CHIEF OF NAVAL OPERATIONS

Functional Requirements Document
For
REQUIRED NAVIGATION PERFORMANCE
AREA NAVIGATION

[FRD for RNP RNAV]

Revision A

17 April 2006

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FUNCTIONAL REQUIREMENTS DOCUMENT FOR REQUIRED NAVIGATION PERFORMANCE AREA NAVIGATION (FRD for RNP RNAV)

PROGRAM TITLE: COMMUNICATION/NAVIGATION/SURVEILLANCE/AIR TRAFFIC MANAGEMENT (CNS/ATM)

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CHANGE SUMMARY PAGE

This change summary page is provided to maintain a record of change to the last issue of the FRD. Upon receipt of a change or revision, the holder of the FRD should incorporate the change(s)/revision(s) into the original and make an appropriate entry on the Record of Change listing below:

RECORD OF CHANGE

CHANGE NO.	*DATE*	*TITLE OR BRIEF DESCRIPTION (List of Change Pages)*	*ENTERED BY:*
Initial Issue	*26 November 2002*	*Document baseline (under formal PMA209 Configuration Control)*	*CDR D. J. McNamara*
FRD for RNP RNAV Revision A	*17 April 2006*	1. General (throughout the document) - Updated numerous references and deleted references not used in the revised FRD. 2. Paragraph 1.2 Scope - Revised the sentence for transport and trainer aircraft certification, deleted the subparagraph that discussed RVSM, and changed NIMA to its new name, NGA. 3. Paragraph 1.3 - Revised Table 1 entries for RNP-10, RNP-5, and RNP-4 to be RNP-10 RNAV, BRNAV, and RNP-4 RNAV, respectively. Inserted note with reference to ICAO Doc 9613-AN/937, ICAO Manual on Required Navigation Performance. 4. Paragraph 2.1, 2.2 and 2.3 - Updated references to be complete and up to date. 5. Paragraph 3.2 - Added subparagraph requiring PPS GPS, permitting blended INS/PPS GPS, and requirements for horizontal position uncertainty, alerting equation for loss of navigation and integrity and containment alerts. 6. Paragraph 3.2.2 - Added Figure 1 below paragraph 3.2.2 showing containment. 7. Paragraph 3.2.3 - Clarified containment requirement for single thread avionics and note 1. 8. Paragraph 3.2.4.3, - Replaced the requirement for containment radius with the requirement for cross-track containment limit and added the requirement for an alert when aircraft Total System Error exceeds the containment limit. 9. Paragraph 3.2.5 - Added Note 2 stating that Geodesic and Great Circle are interchangeable for the purposes of this document up to 600 nm. 10. Paragraph 3.2.5.1.2 - Clarified insertion of along-track reference points. 11. Paragraph 3.2.5.2 Leg definitions - Clarified the listed leg types are minimum requirements and added a reference. 12. Figure 2. Revised title for clarification. 13. Paragraph 3.2.5.2.3 (h). - Moved requirement to Appendix C, VNAV, as it was a requirement related to VNAV, an option for Navy RNP RNAV certification. 14. Paragraph 3.2.5.2.6 - Revised format and changed note 1: “the FRD does not support…” to “the FRD does not require…”	*Timothy Thomas CNS/ATM Lead Engineer*

		15. Paragraph 3.2.5.3.1 - Changed acronym for HM Legs to comply with RTCA nomenclature. 16. Paragraph 3.2.5.4.2 (a). – Added "and display" to ensure that CF legs are properly displayed. 17. Paragraph 3.2.5.4.2 (a) 3. - Changed the model from “actual magnetic variation” to “actual measured magnetic variation”. 18. Paragraph 3.2.5.4.2. b. Note 2, 2 - Deleted the ability to insert / place bearing/place/bearing user-defined fixes. 19. Paragraph 3.2.5.4.3 - Revised requirement for data resolution for clarity. 20. Paragraph 3.2.5.4.3.2 - Added a note for clarify that turn radius resolution is related to optional RF legs. 21. Paragraph 3.2.5.5 -Added requirement for the aircraft to fly the procedure coded in the database. 22. Paragraph 3.2.5.5.1, Deleted sentence prohibiting fly-by for turns greater than 120°. 23. Paragraph 3.2.8.2 (b), (formerly 3.2.13) -Deleted reference to FAA procedures not applicable to Navy tactical aircraft. 24. Paragraph 3.2.8.2 (k), formerly paragraph 3.2.13 - Mandated requirement to have a graphical display of information in the pilot’s primary field of view including waypoints, procedures, and own-aircraft position . 25. Paragraph 3.2.10.3f, Table 6 - Added reference for UHMI. 26. Paragraph 3.2.11(c) 3 - Revised wording to indicate that this applies to multiple-sensor systems with automatic selection/de-selection of sensors. 27. Paragraph 3.2.12 - Revised heading to “Specific Requirements for Navigation Data and Navigation Data Processing”, revised data elements and addressed specific requirements for navigation data and navigation data processing, data corruption requirements, and defined essential data. 28. Paragraph 3.2.12.1 - Moved existing paragraph 3.2.12.1 with the exception of paragraph (d) to 3.2.12.3 and added a new paragraph 3.2.12.1 for mission planning/data processing and formatting system requirements. Former paragraph 3.2.12.1(d) is now 3.2.12.1 (a). 29. Paragraph 3.2.12.2 - Moved existing paragraph 3.2.12.2 to 3.2.12.4 and added a new paragraph 3.2.12.2. concerning aircraft flight management system. 30. Paragraph 3.2.12.3 – Revised requirement (former paragraph 3.2.12.1) to permit only the use of only a DoD-approved aeronautical database. 31. Paragraph 3.2.12.4 (Formerly 3.2.12.2) - Updated NIMA to NGA, added information on AIRAC cycle and added sentence requiring DAFIF Edition 7 or later editions to be used. 32. Paragraph 3.2.13 - Relocated to Paragraph 3.2.8.2 (k) and mandated that a display is required.. 33. Paragraph 3.2.15.1 – Added requirement to provide a means to preview and verify the flight plan. 34. Paragraph 3.2.15.3 (c) - Deleted the requirement to manually enter a fix from two fixes place/bearing/place	

		bearing. 35. Paragraph 3.3.1(d). - Revises RNP-4 and RNP-10 to RNP-4 RNAV and RNP-10 RNAV and references. Authorizes use of RNP-4 RNAV in lieu of BRNAV/RNP-5. 36. Paragraph 3.4.3.1.1 - Table of Permissible leg types changed from “Permissible Leg Types” to “Minimum Leg Types” and Note 2 amended to mention specific optional leg types as not Navy minimum requirements for RNP RNAV. 37. Paragraph 3.6.1.1 - Revised first sentence for clarity. 38. Paragraph 3.6.1.6 - For RNAV/LNAV, LNAV and GPS NPA procedures the wording was changed from “no waypoints can be added or deleted” to “no waypoints can be added or deleted in an instrument approach procedure.” Additionally, added a note permitting but not recommending changes to a procedure after it is part of the flight plan. 39. Paragraph 3.6.1.11 Revised the wording to delete the requirement for an approach enable alert if approach sequencing is automatic. 40. Paragraph 3.6.1.13 (b) was blank in the approved FRD. To prevent confusion, inserted the word “Deleted”. 41. Paragraph Appendix A – Inserted acronym “AIRAC”, and Redefined HM from “HM, Holding for Manual Termination” to “HM, Holding for Clearance” to comply with RTCA nomenclature. 42. Appendix B – Added cross-track containment limit. 43. Paragraph 1.0 Appendix C –Added reference. 44. Appendix C, Paragraph 1.2 – Inserted new paragraph 1.2 Direct to Fix and renumbered subsequent paragraphs. . 45. Appendix C, Paragraph 1.3 (formerly paragraph 1.2) - Changed heading to “Radius to a Fix (RF), If Implemented” and added note 2 that RF legs are optional. 46. Appendix C paragraph 1.15.1 - Added paragraph on VNAV temperature compensation and renumbered existing paragraph 1.15.1 as 1.15.2 and existing paragraph 1.15.2 as 1.15.3 47. Paragraph Appendix D - Added paragraph 1.0 and reference (a). 48. Paragraph Appendix E - Added reference (b) to paragraph 1.1. *Paragraph Appendix F - Deleted entire Appendix on RNP-10 as not required by naval tactical aircraft.*	

COMMENT INFORMATION

This document is under Configuration Management Control at NAVAIR, PMA209 Patuxent River, MD. Comments and suggested changes and updates to the document should be addressed to the following NAVAIR, PMA209, Configuration Management Control Point.

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EXECUTIVE SUMMARY

International Civil Aviation Organization (ICAO) standards introduced unique requirements to assure navigation performance accuracy in airspace worldwide. Sovereign nations may enact the resulting specifications for containment integrity, containment continuity, path definition, path steering, position estimation and area navigation functions.

The Chairman of the Joint Chiefs of Staff (CJCS) 6130.01C, 2003 CJCS Master Positioning, Navigation and Timing Plan, 31 March 2003 notes:

"Aircraft must be equipped with instruments and navigation equipment appropriate to the routes to be flown. The Federal Aviation Administration (FAA) issues Technical Standard Orders (TSOs) that prescribe minimum performance standards for navigation equipment used by the civil aviation community in the National Airspace System (NAS). The International Civil Aviation Organization (ICAO) issues Standards and Recommended Practices (SARPS) for international civil aviation. The development of minimum performance standards for military users is the responsibility of the Services. These military standards must conform with civil airspace Required Navigation Performance (RNP) requirements, prevent violation of civil air traffic clearances, and ensure safe separation of military and civil air traffic. While meeting the ICAO SARPS is essential, military combat, and combat support aircraft must have Positioning, Navigation, and Timing (PNT) capabilities designed to operate in a combat or stressed environment where civil PNT services are likely to be jammed or severely limited."

This document establishes the minimum functional requirements needed for Navy and Marine Corps aircraft to conform to civil airspace Required Navigation Performance (RNP) Area Navigation (RNAV) requirements. However, it should be understood that this Functional Requirements Document (FRD) does not usurp any international agreements or treaties that pertain to “State Owned Aircraft” being operated in accordance with rules governing Operational Air Traffic (OAT) that may differ from civil General Air Traffic (GAT) Requirements.

PMA209 is designated as the Navy Lead Program Office to coordinate Communication, Navigation, Surveillance / Air Traffic Management (CNS/ATM) efforts as recommended by Deputy Chief of Naval Operations for Air Warfare (N78) Letter (CNO Ser 7U660859 dated 14 October 1997). CNS/ATM is the term used to designate the ever-increasing airspace requirements that are evolving around the globe to resolve civil air traffic congestion. In accordance with this tasking, PMA209 has developed this FRD to meet the CNS/ATM functionality of RNP RNAV for Naval and Marine Corps Aviation.

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1 INTRODUCTION

1.1 PURPOSE

This document establishes the minimum functional requirements for Navy and Marine Corps aircraft to conform to civil airspace Required Navigation Performance (RNP) Area Navigation (RNAV). To meet these requirements, the primary navigation source shall be a Global Positioning System (GPS) Precise Positioning Service (PPS)-based navigation system, with appropriate displays. Aircraft that are designed, integrated and tested to meet the navigational functional performance specified herein will be capable of filing and flying RNP RNAV flight plans from takeoff through a published Non Precision Approach (NPA).

1.2 SCOPE

This Functional Requirements Document (FRD) specifically addresses the minimum requirements for U.S. Navy and U.S. Marine Corps aircraft carrying GPS PPS navigation systems to conform with civil airspace RNP RNAV requirements, and to ensure safe separation of military and civil air traffic. Navy and Marine Corps commercial derivative transport or trainer aircraft eligible for FAA Type Certification (TC) or Supplemental Type Certification (STC) with SPS GPS should be certified by their platform PMA's to the limits of their TC/STC certification eligibility.

Requirements to fly with vertical guidance are beyond the scope of this document except for optional Vertical Navigational (VNAV) requirements that are contained in Appendix C. It is further envisioned that when vertical guidance is mandated it will be part of Precision Landing System requirements.

Some aircraft may not require the full spectrum of the RNP RNAV functions as determined by mission analysis, or may need interim capabilities prior to the full implementation of RNP RNAV in civil controlled airspace. Appendix D contains requirements for Basic Area Navigation (BRNAV) (5 nm accuracy) as a guide for obtaining fleet release to file and use this capability. In either case, the determination and justification to proceed will be included in the Fleet Release request. Appendices E and F contain the requirements for Precision Area Navigation (PRNAV) (1 nm accuracy) and RNP-10 (10 nm accuracy) respectively.

Please note that references used in this document may or may not be quoted verbatim. They have been modified as necessary to meet Navy and Marine Corps Aviation needs.

Within this document, the term "shall" is used to indicate firm requirements. An approved design should comply with every "shall" requirement, which can be assured by inspection, test, analysis or demonstration. The term "must" is to identify items which are important but are either duplicated somewhere else in the document as a "shall", or are considered outside of the scope of this document. For example in the Appendix for RNP-10, para. 1.8 states that the Fault Detection and Exclusion algorithm must perform in accordance with the GPS Integration Guidance. The term, "should" is used to denote a recommendation that would improve the equipment, but does not constitute a requirement. The term, "may" is used to denote a recommendation that is optional.

All references to database within this document refer to the Digital Aeronautical Flight Information Files (DAFIF) database as approved by National Geospatial-Intelligence Agency (**NGA**) or the DAFIF approach database approved by Naval Flight Information Group (NAVFIG).

