordance with the guidelines of 9.1, and in a format using the template given in Appendix E; or

(b) Submit a compliance statement as discussed in 8.1.2 together with a proposed Operational Specification that includes information equivalent to that normally contained in a Flight Manual.

9.4 Systems approved for RNP operations have capabilities exceeding that required for P-RNAV operations. These systems provide higher navigation integrity through implementation of containment integrity and by giving the flight crew better awareness of accuracy through the availability of estimated position uncertainty. Therefore, reference in the AFM to specific RNP(s) of the system may then be used in determining

compatibility of the RNAV capability with the performance required for specific flight operations.

10. OPERATIONAL CRITERIA

10.1 General

10.1.1 An operational evaluation based on the criteria /rationale of paragraphs 8.1.1(c) to (f), or paragraph 8.1.2, as applicable, will need to be made to confirm the adequacy of the operator's normal and contingency procedures for the particular equipment installation.

10.1.2 The following guidelines may be used by the operator to develop operating procedures that are appropriate to the aircraft installation and to the environment within which the aircraft Operations Specifications or Letter of Authorization as appropriate will be operated. It should be noted that airworthiness approval alone does not authorise flight in airspace, along routes, or for terminal area procedures for which P-RNAV approval is required. Operational approval will be stated in the applicable.

10.2 Normal Procedures

10.2.1 Pre-flight Planning

10.2.1.1 During the pre-flight planning phase, the availability of the navigation infrastructure, required for the intended operation, including any non-RNAV contingencies, must be confirmed for the period of intended operation. Availability of the onboard navigation equipment necessary for the route to be flown must be confirmed. The onboard navigation database must be appropriate for the region of intended operation and must include the navigation aids, waypoints, and coded terminal airspace procedures for the departure, arrival and alternate airfields.

10.2.1.2 Where the responsible airspace authority has specified in the AIP that dual PRNAV systems are required for specific terminal P-RNAV procedure, the availability of dual P-RNAV systems must be confirmed. This typically will apply where procedures are effective below the applicable minimum obstacle clearance altitude or where radar coverage is inadequate for the purposes of supporting P-RNAV. This will also take into account the particular hazards of a terminal area and the feasibility of contingency procedures following loss of P-RNAV capability.

10.2.1.3 If a stand-alone GPS is to be used for P-RNAV, the availability of RAIM must be confirmed with account taken of the latest information from the US Coastguard giving details of satellite non-availability.

Note: RAIM prediction may be a function of the equipment provided that satellite nonavailability data can be entered. In the absence of such a function, an airspace service provider may offer an approved RAIM availability service to users.

10.2.2 Departure

10.2.2.1 At system initialisation, the flight crew must confirm that the navigation database is current and verify that the aircraft position has been entered correctly. The active flight plan should be checked by comparing the charts, SID or other applicable documents, with the map display (if applicable) and the MCDU. This includes confirmation of the waypoint sequence, reasonableness of track angles and distances, any altitude or speed constraints, and, where possible, which waypoints are fly-by and which are fly-over. If required by a procedure, a check will need to be made to confirm that updating will use a specific navigation aid(s), or to confirm exclusion of a specific navigation aid. A procedure shall not be used if doubt exists as to the validity of the procedure in the navigation database

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

10.2.2.2 The creation of new waypoints by manual entry into the RNAV system by the flight crew is not permitted as it would invalidate the affected P-RNAV procedure. Route modifications in the terminal area may take the form of radar headings or 'direct to' clearances and the flight crew must be capable of reacting in a timely fashion. This may include the insertion in the flight plan of waypoints loaded from the database.

10.2.2.3 Prior to commencing take off, the flight crew must verify that the RNAV system is available and operating correctly and, where applicable, the correct airport and runway data have been loaded.

10.2.2.4 Unless automatic updating of the actual departure point is provided, the flight crew must ensure initialisation on the runway either by means of a manual runway threshold or intersection update, as applicable. This is to preclude any inappropriate or inadvertent position shift after take-off. Where GNSS is used, the signal must be acquired before the take-off roll commences and GNSS position may be used in place of the runway update.

