Advisory Circular
AC91-7

Revision 1

Required Navigation Performance (RNP 10)

18 March 1999

General

Civil Aviation Authority advisory circulars (ACs) contain information about standards, practices, and procedures that the Director has found to be acceptable for compliance with the associated rule.

Consideration will be given to other methods of compliance that may be presented to the Director. When new standards, practices, or procedures are found to be acceptable they will be added to the appropriate AC.

Purpose

This AC describes an acceptable means of compliance with requirements relating to the approval of operators for RNP10 operations.

Related Rules

This AC relates specifically to 91.246, 91.407, 91.409 and 91.519.

Change Notice

This revised AC supersedes AC91-7 dated 23 April 1998 and it provides a means of assessment for New Zealand Defence Force (NZDF) aircraft in para 7.4.2.

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Introduction

States are beginning to introduce Required Navigation Performance (RNP) as part of a world-wide ICAO effort to implement Communication, Navigation and Surveillance (CNS) and Air Traffic Management (ATM) concepts. Reduced separation minima are an integral part of these initiatives.

Through ICAO, the Informal South Pacific Air Traffic Services Co-ordinating Group (ISPACG) and other forums, new separation minima – 50 nm lateral and 50 nm longitudinal – have been developed for use in oceanic and remote areas. These reduced separations will be introduced in the Tasman Sea area on 23 April 1998 with the reduced separation being available to operators and aircraft with RNP10 approvals.

In accordance with ICAO co-ordinated regional agreements, operators must obtain an RNP 10 approval from the appropriate State of Registry or State of the Operator in order to operate to the reduced separations in RNP airspace/air routes. The RNP 10 criteria and a means of obtaining operational approval from the Civil Aviation Authority (CAA) are described in this AC.

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Operational Approval for Required Navigation Performance 10

1. Purpose

This AC provides policy and direction to operators for obtaining operational approval of Required Navigation Performance 10 (RNP 10) capability. It includes guidance on airworthiness and operational approvals processes. The AC enables an applicant to be approved as capable of meeting the navigation element of Communications/ Navigation/Surveillance (CNS) requirements when and where RNP 10 is specified. The AC does not address communications or surveillance requirements that may be specified to operate on a particular route or in a particular area. Those requirements are specified in other documents such as Civil Aviation Rules, Aeronautical Information Publications (AIP) and the International Civil Aviation Organisation (ICAO) Regional Supplementary Procedures Document (DOC 7030).

2. Promulgation

This AC should be read in conjunction with Civil Aviation Rules 91.246, 91.407, 91.409, 91.519, Aeronautical Information Circular (AIC) 1/98, and Aeronautical Information Publication Supplement (AIP SUP) 1/98.

3. Background

States are beginning to introduce RNP as part of a worldwide ICAO effort to implement CNS and Air Traffic Management (ATM) concepts. Reduced separation minima are an integral part of these initiatives.

Through ICAO, the Informal South Pacific Air Traffic Services Coordinating Group (ISPACG) and other forums, new separation minima – 50 nm lateral and 50 nm longitudinal –have been developed for use in oceanic and remote areas. Initially, these new lateral and/or longitudinal minima will be introduced on routes in the North Pacific (NOPAC), Central East Pacific (CEPAC), South Pacific (SOPAC) and Tasman Sea. In the Tasman Sea the minimum longitudinal separation will be in accordance with ICAO Doc 7030/4 MID/ASIA/RAC paragraph 6.2.

In accordance with ICAO coordinated regional agreements, operators must obtain an RNP 10 approval from the appropriate State of Registry or State of the Operator in order to operate at the reduced separations in RNP airspace/air routes. The RNP 10 criteria and a means of obtaining operational approval from the CAA are described in the following sections of the AC.

4. Applicability

This guidance material applies to all RNP 10 operations conducted under 91.407 and 91.409.

New Zealand registered aircraft, when operating outside New Zealand airspace must comply with ICAO Annex 2 when over the high seas and the regulations of another State when operating within that State's airspace.

5. Related Publications

Civil Aviation Authority

- Civil Aviation Rules Part 91 and Part 19

- New Zealand Aeronautical Information Publication (NZAIP 1/98)
- Aeronautical Information Circular (AIC 1/98)

Civil Aviation Safety Authority (CASA)

- CAAP RNP 10-1

Federal Aviation Administration (FAA)

- FAA Order 8400.12 (provides a list of all FAA documents used to develop Order 8400.12)
- Federal Aviation Regulations Part 121 Annex G
- FAA Notice 8110.60

International Civil Aviation Organisation (ICAO)

- Manual on Required Navigation Performance (RNP), ICAO DOC 9613-AN/937
- Asia Pacific Guidance Material for RNAV Operations

Copies may be obtained from Document Sales Unit, ICAO, 999 University Street, Montreal, Quebec, Canada H3C 5H7

RTCA

- Minimum Aviation System Performance Standards (MASPS): Required Navigation Performance for Area Navigation, RTCA

Copies may be obtained from RTCA, Inc., 1140 Connecticut Avenue, NW., Suite 1020, Washington, DC 20036

6. Operational approval

6.1 General

A number of steps must be completed before an operational approval is issued to an operator. These steps are—

- aircraft eligibility for RNP 10 must be determined by the CAA
- flight crew procedures for the navigation systems to be used must be identified by the operator
- the operator database use and operating procedures must be evaluated by the CAA

6.2 Determining eligibility and approval of aircraft for RNP 10

Many aircraft and navigation systems currently in use in oceanic or remote area operations will qualify for RNP 10 based on one or more provisions of existing certification criteria. Thus, additional aircraft certification action may not be necessary for the majority of RNP 10 approvals. Aircraft re-certification will only be necessary if the operator chooses to claim better system performance than that originally certified or stated in the Aircraft Flight Manual (AFM) and the operator cannot demonstrate the desired performance through data collection. The certification approval for this situation is addressed in paragraph 9.

6.3 Approved aircraft/system list

The CAA’s Aircraft Certification Unit will maintain a list of aircraft/navigation systems that have received approval. It will not be used as a means of determining qualifications for approval. The list will be maintained for statistical purposes only.

7. Operational approval process

The following paragraphs provide application guidelines for operators requiring RNP 10 operational approval. Appendix 5 shows a checklist for the application process.

7.1 Pre-Application meeting

Each individual operator should schedule a pre-application meeting with the CAA. The intent of this meeting is to discuss with the operator the CAA's airworthiness and operational requirements for approval to operate in RNP 10 airspace, including—

- the contents of the operator's application
- CAA review and evaluation of the application
- limitations
- conditions for removal of the operational approval

7.2 Form of application

A sample letter of request for an operator to obtain RNP 10 operational approval is at Appendix 3.

7.3 Contents of operator's RNP 10 application

7.3.1 Airworthiness documents

Relevant documentation, e.g. the Aircraft Flight Manual, should be available to establish that the aircraft is equipped with long range navigation systems (LRNS) which meet the requirements of RNP 10.

7.3.2 Description of aircraft equipment

The applicant should provide a configuration list which details pertinent components and equipment to be used for long range navigation and RNP 10 operations.

7.3.3 RNP 10 time limit for Inertial Navigation Systems (INS) or Inertial Reference Units (IRU) (if applicable)

The applicant's proposed RNP 10 time limit for the specified INS or IRU should be provided – refer paragraph 9. The applicant should consider the effect of headwinds in the area of operations in which RNP 10 operations are intended to be carried out – refer paragraph 12 – to determine the feasibility of the proposed operation. In addition, operators of aircraft which are unable to couple the RNAV systems to the flight director or to the autopilot must assume a Flight Technical Error (FTE) of 2 nm for oceanic operations. The addition of the 2 nm FTE to the assumed navigation position error will further time limit INS/IRU equipped aircraft operating to RNP 10.

7.3.4 Operational training programmes and operating practices and procedures

Part 119 certificate holders should submit training syllabi and other appropriate material to the CAA to show that the operational practices and procedures and training items related to RNP 10 operations are incorporated in training programmes where applicable, such as initial, upgrade, or recurrent. Practices and procedures in the following areas should be standardised using the guidelines of Appendix 4—

- flight planning
- pre-flight procedures at the aircraft for each flight

- procedures before entry into an RNP 10 route or airspace
- in-flight contingency
- flight crew qualification procedures

Private operators should demonstrate that they will operate using the practices and procedures identified in Appendix 4.

7.3.5 Operational manuals and checklist

Part 119 certificate holders should revise the operations manual and checklists to include information/guidance on standard operating procedures detailed in Appendix 4. Appropriate manuals should include navigation operating instructions and contingency procedures. Manuals and checklists should be submitted for review as part of the application process.

For private operators, appropriate manuals should include navigation operating instructions and contingency procedures. The manual(s) and the aircraft navigation equipment manufacturer's checklist, as appropriate, should be submitted for review as part of the application process.

7.3.6 Past performance

An operating history for the operator should be included in the application. The applicant should address any events or incidents related to navigation errors for that operator (e.g. as reported by form CAA 005) which have been covered by training, procedures, maintenance, or aircraft/navigation modifications for the systems that are to be used.

7.3.7 Minimum Equipment List (MEL)

A revised MEL should be included which addresses RNP 10 capability. Any MEL revisions necessary to address the RNP 10 provisions of the guidance material in this AC must be approved

Note: If approval is based on 'Triple-Mix' the MEL should reflect that three navigation units must be operating.

7.3.8 Maintenance

Where applicable, the operator should submit maintenance documents for approval, in accordance with paragraph 11, at the time the operator applies for operational approval.

7.4 CAA evaluation of applications

7.4.1 Civilian operated aircraft

Once the application has been submitted, the CAA will begin the process of review and evaluation. If the content of the application is deficient, the CAA will request additional information from the operator. When all the airworthiness and operational requirements of the application are met, the CAA will issue the approval to operate in RNP 10 airspace.

7.4.2 NZDF operated aircraft

For aircraft operated by the NZDF, the CAA will accept an application for the issue of an RNP 10 approval from the Assistant Chief of Air Staff (Operations), Royal New Zealand Air Force. The application should be preceded by an NZDF assessment of the aircraft, flight operations and continued airworthiness aspects to determine compliance with the requirements outlined in this AC. The application should state—

- the model(s) of aircraft and applicable registrations

- RNP 10 time limit if any
- navigation equipment installed
- compliance with RNP 10 requirements outlined in this AC

7.5 Form of approval

RNP 10 operational approvals will be issued as either an Operations Specification amendment or a Letter of Authorisation and will identify any conditions or limitations on operations in RNP 10 airspace, including—

- required navigation systems or procedures
- limits on time, routes, or areas of operation

A sample Operations Specification amendment and a Letter of Authorisation are at Appendix 6.

7.6 Investigation of navigation and system errors

Demonstrated navigation accuracy provides the basis for determining the lateral spacing and separation necessary for traffic operating on a given route. Accordingly, lateral and longitudinal navigation errors are investigated to prevent their recurrence. Radar observations of each aircraft's proximity to track and altitude, before coming into coverage of short-range navaids at the end of the oceanic route segment, are typically noted by Air Traffic Service (ATS) facilities. If an observation indicates that an aircraft is not within the established limit, the reasons for the apparent deviation from track or altitude may need to be determined and steps taken to prevent a recurrence. Additionally, pilots/operators are to notify the CAA and Airways Corporation of New Zealand (ACNZ) of any lateral navigation errors greater than 15 nm or more, longitudinal navigational errors of 10 nm or more, longitudinal navigational errors or 3 minutes or more variation between the aircraft's estimated time of arrival at a reporting point and its actual time of arrival or navigation system failures.