1.3 BACKGROUND

Development of the Required Navigation Performance (RNP) Concept. The International Civil Aviation Organization (ICAO) recognized a need for dramatic improvements to the existing air navigation system. To meet this need, an ICAO Special Committee of Future Air Navigation Systems (FANS) developed a new concept expressed in terms of communication, navigation, surveillance and air traffic management, "CNS/ATM." To obtain benefits under CNS/ATM and improve operational flexibility, accurate, repeatable and predictable navigation performance, or Required Navigation Performance (RNP), must exist.

RNAV Concept. In building upon the benefits of CNS/ATM functionality, geodetic fixes will define the future-operating environment. Ground-based navigation aids will no longer define and restrict development of routes and instrument procedures. While this concept, known as Area Navigation (RNAV), is not new, air traffic service providers have employed RNAV operations without full confidence in navigation accuracy. Nevertheless RTCA, Inc. standards contained in RTCA/DO-236B, integrates the concepts of RNP with RNAV providing the necessary levels of confidence for a variety of operations.

RTCA/DO-236B. In essence, RTCA/DO-236B contains the Minimum Aviation System Performance Standards (MASPS) for RNAV systems operating in an RNP RNAV environment. These standards provide procedures designers, avionics manufacturers, avionics technicians, air traffic service providers and aircraft operators the guidance and tools to benefit from improved navigation capabilities and the guidelines to develop more efficient world-wide operations.

RTCA/DO-236B Additions to the Review of the General Concept of Separation Panel (RGCSP) RNP Requirements. To fully realize the benefits of RNP, the standards in RTCA/DO-236B are compatible with the definitions of RNP developed by the ICAO Review of the General Concept Of Separation Panel (RGCSP). However, in contrast to the RGCSP's definition of RNP, the ***DO-236B standards introduced unique requirements to assure navigation performance accuracy by managing and mitigating operational risk through its specifications for containment integrity, containment continuity, path definition, path steering, position estimation and area navigation functions."*** *(Italics and boldprint added for emphasis.)*

RNP RNAV. ***To differentiate generic applications of RNP under the RGCSP's RNP concept and the specific requirements for RNP in DO-236B and this document, this FRD uses the term "RNP RNAV."*** This term merges the accuracy standards in the ICAO RNP Manual with the containment/integrity requirements in RTCA/DO-236B resulting in the RNP RNAV standards in this FRD.

RNP RNAV Specification. Specification of RNP RNAV includes performance and functional capabilities that may vary by RNP RNAV type. The performance requirements include an

accuracy requirement (the RNP value) along with integrity and continuity requirements. A number, in nautical miles (nm), represents the RNP RNAV accuracy requirement. This number represents the 95% total system error in both along-track and cross-track dimensions.

Integrity Requirement for RNP RNAV. The integrity requirement for RNP RNAV is specified with a fixed relationship to RNP and a maximum risk probability dimension known as a containment limit. These containment limits support application of RNP RNAV as a tool for aircraft separation and/or obstacle/terrain clearance.

RNP-based operations may include:

Table 1. RNP-Based Operations

OPERATION	RNP TYPE	EXAMPLE APPLICATION
Oceanic/Remote	RNP - 20	Separation between Tracks/ATS Routes
Oceanic/Remote	RNP - 12.6	North Atlantic FL 285-420
Oceanic/Remote	RNP - 10 RNAV	50 nm Separation
Enroute Europe	BRNAV	20 nm Separation
Oceanic/Remote	RNP - 4 RNAV	30/30 nm Separation
Enroute Domestic	RNP - 2 RNAV	8 nm Route Separation
Terminal Area	RNP - 1 RNAV	4 nm Separation
Approach	RNP - 0.3 RNAV	Lateral Navigation (LNAV) (Non Precision Approach (NPA))
Departure	RNP - 1.0 RNAV	LNAV

Note 1: Sovereign states may develop related navigation operations. In some cases (e.g., Basic Area Navigation (BRNAV) in Europe), Air Traffic Services (ATS) providers may base operations solely on RNP accuracy goals. These RNP applications may mitigate the integrity and continuity risks through requirements for radar coverage and/or coverage by conventional ground-based navigation aids.
Note 2: There is no intent to limit RNP operations to solely the operations in this list. For example, an ATS provider may develop RNP-0.3 RNAV terminal area operations.
Note 3: Doc 9613-AN/937, ICAO Manual on Required Navigation Performance, Second Edition, 1999 with Amendment 1, 1 March 2001 addresses RNP 1, 4, 12.6 and 2 for enroute flight. RNP-5 (BRNAV) is a unique European requirement (see below entry). RNP-0.3 is addressed in RTCA/DO-236B, Minimum Aviation System Performance Standards (MASPS): Required Navigation Performance for Area Navigation (RNP RNAV), 28 October 2003.

Basic Area Navigation (BRNAV). BRNAV was introduced in Europe to enable capacity gains to be achieved through modifications to the en-route structure. It requires aircraft conformance to a track keeping accuracy of ±5 nm for at least 95% of the time. BRNAV requirements have been identified in FAA Advisory Circular 90-96 and JAA Temporary Guidance Leaflet 2 (TGL-2). BRNAV can be considered equivalent to RNP-5 from an accuracy standpoint. BRNAV requirements became mandatory in European Civil Aviation Conference (ECAC) airspace on 23 April 1998 and on the entire ATS route structure above FL 95.

Note: If an aircraft system meets the requirements of the body of this FRD, then it meets BRNAV requirements.

Precision Area Navigation (PRNAV). Similarly, PRNAV is being introduced to enable RNAV applications to be introduced to terminal airspace. It requires aircraft conformance to a track

keeping accuracy of ±1 nm for at least 95% of the time, and additional functionality, including high integrity navigation databases, path coding in accordance ARINC, Incorporated (ARINC) 424 or equivalent, and automatic selection, verification, and de-selection of navigation aids. PRNAV will be introduced to some terminal areas in Europe as early as 2003, but will not be mandated before 2005. PRNAV can be considered equivalent to RNP-1 from an accuracy standpoint.

Note: If an aircraft system meets the requirements of the body of this FRD, then it meets PRNAV requirements.

1.4 RNP RNAV COMMON TERMINOLOGY

Development and explanation of RNP RNAV requires on the understanding of several key terms. Many key terms are contained in the Glossary to this document. Some important terms are defined below:

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

Navigation performance accuracy. The total system error (TSE) allowed in the individual lateral and longitudinal dimensions. TSE in each dimension must not exceed the specified RNP type for 95 per cent of the flight time on any portion of any single flight.

Required navigation performance (RNP). A statement of the navigation performance necessary for operation within a defined airspace. Navigation performance and requirements are defined for a particular RNP type and/or application.

Required navigation performance Area Navigation (RNP RNAV). Merges the accuracy standards of RNP with specific containment integrity and containment continuity requirements, as well as RNAV functional and performance standards.

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.

Total System Error (TSE). The combination of navigation system error, RNAV computation error, display system error and FTE.

RNP types for en-route operations are established according to navigation performance accuracy in the horizontal plane (e.g., lateral and longitudinal position fixing). This accuracy is expressed as a single parameter, the containment value. The containment value is the distance from the intended position within which flights would be found for at least 95% of the total flying time. The deviations may be considered, to be contained within a circle centered upon the aircraft's desired position. For example, if the accuracy of an RNP type is 1 nm (1.85 km) it is assumed that, for 95% of the total flying time, an aircraft would maintain a position within 1 nm (1.85 km) of its Air Traffic Control (ATC) cleared position. The containment limit is a design assurance that the aircraft will not depart twice the RNP without annunciation to the aircrew.

1.5 DOD POLICY ON POSITIONING, NAVIGATION AND TIMING (PNT)

Policy for the use of GPS, including use for instrument navigation operations, is given in 2003 Chairman, Joint Chiefs of Staff Instruction (CJCSI) 6130.01C, Master Positioning, Navigation and Timing Plan, of 31 March 2003. Specific policy statements in Enclosures A, D, and E apply to GPS instrument navigation.

Ref: Chairman, Joint Chiefs of Staff Instruction (CJCSI) 6130.01C, 2003 Chairman Joint Chiefs of Staff (CJCS) Master Positioning, Navigation and Timing Plan, 31 March 2003

1.6 NAVY GPS POLICY

It is essential to note that current DOD GPS User Equipment installed and integrated into Navy and United States Marine Corps (USMC) aircraft platforms do not meet integrity requirements for RNP operations where GPS is the selected navigation sensor. Upgrades to DOD GPS User Equipment are in progress. When approved and validated equipment meeting integrity requirements is installed and certified in type, DOD GPS User Equipment is approved for Instrument Flight Rules (IFR)/Instrument Meteorological Conditions (IMC) operation.

2 REFERENCE PUBLICATIONS

2.1 U.S. GOVERNMENT DOCUMENTS

(a). CJCSI 6130.01C, 2003 CJCS Master Positioning, Navigation and Timing Plan, 31 March 2003

(b). Deleted

(c). FAA Advisory Circular (AC) 20-130A, Airworthiness Approval of Navigation or Flight Management Systems Integrating Multiple Navigation Sensors, 14 June 1995

(d). FAA Advisory Circular (AC) 20-RNP, Airworthiness Approval of Required Navigation Performance, Draft 8a, 13 July 2001

(e). FAA Advisory Circular AC20-138A, Airworthiness Approval of Global Navigation Satellite System (GNSS) Equipment, 22 December 2003

(f). FAA AC 90-96, Approval of U.S. Operators and Aircraft to Operate Under Instrument Flight Rules (IFR) in European Airspace Designated for Basic Area Navigation (BRNAV/RNP-5), 20 March 1998

(g). FAA Technical Standard Order (TSO)-C115b, Airborne Area Navigation Equipment Using Multi-sensor Inputs, 30 September 1994

(h). FAA TSO-C129a, Airborne Supplemental Navigation Equipment Using Global Positioning System (GPS), 20 February 1996

(i). FAA ORDER 8400.12, Required Navigation Performance 10 (RNP-10) Operational Approval, 24 January 1997

(j). FAA ORDER 8260.40B, Flight Management System (FMS) Instrument Procedures Development, 31 December 1998

(k). FAA ORDER 7110.65N Handbook For Air Traffic Control 21 February 2002

(l). FAA Aeronautical Information Manual 17 July1997

(m). Code of Federal Regulations (CFR) 14 Part 97 FY2000

(n). Deputy Chief of Naval Operations for Air Warfare (N78) Letter (CNO Ser 7U660859 dated 14 October 1997

(o). CNO GPS Integration Guide (GIG), 6 May 1994

(p). FAA Notice, N8100.60, GPS as a Primary Means of Navigation for Oceanic/Remote Operations, 4 December, 1995

(q). FAA Advisory Circular AC 23.1309-1C, Equipment, Systems, and Installations in Part 23 Airplanes, 12 March 1999

(r). FAA Advisory Circular AC 25.1309-1A, System Design Analysis, 21 June 1988

(s). Memorandum of Agreement between Federal Aviation Administration and Department of Defense for National Airspace System Integration, Annex C, Terminal Airspace and Route Redesign

(t). NAVSTAR GPS Joint Program Office Memorandum, subject: "Coordination of Department of Defense (DOD) GPS Non-Precision Approach (NPA) Integrity Requirements", 23 October 1995

2.2 INTERNATIONAL DOCUMENTS

(a). Doc 9613-AN/937, ICAO Manual on Required Navigation Performance, Second Edition, 1999 with Amendment 1, 1 March 2001.

(b). All Weather Operation Panel (AWOP) AWOP-WP/756, DRAFT ICAO Manual on Required Navigation Performance (RNP) for Approach, Landing and Departure Operations, (no date)

(c). Joint Aviation Authorities (JAA) Temporary Guidance Leaflet (TGL) TGL-10, "Airworthiness and Operational Approval for Precision RNAV Operations in Designated European Airspace", 1 November 2000.

(d). JAA TGL-2 - "Advisory Material for the Airworthiness Approval of Navigation Systems for use in European Airspace designated for Basic RNAV Operations", 1997

(e). European Organization for the Safety of Air Navigation (EUROCONTROL) Standard 003-93, "Area Navigation Equipment - Operational Requirements and Functional Requirements", December 1998

2.3 OTHER DOCUMENTS

(a). RTCA/DO-236B, Minimum Aviation System Performance Standards (MASPS): Required Navigation Performance for Area Navigation (RNP RNAV), 28 October 2003.

(b). RTCA/DO-229C, Minimum Operational Performance Standards (MOPS) for Global Positioning System/Wide Area Augmentation Systems (WAAS) Airborne Equipment, 28 November 2001

(c). RTCA/DO-201A, Standards for Aeronautical Information, 19 April 2000

(d). RTCA/DO-200A, Standards for Processing Aeronautical Data, 28 September 1998

(e). RTCA/DO-187, Minimum Operational Performance Standards for Airborne Area Navigation Equipment Using Multi-Sensor Inputs, 13 November 1984

(f). RTCA/DO-283A, Minimum Operational Performance Standards for RNP RNAV, 28 October, 2003

(g). ARINC 424 Specification, Navigation System Database, August, 2004

3 REQUIREMENTS

3.1 BACKGROUND INFORMATION

(a). Compliance with the stated requirements satisfies RNP RNAV airspace performance in all phases of flight in all RNP environments including RNP-0.3, RNP-1, RNP-2, RNP-4, RNP-5, RNP-10, RNP-12.6 and RNP-20.