10.2.2.5 During the procedure and where feasible, flight progress should be monitored for navigational reasonableness, by cross-checks, with conventional navigation aids using the primary displays in conjunction with the MCDU. Where applicable and when used, the flight crew procedures will need to include monitoring to verify automatic updating of the inertial systems to ensure the period without updating does not exceed the permitted limit.

(See paragraph 8.4).

10.2.2.6 Where the initialisation of paragraph 10.2.2.4 is not achieved, the departure should be flown by conventional navigation means. A transition to the P-RNAV structure should be made at the point where the aircraft has entered DME/DME coverage and has had sufficient time to achieve an adequate input.

Note: If a procedure is designed to be started conventionally, then the latest point of transition to the P-RNAV structure will be marked on the charts. If a pilot elects to start a P-RNAV procedure using conventional methods, there will not be any indication on the charts of the transition point to the P-RNAV structure.

10.2.3 Arrival

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

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

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

10.2.3.3 Where the contingency to revert to a conventional arrival procedure is required, the flight crew must make the necessary preparation.

10.2.3.4 During the procedure and where feasible, flight progress should be monitored for navigational reasonableness by cross-checks with conventional navigation aids using the primary displays in conjunction with the MCDU. In particular, for a VOR/DME RNAV procedure, the reference VOR/DME used for the construction of the procedure must be displayed and checked by the flight crew. For RNAV systems without GNSS updating, a navigation reasonableness check is required during the descent phase before reaching the Initial Approach Waypoint (IAWP). For GNSS based systems, absence of an integrity alarm is considered sufficient. If the check fails, a conventional procedure must then be flown.

Notes:

(1) For example, where feasible, display bearing/range to a VOR/DME from the RNAV system and compare the result with the RMI read-out (selected to same VOR/DME).

(2) For some systems the accuracy may be derived from the navigation mode or accuracy mode.

(3) Where the MCDU shows only integers and is unable to display errors with sufficient resolution for P-RNAV accuracy checks, an alternative means of checking will need to be followed.

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

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

Note: Appendix D provides further information on vertical navigation.

10.3 Contingency Procedures

10.3.1 Contingency procedures will need to be developed by the operator to address Cautions and Warnings for the following conditions:

(a) Failure of the RNAV system components including those affecting flight technical error (e.g. failures of the flight director or automatic pilot).

(b) Multiple system failures.

(c) Failure of the navigation sensors.

(d) Coasting on inertial sensors beyond a specified time limit.

10.3.2 The flight crew must notify ATC of any problem with the RNAV system that results in the loss of the required navigation capability, together with the proposed course of action.

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

10.3.4 In the event of loss of P-RNAV capability, the flight crew should invoke contingency procedures and navigate using an alternative means of navigation which may include the use of an inertial system. The alternative means need not be an RNAV system.

10.4 Incident Reporting

Significant incidents associated with the operation of the aircraft which affect or could affect the safety of RNAV operations, need to be reported to ECAA.

Specific examples may include:

(a) Aircraft system malfunctions during P-RNAV operations which lead to:

(1) Navigation errors (e.g. map shifts) not associated with transitions from an inertial navigation mode to radio navigation mode.

(2) Significant navigation errors attributed to incorrect data or a navigation database coding error.

(3) Unexpected deviations in lateral or vertical flight path not caused by pilot input.

(4) Significant misleading information without a failure warning.

(5) Total loss or multiple navigation equipment failure.

(b) Problems with ground navigational facilities leading to significant navigation errors not associated with transitions from an inertial navigation mode to radio navigation mode.

10.5 Flight Crew Training

All flight crews must receive appropriate training, briefings and guidance material in the operation of RNAV-based departure and arrival procedures. This should cover the normal and contingency procedures identified in paragraphs 10.2 (Normal Procedures) and 10.3 (Contingency Procedures). Wherever practicable, standard training events (simulator checks/proficiency checks) should include departures and arrivals using the RNAV-based procedures. The operator must ensure that the Training Manual contains appropriate material to support P-RNAV operations. As a minimum, the items listed in Table 3 should be addressed in the Training Manual

10.5.1 RNAV Training Items

(a) - Theory of R-NAV, including the differences between B-RNAV, P-RNAV and RNP-RNAV.