7.7 Cancellation of RNP 10 approval

When appropriate, the CAA may consider any navigation error reports in determining remedial action. Repeated navigation error occurrences attributed to a specific piece of navigation equipment, may result in cancellation of the RNP 10 approval for use of that equipment. Information that indicates the potential for repeated errors may require a modification of an operator's training programme. Information that attributes multiple errors to a particular pilot crew may necessitate remedial training or licence review.

8. RNP 10 requirements

8.1 Cross-track/along-track requirements

All aircraft operating in RNP 10 airspace shall have a cross-track error of less than 10 nm for 95% of the flight time. This includes positioning error, flight technical error (FTE), path definition error and display error. All aircraft shall also have an along-track positioning error of less than 10 nm for 95% of the flight time.

Note: For RNP 10 approval of aircraft capable of coupling the RNAV system to the flight director or autopilot, navigational positioning error is considered to be the dominant contributor to cross-track and along-track error. Flight technical error, path definition error, and display errors are considered to be insignificant for the purposes of RNP 10 approval. RNP 10 is intended for oceanic and remote areas where 50 nm lateral and 50 nm longitudinal separation minima are applied.

8.1.1 Types of errors

When using the method described in Appendix 1 as the basis for RNP 10 approval, the error types noted in Section 8.1 are included, but for the data collection method described in Appendix 8, they are not since the Appendix 8 method is more conservative. The Appendix 8 method uses radial error instead of cross-track and along-track error.

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

Note: For aircraft which are not capable of autopilot or flight director coupling, an FTE of 2 nm for oceanic operations must be taken into account in determining any limitations.

Path Definition Error (PDE): The difference between the *defined path* and the *desired path* at a specific point and time.

Display Errors (Display System Error): These errors may include error components contributed by any input, output or signal conversion equipment used by the display as it presents either aircraft position or guidance commands (e.g. course deviation or command heading) and by any course definition entry device employed. For systems in which charts are incorporated as integral parts of the display, the display system error necessarily includes charting errors to the extent that they actually result in errors in controlling the position of the aircraft relative to a desired path over the ground. To be consistent, in the case of symbolic displays not employing integral charts, any errors in way-point definition directly attributable to errors in the reference chart used in determining way-point positions should be included as a component of this error. This type of error is virtually impossible to handle and in general practice highly accurate, published way-point locations are used to the greatest extent possible in setting up such systems to avoid such errors and reduce workload.

Navigation System Error (NSE): This is the *root-sum-square* of the ground station error contribution, the airborne receiver error and the display system contribution.

Total System Error (TSE): This is the system use error. $TSE = \sqrt{\left(NSE^2 + FTE^2\right)}$

Position Estimation: This is the difference between *true position* and *estimated position*.

8.2 Navigation systems

RNP 10 requires that aircraft operating in oceanic and remote areas be equipped with at least two independent and serviceable Long Range Navigation Systems (LRNS) comprising INS, IRS/FMS or GPS, of integrity such that the navigation system does not provide misleading information with an unacceptable probability.

9. Aircraft groups (fleets of aircraft)

9.1 Group aircraft

For aircraft to be considered as members of a group for the purposes of RNP 10 approval, they should satisfy the following conditions—

- aircraft should have been manufactured to a nominally identical design and approved by the same Type Certificate (TC), TC amendment, or supplemental Type Certificate (STC), as applicable

Note: For derivative aircraft it may be possible to utilise the database from the parent configuration to minimise the amount of additional data required to show compliance. The extent of additional data required will depend on the nature of the changes between the parent aircraft and the derivative aircraft.

- the antennas – for systems with automatic or those in which manually updating is used for approval – should be installed in a nominally identical manner and position

- the navigation system installed on each aircraft to meet the minimum RNP-10 approval should be manufactured to the manufacturer's same specifications and have the same part numbers.

Note: Aircraft which have INS/IRUs which are of a different manufacturer or part number may be considered part of the group, if it is demonstrated that this standard of navigation equipment provides equivalent navigation performance.

- where an approval is sought for an aircraft group, the data package should contain the following information—
  - a list of the aircraft group to which the data package applies
  - a list of the routes to be flown and the maximum estimated time from alignment to the time which the flight will leave Class II Navigation
  - the compliance procedures to be used to ensure that all aircraft submitted for approval meet RNP 10 navigational capabilities for the RNP 10 approved time duration
  - the engineering data to be used to ensure continued in-service RNP 10 capability for the RNP 10 approved time duration

Note: Class II navigation is any en route operation which is conducted outside the operational service volumes of ICAO standard NAVAIDS (VOR, NDB, VOR/NDB). Class I operations are those conducted within the operational service volumes of ICAO standard NAVAIDS. These terms are used extensively in FAA documentation. Further explanation can be found in FAA Order 8400.10, Air Transportation Operations Inspector's Handbook.

9.2 Non-group aircraft

A non-group aircraft is one which the operator applies for approval on the characteristics of the unique airframe and navigation system used, rather than on a group basis.

For non-group aircraft where airworthiness approval has been based on data collection, the continuing integrity and accuracy of the navigation system shall be demonstrated by periodic validation flights at periods to be agreed with the approving authority. However, alleviation of the validation flight requirement may be given if it can be adequately demonstrated that the relationship between any subsequent airframe/system degradation and its effects on navigation capabilities is understood and adequately compensated/corrected for.

Note: Data collected by one or more operators may be used as the basis for approval by another operator and may reduce the number of trials required to obtain approval. Appendix 9 describes a sample data collection procedure and provides sample forms to be used to collect the data.

10. Determining aircraft eligibility

It is important to note that the following groupings are different to the groupings discussed in Section 9. The groupings below are *eligibility groups*. These groups were established to assist in the discussion and do not have a precise definition. The definitions used are meant to assist in determining the approval method that may be used to approve specific aircraft and navigation systems. It should be noted that Doppler systems cannot be approved for RNP 10.

10.1 Aircraft eligibility through RNP certification – Group 1

Group 1 aircraft are those that have obtained formal certification and approval of RNP integration in the aircraft.

10.1.1 RNP compliance

RNP compliance is documented in the AFM, and is typically not limited to RNP 10. The AFM will address RNP levels that have been demonstrated and any related provisions applicable to its use such as navaid sensor requirements. Operational approval of Group 1 aircraft will be based upon the performance stated in the AFM.

10.1.2 Airworthiness approval

An airworthiness approval specifically addressing RNP 10 performance may be obtained. Part of that approval includes an appropriate AFM supplement, containing the system limitations and having reference to the manufacturer's operating procedures applicable to the equipment installed. The AFM supplement should be submitted to the CAA for approval. The layout of the AFM supplement should follow the format for the approved flight manual. The AFM supplement should include the following wording, or similar—

> **The XXX navigation system has been demonstrated to meet the criteria of YYY as a primary means of navigation for flights up to ZZZ hours in duration without updating. The determination of flight duration starts when the system is placed in navigation mode.**
>
> **For flights which include airborne updating of navigation position, the operator must address the effect that updating has on position accuracy, and associated time limits for RNP operations, pertinent to the updating navaid facilities used, and the area, routes, or procedures to be flown.**
>
> **Demonstration of performance in accordance with the provisions of AC91-7 does not constitute approval to conduct RNP operations.**

Note: The above wording in an AFM is based upon performance approval by the CAA, and is only one element of the approval process. Aircraft which have had this wording entered into their flight manual will be eligible for approval through issuance of Operation Specifications amendment or a Letter of Authorisation if all other criteria are met. The ZZZ hours specified in the AFM supplement does not include updating. When the operator proposes a credit for updating, the proposal must address the effects the updating has on position accuracy, and any associated time limits for RNP operations pertinent to the updating navaid facilities used, and the area, routes, or procedures to be flown.

10.2 Aircraft eligibility through prior navigation system certification – Group 2

Group 2 aircraft are those that can equate their certified level of performance, under previous standards, to the RNP 10 criteria. The standards listed in 10.2.1 to 10.2.6 can be used to qualify an aircraft under Group 2. Other standards may also be used if they are sufficient to ensure that the RNP 10 requirements are met. If other standards are to be used, the applicant must propose an acceptable means of compliance. As new standards are used for the basis of RNP 10, this AC will be revised to reflect the new standards.

10.2.1 Transport category aircraft equipped with dual FMSs, and other equipment, in accordance with Appendix 7

Aircraft equipped with INSs or IRUs, Radio Navigation Positioning Updating and Electronic Map Displays in accordance with Appendix 7 meet all of the RNP 10 requirements for up to

6.2 hours of flight time. This time starts when the systems are placed in the navigation mode or at the last point at which the systems are updated. If systems are updated en route, the operator must show the effect that the accuracy of the update has on the time limit (see Section 10.5 below for information on the adjustment factors for systems that are updated en route).

Note: The 6.2 hours of flight time is based on an inertial system with a 95% Radial Position Error Rate – circular error rate – of 2.0 nm/hr which is statistically equivalent to individual 95% cross-track and 95% along-track position error rates – orthogonal error rates – of 1.6015 nm/hr each, and 95% cross-track and 95% along-track position error limits of 10 nm each. For example 10 nm/1.6015 nm/hr = 6.2 hours

10.2.2 Aircraft equipped with INSs or IRUs that have been approved in accordance with FAR Part 121, Appendix G

Inertial systems approved in accordance with FAR Part 121, Appendix G, are considered to meet RNP 10 requirements for up to 6.2 hours of flight time. This time starts when the system is placed in the navigation mode or at the last point at which the systems are updated. If systems are updated en route, the operator must show the effect that the accuracy of the update has on the time limit. INS accuracy, reliability and maintenance, as well as flight crew training, required by Appendix G and Section 121.355 are applicable to an RNP 10 authorisation. Cross checking procedures associated with basic area navigation systems are applicable to operations with these navigation systems. Aircraft are required to be equipped with at least two eligible INSs.

10.2.3 Aircraft equipped with INSs or IRUs approved for MNPS or RNAV operations in Australia (AUSEP)

Aircraft equipped with dual INSs or IRUs approved for MNPS or RNAV operations in Australia meet RNP 10 requirements for up to 6.2 hours after the system is placed in the navigation mode or following an en route update. If systems are updated en route, the operator must show the effect that the accuracy of the update has on the time limit.

10.2.4 Aircraft equipped with single INS or IRU and single GPS approved for Primary Means of Navigation in oceanic and remote areas

Aircraft equipped with a single INS or IRU and a single GPS meet RNP 10 requirements without time limitations. The maximum allowable time for which the FDE capability is projected to be unavailable is 34 minutes. The maximum outage time should be included as a condition of the RNP 10 approval. The AFM should indicate that the particular INS/GPS installation meets the appropriate CAA requirements.

The INS or IRU must be approved to FAA Part 121 Appendix G standards.

The GPS must be approved to FAA TSO-C129, be certified in accordance with FAA Order 8110.60, and have been approved by the CAA for use in the aircraft as a sole means en route oceanic navigation aid.

10.2.5 Aircraft equipped with Global Positioning Systems (GPSs) approved for Primary Means of Navigation in oceanic and remote areas

Aircraft approved to use GPS as a primary means of navigation for oceanic and remote operations in accordance with 19.209(b) are considered to meet the RNP 10 requirements without time limits. The AFM and CAA 2129 should indicate that a particular GPS installation meets the appropriate CAA requirements. Dual TSO authorised GPS equipment certified under FAA Notice 8110.60 is required, and an approved dispatch fault detection and exclusion (FDE) availability prediction program must be used. The prediction program should be used with a lateral separation protected area of 20 nm for RNP 10. The maximum allowable time for which FDE capability is projected to be unavailable is 34 minutes. The maximum outage time should be included as a condition of the RNP 10 approval.