(b). Requirements within this FRD are taken primarily from RTCA and FAA documents. This is to ensure that the intent of RTCA standards is not changed by simply referring to the documents in the requirements of this Chief of Naval Operations (CNO) FRD. This document deviates from these requirements only when unique Navy considerations dictate.

3.2 GENERAL REQUIREMENTS

General Requirements apply to all phases of flight and all RNP levels.

A Precise Positioning Service (PPS) GPS receiver with integrity shall be the positioning source for both navigation and containment. The positioning source for navigation and containment shall be the same receiver. Using a blended INS/PPS GPS solution for positioning is acceptable. Each navigation system operating in RNP airspace shall make available a continuous estimate of the horizontal position uncertainty under the prevailing conditions of flight and shall include any differences between the blended position solution and PPS GPS position solution with integrity. The alerting equation for loss of navigation shall include those differences. The PPS GPS navigation solution shall drive loss of integrity and containment alerts.

3.2.1 Accuracy

Each aircraft operating in RNP airspace shall have total system error components in the cross-track direction that is less than the RNP value 95% of the flying time.

Ref: RTCA/DO-236B, Para. 2.1.1 (Amended)

3.2.2 Containment Integrity

The probability that the total system error of each aircraft operating in RNP RNAV airspace exceeds the specified cross track containment limit, without annunciation, shall be less than 10^{-5} per flight hour. The cross track containment limit is twice the RNP RNAV value (e.g., $\pm$8 nm for RNP-4 RNAV). See Figure 1.

There are no cross track (lateral) containment integrity requirements for RNP-12.6 RNAV and RNP-20 RNAV airspace.

Note 1: Containment integrity and containment continuity requirements are based on the concept of a defined containment region. The cross-track containment limit defines a corridor, centered on the desired track, within which the aircraft is to navigate, and may be one component used to provide aircraft separation. All potential failures or events that could lead to an undetected containment violation must be considered, including undetected faults and flight technical error. The flight technical error may be directly monitored in real-time. For example, if analysis is performed assuming a certain FTE distribution, it is acceptable to monitor the FTE so that it is consistent with that distribution. The analysis to demonstrate compliance must, as a minimum, consider the likelihood that the fault or rare condition will occur during the flight hour beginning from a fault-free state.

Ref: RTCA/DO-236B, Para. 2.2.1, amended.

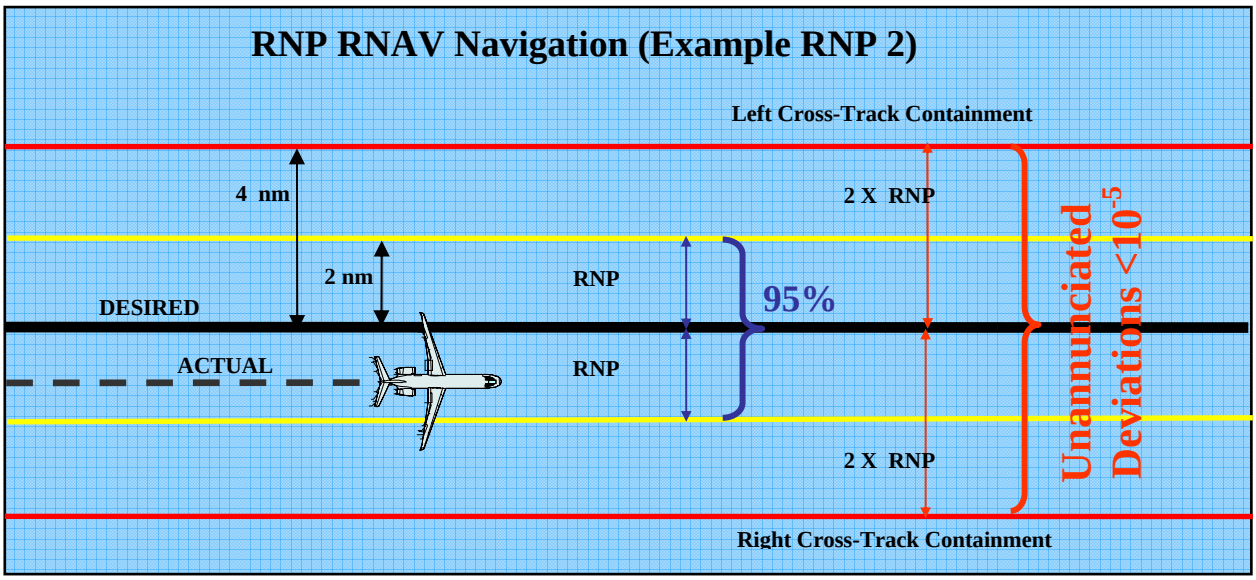


Figure 1. RNP RNAV Navigation Accuracy and Containment

3.2.3 Containment Continuity

The probability of annunciated loss of RNP RNAV capability (for a given RNP RNAV type) shall be less than 10^{-4} per flight hour. The continuity due to failure of the airborne system, not the signal in space, shall be reduced to 10^{-3} per flight hour for aircraft already approved to utilize single-thread avionics systems for navigation.

Note 1: Some tactical aircraft have only single thread navigation systems with no redundancy. Only aircraft with single thread avionics may apply a probability of annunciated loss of RNP RNAV capability of 10^{-3} per flight hours (which equates to a Mean Time Between Failures (MTBF) of 1000 hours) that is achievable with a single GPS navigation system with today's technology. This approach provides a containment capability not included in RNP requirements presently being implemented and limits penalty of cost, weight, and space that may be required by the 10^{-4} per flight hour requirement contained in RTCA/DO-236B that will lead to redundancy. This line of attack is consistent with the Memorandum of Agreement between Federal Aviation Administration and Department of Defense for National Airspace System Integration, Annex C, Terminal Airspace and Route Redesign, which states; "The FAA has not made a policy decision on use of a Required Navigation Performance (RNP)/RNAV capability

that would drive avionics requirements that could limit DoD access to capacity constrained airports." and "The FAA will coordinate policy decisions with the DoD on RNP/RNAV requirements and avionics issues."
Note 2: The application of this requirement defines the equipment that must be available at dispatch or upon initiating an RNP RNAV operation. For example, the equipment necessary for all planned RNP RNAV operations within a single flight plan would constitute a dispatch requirement, while the equipment necessary to meet this requirement for an approach RNP RNAV type might be required at the start of the operation.
Note 3: Containment limits are the technical basis for defining the continuity of function and the integrity of the navigation system to limit exposure to hazardous conditions of flight and frequent failures. The cross-track containment limit defines a corridor, centered on the desired track within which the aircraft is to navigate, and may be one component used to provide aircraft separation. All potential failures or events that could lead to the detected loss of RNP RNAV capability must be considered. The analysis of containment continuity must reflect the alerting algorithms used in the equipment, including faults, false detection, and excessive flight technical error.

Ref: (for notes 2 and 3 only): EUROCONTROL Document 003-93 Dec 1998 Edition 2.2 and RTCA/DO-236B, Para. 2.3.1

3.2.4 Position Estimation Requirements

3.2.4.1 Estimate of Position

The navigation system shall estimate the present position of the aircraft.

Ref: RTCA/DO-236B, Para. 3.1.1.1

3.2.4.2 Estimate of Position Uncertainty

Each navigation system operating in RNP airspace shall provide a selectable continuous estimate of its horizontal position uncertainty under the prevailing conditions of flight. The displayed Estimate of Position Uncertainty (EPU) value shall be consistent with the alert provided when the equipment fails to comply with the containment integrity. That is, the displayed EPU shall be scaled such that the containment alert occurs no later than when the displayed EPU value exceeds the RNP RNAV type in effect.

Note: Prevailing conditions include airborne equipment condition, airborne equipment in use, and external signals in use.

Ref: RTCA/DO-236B, Para. 3.1.2 (Wording differs)

3.2.4.3 Cross-Track Containment Limit

The cross-track containment limit for RNP RNAV shall equal twice the RNP value in effect. Each navigation system operating in RNP airspace shall determine the cross-track containment limit under the prevailing conditions of flight and provide an alert in the pilot's field of view when the aircraft's Total System Error exceeds the containment limit.

See Figure 1 in paragraph 3.2.2 above.

Note: The cross-track containment limit is the distance that defines the one dimensional containment limit in the cross-track dimension. The resulting containment region is centered on the desired path and is bounded by +/- the cross-track containment limit. There is a required cross-track containment limit associated with a particular RNP RNAV type.

Ref: RTCA/DO-283A, Para. 1.9.3, amended.

3.2.5 Path Definition Requirements

(a). The navigation system shall construct a path over the earth which defines the flight path for the intended route.
(b). The defined flight path shall be made up of elements that establish the horizontal, as well as the optional vertical and time dimensions, including the leg types, fixes and path attributes (altitude, speed, location, time, etc) described in the following subsections.
(c). The error components associated with the defined path relative to the desired path shall be determined. These error terms shall be used as part of the total system error allocation.

Note 1: To achieve the objectives set forth by the ICAO FANS report, future navigation systems must address repeatability as well as system performance (containment) issues. Repeatability is achieved by defining paths that are consistent and flown in the same manner by all aircraft. This will involve not only the path definition function of the navigation computer, but also the path definition parameters stored in the aircraft navigation database. The path definition function contribution to the containment requirements is demonstrated by determining the errors associated with the definition of the lateral path.
Note 2. For the purposes of this document, the terms "Geodesic" and "Great Circle" will be considered interchangeable for all distances of 600 nautical miles (nm) or less.

Ref: RTCA/DO-236B, Para. 3.2, for subparagraphs (a) and (b), amended.

3.2.5.1 Flight Path Legs Developed from User-Defined Data

3.2.5.1.1 Fix-by-Fix Entered Routes

In the case where all or part of a route is created through the manual entry of fixes, from the navigation database or user-defined fixes, a Track to Fix (TF) leg type shall be used to define the path between a manually-entered fix and the preceding and following fixes.

Note: Examples of user-defined fixes are lat/long fixes, and place/bearing/distance fixes.

Ref: RTCA/DO-236B, Para. 3.2.2.1

3.2.5.1.2 Insertion of Along-Track Reference Points into an Existing Route

If implemented:

1. These along-track reference points shall not modify the desired track of the original flight plan on which they are inserted.
2. These waypoints should only be entered on Course to Fix (CF), Direct to Fix (DF), or Track to Fix (TF) legs.

Note: Examples of along-track reference points are along-track fixes, abeam fixes, and lat/long crossing points.

Ref: 1. RTCA/DO-236B, Para. 3.2.2.2,amended 2. RTCA/DO-283A, MOPS for RNP RNAV

3.2.5.2 Leg Definition

Table 2. Minimum Leg Types

MINIMUM LEG TYPES	
IF	Initial Fix
TF	Track to Fix
DF	Direct to Fix
CF	Course to Fix

Ref: RTCA/DO-236B, Para. 3.2.1.1, amended.

3.2.5.2.1 Initial Fix (IF)

(a). The system shall provide the capability to define an Initial Fix (IF) leg.
(b). An IF leg is a fix.
(c). An IF leg is used only to define the beginning of a Route or procedure.
(d). Where required by a procedure, altitude and speed constraints will be provided in the navigation database.

Note: An IF leg does not define a desired track in and of itself, but is used in conjunction with another leg type (e.g. TF) in order to define the desired path.
Ref: RTCA/DO-236B, Para. 3.2.3.1, paragraphs (b), (c) and note.

3.2.5.2.2 Track to Fix (TF)

(a). The system shall be capable of constructing Track to Fix (TF) leg types.
(b). A TF leg is defined as a geodesic path between two fixes.
(c). The first fix is either the previous leg termination or an IF leg.
(d). The termination fix is normally provided by the navigation database, but may also be a user-defined fix.

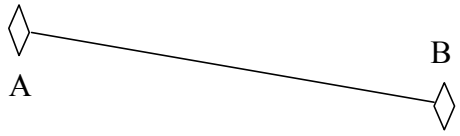


Figure 2. Track to Fix (TF) Leg

Path: Geodesic Path between A and B
Termination: Fix B

Ref: RTCA/DO-236B, Para. 3.2.3.2, FAA AIM 17 Jul 97, Ch. 1 Section 2.

3.2.5.2.3 Direct to Fix (DF)

(a). The system shall provide the capability to execute a Direct-To clearance to any fix.
(b). A DF leg is defined as a geodesic path that starts near the area of initiation and terminates at a fix.
(c). The navigation system shall have a Direct-To function that shall be able to be activated at any time by the flight crew when required.
(d). The Direct-To function shall be available to any fix. (Note: We do not advise that operators use the Direct-To function to a Missed Approach Point without the air traffic controller's

approval.)

(e). The system shall be capable of generating a geodesic path to the designated "To" fix.

(f). The aircraft shall capture this path without "S-turning" and without undue delay.

(g). Where required by procedure, altitude and speed constraint shall be provided in the navigation database.

(h). Moved to optional Appendix C, VNAV, paragraph 1.2.

(i). The system shall generate command signals or guidance cues to allow this path to be shown.

Ref: RTCA/DO-236B, Para. 3.7.2.2.1, Para.3.2.3.8, Para. 3.2.3.8.1 and 3.2.4.2 and FAA AIM 17 Jul 97, Ch. 1 Section 2 (except for the note regarding using the Direct-To function to the Missed Approach Point (MAP) which is Navy unique.)