(b) - Limitations of RNAV

(c) Charting, database and avionics issues including:

- Waypoint naming concepts.
- RNAV Path terminator concepts and especially:
  - Use of the 'CF' path terminator.

. Use of the 'TF' path terminator.

- Fly-by and fly-over waypoints.
- Use of the RNAV equipment including, where appropriate:
- Retrieving a procedure from the database.
- Verification and sensor management.
- Tactically modifying the flight plan.
- Addressing discontinuities.
- Entering associated data such as:
  . Wind.
  . Altitude/Speed constraints.
  . Vertical Profile/Vertical Speed.
- Flying the procedure.
- Use of Lateral Navigation Mode and associated lateral control techniques.
- Use of Vertical Navigation Mode and associated vertical control techniques.
- Use of automatic pilot, flight director and auto-throttle at different stages of the procedure.

(d) RT phraseology for RNAV

The implications for RNAV operations of system malfunctions which are not RNAV related (e.g. hydraulic failure or engine failure).

10.6 Database Integrity

10.6.1 The navigation database should be obtained from an approved supplier who has complied with EUROCAE/RTCA document ED-76/DO-200A, Standards for Processing Aeronautical Data.

10.6.2 Until such approved suppliers become available, prior to the effective date of the navigation database, as a minimum, the operator must implement navigation database integrity checks using appropriate software tools or approved manual procedures to verify data relating to waypoints below the applicable minimum obstacle clearance altitude. Such checks are in addition to any checks previously performed by the Aeronautical Information Services, unapproved navigation database suppliers, or navigation equipment manufacturers. The integrity checks need to identify any discrepancies between the navigation database and the published charts/procedures. Integrity checks may beperformed by an approved third party.

10.6.3 Discrepancies that invalidate a procedure must be reported to the navigation database supplier and affected procedures must be prohibited by a operator's notice to its flight crew.

10.6.4 Aircraft operators should consider the need to continue their own database checks even for products obtained from approved suppliers.

10.6.5 To aid database integrity checking, a suitable tool having functionality as defined in Appendix B may be used.

10.7 Flight Operations Documentation

10.7.1 The aircraft Operations Manual (e.g. Aircraft or Flight Crew Operating Manuals (A/FCOM)) and check lists must be revised to take account of the information specified in 9.1, 9.2 and 9.3, and the operating procedures detailed in paragraphs 10.2 (Normal Procedures) and 10.3 (Contingency Procedures). The operator must make timely amendments to his Operations Manual to reflect relevant P-RNAV procedures and database checking strategies. Manuals and checklists need to be submitted for review by ECAA as part of the approval process.

10.7.2 The aircraft operator should propose an amendment to the Minimum Equipment List (MEL) appropriate to P-RNAV operations.

APPENDIX -A
GLOSSARY

The following are definitions of key terms used in the context of area navigation. For the purposes of P-RNAV, these definitions have been adapted from those given in corresponding ICAO documents.

Area Navigation (RNAV). A method of navigation which permits aircraft operation on any desired flight path.

Accuracy. The degree of conformance between the estimated, measured, or desired position and/or the velocity of a platform at a given time, and its true position or velocity.

Navigation performance accuracy is usually presented as a statistical measure of system error and is specified as predictable, repeatable and relative.

Availability. An indication of the ability of the system to provide usable service within the specified coverage area and is defined as the portion of time during which the system is to be used for navigation during which reliable navigation information is presented to the crew, automatic pilot, or other system managing the flight of the aircraft.

Continuity of Function. The capability of the total system (comprising all elements necessary to maintain aircraft position within the defined airspace) to perform its function without non-scheduled interruptions during the intended operation.

Integrity. The ability of a system to provide timely warnings to users when the system should not be used for navigation.

Receiver Autonomous Integrity Monitoring (RAIM). A technique whereby a GNSS receiver / processor determines the integrity of the GNSS navigation signals using only GNSS signals or GNSS signals augmented with altitude. This determination is achieved by a consistency check among redundant pseudo-range measurements. At least one satellite in addition to those required for navigation must be in view for the receiver to perform the RAIM function.