Note: If predictions indicate that the maximum allowed RAIM outage time for the intended RNP 10 operation will be exceeded, then the operation must be rescheduled when RAIM is available, or RNP 10 must be predicated on an alternate means of navigation.

10.2.6 Multi-sensor systems Integrating GPS (with GPS integrity provided by Receiver Autonomous Integrity Monitoring (RAIM))

Multi-sensor systems integrating GPS with RAIM that are approved using the guidance of FAA AC 20-130A, Airworthiness Approval of Navigation or Flight Management Systems Integrating Multiple Navigation Sensors, or equivalent, meet RNP 10 requirements without time limitations. In this case, the INS or IRU must be approved in accordance with FAR Part 121, Appendix G.

Appendix 9 provides a sample description of an updating procedure.

Note: Doppler systems cannot be approved for RNP 10.

10.2.7 New Zealand Defence Force aircraft

The New Zealand Defence Force must meet the requirements specified in this AC to be granted an RNP 10 approval. When showing compliance with these requirements equivalence may be determined for sole means GPS equipment where it can be demonstrated that the military GPS equipment installed meets the requirements of—

- FAA TSO-C129 and FAA Notice 8110.60
- FAA TSO-C129 and a CAA-approved predictive RAIM program is run for the route being flown within three days before each flight, and a navigator is utilised. The navigator must cross-check the aircraft's position at least every 15 minutes

10.3 Aircraft eligibility through data collection – Group 3

A data collection programme should address the appropriate navigational accuracy requirements for RNP 10. The data collection should ensure that the applicant demonstrates to the CAA that the aircraft and navigation system provides the flight crew with navigation situational awareness relative to the intended RNP 10 route. The data collection should also ensure that a clear understanding of the status of the navigation system is provided, and that failure indications and procedures are consistent with maintaining the required navigation performance.

Two types of data collection methods are described in this AC—

- the sequential method is a data collection programme meeting the provisions of Appendix 1. This method allows the operator to collect data and plot it against the *Pass-Fail* graphs to determine if the operator's aircraft system will meet the RNP 10 requirements for the length of time needed by the operator
- the periodic method of data collection employs the use of a hand-held GPS receiver as a base line for collected INS data, which is described in Appendix 8 – Periodic Method. The data collected is then analysed as described in Appendix 8 to determine if the system is capable of maintaining RNP 10 for the length of time needed by the operator

10.4 Obtaining approval for an extended time limit for INS or IRU systems

The baseline RNP 10 time limit for INS and IRU systems (after the system is placed in the navigation mode or following an en route update) is 6.2 hours, as detailed in paragraphs 10.2.1, 10.2.2 and 10.2.3. This time limit may be extended by one of the following methods—

- an extended time limit may be established when RNP is integrated into the aircraft navigation system through a formal certification process as described in paragraph 9.1
- when an INS or IRU has been approved using an existing approval standard, as detailed in paragraphs 10.2.1, 10.2.2, 10.2.3 and 10.2.4, an extended time limit may be established by an applicant presenting justifying data to the CAA. Data collected by one or more operators may be used as the basis for approval by another operator
- an applicant may establish an extended time limit by showing that the carriage of multiple navigation sensors, that mix or average navigation position error, justifies such an extension, such as triple mixed INSs. If the applicant uses an extended time limit based on mixing, then the mixing capability must be operational at take-off for flight on RNP 10 routes or in RNP areas. If the mixing or averaging function is not available at take-off, then the applicant must use a time limit that does not depend on mixing
- when an INS or IRU has been approved using an existing approval standard, an applicant can establish an extended time limit by conducting a data collection programme in accordance with the guidance provided in Appendixes 1 and 8

10.5 Effect of en route updates

Operators may extend their RNP 10 navigation capability time by updating. Approvals for various updating procedures are based upon the baseline for which they have been approved minus the time factors shown below—

- automatic updating using DME/DME = Baseline minus 0.3 hours

For example, an aircraft that has been approved for 6.2 hours can gain 5.9 hours following an automatic DME/DME update

- automatic updating using DME/VOR = Baseline minus 0.5 hours
- manual updating using a method similar to that contained in Appendix 9 or approved by the CAA = Baseline minus one hour

10.6 Conditions under which automatic radio position updating may be considered as acceptable for flight in airspace where RNP 10 is required

Automatic updating is any updating procedure that does not require flight crew to manually insert coordinates. Automatic updating is acceptable provided that—

- procedures for automatic updating are included in an operator's training programme
- flight crews are knowledgeable of the updating procedures and of the effect of the update on the navigation solution
- an acceptable procedure for automatic updating may be used as the basis for an RNP 10 approval for an extended time as indicated by data presented to the CAA. This data must present a clear indication of the accuracy of the update and the effect of the update on the navigation capabilities for the remainder of the flight

10.7 Conditions under which manual radio position updating may be considered as acceptable for flight in airspace where RNP 10 is required

If manual updating is not specifically approved, manual position updates are not permitted in RNP 10 operations. Manual radio updating may be considered acceptable for operations in airspace where RNP 10 is applied provided that—

- procedures for manual updating are reviewed by the CAA on a case-by-case basis. An acceptable procedure for manual updating is described in Appendix 9 and may be used as the basis for an approval by the CAA
- the operator shows that updating procedures and training contain measures/cross checking to prevent human factor errors
- the operator provides data that establishes the accuracy with which the aircraft navigation system can be updated using manual procedures and representative navigation aids. Data should be provided that shows the update accuracy achieved in in-service operations. This factor must be considered when establishing the RNP 10 time limit for INSs or IRUs
- the flight crew qualification curriculum must be found to provide effective pilot training

11. Minimum Equipment List (MEL)

Operators should make any necessary MEL amendments, as applicable to RNP 10 operations, and submit them to the CAA for approval. MEL applicability to systems such as INS, single or dual FMS, Distance Measuring Equipment (DME) updating capability, and mode or annunciation capability should be clearly specified for the procedures to be used. If an RNP 10 Operational Approval is granted on the basis of a specific operational procedure, such as credit for triple-mix, operators must adjust the MEL and specify the required dispatch conditions.

12. Continuing airworthiness (maintenance requirements)

12.1 General

The holder of the design approval, including either the type certificate (TC) or supplemental type certificate (STC) for each individual navigation system shall furnish at least one set of complete Instructions for Continued Airworthiness for the maintenance requirements for operations conducted in accordance with this AC.

12.2 Maintenance documents requirements

The following items should be reviewed as appropriate for RNP 10 maintenance approval—

- Maintenance Manuals
- Structural Repair Manuals
- Standard Practice Manuals
- Illustrated Parts Catalogues
- Maintenance Schedule
- MEL

13. Operational requirements

13.1 Navigational performance

All aircraft must meet a cross-track keeping accuracy and along-track positioning accuracy no greater than ±10 nm for 95% of the flight time in RNP 10 airspace.

13.2 Navigation equipment

All aircraft operating in RNP 10 oceanic and remote airspace, except as authorised by the CAA, must have at least two independent navigation systems of integrity such that the navigation system does not provide misleading information.

13.3 Flight plan

Operators should indicate the ability to meet RNP 10 for the route or area in accordance with ICAO Doc 4444 (PANS-RAC) Appendix 2 Item 10: Equipment. The letter “R” should be placed in Field 10 of the flight notification to indicate the pilot has—

- reviewed the planned route of flight, including the routes to any alternate aerodromes, to identify the types of RNP involved
- confirmed that the operator and aircraft have been approved by the CAA for RNP operations
- confirmed that the aircraft can be operated in accordance with the RNP requirements for the planned route of flight, including the routes to any alternate aerodromes

13.4 Availability of navaids

At dispatch or during flight planning, the operator should ensure that adequate navigation aids are available en route to enable the aircraft to navigate to RNP 10.

13.5 Route evaluation for RNP 10 time limits for aircraft equipped with only INSs or IRUs

As detailed in paragraph 10, an RNP 10 time limit should be established for aircraft equipped with INSs or IRUs. When planning operations in areas where RNP 10 is applied, the operator should establish that it will comply with the time limitation on the routes that it intends to fly. In making this evaluation, the operator should consider the effect of headwinds and, for aircraft not capable of coupling the navigation system or flight director to the autopilot, FTE. The operator may choose to make this evaluation on a one time basis or on a per flight basis. The operator should consider the points listed in the following sub-sections in making this evaluation.

13.5.1 Route evaluation

The operator should establish its capability to comply with the RNP 10 time limit on all RNP 10 routes – fixed or flexible tracks – on which it intends to fly.

13.5.2 Start point for calculation

The calculation should start at the point where the system is placed in the navigation mode or the last point at which the system is expected to be updated.

13.5.3 Stop point for calculation

The stop point may be one of the following—

- the point at which the aircraft will begin to navigate by reference to ICAO standard navaids (VOR, DME, NDB) and/or comes under radar surveillance from ATC
- the first point at which the navigation system is expected to be updated

13.5.4 Sources of wind component data

The headwind component to be considered for the route may be obtained from any source found acceptable to the CAA. Acceptable sources for wind data include—

- the Meteorological Service of New Zealand Limited
- Bureau of Meteorology
- National Weather Service
- Bracknell
- industry sources such as—
    - Boeing Winds on World Air Routes
    - historical data supplied by the operator.

13.5.5 One time calculation based on 75% probability wind components

Certain sources of wind data establish the probability of experiencing a given wind component on routes between city pairs on an annual basis. If an operator chooses to make a one time calculation of RNP 10 time limit compliance, it may use the annual 75% probability level to calculate the effect of headwinds. This level has been found to be a reasonable estimation of wind components.

13.5.6 Calculation of time limit for each specific flight

The operator may choose to evaluate each individual flight using flight planned winds to determine if the aircraft will comply with the specified time limit. If it is determined that the time limit will be exceeded, then the aircraft must fly an alternate route or delay the flight until the time limit can be met. This evaluation is a flight planning or dispatch task.

14. Discussion of certification actions related to RNP10

14.1 Improved performance

An operator may elect to certify the aircraft navigation performance to a new standard to take advantage of the aircraft capability. The aircraft may obtain credit for improved performance through operational data collection, in which case certification is not necessary. The following paragraphs provide guidelines for different types of navigation systems. The applicant must propose an acceptable means of compliance for any systems not identified in Section 14.1.1 and 14.1.2.

14.1.1 Aircraft incorporating INS

For aircraft with INS certified under FAA Part 121, Appendix G, additional certification is only necessary for operators who choose to certify INS accuracy to better than 2 nm per hour. Aircraft originally certified to a different standard may elect to upgrade their certification to be compliant with Appendix G, using a more stringent accuracy standard.

The certification of INS performance must address all issues associated with maintaining the required accuracy including, accuracy and reliability, acceptance test procedures, maintenance procedures, and training programmes. FAA AC 25-4, Inertial Navigation Systems (INS), describes an acceptable means of addressing these issues.

The applicant should identify the standard against which INS performance is to be demonstrated. This standard may be a regulatory – Appendix G, industry, or applicant unique specification. Consistent with FAA AC 25-4, paragraph 5b(4), a statement should be added to the AFM identifying the accuracy standard used for certification – refer paragraph 10.1.2.

14.1.2 Aircraft incorporating GPS

FAA AC20-138 provides an acceptable means of complying with installation requirements for aircraft that use GPS, but do not integrate it with other sensors. FAA AC20-130A describes an acceptable means of compliance for multi-sensor navigation systems that incorporate GPS. Aircraft which intend to use GPS as the only navigation system, that is no INS or IRS, on RNP 10 routes or in RNP 10 airspace, must also comply with related Civil Aviation Rules and AIP requirements, and other related advisory documentation, except for specific GPS requirements described in this AC.