Note 1: The purpose of the Direct-To function is to navigate the aircraft expeditiously from the aircraft's present position to the crew designated "To" fix.
Note 2: It must be recognized that in terms of a predetermined repeatable flight path, a DF leg is highly variable. This variability is in contrast to the applicability of a DF leg to RNP RNAV characteristics once established on the leg. When established on a DF leg, the containment region for that leg can be defined and the RNP RNAV type may be specified relative to the defined path.

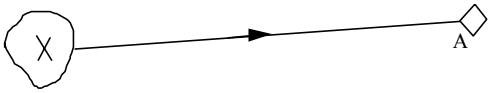


Figure 3. Direct to a Fix (DF) Leg

3.2.5.2.4 Course To A Fix (CF)

(a). The system shall provide the capability to define a user-defined course to a fix.

(b). A CF leg is defined as a geodesic path that terminates at a fix with a specified course at that fix.

(c). The inbound course at the termination fix and the fix are provided by the navigation database.

(d). If the inbound course is defined as a magnetic course, the source of the magnetic variation needed to convert magnetic courses to true courses is detailed in Section 3.2.5.4.2. Vertical Navigation requirements are beyond the scope of this document. Requirements for Radius To A Fix VNAV requirements are contained in Appendix C.

Note: It must be recognized that in terms of a predetermined repeatable flight path, the applicability of a magnetically-specified CF leg to the definition of an RNP RNAV procedure is limited. The CF leg is used in many approach procedures because ARINC 424 previously specified it as the only type of leg to be used for coding the final segment of an approach. This was due to course-based legs being consistent with operational procedures at the time. Supplement 12 of ARINC 424 allowed the use of TF legs as an alternative to CF and, as a consequence, it is believed that CF legs will now exist in RNP RNAV procedures during a transition period.

Ref: RTCA/DO-236B, Paras. 3.7.2.2.2, 3.2.3.9, 3.2.5.2 and FAA AIM 17 Jul 97, Ch. 1 Section 2.

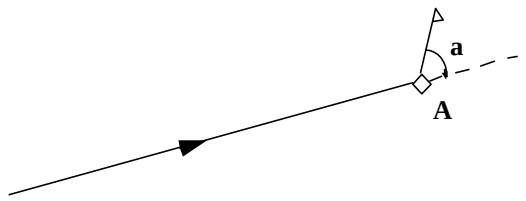


Figure 4. Course to a Fix (CF) Leg

Path: Geodesic Path to Fix A with Inbound Track "a"
Termination: Fix A

3.2.5.2.5 User-Defined Course To A Fix

The equipment shall provide the capability to intercept a user-defined course to a fix. The resolution of the defined course shall be 1 degree or better.

Ref: RTCA/DO-283A, MOPS for RNP RNAV, Para. 2.2.2.5

3.2.5.2.6 Unsupportable Instrument Procedures

The system shall discriminate between instrument procedures it can and cannot support.

Note: For example, this FRD does not require a Radius-to-a-Fix (RF) capability. Therefore, if a system does not support RF legs, the pilot shall not be able to access or attempt to use a procedure that contains an RF leg.

3.2.5.3 Special Operations

3.2.5.3.1 Holding

The equipment shall provide the capability to proceed to a selected waypoint and fly on a specified inbound course to the waypoint with repeated crossing of the selected waypoint, to facilitate aircraft operation in conventional airspace. This is not an RNP RNAV operation. Systems choosing to automate the holding pattern should utilize the ARINC 424 Holding to an Altitude (HA), Holding for Clearance (HM) and Holding to a Fix (HF) holding leg types. The system shall indicate when it is in an active hold mode.

Ref: RTCA/DO-283A, Para. 2.2.2.6, amended.

3.2.5.4 Error Terms

The error terms defined below contribute to the path definition error component of total system error (TSE). The following table associates the error terms with the RNP RNAV leg types.

Table 3. RNP RNAV Leg Type Error Term Association

Error Terms	TF/DF	CF
Earth Model	X	X
Magnetic Variation		X
Coordinate Resolution	X	X
Course Resolution		X
Altitude/Height Resolution	X	X

Ref: RTCA/DO-236B, Para. 3.2.5, amended.

3.2.5.4.1 Earth Model

World Geodetic System 1984 (WGS-84) shall be the reference earth model for error determination.

Ref: RTCA/DO-236B, Para. 3.2.5.1

3.2.5.4.2 Magnetic Variation

(a). The source of the magnetic variation used for path definition computations and display for CF legs shall be in accordance with the following:

1. If the leg is part of a database terminal area procedure, the magnetic variation to be used is the value specified for that procedure per RTCA DO-201A/European Organization for Civil Aviation Equipment manufacturers (EUROCAE) EUROCAE ED-77.
2. If the leg is not part of a procedure and the terminating fix is a VOR or TACAN, the magnetic variation to be used is the station declination for the VOR or TACAN.
3. If the leg is not part of a procedure and the terminating fix is not a VOR or TACAN, the magnetic variation to be used shall be defined by the system using either an internal model or the Earth's actual measured magnetic variation and referenced to the termination fix.

(b). The navigation system shall have the capability of assigning a magnetic variation at any location within the region that flight operations may be conducted using Magnetic North reference.

Note 1: In the navigation environment, there are a number of different sources of magnetic variation that could be used for flight path definition where magnetic course information is required. For flight path segments that require magnetic course information, a common source of magnetic variation would have to be used to define the flight path in order to provide repeatability between aircraft for the flight paths flown.

Note 2: The requirement that the navigation system contain magnetic variation model data is derived from requirements such as the following:

1. *The ability to create place/bearing/distance user-defined fixes.*
2. *Deleted.*
3. *The ability to create legs specified by a course to a fix.*

Ref: RTCA/DO-236B, Para. 3.2.5.2 except for the following :

(a) 2 Adds TACAN -Navy unique; (a) 3 Adds "or the Earth's actual measured magnetic variation and referenced to the termination fix". - Navy unique.

3.2.5.4.3 Data Resolution

The data resolution shall be equal to or better than that defined in RTCA/DO-201A paragraph 2.1.5 or the disparity between the required and implemented resolutions shall be accounted for in the path definition error calculation.

Note 1: When the data resolution in the equipment is equal to or better than that defined in RTCA/DO-201A, the following sections (3.2.5.4.3.1 through 3.2.5.4.3.4) shall not apply.
Note 2: The resolution at which the fix coordinates, turn radius, and course data is stored and operated upon may contribute to the path definition error.

Ref: RTCA/DO-236B, Para. 3.2.5.3(b) note RTCA/DO-283A, Para. 2.2.2.10, and RTCA/DO-201A paragraph 2.1.5, amended

3.2.5.4.3.1 Coordinate Resolution

For all leg types, the path definition error term shall include or account for the resolution of the fix coordinates. This error contribution is directly equivalent to the coordinate resolution.
Ref: RTCA/DO-236B, Para. 3.2.5.3.1

3.2.5.4.3.2 Turn Radius Resolution

(a). For systems that compute the ground track of an arc leg using the turn center and the specified turn radius, the path definition error term shall include or account for the turn radius resolution. This error contribution is directly equivalent to the turn radius resolution.
(b). For systems which compute either the turn center or turn radius (in lieu of using the specified value), the error term shall account for both the data resolution as well as the difference between the computed and specified coordinates or radius.

Note: The concept of turn radius resolution is related to RF Legs. RF legs are optional for this FRD.

RTCA/DO-236B, Para. 3.2.5.3.2, amended.

3.2.5.4.3.3 Course Resolution

For leg types that are specified by magnetic course, the path definition error term shall include or account for the resolution of the defined course.

Note: The effect of this inaccuracy will vary with the distance from the fix and is computed as the product of the current distance from the leg termination fix and the course resolution in radians.

Ref: RTCA/DO-236B, Para. 3.2.5.3.3

3.2.5.4.3.4 Magnetic Variation Resolution

For leg types that are specified by magnetic course, the path definition error term shall include or account for the resolution of the defined magnetic variation.

Note: The effect of this inaccuracy will vary with the distance from the fix and is computed as the product of the current distance from the leg termination fix and the magnetic variation resolution, in radians.

Ref: RTCA/DO-236B, Para. 3.2.5.3.4

3.2.5.5 Transitions

(a). The navigation system shall provide a means to automatically transition from one leg to another. Two categories of transition between fixed path segments have been defined: fly-by transitions and fly-over transitions. As a Navy minimum, the navigation system shall be capable of accomplishing fly-by and fly-over transitions.

(b). For Fly-by transitions, no predictable and repeatable path is specified, because the optimum path varies with airspeed and bank angle. Instead, predictable and repeatable boundaries of the transition area are defined below for these types of transitions.

(c). For Fly-by transitions, the path definition error is defined to be the difference between the defined path and the theoretical transition area. If the path lies within the transition area, there is no path definition error.

(d). Aircraft shall fly the procedure as coded in the database. Fly-by transitions shall be the default transition when the transition type is not specified.

(e). The theoretical transition area requirements for fly-by transitions which follow this section are only applicable if the following assumptions are followed; course changes do not exceed 120 degrees for low altitudes (less than Flight Level 195 (FL 195) or 70 degrees for high altitudes (FL 195 or above). When passing through FL 195 during a fly-by transition, the high altitude values may be applied for determining the theoretical boundaries throughout the transition.

(f). For fly-by transitions, the general principle is to define a theoretical area which contains or bounds the transition trajectories independently of the applicable RNPs. Then accuracy and containment limits can be defined around this theoretical area as a function of the RNP type.

(g). The equipment shall define a path to accomplish fly-over turns that passes through the transition waypoint.

3.2.5.5.1 Fly-by Transitions

The transition area for fly-by transitions is shown in Figure 5. While the inner boundary of the transition area is defined as an arc of a circle, it is not required such an arc to be flown by the aircraft. For fly-by transitions of less than or equal to 120°, the defined path shall remain in the shaded area shown. An infinite number of acceptable ground tracks can be defined per individual airborne system design.

Note: Non-Standard Transitions. When course changes exceed those assumed above, there may be cases where a route could be created in which transition containment will not be possible due to factors such as aircraft performance, course change and leg length. In effect, the defined path is not flyable. This situation should not occur in a database-defined procedure, but may occur as a result of user modification to the defined flight plan. For situations such as this, the navigation system should attempt to stay within the containment area to the extent practicable, but may deviate from the defined path base upon operational considerations.

Ref: RTCA/DO-283A, para. 2.2.2.9.1 amended to include transitions equal to 120°.

3.2.5.5.2 Fly-By Transition Parameters

(a). The parameters which specify the boundary area of the transition shall be defined by:

1. Radius of turn $R = (V + W)^2 * (\tan(\Phi))^{-1} * 1.458 \times 10^{-5}$ nm

2. Turn Initiation Boundary Distance (Y) = R * tan(0.5*α)

Where, V+W is the maximum Groundspeed assumed for the transition. It is the magnitude of the sum of the aircraft velocity vector (V) and wind velocity vector (W).

α = track change, in degrees

Φ is the maximum aircraft bank angle.

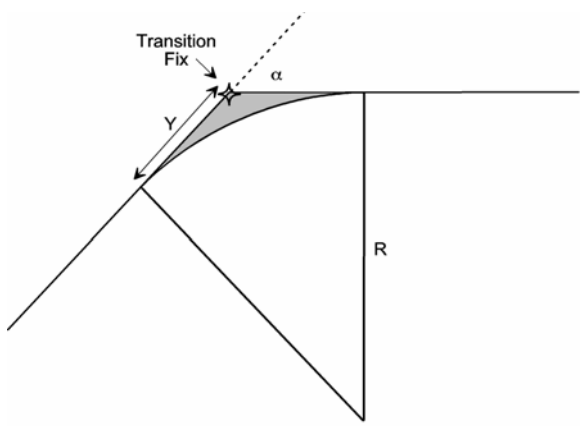
(b). Low Altitude Transitions

1. (V+W) = 500 kts
2. Φ = min(0.5 * α, 23°); *Note: min is the lesser of (0.5 * α) or 23°.*

(c). High Altitude Transitions

1. (V+W) = 750 kts
2. Φ = 5°, by default.
3. If 5° results in Y > 20 nm, then Y = 20 nm and R= 20/tan(0.5*α)

Ref: RTCA/DO-236B, Para. 3.2.5.4.1 --1, --2
Note 1 The initiation of the turn shall not occur prior to 20 nm from the fix, regardless of the track angle change.
Note 2: The requirement of paragraph (c) 3. has the effect of limiting the initiation of a turn to 20 nm.
Note 3: While the inner boundary of the theoretical transition area is defined as an arc of a circle, this does not require such an arc to be flown by the aircraft.
Note 4: The definition of the theoretical transition area is based upon data contained in the current revision of FAA Order 8260.40, FMS Instrument Procedures Development, which have been derived from evaluations of a large set of existing navigation systems performance. Order 8260.40 defines terminal area performance for a variety of flight conditions. As such, the definitions are complex in terms of airspeed and altitude. This FRD for RNP RNAV generalizes these flight conditions by assuming near worst-case ground speeds, one for low altitude and one for high altitude. The result is increased airspace requirements for transitions.



Note: Shaded area indicates Fly-By Transition Area

Figure 5. Fly-By Theoretical Transition Area

Note: This type of turn can be used to define transitions at all altitudes. Both legs pass through the transition fix. The only parameter needed is the definition of the transition fix.

3.2.5.6 Applicable RNP RNAV Type

The following RNP RNAV sections define the rules for the airborne equipment to assign an RNP RNAV type to the flight plan legs and the transitions between these legs.