Vertical Navigation. A method of navigation which permits aircraft operation on a vertical flight profile using altimetry sources, external flight path references, or a combination of these.

The following acronyms are used in the document:

ADF Automatic Direction Finding
AFM Aircraft Flight Manual
AIP Aeronautical Information Publication
AIRAC Aeronautical Information Regulation and Control
AIS Aeronautical Information Service
ATC Air Traffic Control
B-RNAV Basic RNAV
CDI Course Deviation Indicator
CF Course to a Fix
CG Centre of Gravity
CNF Computer Navigation Fix
DF Direct to a Fix
DME Distance Measuring Equipment
DTK Desired Track
EGNOS European Geo-stationary Navigation Overlay System
(E)HSI (Electronic) Horizontal Situation Indicator
FA Course from a Fix to an Altitude
FACF Final Approach Course Fix
FAWP Final Approach Waypoint
FDE Fault Detection and Exclusion
FMS Flight Management System
FTE Flight Technical Error
GPS Global Positioning System

GNSS Global Navigation Satellite System
HA Holding Pattern to an Altitude
HF Holding Pattern to a Fix
HM Holding Pattern to a Manual Termination
ICAO International Civil Aviation Organisation
IF Initial Fix
IFR Instrument Flight Rules
ILS Instrument Landing System
INS Inertial Navigation System
IRS Inertial Reference System
MASPS Minimum Aviation System Performance Standards
MCDU Multi-function Control Display Unit
MEL Minimum Equipment List
MLS Microwave Landing System
NDB Non Directional Beacon
NM Nautical Mile
NOTAM Notice to Airmen
P-RNAV Precision RNAV
RAIM Receiver Autonomous Integrity Monitoring
RF Radius to a Fix
RMI Radio Magnetic Indicator
RNAV Area Navigation
RNP Required Navigation Performance
RTA Required Time of Arrival
SID Standard Instrument Departure
STAR Standard Arrival Route
TF Track between Two Fixes
VOR VHF Omni-directional Range
WGS World Geodetic System

APPENDIX- B
SPECIFICATION FOR A DATABASE INTEGRITY CHECK TOOL

A database integrity check tool is a software tool which enables an aircraft operator to conduct independent checks on specific data areas in a navigation database to ensure that integrity is maintained. These checks can be delegated to a service organisation.
The tool should include the following functionality:

(a) Allow a user to specify the data areas to be checked and the critical data items to be monitored.
(b) Detect any changes in monitored data items.
(c) Generate reports listing all identified changes.
(d) Provide a full data history to support configuration control.
(e) Maintain non editable log-files of all online actions.
(f) Provide analyses of database quality and changes in quality levels by tracking of rates of discovered errors.
(g) Provide a flexible data input interface to enable database integrity checks for a variety of database providers.

APPENDIX- C
EVOLUTION FROM CONVENTIONAL TERMINAL AIRSPACE PROCEDURES TO RNP-RNAV

There are a number of steps envisaged in the transition from today's conventional terminal airspace procedures to future RNP-RNAV procedures:

(a) Conventional Procedure

A conventional procedure design (VOR radials, NDB bearings and DME fixes/arcs, ILS, MLS). Flown with conventional means (VOR, DME, ADF, ILS and MLS).

(b) Conventional Procedure flown by an RNAV system coded to ARINC 424

A conventional procedure design but stored in a navigation database using the full set of ARINC 424 Path Terminators.

(c) Conventional Procedure meeting RNAV criteria

A conventional procedure designed specifically to meet RNAV criteria using sensors such as VOR/DME, DME/DME and GNSS. This procedure is published as a conventional procedure and may reference VOR radials, NDB bearings and DME fixes. However, it will have associated waypoints to define the RNAV path. This removes the ambiguity/approximations found in conventional procedures of paragraph (b), when flown using RNAV systems and ensures repeatability of the intended path over the ground.

Note: This is the first step towards achieving predictable track-keeping resulting from consistent and correct coding in the navigation databases, published waypoints and the application of fly-by turns. This can be used as a learning period for designers, chart and AIS providers, introducing as it does the concepts of path terminators, procedure validation, database issues, charting and publication issues.