14.2 Equipment configuration – MEL

The equipment configuration used to demonstrate the required accuracy must be identical to the configuration which is specified in the MEL.

14.3 Equipment configuration – Accuracy

The equipment configuration used to demonstrate the required accuracy must be supportable in RNP 10 oceanic and remote airspace. For example, the statistical benefit of estimating position using INS position data filtered with DME data, will not be considered.

Appendix 1 – Aircraft eligibility through data collection

1. General

This appendix offers broad guidance to operators, engineers, and navigation specialists in the use of a statistical procedure to determine whether aircraft should be approved for flight in RNP 10 airspace. Each application should be considered on its own merit, and should weigh such factors as the operator's experience, crew training procedures, the locations at which error data are accumulated, and the age of the data, and should request a review of the data by the CAA.

RNP 10 approvals will be issued for specific combinations of aircraft and navigation systems. If the navigation system which is a candidate for RNP 10 is an INS, IRS or any other system whose accuracy decreases with increasing flight time, the approval must be limited to the number of hours in which the aircraft can be expected to satisfy both the lateral – *cross-track* – and longitudinal – *along-track* – accuracy criteria of RNP 10.

This appendix describes statistical tests that use data gathered from repeated flights. Invoking standard statistical terminology, the appendix refers to a flight trial. This means for example an aircraft with three INSs could provide three data points – trials per flight. In each trial the operator measures two errors—

- the longitudinal position-determination error of the candidate navigation system
- the lateral deviation of the candidate aircraft from its planned route centre line

The longitudinal position-determination error measured in the i^{th} trial is called a_i, the lateral deviation measured in the i^{th} trial is called c_i. In order for the statistical test to be valid, the data gathered in each trial must be independent of those gathered in any other trial. In other words, the outcome of each trial must not influence the outcome of any subsequent trial. In general, data will be gathered after an aircraft has flown a time at least equivalent to that for which operational approval is requested, guided solely by the navigation system which is a candidate for RNP 10 approval.

An operator requesting RNP 10 approval for a candidate aircraft and navigation system must inform the CAA of the flights during which the operator plans to collect error data. The operator should collect data on every eligible flight until the statistical procedure described in this appendix indicates that the data collection should cease. The operator must use all valid data. In particular, the operator may not ignore data which shows large errors and submit only those showing small errors.

2. Data collection guidelines

Operators using the methods described in this appendix are to collect position estimates and use those estimates to compute the lateral and longitudinal errors of their aircraft. If a combination of aircraft and navigation system is a candidate for RNP 10 approval for a stated number of hours *h*, the data must be collected at least *h* hours after that navigation system was last updated or initialised. Furthermore, the data must be collected after the aircraft has been guided solely by that navigation system for a period long enough to eliminate the effects of prior guidance by any other navigation system that the aircraft may have used during its flight.

In order to determine the lateral and longitudinal error data, the operator must simultaneously obtain positions estimates from—

- the navigation system which is a candidate for RNP 10 approval and which has guided the aircraft for at least the preceding *h* hours

- a reference system which must be highly accurate in the area where the aircraft is conducting the data collection

The estimate from the reference system is taken to represent the aircraft's actual position. The position must be measured simultaneously, at a time when the aircraft has been flying along a straight segment of its planned route for several minutes, and is expected to continue flying along that segment for several more minutes. The operator should ensure that the aircraft's actual position at the time of the measurement is due to guidance derived solely from the candidate system. In particular, the operator should ensure that no other navigation system (especially the reference system) contributed, to any significant extent, to the aircraft's position at the time of the measurement.

The operator is responsible for establishing that reference system positions are accurate. The operator may wish to consider the following in selecting reference systems—

- DME/DME positions taken within 200 nm of both DME stations, derived automatically and displayed on systems such as Flight Management Computers

- GPS derived positions

- VOR/DME positions taken within 25 nm of the navigation aid

Note: Operators considering the use of these systems are reminded that many of them are installed so that their outputs are automatically used to guide the aircraft. If any system other than the candidate system has significant influence on the aircraft's position at the time when position estimates are obtained, the test of the candidate system will not be valid.

The positions simultaneously reported by the candidate system and the reference system must both be expressed, or re-expressed, in terms of the same coordinate system.

The longitudinal error a_i is the distance between the position reported by the reference system and the position reported by the candidate system, measured along a line parallel to the planned route of flight. Thus, if the two reported positions are connected by a vector, and the vector is resolved into a component parallel to the route and a component perpendicular to the route, a_i is the magnitude of the component parallel to the route.

The lateral deviation c_i is the distance between the planned route of flight and the position reported by the reference system (Note that the position reported by the candidate system has no role in determining the value of c_i). The distances a_i and c_i must be the absolute error distance expressed in nm. Errors are expressed in absolute terms so that longitudinal errors in opposite directions do not offset each other; nor do lateral deviations to the left and right offset each other.

Suppose, for example, that an operator wishes to obtain RNP 10 approval of an aircraft equipped with an INS, and that the RNP 10 time limit being sought for the INS is 6 hours. Suppose also that the aircraft can very accurately determine its position when it is in such airspace with multiple DME coverage, and that it usually enters a large block of airspace 5½ hours after last using another navigation system or signal to adjust its INS output. On each occasion when—

- the aircraft is flying in an area of multiple DME coverage

- at least 6 hours have passed since the last adjustment of INS output
- the aircraft has been flying straight for several minutes, and is expected to continue flying straight for several more minutes—

the crew records the time, desired track, the position reported by the INS and the position reported by the multiple-DME system. The operator later computes the longitudinal error and lateral deviation, a_i and c_i

The following is a non-technical summary of the steps used in collecting, plotting, and analysing data collected for the purpose of using the pass-fail graphs in this appendix. The data collected indicates the difference between the aircraft's navigation system and a highly accurate reference system. The position determined from the reference system is the aircraft's actual position. The point at which this data should be taken is when first leaving Class II Navigation at the designation end of the flight.

Step 1

Operator collects the following independent data on each eligible flight—

- on the desired flight path, the last waypoint and the to waypoint – these points should be taken from the flight plan
- taken simultaneously the—
    - reference system - such as DME/DME – computed aircraft position
    - guidance system – such as INS – computed aircraft position for each system

Step 2

The data must be taken after the guidance system – candidate navigation system – has been operating without any external update for a time at least as long as the time limit being requested.

Step 3

The data gathered in Step 1 is now used to calculate—

- cross track error – lateral deviation – c_i
- along track error – longitudinal error – a_i

Note: a_i above is considered to represent along track error.

Step 4

Cross Track Error (c_i). Calculate the perpendicular distance from the reference system computed aircraft position to the desired flight path. The desired flight path is a great circle line between the last waypoint and the to waypoint.

Step 5

Along Track Error (a_i). Calculate the distance between the reference system computed aircraft position and the guidance system – INS etc. – computed aircraft position along a line parallel to the desired flight path.

Step 6

Cross Track Pass/Fail. Following the first flight, errors are summed – for example, if the error was 2 nm on the first flight and 3 nm on the second flight then the cumulative error would equal 5. The cumulative error is the value of the ordinate – *y* coordinate in a Cartesian coordinate system – and the number of trials is the value of the abscissa – *x* coordinate in a Cartesian coordinate system. The intersection of these two is then plotted on Figure 1. The cross track RNP 10 requirements are passed when the plots of the cumulative errors fall below the lower pass line or fail if they pass the upper fail line.

Step 7

Along Track Pass/Fail. Following each flight, the errors are squared and following the first flight, the errors are summed – for example, if the error was 2 nm on the first flight and 3nm on the second flight then the cumulative squared errors would equal 4 + 9 = 13. The cumulative error squared is the value of the ordinate – *y* coordinate in a Cartesian coordinate system – and the number of trials is the value of the abscissa – *x* coordinate in a Cartesian coordinate system. The intersection of these two values is then plotted on Figure 2. The along track RNP 10 requirements are passed when the plots of the cumulative errors squared fall below the lower pass line or fail if they pass above the upper fail line.

It is recommended, but not mandatory, that operators planning to use their aircraft in a particular route system should gather error data from flights through that system –Tasman Sea area for example. If operations are planned in a new area of operations, an area different from that where data was collected, the operator should show that system accuracy will not be significantly affected by factors such as the direction of flight.

The operator should develop a standard form on which to document data for each flight. It should include—

- Date
- Departure aerodrome
- Destination aerodrome
- Aircraft type, series, and registration number
- Make/model of navigation system
- Time system placed in navigation mode
- If applicable, time aircraft navigation system was updated en route
- Time that reference position was taken
- Source of reference position –VOR/DME, DME/DME
- Reference position coordinates
- Aircraft navigation system position coordinates
- Desired track or waypoints passed immediately before and after the recorded positions
- To be calculated post fight – lateral and longitudinal error estimated per the guidance in this appendix

- Gate check information – Gate coordinates, individual INS or IRU coordinates, calculated error rate

3. Statistical Procedures

Background

Sequential sampling procedures are used to determine whether a candidate aircraft and navigation system should be approved for flight in RNP 10 airspace. After each trial the operator recomputes certain statistics and compares them to numbers indicated below. The comparison will infer one of three possible results—

- the candidate aircraft and navigation system satisfy the RNP 10 performance requirements, and the statistical test is terminated
- the candidate aircraft and navigation system do not satisfy the RNP 10 performance requirements, and the statistical test is terminated
- the operator needs to perform another trial – that is gather more data – and continue the statistical test, as it cannot yet reach a decision with the required level of confidence

A sequential sampling procedure typically requires fewer trials than does a statistical test which has a fixed number of trials and has the same probability of making the correct decision. In general, the better an aircraft navigates, the fewer trials it will need to *pass* the test – that is to demonstrate RNP 10 compliance.

However, for the CAA to have sufficiently high confidence in the test results, even an aircraft that navigates perfectly will need to perform at least 13 trials in order to demonstrate that it meets the RNP 10 lateral containment criterion, and at least 19 trials to demonstrate that it meets the RNP 10 longitudinal accuracy criterion. An aircraft that navigates poorly will need relatively few trials before "failing" the test. The test has been designed so that the average number of trials needed for it to reach a decision is approximately 100.

Test of lateral conformance

To establish whether or not the navigation system can meet RNP 10 in the lateral containment criteria, the operator may use the mathematical process described in this paragraph or use the graph provided in Figure 1, as described below. After conducting at least 13 trials, the operator should add together all of the lateral deviations obtained up to that point. Suppose, in particular, that n trials have been conducted. If the sum of the lateral deviations does not exceed $2.968n - 37.853$ then the candidate aircraft and navigation system have demonstrated compliance with the RNP 10 lateral containment criterion and the operator should stop computing lateral deviation data. If the sum of the lateral deviations equals or exceeds $2.968n + 37.853$ then the candidate aircraft and navigation system have demonstrated that they do not meet the RNP 10 lateral containment criterion and the operator should stop computing lateral deviation data. If the sum of the lateral deviations is between $2.968n - 37.853$ and $2.968n + 37.853$ the test cannot yet yield a decision. The operator must perform another trial to obtain an additional lateral deviation. This new lateral deviation is added to the sum obtained previously and the new sum is compared to

$2.968(n+1) - 37.853$ and $2.968(n+1) + 37.853$.

In other words, let $S_{c,n} = c_1 + c_2 + ... + c_n$ be the sum of the absolute values of the lateral deviations obtained in the first n trials.

If $S_{c,n} \leq 2.968n - 37.853$ then the aircraft and its navigation system pass the lateral conformance test.

If $S_{c,n} \geq 2.968n + 37.853$ then the aircraft and its navigation system fail the lateral conformance test.