Ref: RTCA/DO-236B, Para. 3.2.6

3.2.5.6.1 RNP RNAV Type Associated with a Flight Plan Leg & Transition

(a). The RNP RNAV type of any leg type shall be assigned in the following order of precedence:
   1. Use the pilot entered RNP RNAV type, if defined;
   2. Use the RNP RNAV type coded in the navigation database for the current leg or route, if defined; (Reference the RNP Database matrix); or
   3. Use the RNP RNAV type coded in the navigation database for the area if defined.

(b). If the original leg is divided into multiple legs, the RNP RNAV type of the original leg will be applied to each newly created leg.

(c). When flying a parallel offset, the RNP RNAV value applicable to the host route in the active flight plan shall be applicable to the offset route.

Note 1: For the airborne equipment, the RNP RNAV type when transitioning between legs may be the RNP RNAV type associated with either leg defining the transition.
Note 2: There are two different aspects associated with RNP RNAV when transitioning between legs. One aspect is related to airspace planning/obstacle clearance concerns and the other is related to navigation computer containment/alerting.
Note 3: The RNP RNAV type for airspace planning is the largest RNP RNAV type associated with the two legs defining the transition (e.g., when transitioning from an RNP-1 RNAV leg to an RNP-0.3 RNAV leg, the airspace planners should assume transition containment based on RNP-1). The intent is to eliminate the need of the airborne equipment to specify when the transition from one leg to another is completed.

Ref: RTCA/DO-236B, Para. 3.2.6.1 & 3.2.6.2

3.2.5.6.2 Prohibited Flight Plan Elements

Note: The intent of this section is to provide a list of flight plan elements which are prohibited from having an assigned RNP RNAV type by the airspace planners. Navigation management system manufacturers may also use it as a set of assumptions to design their future systems to be certified for use in the RNP RNAV environment.

The following flight plan elements shall not have an assigned RNP RNAV type:

1. Heading/vector segments
2. Track segments without a fixed termination waypoint
3. Procedure Turn segments
4. Radial or distance terminated legs

Note 1: This includes the following ARINC 424 leg types: CA, CD, CI, CR, VA, VD, VI, VM, VR, PI, FC, FD, FM, and AF.
Note 2: The particular cases of ARINC 424 CF, and DF legs are treated in paragraphs 3.2.5.2.4 and 3.2.5.2.3.

Ref: RTCA/DO-236B, Para. 3.2.7

3.2.6 Path Steering Requirements

(a). The system shall provide data to enable the generation of command signals for autopilot/flight director/Course Deviation Indicator (CDI), as applicable.
(b). The system shall recognize the flight path transition requirements (i.e., fly-by), routes and procedures embedded in the navigation database.
(c). In all cases a Path Steering Error (PSE) budget shall be defined at the time of certification which will, in combination with the other system error budgets, meet the requirements of the desired RNP RNAV operation.
(d). During the certification process, the ability of the crew to operate the aircraft within the specified PSE shall be demonstrated.
(e). Aircraft type, operating envelope, displays, autopilot performance, and leg transitioning guidance (specifically between arc legs) should be accounted for in the demonstration of PSE compliance.
(f). A measured value of PSE may be used to monitor system compliance to RNP RNAV requirements.
(g). For operation on all leg types, the measured value shall be the distance to defined path.
(h). For cross-track containment compliance, any inaccuracies in the cross-track error computation (e.g., resolution) shall be accounted for in the total system error.
(i). Systems designed for RNP-12.6 RNAV or less shall provide guidance interface data to enable the generation of command signals for autopilot/flight director use.
(j). When a procedure is drawn from the database, the system shall be capable of flying it as published.

Note: If the system is not interfaced with an autopilot, operational limitations may be applied to the aircraft, restricting access to certain procedures and transitions.

Ref: (a),(c)-(h) RTCA/DO-236B, Para. 3.3.1, (deleted reference in para. (b). to fixed radius), (b), (i), (j), 3.7.4.1.

3.2.6.1 Flight Technical Error (FTE)

The navigation error introduced by the pilot's (or autopilot's) capability to utilize displayed guidance information to track the desired flight path is commonly referred to as flight technical error (FTE). In the RNP environment, the overall navigation performance shall account for the contribution of FTE. During real-time operation of the system, the FTE can be measured, however during the system certification, an estimated system FTE shall be established.

Note 1: See Appendix D of RTCA/DO-236B for ICAO FTE data.

Ref: RTCA/DO-236B, Para. 3.3.1, --4

3.2.7 Estimated Time of Arrival

(a). The navigation equipment shall provide for display of the estimated time of arrival at each fix in the flight plan to the nearest minute.
(b). The equipment shall utilize all of the following flight parameters to calculate the estimated time of arrival at a downstream waypoint:
    1. Predicted ground speed profile,

2. Distances along the lateral path.

Ref: RTCA/DO-236B, Para. 3.4.1, Para. 3.7.7 (Amended to delete forecast environmental conditions.)

3.2.8 User Interface Requirements

3.2.8.1 General

The development of an RNP capable system will require specific functions and features that must be allocated as appropriate within the system architecture. Some of the essential design considerations to accommodate human factors considerations include:

1. Minimizing reliance on flight crew memory for any system operating procedure or task.
2. Developing a clear and unambiguous display of system modes/submodes and navigational data with emphasis on enhanced situational awareness requirements for any automatic mode changes (if provided).
3. The use of context sensitive help capability and error messages; e.g., invalid inputs or invalid data entry messages should provide a simple means to determine how to enter "valid" data.
4. Fault tolerant data entry methods rather than rigid rule based concepts.
5. Placing particular emphasis on the number of steps and minimizing the time required to accomplish flight plan modifications to accommodate Air Traffic Service (ATS) clearances, holding procedures, runway and instrument approach changes, missed approaches and diversions to alternate destinations.
6. Minimizing the number of nuisance alerts such that the flight crew will recognize and react appropriately when required.

Ref: RTCA/DO-236B, Para. 3.6.1

3.2.8.2 Display and Controls

(a). Each display element used as a primary flight instrument in the guidance and control of the aircraft, for maneuver anticipation, or for failure/status/integrity annunciation, shall be located where it is clearly visible to the pilot (in the pilot's primary field of view) with the least practicable deviation from the pilot's normal position and line of vision when looking forward along the flight path.

(b). Deleted.

(c). All system displays, controls and annunciators shall be readable under normal cockpit conditions and expected ambient light conditions.

(d). Night lighting provisions shall be compatible with other cockpit lighting.

(e). All displays and controls must be arranged to facilitate flight crew accessibility and usage.

(f). Controls that are normally adjusted in flight shall be readily accessible with standardized labeling as to their function.

(g). System controls and displays shall be designed to maximize operational suitability and minimize pilot workload.

(h). Controls intended for use during flight shall be designed to minimize errors, and when operated in all possible combinations and sequences, shall not result in a condition whose presence or continuation would be detrimental to the continued performance of the system.

(i). System controls shall be arranged to provide adequate protection against inadvertent system

shutdown.

(j). The following table presents the required minimum display/entry resolution for the navigation system:

Table 4. Display – Error Resolution

Parameter	Resolution Display	Resolution Entry
Numeric Cross-Track (XTK)	0.1 nm to 9.9 nm, 1.0 nm to 20 nm	Not Applicable
Distance	0.1 nm≤ 9.9 nm, 1.0 nm ≥10.0 nm	0.1 nm ≤ 9.9 nm, 1.0 nm ≥ 10.0 nm
Desired Track (DTK)	1 degree	1 degree
Track Angle Error (TAE)	1 degree	Not Applicable
Groundspeed	1 knot	Not Applicable
Fix Latitude/Longitude*	0.01 min	0.1 min
Bearing	1 degree	1 degree
Track Angle	1 degree	Not Applicable
RNP RNAV type	x.xx < 10, xx.x ≥ 10	x.xx < 10, xx.x ≥ 10
Present Position Display	0.1 min	0.1 min
Altitude	Flight level or 1 foot	Flight level or 1 foot
Estimated Time of Arrival	1 min	Not Applicable
Required Time of Arrival	0.1 min	0.1 min
Vertical Speed	1 ft/min	1 ft/min
Airspeed	1 knot, 0.01 M	1 knot, 0.01 M
Vertical Path Deviation	10 feet	Not Applicable
Flight Path Angle	0.01 degree	0.01 degree
Temperature	1 degree	1 degree
EPU Display Resolution	0.01 nm	Not Applicable

** The latitude/longitude display requirement is intended to allow pilot verification of navigation database fix coordinates to the required resolution.*

Note 1: With all display information, it is required to display computed values rounded rather than truncated.
Note 2: EPU = Estimated Position Uncertainty

(k). The aircraft shall have, at a minimum, a graphical display of information in the pilot's primary field of view including waypoints, procedures, and own aircraft position. The requirements of this FRD shall apply to such a display when it is used for primary RNP RNAV display and system alerting functions.

Note: User assessment of navigation performance and situational awareness may be achieved by an integrated presentation of a flight plan, map ranges consistent with the flight operation and/or RNP RNAV, available navigation aids and airports on a graphical map display.

Ref: RTCA/DO-236B, Para. 3.6.2, 3.10, amended. EPU Resolution: RTCA/DO-283A, Para. 2.2.1.2, amended.

3.2.9 Control Display Response Time

The tasks shown below shall be capable of being accomplished within the indicated time. The specified times are worst case, regardless of where the functions are initiated (i.e., the pilot may be in the middle of doing something else before initiating the function):

Enroute/terminal-related functions

Access primary navigation information	2 sec.
Direct-to any named waypoint in a published departure, arrival, or approach procedure already in the active flight plan (including selecting the waypoint)	10 sec.
Direct-to any waypoint in the database, but not in the active flight plan (including selecting a five character waypoint)	20 sec.
Select a course to or from an active waypoint	10 sec.

Approach-related functions

Select and activate an approach at the departure airport, which may be pre-programmed as an alternate flight plan	10 sec.
Select and activate an approach at an airport, given that the airport is the active waypoint	13 sec.
Runway change after an approach has been selected and activated	10 sec

Ref: RTCA/DO-283A, para. 2.2.4.12

3.2.10 Displays/Status

3.2.10.1 Flight Progress

(a). The system shall provide the capability to present progress/situation information to the crew.
(b). The system shall display numeric cross-track deviation and desired track.
(c). A display of along-track distance from present position to the next (active/TO), next-plus-one and the destination flight plan fixes shall also be provided.
(d). The system shall indicate to the crew an impeding flight plan leg change.
(e). It shall also indicate any approaching flight plan discontinuities
(f). The system shall display the current RNP RNAV type and whether the value is manually entered or automatically provided via the navigation database.
(g). A scaleable Course Deviation Indicator / Horizontal Situation Indicator (CDI/HSI) or electronic map shall be provided in the pilot's primary field of view.
(h). Cross-track deviation Full Scale Deflection (FSD) shall be based on the currently selected

RNP type: 0.3 nm FSD for RNP Type 0.3, 1.0 nm FSD for RNP Type 1.0, 2.0 nm FSD for RNP Type 2.0, and 4.0 nm FSD for RNP Type 4.0 and greater.

(i). The CDI full-scale deflection value shall be known or available for display to the flight crew.

(j). The display of non-numeric deviations shall have the following characteristics:

Table 5. Non Numeric Display Requirements

	Percentage of Full-Scale
Readability*	10%
Minimum Discernible Movement	2%
Accuracy of Centered Display	3%
Linearity of Display	5%

**Readability refers to the ability to determine the magnitude of deviation (as a percentage of full-scale deflection).*

Ref: a) - g),i) - j) RTCA/DO-236B, Para. 3.7.5.1, h) RTCA/DO-283A, Para. 2.2.4.1.2.1, amended to delete ranges.

3.2.10.2 Navigation Data

(a). The system shall provide for the presentation of navigation information to determine aircraft position and track.

(b). The system shall provide a display of the aircraft's present position latitude and longitude.

(c). Bearing and distance from present position to any selected fix shall be provided.

(d). The system shall indicate the aircraft's actual track angle, and the desired track between consecutive flight plan fixes.

(e). The system shall have the capability to display ground speed or time to the active waypoint, either in the pilot's primary field of view, or on a readily accessible page on a Multifunction Control Display Unit (MCDU), readily visible to the flight crew.

(f). A display of the altitude restrictions associated with flight plan fixes shall be available to the pilot.

(g). The system shall provide a numeric display of cross-track deviation to at least ±20 nm (left and right).

(h). If appropriate, the system shall provide a continuous display or electrical output to show whether the aircraft is behind or ahead of the active fix relative to an imaginary line perpendicular to the defined path and passing through the active fix.

(i). Provisions shall be made to display the identification of the active fix, the next fix in the flight plan, and the destination. These fix identifications need not be displayed simultaneously. Means shall be provided to indicate whether or not the displayed fix is the active fix.

Ref:(a) – (f) RTCA/DO-236B, Para. 3.7.5.2 [However, (e). was amended.],
(g)-(i). RTCA/ DO-283A. (g). Para. 2.2.4.1.1(amended), (h) Para. 2.2.4.3, (i) Para. 2.2.4.5

3.2.10.3 Navigation Modes and Performance

(a). The system shall provide the flight crew with an indication of the current navigation

sensor(s) in use.

(b). The system shall indicate navigation equipment failure to the fight crew.

(c). The system shall make available to the crew an Estimate of Position Uncertainty (EPU).