(d) RNAV Procedure (Not RNP)

A procedure designed specifically for RNAV using sensors such as DME/DME, GNSS and VOR/DME. Use is made of waypoints located according to minimum distance requirements as laid down in PANS-OPS. This procedure is identified as an RNAV procedure and the sensor used for the design must be published. The procedure is intended for Precision RNAV or RNP-RNAV certified system.

(e) RNP-RNAV Procedure

A procedure designed according to RNP-RNAV criteria. This procedure is identified as RNP-RNAV and may be used for all applicable sensors, and is protected as such. The procedure is intended for RNP-RNAV certified systems.

The conventional procedure of paragraph (a) was originally designed for hand-flown operations and does not always lend itself to the use of RNAV systems. Navigation database providers have had to interpret the procedure specification using the leg types available in the full ARINC 424 tool kit. This has resulted in the need for additional fixes (Computer Navigation Fixes (CNF)) to be defined in order to construct a best fit to the procedure path. In general, these aspects are transparent to ATC, but can result in path deviations under given conditions of aircraft type, configuration (weight, CG), FMS manufacturer, and wind. The RNAV system, whilst commanding path steering, may be restricted by built-in bank angle or performance limits. The consequence of such limits may be a path deviation which may be recovered automatically or may require pilot intervention.

At all times, the conventional procedure, be it coded according to ARINC 424 or not, may be monitored by the flight crew against raw radio aid data, and the integrity of the navigation database is not really an issue. From the aircraft perspective, the safety of flight envelope is maintained, although separation from obstacles or other traffic may be lost. Hence, the major concern with these types of procedures is their compatibility with the RNAV system and how well the procedure can be flown under all conditions for all aircraft types. It would be preferable for conventional procedures to be designed to take into account the limitations and constraints of the RNAV system.

When P-RNAV is subsequently mandated, the underlying conventional procedure may bewithdrawn leaving a stand-alone RNAV procedure.

The RNP-RNAV procedures of paragraph (e) are expected to be introduced initially to take advantage of the reduced obstacle clearance requirements associated with RNP<1 instrument procedures and RNP MASPS compliant systems. They are expected to replace all RNAV procedures.

APPENDIX- D
VERTICAL NAVIGATION

(a) Although this Advisory Circular does not set criteria for approval of vertical navigation systems, the following provides a brief description to aid understanding of the overall navigation function and the relationship of VNAV to this the guidance material. The flight crew must clearly understand the application of vertical navigation mode and/or speed management, as appropriate, particularly in the context of a continuous descent profile.

(b) For vertical navigation, the system compares the determined vertical position (barometric altitude) with a desired vertical profile derived from altitude data, a vertical angle, or a vertical flight profile, applicable to that route or procedure and selected from an on-board navigation database. The desired vertical profile to be followed and the difference between it and the determined vertical position are then output to the following types of system to enable the profile to be followed:
- Vertical Profile Deviation Indicator
- Vertical Profile Display.
- Automatic Thrust System.
- Flight Director.
- Automatic pilot.

(c) Some systems may provide the capability to determine optimised climb and descent profiles based on aircraft performance characteristics (including engine performance), aircraft weight, aircraft speed, prevailing meteorological conditions, operator cost constraints, and published altitude and speed constraints associated with a particular arrival/approach/departure procedure.

(d) A VNAV capability is optional for P-RNAV. It should be possible to fly a published descent profile conventionally manually, given adequate flight deck information and with appropriate crew training.

(e) Unless a published VNAV procedure is being flown, the vertical profile between two altitude constraints is always at the pilot's discretion. However, the flight crew should aim, wherever possible, to adhere to the optimum vertical profile. Crews should recognise that there are a number of methods by which adherence to the path can be achieved. Where a VNAV procedure is published, the flight crew are required to fly in accordance with the published constraints.

(f) Use of GNSS is only considered as a sensor for the purposes of lateral navigation and its use for vertical navigation is not addressed by this Advisory Circular.

(g) Further description of VNAV functionality and performance requirements, and their relationship with RNP-RNAV, may be found in EUROCAE/RTCA documents ED-75A/DO- 236A.