If $2.968n - 37.853 < S_{c,n} < 2.968n + 37.853$ then the operator must—

- perform another trial to obtain c_{n+1}
- compute $S_{c,n+1} = c_1 + c_2 + \ldots + c_n + c_{n+1} = S_{c,n} + c_{n+1}$
- compare $S_{c,n+1}$ to $2.968(n+1) - 37.853$ and to $2.968(n+1) + 37.853$
- determine whether the candidate aircraft and navigation system pass the test or fail the test, or whether an $(n + 2)^{th}$ trial is needed

Figure 1 illustrates these rules for the lateral conformance test. The operator may wish to plot points on figure 1 as lateral deviation data are collected. The abscissa – horizontal component – of each plotted point is *n*, the number of trials completed; and the ordinate – vertical component – of each point is $S_{c,n}$, the sum of the absolute values of the lateral deviations observed in the *n* trials. The test ends as soon as a point falls into the lower right region or the upper left region of the graph. If a point is plotted in the lower right region, the aircraft/navigation system has shown that it satisfies the RNP 10 lateral containment criterion. If a point is plotted in the upper left region the aircraft/navigation system has demonstrated that it does not meet the criterion. Whenever a point is plotted in the middle region, the operator needs to accumulate more data.

In the event that the tests of $S_{c,n}$ do not yield a decision on the aircraft's lateral performance after 200 trials, the operator should perform the following computations—

Note: If D_C^2 does not exceed 18.649, *the aircraft and navigation system satisfy the RNP 10 lateral containment criterion. If D_C^2 does exceed* 18.649, *the aircraft and navigation system do not meet the criterion, and do not qualify for RNP 10 approval.*

- Compute the quantity, $D_1 = c_1^2 + c_2^2 + \ldots + c_{200}^2$
- Compute the quantity, $D_2 = \dfrac{S_{c,200}^2}{200} = \dfrac{(c_1 + c_2 + \ldots + c_{200})^2}{200}$
- Compute the quantity, $D_C^2 = \dfrac{D_1 - D_2}{200}$

Test of longitudinal accuracy

To establish whether or not the navigation system can meet RNP 10 in the longitudinal dimension the operator may use the mathematical process described below or use the graph provided in Figure 2.

After conducting at least 19 trials, the operator should add together the squares of all the longitudinal errors obtained up to that point. Suppose, for example, that *n* trials have been conducted. If the sum of the squares of the longitudinal errors does not exceed *22.018n - 397.667,* then the aircraft and navigation system have demonstrated compliance with the RNP 10 longitudinal accuracy requirement, and the operator should stop computing longitudinal error data.

If the sum of the squares of the longitudinal errors exceeds *22.018n + 397.667* then the aircraft and navigation system have demonstrated that they do not meet the RNP10 longitudinal accuracy requirement, and the operator should stop computing longitudinal error data.

If the sum of the squares of the longitudinal errors is between *22.018n - 397.667* and *22.018n + 397.667* then the test cannot yield a decision. The operator must perform another trial to obtain an additional longitudinal error. The square of this new longitudinal error is added to the sum obtained previously, and the new sum is compared to *2.018(n+1) - 397.667* and to *22.018(n+1) + 397.667.*

In other words, let $S_{a,n} = a_1^2 + a_2^2 + ... + a_n^2$ be the sum of the squares of the longitudinal errors obtained in the first n trials.

If $S_{a,n} \leq 22.018n - 397.667$ then the aircraft and its navigation system pass the longitudinal accuracy test.

If $S_{a,n} \geq 22.018n + 397.667$ then the aircraft and its navigation system fail the longitudinal accuracy test.

If $22.018n - 397.667 < S_{a,n} < 22.018n + 397.667$ then the operator must—

- perform another trial to obtain another longitudinal error a_{n+1}
- compute—

$$S_{a,n+1} = a_1^2 + a_2^2 + ... + a_n^2 + a_{n+1}^2 = S_{a,n} + a_{n+1}^2$$

- compare $S_{a,n+1}$ to *22.018(n+1) - 397.667* and to *22.018(n+1) + 397.66*
- determine whether the candidate aircraft and navigation system pass the test or fail the test, or whether an $(n + 2)^{th}$ trial is needed

Figure 2 illustrates the rules for the sequential test of longitudinal accuracy. The operator may wish to plot points on figure 2 as longitudinal error data are collected. The abscissa – horizontal component – of a plotted point is n, the number of trials completed; and the ordinate – vertical component – of a point is $S_{a,n}$, the sum of the squares of the longitudinal errors observed in the n trials.

The test ends as soon as a point falls in the lower right hand region or the upper left hand region of the graph. If a point is plotted in the lower right hand region, the candidate aircraft and navigation system have shown that they satisfy the RNP 10 longitudinal accuracy criterion. If a point is plotted in the upper left region, the aircraft and navigation system have demonstrated that they do not meet that criterion. Whenever a point is plotted in the middle region, the operator needs to accumulate more data.

In the event that the sequential sampling procedure described above does not yield a decision on the aircraft's longitudinal performance after 200 trials, the operator should perform the following computations—

- Compute the quantity

$$D_3 = \frac{(a_1 + a_2 + \ldots + a_{200})^2}{200}$$

- Compute the quantity

$$D_a^{\ 2} = \frac{S_{a,200} - D_3}{200}$$

If Da^2 does not exceed *21.784*, the aircraft and navigation system satisfy the RNP 10 longitudinal accuracy criterion. If Da^2 does exceed *21.784*, the aircraft and navigation system do not meet the criterion, and do not qualify for RNP 10 approval.

Figure 1: Acceptance, Rejection, and Continuation Regions for Sequential Test of Lateral Conformance

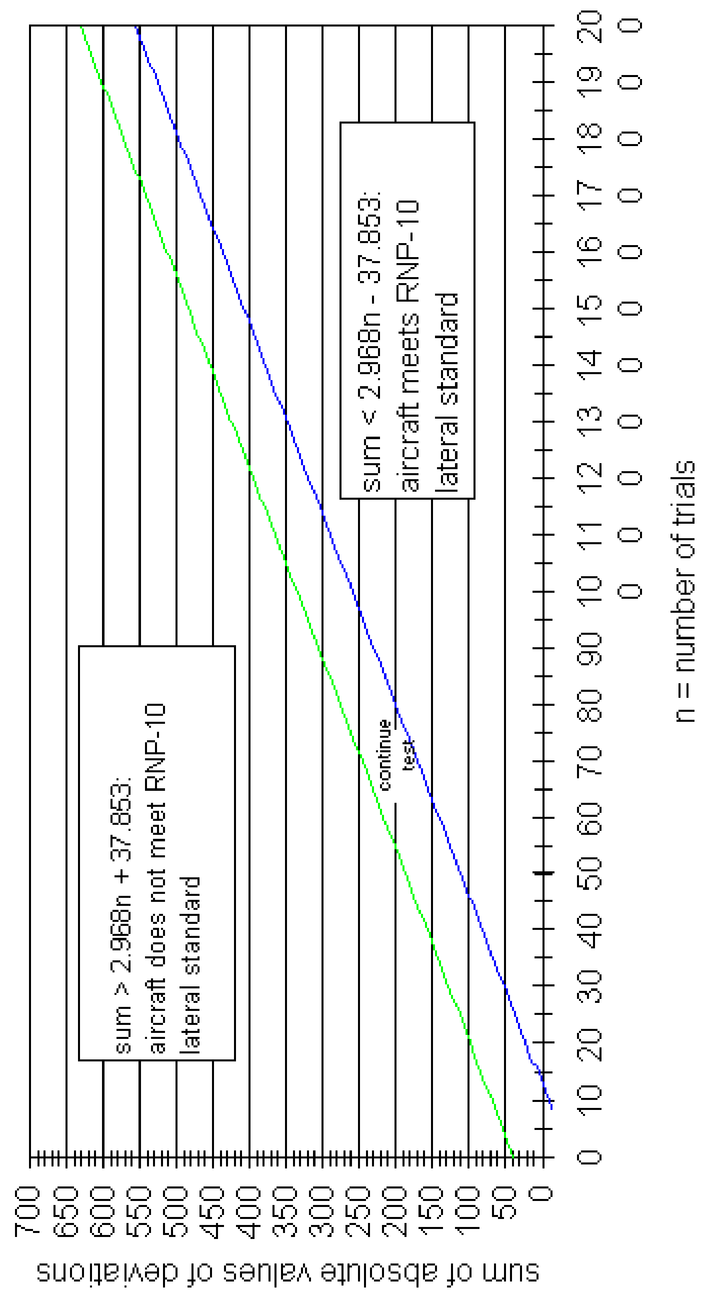
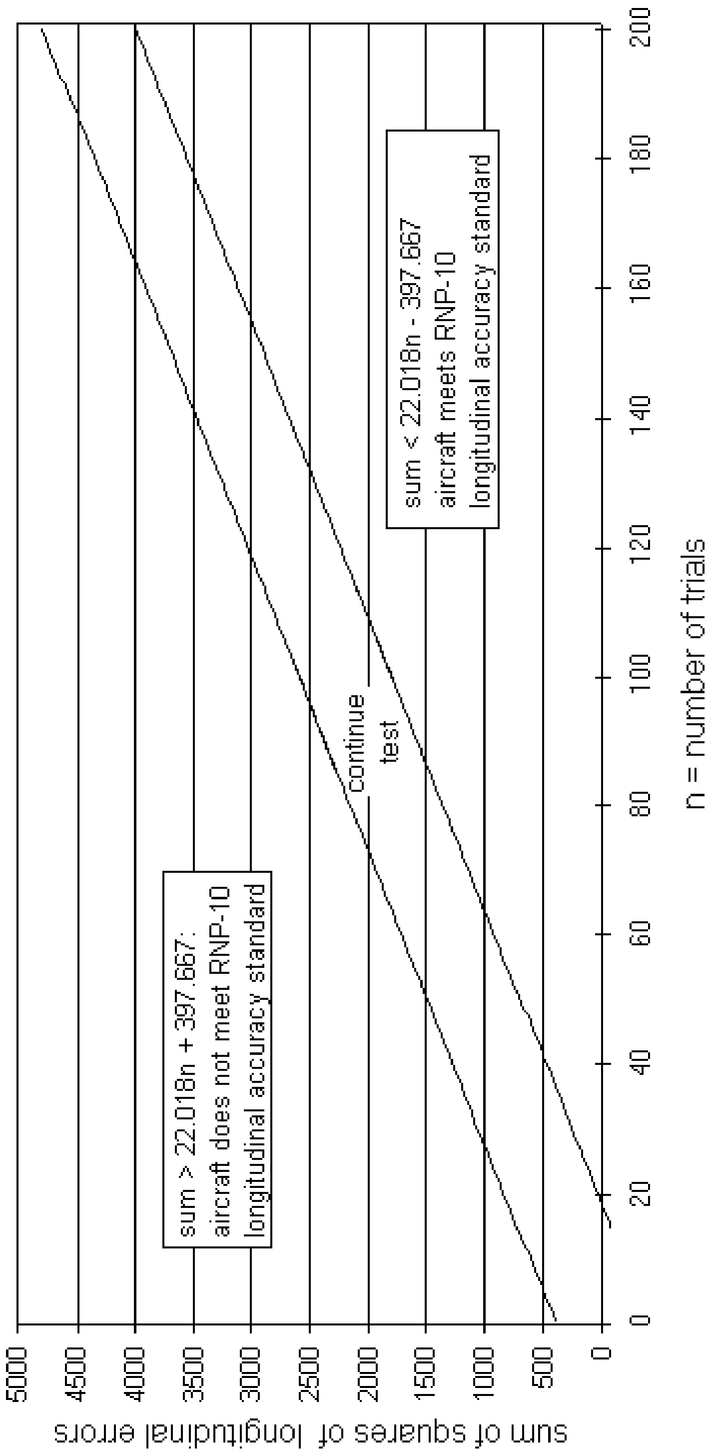


Figure 2: Acceptance, Rejection and Continuation
Regions for Sequential Test of Longitudinal Accuracy



Appendix 2 – Certification of IRU performance

1. Guidelines and assumptions

IRUs that meet the current requirements of FAA Part 121, Appendix G, meet all of the RNP 10 requirements for up to 6.2 hours of flight time without radio position updating. IRU accuracy, reliability, training, and maintenance issues that are required by Appendix G, are part of the aircraft certification. However, IRU manufacturers believe that the actual performance of some types of IRUs exceeds the current Appendix G requirements. A methodology for analysing IRU performance, combined with requirements to update IRU manufacturer's Specification Control Drawings (SCD), Acceptance Test Procedures (ATP), and airline IRU maintenance /removal criteria is described in the following paragraph.