(d). The system shall annunciate when the system is operating in a parallel offset mode.

(e). The equipment shall indicate inadequate or invalid navigation signal(s) or source(s).

(f). Integrity of the GPS PPS Navigation System shall be in accordance with the Table 6, below:

Table 6. Integrity Requirements

Integrity Parameter (Note 1)		PPS Operation (Keyed)	
1.	**Enroute navigation:**	**Domestic enroute**	**Oceanic enroute**
a.	Time to Alert (TTA) Note 2	30 seconds	1 minute
b.	Horizontal Alert Limit (HAL)	2 nm	4 nm
2.	**Terminal Navigation:**		
a.	Time to Alert (TTA) Note 2	10 seconds	
b.	Horizontal Alert Limit (HAL)	1 nm	
3.	**Non-Precision Approach Navigation:**		
a.	Time to Alert (TTA) Note 2	10 seconds	
b.	Horizontal Alert Limit (HAL)	0.3 nm	
4.	**All Phases of Navigation:**		
a.	Probability of Unalarmed Hazardously Misleading Information (UHMI) with Fault Detection	1×10^{-7}	

Note 1: All parameters shall be as defined in RTCA Document DO-229C except UHMI. UHMI was established by reference (t), NAVSTAR GPS Joint Program Office Memorandum, Subject: "Coordination of Department of Defense (DOD) GPS Non-Precision Approach (NPA) Integrity Requirements", 23 October 1995.

Note 2: This is the TTA from event to display in the primary field of view.

Note 3. The performance requirements in this Table must be compared to approval requirements for each intended operation. In general, these requirements exceed currently published GPS ops approval requirements, but that does not ensure all future airspace requirements will be met. In particular, the availability of FDE may need to be improved for FAA Notice N8110.60 and PRNAV operations, and/or capability to predict FDE outages implemented for these operations.

3.2.11 Alerting

(a). **Loss of Navigation Caution.** Equipment shall continuously provide a caution, independent of any operator action, which indicates the loss of navigation capability. This caution shall be a unique annunciator capable of installation in the pilot's field of view. This caution may be implemented by flagging the primary navigation display. The loss of navigation caution shall be output/displayed within one second of the onset of any of the following conditions:

1. The absence of power (loss of function is an acceptable indicator);

2. Probable equipment malfunction or failure (must consider all malfunctions and failures that could affect the navigation function and are more probable than 10^{-5} /hour);
3. The presence of a condition lasting five seconds or more where there are an inadequate number of satellites to compute a position solution;
4. Fault detection detects a position failure which cannot be excluded within the time-to-alert. When in the Non Precision Approach (NPA) Mode, the fault detection function shall detect positioning failures within 10 seconds after the onset of the positioning failure.
5. The fault detection function shall detect positioning failures within the prescribed times-to-alert (See Table 6.)
6. The navigation system does not comply with the containment integrity requirement of the current RNP RNAV type.
7. In Oceanic, En Route, and Terminal modes, the equipment shall distinguish between these different causes of the loss of navigation capability. For example, a single loss of navigation caution can be provided, if it is accompanied by a message for conditions 2 through 6 indicating the cause of the alert. A blank display could indicate condition1. The caution shall be returned to its normal state immediately upon termination of the responsible condition.

Note: A loss of navigation alert does not require removal of navigation information from the navigation display. Consideration should be given to continued display of navigation information concurrent with the failure/status annunciation when conditions warrant.

Ref: Paragraph (a) 1 through (a) 7 DO-229C, para. 2.2.1.6.2, 2.2.2.6.2, 2.2.2.6.3, 2.2.3.6.3, 2.2.4.6.3 except para. 6 which is a Navy unique requirement.

(b). **Loss of Integrity Caution.**

1. The loss of integrity caution shall be located in the pilot's primary field of view.
2. The equipment shall provide a loss of integrity caution when the Horizontal Protection Level (HPL) computed by the equipment exceeds the Horizontal Alert Limit for the current operation.
3. The equipment shall also provide a loss of integrity caution when, for any reason, a positive integrity check of the navigation solution is not available.

Ref: 2. DO-229C para. 2.2.3.6.3: the remainder are Navy unique requirements.

(c). **Additional Alerts**.

1. The system shall indicate when a manually entered RNP RNAV value is larger than the RNP RNAV type associated with the current airspace, as defined in the navigation database or as defined by the system defaults. Any subsequent reduction of the RNP RNAV type associated with the current airspace shall reinstate this annunciation. Upon termination of a parallel offset, the system shall indicate when a manually entered RNP RNAV value is larger than the RNP RNAV type associated with the current airspace, as defined in the navigation database or as defined by the system defaults. (The intent is to reinstate the indication in case of a manually entered RNP

RNAV value has been entered for the parallel offset operation.)

2. When approaching RNP RNAV airspace from non-RNP RNAV airspace, alerting shall be enabled when the cross-track to the desired path is equal to or less than one-half (1/2) the RNP RNAV value and the aircraft has passed the first fix in RNP RNAV airspace.
3. Multi-sensor navigation systems which perform automatic selection and de-selection of navigation sensors shall indicate when the system attempts to use a navigation sensor(s) not authorized by the published procedure.

.

Ref: subparagraph (c): DO-283A, para. 2.2.4.11 f., g., h.

3.2.12 Specific Requirements for Navigation Data and Navigation Data Processing

(a). The system shall utilize the data elements necessary to execute RNP RNAV operations from a DoD approved aeronautical database. Data elements shall contain at least the following location information for the area(s) in which RNP RNAV operations are intended:

1.Airports. (Note: Airport identifiers shall be accessible using standard ICAO and/or Host Country nomenclature when available (e.g., KJFK, KF70, OM10)).
2.NAVAIDS.
3.Waypoints.
4.All RNP RNAV procedures (including associated waypoint descriptive data)/DPs within the limitations stated in Section 3.2.5.2.6 (Unsupportable Instrument Procedures).
5.Magnetic Variation information.

Ref: (1) – (4) RTCA/DO-236B, Para. 3.8.1, (1) – (5) RTCA/DO-283A, Para. 2.2.2.11.

(b). The probability of undetected corruption of essential data from the source data to the aircraft mission computer/display shall not exceed 1 X 10-5.

Ref: RTCA/DO-200A, Appendix C, page C-4, Table C-1, Assurance Level 2, Para. 2.3.3, Para. 2.4.1 (1)-(14), Para. 1.5.5, Appendix A, Definition of Distribute and RTCA/DO-236B, Para. 3.8.3.

(c). The following data shall be treated as essential data:

1.RNAV Non-Precision Approaches, RNAV departure procedures, and RNAV Standard Terminal Arrivals.

a. Latitude and longitude data
b. Bearing data
c. Length or distance data
d. Waypoint Identifier
e. Waypoint Type (IAF, FAF, MAP, Hold) (applies to approaches only)
f. Waypoint Designation (fly-by/fly-over)
g. Waypoint Altitude data
h. Waypoint Turn Direction
i. Segment Leg Type (i.e. Track Code)
j. RNP value

Note: For any leg, if bearing and/or distance is calculated by the FMS, (c).1b. and (c).1c. do not apply.

2.Enroute Waypoints (Latitude/Longitude)

3.Navigation Aids (Latitude/Longitude, Elevation, Declination/Magnetic Variation)
4.Runways (Latitude/Longitude, Elevation, Length/Distance)
5.Airports (Elevation, Declination/Magnetic Variation)

Ref: RTCA/DO-201A, Para. 2.1.6.5, Tables 2.1 - 2.5

3.2.12.1 Mission Planning/Data Processing and Formatting System.

Mission Planning/Data Processing and Formatting systems are used to format data for use by aircraft Flight Management Systems (FMS)/Mission Computers (MC)/Computer Display Units (CDU).

The system:

(a). shall provide a means to identify the navigation database version and valid operating period;
(b). shall indicate if the navigation database is not yet effective or out of date;
(c). shall transfer to the aircraft portable memory device, the information that identifies the version and valid operating period of the navigation database.

Ref (a)-(c): RTCA/DO-200A, Para. 2.3.2 (5)

(d). shall validate the essential data to ensure system compatibility/usability and to ensure all of the data needed to support RNAV functionality is provided (completeness). The system shall not load an approach transition or a procedure that contains data elements that do not pass the validity and completeness evaluation.

Ref: RTCA/DO-200A, Para. 2.4.1 (6), (7), Para. 2.3.2, Para. 2.3.3, Para C.2.1

(e). shall only load instrument procedures the host platform can support.

Ref: RTCA/DO-200A, Para. 2.3.4 (1)

Note: For example, aircrew shall not be able to access or attempt to use a procedure that contains an RF leg with a system that does not support RF legs.

(f). shall provide a means to identify the flight plan/route database version and valid operating period.
(g). shall indicate if the flight plan/route database is not yet effective or out of date.
(h). shall transfer to the aircraft portable memory device, the information that identifies the version and valid operating period of the flight plan/route database.
(i). shall provide an indication if the version and valid operating period of the flight plan/route database is not identical to the version and valid operating period of the navigation database anytime a data transfer results in both a navigation database and a flight plan/route being resident on the aircraft portable memory device.

Ref (f)-(i): RTCA/DO-200A, Para. 2.3.2 (5)

3.2.12.2 Aircraft Flight Management System

The Aircraft Flight Management System:

(a). shall meet or exceed the probability of undetected corruption of 1 X 10-5 for essential data that is stored in the Aircraft Flight Management System.

Ref: RTCA/DO-200A, Para. 2.4.1 (3)

(b). shall provide a means to identify the navigation database version and valid operating period.
(c). shall indicate if the navigation database is not yet effective or out of date.
(d). shall compare flight plan/route DAFIF data with the navigation database. If the data is not identical, the system shall update the flight plan/route DAFIF data to be identical or indicate that they are not identical.

Ref (b)-(d): RTCA/DO-200A, Para. 2.3.2 (5)

3.2.12.3 Data Access

(a). The navigation database shall provide access to navigation information in support of the navigation systems reference and flight planning features.
(b). The navigation database shall only contain data from a DoD approved aeronautical database.
(c). Manual modification of the navigation database shall not be possible. This requirement does not preclude the storage of "user defined data" within the equipment.
(d). When data are recalled from storage they shall also be retained in storage.

Ref: RTCA/DO-236B, Para. 3.8.2, amended.

3.2.12.4 Database Standard (Relocated from paragraph 3.2.12.2)

The aeronautical information used in the development of a navigation database shall be based on the one provided by the National Geospatial-Intelligence Agency (NGA), which is updated on a 28-day Aeronautical Information Regulation and Control (AIRAC) cycle. DAFIF Database, Edition 7 and later editions shall be used.

Ref: CJCSI 6130.01C, 2003 CJCS Master Positioning, Navigation and Timing Plan, DOD Digital Aeronautical Flight Information Files (DAFIF)

3.2.13 Relocated. Incorporated into Paragraph 3.2.8.2 (k).

3.2.14 Initialization Capability

3.2.14.1 Position Initialization

If the system requires position initialization, it shall provide the capability to allow entry and display of position initialization parameters to a resolution consistent with 0.1 minute or better.

Ref: RTCA/DO-236B, Para. 3.7.1.1

3.2.14.2 Time Initialization

For systems including a time of arrival control capability, the navigation equipment shall allow for synchronization to Coordinated Universal Time (UTC by international agreement).

Ref: RTCA/DO-236B, Para. 3.7.1.3

3.2.15 Path Selection

3.2.15.1 General Flight Planning

(a). The system shall provide the capability for the crew to create, review, and activate a flight plan.
(b). The system shall provide the capability for modification (e.g., deletion and addition of fixes and creation of along-track fixes), review and user acceptance of changes to the flight plans.
(c). When this capability is exercised, guidance outputs shall not be affected until the modification(s) is/are activated.
(d). Activation of any flight plan modification shall require positive action by the flight crew after the input and verification by the flight crew.
(e). The system shall indicate to the crew any flight plan discontinuities.
(f). The system shall provide a means to preview and verify waypoint names, position, sequence, course, distance, and altitude information and waypoint type (fly-by vs. fly-over). where specified.

Note: The system should be capable of storing sufficient data to carry out any practical flight plan.

Ref: (a) – (d) RTCA/DO-236B, Para. 3.7.2.1.1, --1 amended, (e). RTCA/DO-283A, Para. 2.2.2.2, (f). AFMAN 11-217V1 3 January 05 amended, and DoD FLIP General Planning Para. 3-8, 24 November 05, amended.

3.2.15.*2* Flight Planning in RNP-4 RNAV or Less Airspace

(a). The system shall have the capability to create flight plans by selection of individual fixes from the database. The systems that incorporate this feature shall provide a minimum 5-character field for input and display of database fix identifiers.
(b). The system shall provide the means to extract from the database and review, for incorporation into a flight plan, flight departure procedures, including Standard Instrument Departures/Departure Procedures (SIDs/DPs), and flight arrival procedures, including Standard Terminal Arrival Routes (STARs) and arrival transitions, for the appropriate/selected airport runway.
(c). Navigation systems shall have the capability to create flight plans by joining routes or route segments from the navigation database and by the use of ATS route identifiers.
(d). Systems providing approach capability shall provide the means to extract from the database and review, for incorporation into the flight plan, approach procedures, to include standard approach and missed approach procedures and approach transitions, for the appropriate/selected airport runway.

Ref: RTCA/DO-236B, Para. 3.7.2.1.1, --3

3.2.15.3 User-Defined Fixes

(a). The equipment shall provide the capability to manually enter the coordinates of a fix in terms of latitude and longitude. The input resolution capability for latitude and longitude shall be 0.1 minutes or better.
(b). The equipment shall provide the capability to manually enter a fix as a range and magnetic bearing from another fix (place/bearing/distance).
(c). Deleted.
(d). If the user defines a fix defined by a VOR or TACAN, then the system shall only use the station declination of the VOR or TACAN, if the VOR or TACAN is part of the FMS solution, otherwise the fix must be defined by latitude & longitude, or be a recognized five-character (5) FAA/ICAO alphanumeric identifier. GPS, LORAN, Inertial Navigation System (INS) and rho-rho FMS solutions shall not be used to define Federal VOR Airways or theta-theta airways fixes.

Note 1: Consideration should be given to allow entry of true bearing for equipment that will be approved for use at higher latitudes.
Note 2: The type of user-defined fix capability of a given system should be commensurate with its intended operational use. For RNP-1 RNAV or less, user-defined fixes should not be used for systematic route creation and are only intended for use in tactical situations and temporary route diversions. It is not intended that user-defined fixes be inserted into approach or missed approach procedures once drawn from the database, and the ramifications of doing so should be clearly understood by the flight crew. User-defined fixes should never be inserted into approach or missed approach procedures once drawn from the database. Doing so would modify an approach procedure that could lead to catastrophic obstacle or terrain conflict.

Ref: RTCA/DO-283A, Para. 2.2.2.4 (Note that Para. (d) and Note 2 have been revised from RTCA/DO-283A.)

3.2.15.4 Selection of RNP RNAV Type

(a). The system shall provide a means to select/modify the RNP RNAV type.
(b). The system shall be capable of automatic entry of RNP RNAV type as defined in the system database.
(c). The system shall be capable of manual entry of RNP RNAV types and manual override of automatic entries.
(d). The system shall provide a means to remove the manual entry of the RNP RNAV type and resume automatic entries.

Ref: (a) – (c) RTCA/ DO-236B, Para. 3.7.2.1.3, (d) RTCA/ DO-283A, Para. 2.2.2.12., amended.

3.2.15.5 Fix Sequencing

The system shall provide the capability for automatic sequencing of fixes.

Ref: RTCA/DO-236B, Para. 3.7.2.1.4

3.2.16 Navigation Aid Selection

(a). The system shall be capable of manual or automatic navigation source selection.
(b). The selected ground NAVAID frequencies and/or identifiers shall be available for display.

(c). The system shall provide the capability to inhibit individual navigation aids from the automatic selection process.
(d). If a ground NAVAID is required for navigation, the system shall enable the pilot to manually select the ground NAVAID for display of raw data.
(e). Systems that use space-based navigation sources shall provide the capability for automatic selection of navigation sources, a reasonableness check and integrity check.
(f). Systems using ground-based navigation sources, and intending to operate in RNP-4 RNAV or less airspace, shall provide the capability for automatic selection (or de-selection) of navigation sources, a reasonableness check, an integrity check and a manual override or deselect.
(g). In lieu of using radio navigation aid Designated Operational Coverage (DOC), the navigation system should provide checks which preclude use of duplicate frequency NAVAIDs within range, over-the-horizon NAVAIDs, and use of NAVAIDs with poor geometry.

Ref: RTCA/DO-236B, Para. 3.7.3

3.3 Enroute Requirements

3.3.1 Oceanic and Domestic Enroute Requirements

(a). Equipment shall provide navigation for both domestic and oceanic/remote area enroute operation.

(b). HORIZONTAL ALERT LIMITS:	Domestic Enroute	- -	2 nm
	Oceanic/Remote	- -	4 nm
(c). TIME-TO-ALERT:	Domestic Enroute	- -	30 seconds
	Oceanic/Remote	- -	1 minute

Note: The equipment can provide a single mode for both operations, which must satisfy all of the enroute requirements. Alternatively, the equipment may provide two separate modes: an oceanic mode and a domestic enroute mode. The only difference between these modes is the horizontal alert limit and the time-to-alert. Unless otherwise specified, the term "enroute" refers to the enroute navigation mode, which can accommodate both domestic and oceanic/remote enroute phases of flight.

(d).

OPERATION	RNP TYPE	EXAMPLE APPLICATION
Oceanic/Remote	*RNP - 20*	*Separation between Tracks/ATS Routes*
Oceanic/Remote	*RNP - 12.6*	*N. Atlantic FL285-420*
Oceanic/Remote	RNP – 10 RNAV	50 nm Separation
Oceanic/Remote	RNP – 4 RNAV	30/30 nm Separation (Note 1)
Enroute Domestic	RNP - 2 RNAV	8 nm Route Separation

Note 1: RNP-4 exceeds requirements for BRNAV/RNP-5 and is authorized for Navy use where BRNAV/RNP-5 is required (Europe).

Ref: (a)-(c): RTCA/DO-229C, Para. 1.4.2, 2.2.2.6.1, 2.2.2.6.3, (d) Advisory Circular 20-RNP, Draft 8a, amended. Items in italics added to table are from Doc 9613-AN/937, ICAO Manual on Required Navigation Performance, Second Edition, 1999 with Amendment 1, 1 March 2001 and amended.

3.3.2 Path Definition Requirements

3.3.2.1 Navigation Database Flight Path Legs for Airways

The navigation system shall utilize TF legs to construct the flight path associated with airways contained within the navigation database.

Ref: RTCA/DO-236B, Para. 3.2.1.2, ARINC 424 (TF Leg Definition).

3.3.2.2 Parallel Offsets

Note: The parallel offset is defined as a route parallel to, but offset from, the original active route. The basis of the offset path is the original flight plan leg(s) and one or more offset reference points as computed by the navigation system. The computed offset reference point is located so that it lies on the intersection of lines drawn parallel to the host route at the desired offset distance and the line that bisects the track change angle (see figure below). An exception to this occurs if there is a route discontinuity (or end of route). In this case, the offset reference point is located abeam of the original flight plan waypoint at the offset distance.

(a). The offset path and associated waypoint shall be created to the same standards as the host route.
(b). WGS-84 earth reference model shall be the reference earth model for error determination and the offset reference point must have the same or better resolution than the host route waypoint.
(c). The parallel offset function shall be available for enroute TF and the geodesic portion of DF leg types at a minimum.

Note: The parallel offset function enables an aircraft to be flown on a flight path offset from the centerline of a route while maintaining all characteristics of that flight path, as if it were being flown centrally on the route. Examples for the use of offsets are weather avoidance, air traffic conflict avoidance, etc.

Ref: RTCA/DO-236B, Paragraphs 3.2.4.3, 3.2.5.1

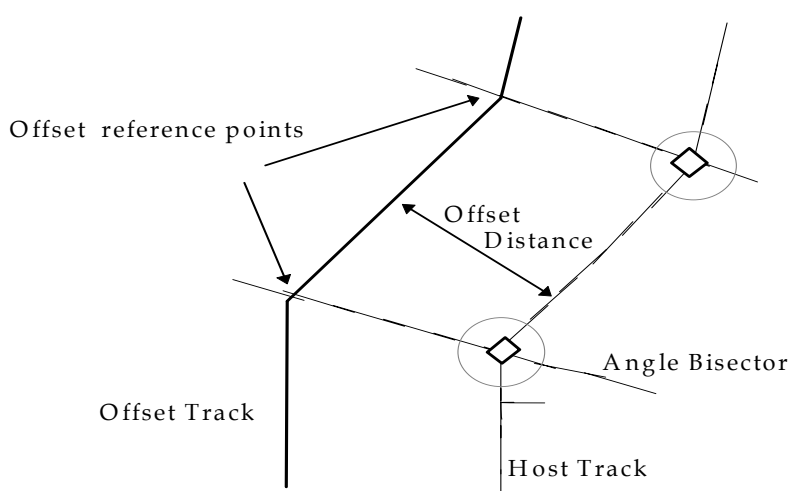


Figure 6. Offset Path Definition

3.3.3 System Features and Capabilities (Enroute Phase)

3.3.3.1 Parallel Offsets for RNP-4 RNAV or Less Airspace

The requirements of this section apply to equipment designed for use in RNP-4 RNAV or less. The following requirements also apply if RNP-12.6 RNAV or RNP-20 RNAV systems provide an offset capability:

1. The system shall have the capability to fly parallel tracks at a selected offset distance.
2. When executing a parallel offset, the RNP RNAV type and all performance requirements of the original route in the active flight plan shall be applicable to the offset route.
3. The system shall provide for entry of offset distances in increments of 1 nautical mile, left or right of course.
4. The system shall be capable of offsets of at least 20 nautical miles.
5. The fact that the system is operating in offset mode shall be clearly indicated to the flight crew.
6. The system shall provide reference parameters (e.g., cross-track deviation, distance-to-go, time-to-go) relative to the offset path and offset reference points.
7. An offset shall not be propagated through route discontinuities, unreasonable path geometries, or beyond the initial approach fix.
8. Annunciation shall be given to the flight crew prior to the end of the offset path, with sufficient time to return to the original path.
9. Once a parallel offset is activated, the offset shall remain active for all flight plan route segments until removed automatically, until the flight crew enters a Direct-To routing, or until flight crew (manual) cancellation.

Ref: RTCA/DO-236B, Para. 3.7.2.2.4

3.3.4 Enroute Alerting

(a). RNAV/LNAV, LNAV and GPS NPA capability, when integrated into an aircraft shall provide an enroute annunciator in the pilot's primary field of view.

(b). Enroute annunciators shall in addition to indicating the horizontal cross track deviation scaling factor, indicate the current integrity operating criteria of Enroute.

3.4 Terminal Requirements

3.4.1 Terminal Accuracy Requirements

Terminal Area navigational accuracy shall be RNP-1.0 RNAV. RNP-1.0 RNAV corresponds to 4.0 nm route spacing airspace. The transition to terminal shall be in accordance with the FRD para. 3.2.5.6.1.

Ref: FAA Advisory Circular 20-RNP Draft 8a, amended from RNP- 1 to RNP 1 RNAV.

3.4.2 Time to Alert

Time-to-alert for the terminal phase shall be 10 seconds or less.
Ref: RTCA/DO-229C, Para. 2.2.2.6.3

3.4.3 Path Definition Requirements

3.4.3.1 Flight Path Legs Developed from the Navigation Database

3.4.3.1.1 Navigation Database Flight Plan Legs for Terminal Area Procedures

Leg types for the definitions of the RNP RNAV flight paths for all navigation database procedures (e.g SIDs, STARs, Approaches, Missed Approaches), with the exception of airways, shall at a minimum include:

Table 7. Minimum Leg Types

Minimum Leg Types	ARINC 424 Leg Type
- Track to Fix leg	TF
- Initial Fix	IF
- Direct to Fix leg	DF
- Course to Fix leg	CF

Ref: RTCA/DO-236B, Para. 3.2.1.1, amended.

3.4.4 Terminal Alerting

(a). RNAV/LNAV, LNAV and GPS NPA capability, when integrated into an aircraft shall provide a Terminal annunciator in the pilot's primary field of view.
(b). Terminal annunciators shall in addition to indicating the horizontal cross track deviation scaling factor, indicating the current integrity operating criteria of terminal mode.

3.5 Departure Requirements

3.5.1 Departure Accuracy Requirements

Departure navigational accuracy shall initially provide a non-precision approach accuracy of RNP-0.3 RNAV and integrity.

Ref: RTCA/DO-229C, Para. 2.2.3.7.2.1, amended from RNP to RNP RNAV.

3.5.2 Mode Switching Requirements

3.5.2.1 Entry Criteria

Departure guidance may be selected manually. Once a departure procedure is activated, the equipment shall provide non-precision approach accuracy and integrity. The annunciated mode may be terminal mode (if a unique precision departure mode is not provided).

Ref: RTCA/DO-229C, Para. 2.2.3.7.2.1

3.5.2.2 Exit Criteria

The equipment shall automatically revert to normal terminal mode operation at the turn initiation point of the first waypoint in a departure procedure.

Ref: RTCA/DO-229C, Para. 2.2.3.7.2.2

3.5.2.3 Display Transition Requirements

The full-scale deflection shall change from ±0.3 nm to ±1 nm at the turn initiation point of the first waypoint in the departure procedure.

Ref: RTCA/DO-229C, Para. 2.2.3.7.2.3

3.6 Approach Requirements (See Appendix C for Optional VNAV Requirements)

3.6.1 General Approach Requirements

3.6.1.1 Single Keystroke Selection of Approach Type

The aircraft integration will allow the pilot to initiate an RNP RNAV Non-Precision Approach (NPA), by a single keystroke, once the desired approach has been selected by the aircraft specific procedures. These procedures will be dictated by equipment capabilities, but shall include the electronic transfer of the complete selected approach so that it can be initiated by a single keystroke.

3.6.1.2 Airport Identifier

The airport identifier shall be displayed during the selection of the approach procedure.

3.6.1.3 Discrete Selection of Initial Approach Fix

The approach selection procedure shall provide for discrete selection of the Initial Approach Fix in the case where there is more than one Initial Approach Fix.

Ref: RTCA DO-229C 2.2.3.2.1

3.6.1.4 Display of Procedure Name and Initial Approach Fix

The procedure name shall be displayed when selecting the IAF. The display of the procedure name and IAF should be readily available for display once selected.