2. Certification guidelines

IRU accuracy and reliability must be analysed in conjunction with the flight management system interface. An analysis performed on a specific manufacturer's aircraft model is not necessarily applicable to other aircraft operating the same equipment. However, other aircraft may be analysed using the same or equivalent methodology as proposed herein—

- the radial navigation error distribution for IRUs is modelled by a Rayleigh Distribution. The 95% statistic of radial position error will be used when demonstrating compliance. It is assumed that cross-track and along-track errors are Gaussian, independent, and have equal variances
- the Radial Position Error will be evaluated for the range of the independent time variable – time in navigation – as certified for the IRU navigation maximum time, for example 18 hours
- time-dependent position error data will be presented. Other non-inertial error sources will not be considered as part of the IRU certification, that is flight technical error. Therefore, the maximum time duration of flight operations in RNP 10 airspace will be evaluated and determined as part of the operational approval
- The assessment of navigation performance may employ system analysis, IRU error modelling –Covariance Analysis – and system simulation. Analytical findings may be validated with empirical data from laboratory testing and aircraft flight testing, as applicable

When credit is required for IRU performance that is superior to the original certification, the existing IRU specification control drawings for the IRU Type Designs should be revised to account for the new tighter tolerance system error budgets. If it has been determined that all IRUs for a given part number meet the minimum requirements of the new performance standard, then the IRU part number may remain the same. When only some of the IRUs for a given part number meet the minimum requirements of the new performance standard, then screening is required and part number updates will be required to identify the IRUs which are compliant to the new performance standard.

The AFM or AFM Supplement (AFMS) must be modified to reflect the certification of IRUs to tighter accuracy requirements. The AFM should provide sufficient time-dependent information so that the maximum time in RNP 10 airspace can be assessed as part of the operational approval.

In addition, production and field acceptance test procedures will require an update by the supplier, to ensure that the installed IRU meets the tighter accuracy tolerance required.

3. Maintenance procedures

Operator maintenance procedures will require updating to ensure appropriate monitoring of IRU performance to the new requirements contained in this AC, and replacement of IRUs on aircraft that do not meet the navigation performance of this new criteria.

4. Operations procedures

Procedures for flight operations should be identified and applied to ensure IRU alignment before extended range flights and time-in-navigation for the intended time duration of flight in RNP 10 airspace.

SOURCE: FAA Order 8400.12A

Appendix 3 – Sample letter of request for RNP10 approval

[file reference] *[date]*

Manager Aircraft Certification
Civil Aviation Authority
PO Box 31-441
Lower Hutt

Dear Sir

APPLICATION FOR RNP 10 OPERATIONAL APPROVAL

[aircraft operator] requests that operational approval be given to conduct en route operations on designated RNP 10 routes and in designated RNP 10 areas with a maximum time of *[number]* hours between navigation system updates.

The following *[aircraft operator]* aircraft meet the requirements and capabilities as defined/specified in AC AC91-7 for RNP 10 operations—

Aircraft Type/Series	Navigation Systems/Equipment	Time Limit
B747-400	List nav equip by name and type/manufacturer/model	No of hours or unlimited
B767-300	As above	As above
B737-200	As above	As above
650 Cessna Citation III	As above	As above

Flight crews have been trained in accordance with the requirements of the ICAO RNP Manual and guidance material in AC AC91-7.

Yours sincerely

[signature]

[name]

[appointment/title

Appendix 4 – Training and operating practices

1. Introduction

The items detailed in paragraphs 2 to 5 should be standardised and incorporated into training programmes and operating practices and procedures. Certain items may already be adequately standardised in existing operator programmes and procedures. New technologies may also eliminate the need for certain crew actions. If this is found to be the case, then the intent of this appendix can be considered to be met.

Note This AC has been written for a wide variety of operator types and, therefore, certain items which have been included may not apply to all operations.

2. Flight crew qualifications

Part 119 operators should ensure that flight crews have been trained to ensure that crews are knowledgeable of the topics contained in this AC, the limits of their RNP 10 navigation capabilities, the effects of updating navigation systems, and RNP 10 contingency procedures.

Private operators should demonstrate to the CAA that pilots are knowledgeable on RNP 10 operations. This AC provides suitable guidance material.

3. Flight planning

During flight planning, the flight crew should pay particular attention to conditions which may affect operations in RNP 10 airspace or on RNP 10 routes. These include, but may not be limited to—

- verifying that the aircraft is approved for RNP 10 operations
- that the approval is for a time limit that will allow compliance with RNP 10 requirements for the total length of the flight
- verifying that the letter 'R' is annotated in Block 10 – *Equipment* – of the ICAO Flight Plan
- the requirements for GPS, such as FDE, if appropriate for the operation
- if required for a specific navigation system, accounting for any operating restriction related to RNP 10 approval

4. Preflight procedures at the aircraft for each flight

The following actions should be completed during pre-flight—

- review maintenance logs and forms to ascertain the condition of equipment required for flight on RNP 10 routes or in RNP 10 areas. Ensure maintenance action has been taken to correct defects to required equipment
- during the external inspection of aircraft, where possible, particular attention should be paid to the condition of navigation antennae and the condition of the fuselage skin in the vicinity of each of these antennae. This check may be accomplished by a qualified and authorised person other than the pilot such as a flight engineer or a maintenance person
- emergency procedures for operations on RNP 10 airspace or on RNP 10 routes are the same as normal oceanic emergency procedures with one exception; crews must be able

to recognise and ATC must be advised when the aircraft is no longer capable of navigating in accordance with its RNP 10 approval requirements

5. En route

At least two long range navigation systems capable of navigating to the RNP should be operational at the oceanic entry point. If this is not the case, then the pilot should consider an alternate routing which does not require that equipment, or diverting for repairs.

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

Operator in-flight operating drills should include mandatory cross checking procedures to identify navigation errors in sufficient time to prevent aircraft from deviating inadvertently from ATC cleared routes.

Crews should advise ATC of any deterioration or failure of the navigation equipment below the navigation performance requirements or of any deviations required for a contingency procedure.

SOURCE: FAA Order 8400.12A

Appendix 5 – Checklist for RNP 10 approval

1.	**Operator Prepares An Application Package As Described In Paragraph 7**	
2.	**Operator Self-Examination** Operators should become familiar with paragraphs 7 and 10 of this AC before contacting the CAA. These sections provide the criteria for approvals by placing aircraft/navigation systems in groups. A knowledge of these sections provides the operator with an indication of how much time might be required in obtaining an approval. Group 1 approvals are administrative and can be granted as quickly as the CAA work loads will permit. Group 2 approvals may be made quite rapidly or may take longer depending upon the aircraft/navigation system configurations. Group 3 approvals will usually involve an extended time for evaluation and an approval may or may not be granted.	
3.	**Operator Schedules A Pre-Application Meeting** The operator should schedule a pre-application meeting with the CAA.	
4.	**Operator Submits A Formal Application For Approval** Application to be in accordance with the CAA expectations discussed in the pre-application meeting. The formal application should be made in writing in a manner similar to those shown in Appendix 3.	
5.	**Operator Trains Crew** An RNP 10 airspace or an RNP 10 route is a special airspace. There are no legal requirements for general aviation operators to have specific training for RNP 10 operations; however, ICAO Rules demand that States ensure that the crew are qualified to operate in special airspace. Thus general aviation operators will be required to satisfy the CAA that they are qualified.	
6.	**Operators Receive Operation Specifications Amendment or an LOA** Specifications enabling operations in RNP 10 airspace or on an RNP 10 route.	
7.	**Crews Are Authorised To Perform RNP 10 Operations** The authority is valid only for the time authorised within the parameters established for their navigation system configuration.	

SOURCE: FAA Order 8400.12A

Appendix 6 – Sample operations specification

1. Draft operations specification amendment

W.X.Y. Navigation/communication systems

(z) Operation within *[state RNP airspace or RNP routes as applicable]* Required Navigation Performance 10 (RNP10) airspace is authorised, provided that such operation is in accordance with applicable requirements, as detailed in ICAO Document 7030/4 “Regional Supplementary Procedures”.

Appendix - Required Navigation Performance (RNP) Airspace

The following aircraft are authorised for RNP10 operations as defined in paragraph W.X.Y (z):

Aircraft: *[make, model, and registration mark]*

2. Draft letter of authorisation

[file reference] *[date]*

[organisation name]
[address]

Dear Sir/Madam

APPROVAL TO OPERATE IN RNP10 AIRSPACE

Pursuant to Civil Aviation Rule 91.519 approval is hereby granted for the following operator, aircraft and navigation systems for en route oceanic and remote area operations on designated RNP 10 routes and in designated RNP 10 airspace with the stated RNP 10 time limit.

Operator: *[name]*

Aircraft: *[make, model, and registration mark]*

Navigation systems: *[type, manufacturer, model, and time limit]*

Designated RNP routes/airspace: *[specify]*

[signature]

[name]

[title

Appendix 7 – Transport category aircraft equippage

Aircraft equipped with a Flight Management System (FMS) with barometric Vertical Navigation (VNAV), oceanic, en route, terminal, and approach capability meet all of the RNP 10 requirements for up to 6.2 hours of flight time. Equipment requirements are—

- dual FMS which meets the specifications of either—
    - FAA AC 25-15, Approval of Flight Management Systems in Transport Category Airplanes
    - FAA AC 20-129, Airworthiness Approval of Vertical Navigation (VNAV) Systems for use in the US National Airspace System (NAS) and Alaska
    - CASA CAAP 35-3, Airworthiness Approval of Navigation or Flight Management Systems Integrating Multiple Navigation Sensors
    - equivalent criteria as approved by CAA
    - a flight director and autopilot control system capable of following the lateral and vertical FMS flight path
    - at least dual inertial reference units (IRUs)
    - a database containing the waypoints and speed/altitude constraints for the route and/or procedure to be flown that is automatically loaded into the FMS flight plan
    - an electronic map

The above have been taken from the US Aeronautical Information Manual (AIM), Table 5-1-2, Aircraft Equipment Suffixes - Area Navigation Systems. Under the US system, these aircraft would qualify for the /E suffix

Appendix 8 - Data collection process (periodic method)

1. Introduction

This section describes a data collection procedure that has been accepted by the CAA on the basis of analysis of the data and multiple validation flights.

There are two methods in which data may be collected. One procedure is based upon the use of a hand-held Global Positioning System (GPS) as a base line for the correct position determination with the GPS readings and the data collection being taken by a non-essential flight crew member. Only authorised flight crews may operate the navigation system. Although no technical specifications are stated for the GPS unit used, it behoves operators to use the best quality unit that is practical. Poorer quality units might malfunction or provide erroneous data that will distort or negate the data collected and make the process excessively expensive.

The second method uses a single, un-updated 'gate position' as a data point and performing the calculations at the end of this appendix to determine an RNP 10 limit.

Further, it is possible to evaluate triple-mix, individual units or both using this data collection procedure - the data collection forms are designed for this purpose. Operators wishing to use 'gate position' only, do not need to use the data pages but can go directly to the destination data page and record the gate position data and time since last update.

2. General instructions

2.1 GPS updates

Pilots should not update the INS to a GPS position. Doing so would invalidate the data collected.

2.2 Data recording

When recording data, all times are to be noted in UTC. Circle latitude and longitude senses (N or S, E or W). Please record any additional information that could be helpful in analysing recorded data.

2.3 Page heading

Flight number and date from the FPF. Enter all information on each page.

2.4 INS initialisation (page 1)

- Record any unusual movement of the aircraft during INS initialisation before NAV mode selected, such as wind gusts or aircraft service vehicle bumping the aircraft or settling during fuelling

- If there was any unusual movement during INS alignment, record INS track (TK/GS) after NAV mode is selected

- Record the published gate coordinates or GPS position where the INS is initialised

- Was triple-mix selected? Check *yes* or *no*

- Check DME updating, *yes* or *no*?

2.5 Times (page 1)

- Before departure, record the time the pilots are observed putting the INS NAV mode selectors in NAV
- Record OFF time
- Record the time following oceanic and remote area navigation when radar contact is first established
- Record IN (at the gate) time

2.6 Destination Gate positions (page 1)

- Pilots should not remove INS updates until INS updated/triple-mix positions are recorded at the gate
- Record the destination gate number published position, the number of GPS SVs (Satellite Vehicles) in view, the GPS DOP and EPE values and the GPS position
- Record INS updated/triple-mix positions
- Remove INS updates
- Record INS un-updated positions and INS distances from the gate position
- INS data should be recorded in the Maintenance Log as usual

2.7 ½ Hourly position readings (page 2 and beyond)

- Once each 30 minutes after take-off (ACARS OFF time), plus or minus 5 minutes, record GPS and INS positions. Do not record data during climb or descent, during pilot INS Waypoint Change procedures or at other times when pilots obviously are busy with other tasks, such as ATC or cabin communications
- Record the desired track (DSRTK/STS) of steering INS
- Record the last and next waypoints lat/long and name
- Freeze the GPS and INS positions simultaneously
- Record GPS position
- Record INS updated / triple-mix positions – HOLD and POS selected
- Record the INS un-updated (Inertial) positions – HOLD and WAY PT, thumbwheel other than 0 selected
- Release the frozen INS and GPS positions

2.8 En route INS updates (Page 2)

- Record the identifier of the navaid over which updating is accomplished and the navaid coordinates
- Record the number of GPS satellites in view and the GPS PDOP value
- Record the time when INS coordinates are frozen before the en route update is accomplished

- After INS positions are frozen and before an updated position is entered—
  - Record the INS updated / triple-mix positions and INS un-updated positions
  - Record the GPS position

2.9 Radio navigation ISN updates

Use this section only if manual updating is being evaluated – for example ground based radio navigation positions are used for INS updates.

Note: There is no data sheet example for radio navigation updates.

Record—

- Navaid identifiers
- Aircraft position derived from ground navaids (update position)
- Time of update
- INS position before update

GPS position

ZK-		**Make/Model:**		**Operator:**	
Flight No:		**UTC Depart Date:**			

INS INITIALIZATION

Were there any unusual motion events during alignment?	Yes	No
If yes, INS Track (TK / GS)		
If yes, provide a brief description of the event(s)		
INS initialisation co-ordinates (published or GPS):	N/S	
	E/W	
Triple-mix selected?	Yes	No
DME up-dating?	Yes	No

TIMES (record all times in UTC)

OFF time:			
Time INS NAV mode selected:			
Time in NAV mode before takeoff: (hours)		(minutes)	
Approx time leaving oceanic airspace:			
Time NAV mode selected:			
Approx time in NAV mode before entering RNP airspace: (hours)		(minutes)	
IN time:			
Time NAV mod selected:			
Total time in NAV mode: (hours)		(minutes)	

DESTINATION GPS / INS POSITIONS

Do not remove INS updates until up-dated / triple-mix positions are recorded at the gate

Destination Gate No:		Published Position			
No of SV:		DOP:		EPE:	•
GPS Position: N/S		E/W			

	Updated/Triple-Mix Positions		Un-Updated Positions		Distance
INS 1					
INS 2					
INS 3					

Name of person recording data (please print)			
Telephone No:		Position:	
Captain:			

Flight No		UTC Departure Date		Departure Aerodrome	

A/C Type		Reg No		Captain		Arrival Aerodrome	

Data Point 1 (after OFF time)

Altitude ______ Time ______

GPS

No of SV ______ DOP ______ EPE ______ • ______ INS DSRTK ______

GPS Position: N/S ______ E/W ______

INS

	Updated/Triple-Mix Positions		Un-Updated Positions		Distance
INS 1					
INS 2					
INS 3					

Last Waypoint

Name ______ N/S ______ E/W ______

Next Waypoint

Name ______ N/S ______ E/W ______

Data Point 2 (after OFF time)

Altitude ______ Time ______

GPS

No of SV ______ DOP ______ EPE ______ • ______ INS DSRTK ______

GPS Position: N/S ______ E/W ______

INS

	Updated/Triple-Mix Positions		Un-Updated Positions		Distance
INS 1					
INS 2					
INS 3					

Last Waypoint

Name ______ N/S ______ E/W ______

Next Waypoint

Name ______ N/S ______ E/W ______

Flight No		UTC Departure Date				Departure Aerodrome	
A/C Type		Reg No		Captain		Arrival Aerodrome	

Data Point 3 (after OFF time)						
Altitude		Time				
GPS						
No of SV		DOP		EPE	•	INS DSRTK
GPS Position: N/S			E/W			
INS						
	Updated/Triple-Mix Positions		Un-Updated Positions		Distance	
INS 1						
INS 2						
INS 3						
Last Waypoint						
Name		N/S		E/W		
Next Waypoint						
Name		N/S		E/W		

Data Point 4 (after OFF time)						
Altitude		Time				
GPS						
No of SV		DOP		EPE	•	INS DSRTK
GPS Position: N/S			E/W			
INS						
	Updated/Triple-Mix Positions		Un-Updated Positions		Distance	
INS 1						
INS 2						
INS 3						
Last Waypoint						
Name		N/S		E/W		
Next Waypoint						
Name		N/S		E/W		
Flight No		UTC Departure Date		Departure Aerodrome		
A/C Type		Reg No		Captain		Arrival Aerodrome

SOURCE: FAA Order 8400.12A

Copy previous pages for use in collecting data points in excess of 4 as needed to collect data for the total flight hours. Use the following procedures following pages to analyse the data

3. RNP 10 data reduction techniques for periodic, in-flight, method of data collected

- Collect reference data (GPS) and INS/IRU data at least every 30 minutes after reaching initial cruise altitude – Lat, Long, Height and time at the same time for each system
- Determine North-South and East-West error in nm – Difference between GPS and INS/IRU position translated into nm
- Graph position error – using GPS as reference – versus time for each flight
- Since the actual time of measurement and the test time interval will vary, establish on each flight chart – plot – an equally spaced interval
- At each time interval calculate the radial position error for each flight. This requires interpolation of the North-South, East-West data from the graphs
- This radial error is the data used to determine the 95 percentile level of error. 'The 95 percentile error level of error' is used here to mean that it is 95 % probable that the error in a given flight will fall below this level or that the level will be below this level in 95% of flights if the number of flights is very large
- After collecting the data for all flights, calculate the Root-Mean-Square (RMS) and Geometric Mean (GM) of the radial errors for each elapsed time point. Also determine the ratio of GM/RMS for each elapsed time point

$$RMS = \left(\frac{1}{n} \sum_{i=1}^{i=n} r_i^{\,2} \right)^{1/2}$$

$$GM = \left(\prod_{i=1}^{i=n} r_i \right)^{1/n}$$

where—

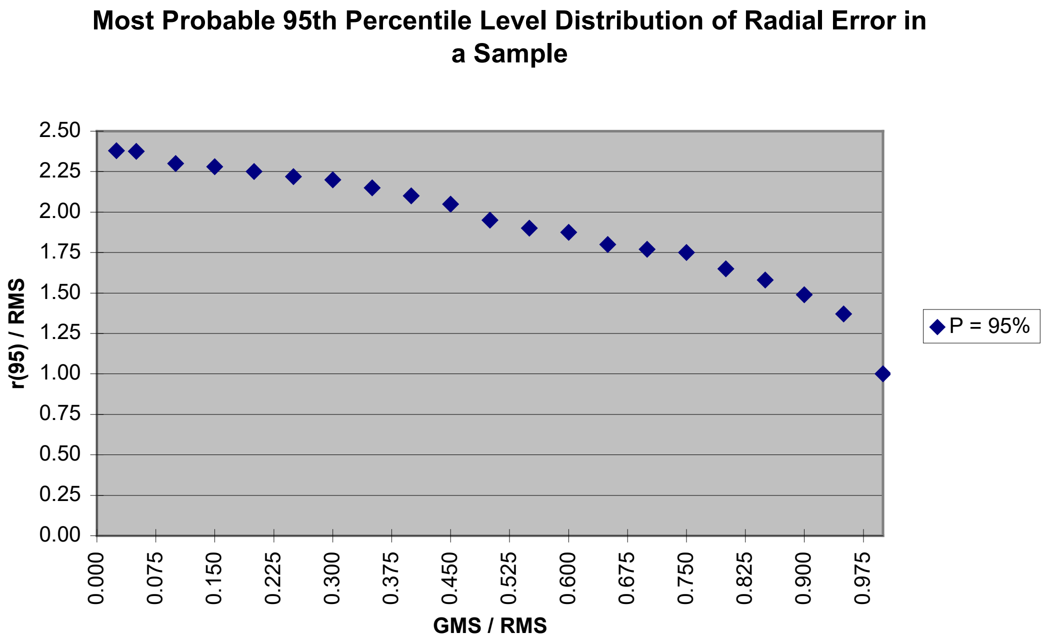
r = radial error at elapsed time point

n = number of observations of radial error at equally spaced time intervals

- Using the P=95 curve from Figure 1 below, find the value of $r_{(P)}$/RMS for the calculated value of GM/RMS. Multiply this $r_{(P)}$/RMS factor by the value of RMS to determine an estimate of the 95th percentile value of radial error at this elapsed time point
- Repeat the above procedure for each elapsed time point. Graph $r_{(95)}$ values of radial error (in nm) versus elapsed time since entering the NAVIGATE mode

Pass-Fail criteria

The elapsed time when radial error $r_{(95)}$ exceeds 10 nm defines maximum flight time wherein the navigation system meets RNP 10 criteria.



4. Periodic method example

As an example, a 6 flight data set is used. In actual practice a much larger data set should be used to provide confidence. For simplicity of illustration, this example uses only the Triple-Mix positions after 10 hours in NAV – the time was an arbitrary selection to illustrate the means of calculation. Data for individual navigation units is not included in this example; if they had been used they would be calculated in exactly the same manner that the Triple-Mix data is calculated in the example. If an operator decided to use gate position only Table 2 should be used.

The symbols used in the figures below are—

r = radial error

r^2 = square of the radial error

Πr = product of radial errors

$\sum$ = Sum

$\sum r^2$ = Sum of the squares of the radial errors

Flight	Radial errors = r	r^2
1	6.5	42.25
2	5.5	30.25
3	12.7	161.22
4	14.0	196.00
5	7.2	51.84
6	7.0	49.00

Table 1: Table of Radial Errors 'r' – Use for Airborne Data Collection

The product of radial errors (Π), column 2 = 320,360

The sum of the radial errors squared ($\sum r^2$), column 3 = 530.63

Calculations

$$RMS = \left(\frac{1}{n} \sum_{i=1}^{i=n} r_i^{\,2} \right)^{1/2} = (1/6\ (530.63))^{½} = 9.40$$

$$GM = \left(\prod_{i=1}^{i=n} r_i \right)^{1/n} = (320.36)^{1/6} = 8.27$$

RATIO = GM/RMS = 8.27/9.40 = 0.88

Find this value (0.88) on the abscissa of the *Most Probable Graph* and intersect it with the 95% curve to find $r_{(95)}$ /RMS –the ordinate of the graph.

Thus $r_{(95)}$ /RMS = 1.47 for this example

The ordinate is defined as $r_{(95)}$ /RMS

where $r_{(95)}$ = 95 percentile of error

Now $r_{(95)}$ for the data in the example is determined from the following—

$r_{(95)}$ = Ordinate value (for the data) x RMS = 1.47 x 9.40 = 13.8 nm

These results indicate that the 95 percentile level of error at 10 hours is 13.8 nm which is greater than the required 10 nm and the system would not qualify for RNP10 for 10 hours based on the data presented.

Guidance on gate position data collection is shown below.

Note: No data is provided for this method. Calculations would be made identical to the procedure used in Table 1.

Time is critical with this set of data and it should be noted that the credited time is that of the smallest time value in the data set.

Flight	Times since last update	Radial Error at Gate = r	r^2

Table 2: Table of Radial Errors – Use for Gate Position Data

1. The product (Π) of radial errors (column 3) = _____________

2. The n^{th} root of Π = _________________ = GM

3. The sum of the radial errors squared ($\sum r^2$) (column 4) = _________________

4. The square root of

$$\left(\frac{1}{n}\sum r_i^{\,2}\right) = RMS$$

After calculating (2) and (4) use Table 1 to determine $r_{(95)}$. Multiply this factor by the RMS to determine the drift in nm. If this value is less than 10 nm then the navigation system can be approved for RNP 10 for the time in nav of this flight. Note that this is the data for one flight only, data must be collected in the same manner and in an equal time length for a minimum of 20 flights

Appendix 9 –Manual updating procedure

1. Introduction

In order to facilitate RNP 10 operations for airborne navigation systems that are unable to achieve RNP 10 performance for greater than 6.2 hours, the following methods of manual position updating are suggested as a means to extend the 6.2 hours. Manual position updating is defined to mean a technique where the crew uses one of the following techniques to adjust their INS output to compensate for the detected error. The detected error is the difference between the radio navigation position and the INS/IRU position wit the radio navigation position being considered the correct position.

Two methods using VOR/DME or TACAN and one method using a Global Positioning System are discussed. One is a position update based on crossing a fix along a route defined by a bearing and distance from/to a VOR/DME facility. The second is based on a route that over flies a VOR/DME facility. The third is similar to the first but uses a TSO-C129 authorised GPS for the update in place of the navigation aid. In each of the three methods, a log (the plotting chart used in each of the procedures is an acceptable log if all required data is entered on the chart) of the procedure must be made of the data and maintained by the operator for a period of 30 days.

The conditions under which either method may be used are—

- Inertial Navigation Systems meeting FAR, Part 121, Appendix G requirements or the criteria established in FAA AC25-4 are used
- for the first and second methods the minimum distance from the reference VOR/DME facility must be at least 50 nm
- both the VOR and DME functions of the reference facility must be operational prior to dispatch release and during the intended updating operation unless the GPS procedures are used as a reference

the flight crew must have in its possession a plotting chart with the information specified in this Appendix

Mandatory Data Required To Accompany All Of The Updating Methods

INS INITIALISATION		
Were there any unusual motion events during alignment?	Yes	No
If yes, INS Track (TK / GS)		
If yes, provide a brief description of the event(s)		
INS initialisation coordinates (published or GPS):		
N / S	E/W	
Triple-mix selected?	Yes	No
Radio navigation up-dating?	Yes	No
TIMES (record all times in UTC)		
Prior to Take-Off		
OFF:		
Time NAV mode selected:		
Time in NAV mode before takeoff: (hours)	(minutes)	
Flight Phase		
Time entering oceanic airspace:		
Time leaving oceanic airspace:		
Time NAV mode selected:		
Approx time in NAV mode before leaving oceanic airspace:		
(hours)	(minutes)	
Arrival Phase		
IN:		
Time NAV mode selected:		
Total Time in NAV mode: (hours)	(minutes)	

2. Training

2.1 Part 119 operators intending on using manual updating procedures must ensure that every flight crew using the procedures is trained in the updating procedures. The operator should be able to demonstrate to the CAA that it has a reliable method of having its crews perform the update. Training manuals must be updated to include the procedures and will be evaluated by the CAA as a part of the approval process.

2.2 Part 91 operators intending on using manual updating procedures must provide evidence to the CAA that crews using the procedures are capable of maintaining the same standards as Part 119 operators.

3. Method 1: Manual updating based on crossing a fix along a route

3.1 Using Method 1, the update is performed when crossing over a fix that is defined by a crossing radial and distance from a VOR/DME or TACAN facility. To accomplish this update, the crossing radial must be at or near perpendicular to the route. The minimum DME/TACAN distance used to define the fix location shall be at least 50 nm.

3.2 The flight crew should tune in the reference VOR/DME or TACAN facility and pre-select the appropriate bearing from the VOR on one CDI. As the CDI centers, the flight crew will note the distance from the VOR/DME or TACAN facility and mark it on the plotting chart. The flight crew will also note the inertial positions of each of the operating INS. The crew will then compare the inertial position against the derived position. The crew then may use the derived position (expressed in lat/long) to update the inertial position. If interpolation is necessary, round up. This procedure would provide a means to re-start the RNP 10 clock for an additional predetermined time.

3.3 To accomplish this manual update, the flight crew should have a plotting chart that displays the route fix and DME fixes of one mile increments located along a line that is perpendicular or near perpendicular to the route along the axis of the VOR/TACAN radial used to define the fix. Each fix should be displayed in both DME distance and latitude/longitude coordinates.

3.4 Put two way fixes along the route, one on either side of the “update” fix and note the coordinates on the plotting chart. Crews should then use these fixes to validate the position update. This is similar to the method used for updating when flying on a route that passes over a VOR/DME or TACAN facility. It is imperative for crews to remember that these additional fixes are to be used for verification only, not as an update fix. They do, however, provide a means of verification of the update.

3.5 If, when measuring the fix displacement error, the crew determines that it is outside the 10 nm point and has been in INS nav for less than 5 hours, they should advise ATC that the flight can no longer maintain RNP 10 navigation performance.

4. Method 2: Manual updating when flying a route that is defined by a VOR/DME facility

4.1 The accuracy of a manual update when over flying a VOR/DME or TACAN facility is questionable due to the “cone of confusion” that exists overhead the facility and varies as a function of the altitude of the aircraft. To increase the accuracy of a manual update in this situation, it is recommended that a plotting chart be created that has fixes depicted along the route at a minimum distance of 50 nm, but not more than 60 nm from the VOR/DME or TACAN. These fixes should display the bearing and distance and the latitude/longitude coordinates expressed to a tenth of a degree. The specified distances will account for slant range error and radial width.

4.2 In this situation, the suggested procedure would be for the flight crew to discontinue INS navigation when receiving the VOR/DME or TACAN signal and attempt to align the aircraft exactly on the desired radial to or from the station. When passing over the specified fix, the crew will compare each of the three INS positions with the reference lat/long position of the fix. The manual update should be attempted if the cross track position error is greater than 1 nm. After the manual update is completed, the crew should continue to navigate by the VOR radial to the next designated fix and compare the coordinates to verify that the update was successful.

4.3 As minimum requirements for use of these procedures, the crew must have on board the appropriate plotting charts with the specified information, and the operator must demonstrate that its crews know how to use the charts and procedures.

4.4 These procedures should be based on the assumption that triple mix position fixing is not used, and each inertial must be updated accordingly. The crew must notify ATC anytime it becomes aware that the aircraft can no longer maintain RNP 10 performance based on evaluation of the position checks.

5. Method 3: Using an IFR approved GPS installation as an updating reference

5.1 Using Method 3, the update is performed by comparing the INS position to the GPS position at a chosen way point.

5.2 Prior to departure the following data must be logged—

- record any unusual movement of the aircraft during INS initialisation before NAV mode selected, such as wind gusts or aircraft service vehicle bumping the aircraft or settling during fuelling. If there was any unusual movement during INS alignment, record INS track (TK / GS) after NAV mode is selected
- record the published gate coordinates or GPS position where the INS is initialised
- before departure, record the time that the INS NAV mode selectors in NAV
- record OFF time

5.3 Updating—

- record the time when INS coordinates are frozen before the en route update is accomplished and the flight level
- record the number of GPS SVs (Satellite Vehicles) locked on and the GPS DOP and Estimated Position Error (EPE) values
- record the desired track (DSRTK / STS) of the steering INS
- freeze the GPS and INS positions simultaneously
- record INS positions – HOLD and POS selected
- record the INS un-updated (Inertial) positions – HOLD and WAY PT, thumbwheel other than 0 selected

- from the data determine the amount of drift per hour flown, make appropriate corrections and continue to navigate
- if data indicates that RNP 10 capability is impossible to maintain, ATC must be notified as soon as flight conditions will permit

5.4 Completion of oceanic and remote area navigation and post flight: This step is important in that it verifies the accuracy of the updating process and will warn operators if there is an equipment or procedural problem that might effect future flights. Additionally, this information can be used in a response to an error investigation report.

- record the time following oceanic and remote area navigation when radar contact is first established or when first within 150 nm of a VOR navaid, Record IN time
- Destination Gate Positions: Do not remove INS updates until updated INS is recorded at the gate
- record the destination gate number, the number of GPS SVs (Satellite Vehicles) in view and the GPS DOP and EPE values
- record updated INS positions
- remove INS updates
- record INS un-updated positions and INS distances from the gate position
- record GPS position. If GPS position is unavailable, record the gate position
- INS data should be recorded in the Maintenance Log as usual

release the frozen INS positions

A SAMPLE DATA COLLECTION FORM

FIRST UPDATE

Altitude: ______

GPS

No of SV		DOP		EPE	•	INS DSRTK	

GPS Position: N/S		E/W	

INS

	Updated/Triple-Mix Positions		Un-Updated Positions		Distance
INS 1					
INS 2					
INS 3					

+30 minutes

No of SV		DOP		EPE	•	INS DSRTK	

GPS Position: N/S		E/W	
Strg INS 1 or 2			

SECOND UPDATE

Altitude: ______

GPS

No of SV		DOP		EPE	•	INS DSRTK	

GPS Position: N/S		E/W	

INS

	Updated/Triple-Mix Positions		Un-Updated Positions		Distance
INS 1					
INS 2					
INS 3					

+30 minutes

No of SV		DOP		EPE	•	INS DSRTK	

GPS Position: N/S		E/W	
Strg INS 1 or 2			

THIRD UPDATE

Altitude							

GPS

No of SV		DOP		EPE	•	INS DSRTK	
GPS Position: N/S				E/W			

INS

	Updated/Triple-Mix Positions		Un-Updated Positions		Distance
INS 1					
INS 2					
INS 3					

+30 minutes

No of SV		DOP		EPE	•	INS DSRTK	
GPS Position: N/S				E/W			
Strg INS 1 or 2							