3.6.1.5 RNAV/LNAV, LNAV and GPS NPA Structure

The RNAV/LNAV, LNAV and GPS NPA consist of an Initial Approach Fix (IAF), Intermediate Approach Fix (when applicable), Final Approach Fix (FAF), Intermediate Missed Approach Waypoint(s) (when applicable), Missed Approach Point (MAP), and Missed Approach Holding Point.

3.6.1.6 RNAV/LNAV, LNAV and GPS NPA Procedure

The RNAV/LNAV, LNAV and GPS NPA procedure shall be recalled from memory as a uniquely defined procedure. The order of the points in a procedure shall not be able to be changed. No waypoints shall be added or deleted in an instrument approach procedure..

Note: Modifications of the procedure once in the flight plan are permitted but not recommended. Modifications of the procedure while in the flight plan should only be accomplished under Air Traffic Control (ATC) guidance in a surveillance environment.

3.6.1.7 Waypoints and Fly Over Designation/Fly By Designation

The waypoint identifier shall not be able to be changed. The waypoint type (Type is IAF, FAF, etc.) shall not be able to be changed. The waypoint latitude and longitude shall not be able to be changed. The fly over designation/fly by designation shall not be able to be changed.

3.6.1.8 Fly-Over Points

Fly over points shall be passed over prior to initiating the turn.

3.6.1.9 Waypoint, Segment, and Display Details

(a). The associated altitude with a waypoint shall not be able to be changed.
(b). The waypoint associated turn direction shall not be able to be changed.
(c). The segment record altitude description shall not be able to be changed (at, at or above, at or below).
(d). The waypoint identifier shall be available for display.
(e). The waypoint type (i.e., IAF, FAF, etc.) shall be available for display.
(f). The waypoint fly-over designation/fly by designation shall be available for display.
(g). The waypoint-associated altitude shall be available for display.
(h). The waypoint turn direction shall be available for display.
(i). The segment record altitude description shall be available for display (at, at or above, at or below).
(j). Bearing and distance to the Missed Approach Point shall be readily available for display during procedure execution when the MAP is not the active waypoint.
(k). Final Approach Fixes shall be uniquely identified on the displays.
(l). Missed Approach Points shall be uniquely identified on the displays.

3.6.1.10 System Operations

(a). The aircraft system shall provide auto sequencing of successive waypoints from procedure initiation until encountering a designated Missed Approach Holding Point.
(b). The aircraft system shall transition to a manual sequence mode that requires aircrew input to provide navigation sequencing at the Missed Approach Holding Point.
(c). The aircraft system shall provide a Direct-To function that provides the capability to select a new active waypoint within a flight plan sequence. The system shall establish a waypoint at the aircraft's present position and operate in the To-To mode of navigation from it to the

new active waypoint. Subsequent to the point's passage, the aircraft system shall continue to auto sequence through the flight plan or transition to manual sequencing if the active waypoint is a designated Missed Approach Holding Point.

(d). The pilot is required to select and accept the approach and the IAF when vectored to an approach.

3.6.1.11 Approach Enable Alert

(a). If approach sequencing is not automatic, the aircraft system shall provide the pilot an "Approach" enable alert.

(b). The "Approach" enable alert shall be displayed when the aircraft's present position is within a 30 nautical mile radius of the flight plan labeled destination airfield, a Non-Precision Approach procedure has not yet been selected, and the aircraft flight plan does not contain any enroute waypoints yet to go beyond 30 nm of the destination airfield. The destination airfield need not be the active waypoint towards which the aircraft is flying.

(c). The Approach enable alert is not required to be displayed in the pilot's primary field of view.

(d). The Approach enable alert may be displayed as text on a Control Display Navigation Unit (CDNU) type device.

(e). The Approach enable alert shall be a pilot clearable display so as to accommodate VFR operations or instrument procedures that don't incorporate the use of GPS or the FMS. The Approach enable alert shall re-arm should the aircraft venture outside the 30 nm radius and then re-enter.

3.6.1.12 Automatic Transition Approaching the Destination Airfield or MAP

If an arrival procedure (STAR) is not included in the active flight plan, the system shall automatically transition to RNP-1 RNAV at a distance of 31 nm to the destination airfield or the MAP if an approach procedure is loaded in the flight plan. If an arrival procedure is selected in the active flight plan the system shall apply the RNP RNAV value assigned to the procedure in the database or, if an RNP RNAV value is not assigned in the database, shall apply RNP-1 RNAV to all legs of the procedure.

3.6.1.13 System Requirements Approaching the Final Approach Fix

(a). When transitioning to the approach, the system shall automatically transition to the RNP RNAV values assigned to the procedure in the database. If the database does not assign RNP RNAV values to the approach procedure, the system shall:

1. Switch to RNP-1 RNAV at the IAF if not previously achieved.
2. Maintain RNP-1 RNAV until the Final Approach Fix (FAF) is the active waypoint.
3. Automatically switch to RNP-0.3 RNAV when the FAF is the active waypoint and the along-track distance to the FAF is 2 nm.

(b). Deleted.

(c). When approaching the FAF, the transition to ±0.3 nm FSD on the CDI shall be delayed until a distance of 2.0 nm from the FAF. At that point, the system shall gradually transition from ±1.0 nm to ±0.3 nm FSD over the 2.0 nm, resulting in ±0.3 nm at the FAF.

(d). If the crew de-selects the approach procedure, RNP-1.0 RNAV shall automatically be selected.

3.6.1.14 System Requirements Approaching the Missed Approach Point

(a). The aircraft system shall remain at a horizontal cross track deviation scaling of ±0.3 nm until the Missed Approach Point.

(b). At the Missed Approach Point the aircraft system shall change from RNP - 0.3 nm RNAV to RNP - 1.0 RNAV.

3.6.1.15 System Requirements When Deselecting GPS Approach

(a). A confirmation with appropriate annunciation displayed shall be required for deselecting the approach when the aircraft is executing the approach.

(b). The default waypoint when GPS Approach mode is deselected shall be the destination airport.

3.6.1.16 Approach Alerting

(a). RNAV/LNAV, LNAV and GPS NPA capability, when integrated into an aircraft shall provide an Approach annunciator in the pilot's primary field of view.

(b). Approach annunciators shall in addition to indicating the horizontal cross track deviation scaling factor, indicate the current integrity operating criteria of Approach.

3.6.2 Detailed Requirements

(a). The navigation system shall maintain in non-volatile memory a destination airfield with associated approach information to select and perform an RNAV/LNAV, LNAV and GPS NPA.

(b). The navigation system shall maintain in non-volatile memory an alternate destination airfield with associated approach information to select and perform an RNAV/LNAV, LNAV and GPS NPA.

(c). The navigation system database shall uniquely identify which airfields have RNAV/LNAV, LNAV and GPS NPAs.

(d). The data transfer device should contain RNAV/LNAV, LNAV and GPS NPA data for at least 200 airfields.

(e). Time to alarm represents the time from the onset of a positioning failure to display of the alarm in the primary field of view.

APPENDIX A. ACRONYMS AND ABBREVIATIONS

AC	Advisory Circular
ADF	Automatic Direction Finder
AFM	Airplane Flight Manual
AIRAC	Aeronautical Information Regulation and Control
APV	Approach with Vertical Guidance
ARINC	ARINC, Inc., formerly known as Aeronautical Radio, Inc.
ATC	Air Traffic Control
ATM	Air Traffic Management
ATS	Air Traffic Services
AWOP	All Weather Operations Panel
BRNAV	Basic Area Navigation
C3I	Command, Control, Communications and Intelligence
CAPT	Captain
CDI	Course Deviation Indicator
CDR	Commander
CDNU	Control Display Navigation Unit
CDU	Control Display Unit
CF	Course To A Fix
CFR	Code of Federal Regulations
CJCS	Chairman of the Joint Chiefs of Staff
CNO	Chief of Naval Operations
CNS	Communications, Navigation, Surveillance
CNS/ATM	Communications, Navigation, Surveillance/Air Traffic Management
DAFIF	Digital Aeronautical Flight Information File
DF	Direct To A Fix
DGPS	Differential Global Positioning System
DME	Distance Measuring Equipment
DOC	Designated Operational Coverage
DOD, DoD	Department of Defense
DR	Dead Reckoning
DP	Departure Procedure
DTK	Desired Track
ECAC	European Civil Aviation Conference
(E)HSI	(Electronic) Horizontal Situation Indicator
ELS	Equivalent Level of Safety
EPU	Estimate of Position Uncertainty
ETE	Estimated Time Enroute
EUROCAE	European Organization for Civil Aviation Equipment
EUROCONTROL	European Organization for the Safety of Air Navigation
FA	Fix to an Altitude
FAA	Federal Aviation Administration
FAF	Final Approach Fix
FANS	Future Air Navigation Systems
FAR	Federal Aviation Regulation
FDE	Fault Detection and Exclusion
FL	Flight Level
FMS	Flight Management System
FPA	Flight Path Angle
FRD	Functional Requirements Document
FSD	Full Scale Deflection
FTE	Flight Technical Error
GAT	General Air Traffic
GATM	Global Air Traffic Management
GIG	GPS Integration Guidance

GPP	Geometric Point to Point
GPS	Global Positioning System
HA	Holding to an Altitude (ARINC 424 Path Terminator)
HAL	Horizontal Alert Limit
HF	Holding to a Fix (ARINC 424 Path Terminator)
HIL	Horizontal Integrity Limit
HM	Hold for Clearance (ARINC 424 Path Terminator)
HSI	Horizontal Situation Indicator
IAF	Initial Approach Fix
IAS	Indicated Airspeed
IAWP	Initial Approach Waypoint
ICAO	International Civil Aviation Organization
IF	Initial Fix
IFR	Instrument Flight Rules
IGRF	International Geomagnetic Reference Field
ILS	Instrument Landing System
IMC	Instrument Meteorological Conditions
INS	Inertial Navigation System
IPT	Integrated Product Team(s)
IRU	Inertial Reference Unit
ISA	International Standard Atmosphere
IWP	Intermediate Waypoint
JAA	Joint Aviation Authorities
JAR	Joint Aviation Requirements
JPO	Joint Program Office
KIAS	Knots Indicated Airspeed
KM	Kilometer
Kts	Knots
LNAV	Lateral Navigation
LORAN	Long Range Navigation
M	Mach
MAP	Missed Approach Point
MASPS	Minimum Aviation System Performance Standards
MCDU	Multifunction Control Display Unit
MOA	Memorandum of Agreement
MOPS	Minimum Operational Performance Standard
MSL	Mean Sea Level
MTBF	Mean Time Between Failure
NAS	National Airspace System
NATOPS	Naval Air Training and Operations Standardization
NAV	Navigation
NAVAID	Navigation Aid
NAVFIG	Naval Flight Information Group
NDB	Non-Directional Beacon
NGA	National Geospatial-Intelligence Agency
NIMA	National Imagery and Mapping Agency
nm	nautical mile
NPA	Non Precision Approach
OASD	Office of the Assistant Secretary of Defense
OAT	Operational Air Traffic
P/CG	Pilot/Controller Glossary
PDE	Path Definition Error
PEE	Position Estimation Error
PMA	Program Manager, Air
PMW	Program Manager, Warfare
PNT	Positioning, Navigation, and Timing

PPS	Precise Positioning Service
PRNAV	Precision Area Navigation
PSE	Path Steering Error
RADM	Rear Admiral
RAIM	Receiver Autonomous Integrity Monitoring
Rc	Containment Radius
RF	Constant Radius to a Fix
RGCSP	Review of the General Concept of Separation Panel
RNAV	Area Navigation
RNP	Required Navigation Performance
RNPC	Required Navigation Performance Capability
RNP RNAV	Required Navigation Performance Area Navigation
RTA	Required Time of Arrival
RTCA	RTCA, Inc. (Formerly Radio Technical Commission for Aeronautics)
RVSM	Reduced Vertical Separation Minimum
SARPS	Standards and Recommended Practices
SID	Standard Instrument Departure
SPS	Standard Positioning Service
STAR	Standard Terminal Arrival Route
STC	Supplemental Type Certificate
TACAN	TACtical Air Navigation
TAE	Track Angle Error
TAS	True Airspeed
TC	Type Certificate
TF	Track to Fix
TGL	Temporary Guidance Leaflet
TOAC	Time of Arrival Control
TOC	Top Of Climb
TOD	Top Of Descent
TSE	Total System Error
TSO	Technical Standard Order
TTA	Time To Alert
UHMI	Unalarmed Hazardously Misleading Information
USGS	United States Geological Survey
USMC	United States Marine Corps
UTC	Coordinated Universal Time (by International Agreement)
VFR	Visual Flight Rules
VHF	Very High Frequency
VNAV	Vertical Navigation
VOR	VHF (Very High Frequency) Omni-directional Range
VORTAC	VHF (Very High Frequency) Omni-directional Range/Tactical Air Navigation
WAAS	Wide Area Augmentation Systems
WG	Working Group
WGS-84	World Geodetic System 1984
XTK	Cross Track

APPENDIX B. GLOSSARY

The degree of conformance between the estimated, measured or desired position and/or the velocity of a platform at a given time and its true position or velocity. Radio navigation performance accuracy is usually presented as a statistical measure of system error and is specified as*:*

1. *Predictable.* The accuracy of a position in relation to the geographic or geodetic coordinates of the earth.
2. *Repeatable.* The accuracy with which a user can return to a position whose coordinates have been measured at a previous time with the same navigation system.
3. *Relative.* The accuracy with which a user can determine one position relative to another position regardless of any error in their true positions.

Approach (Instrument Approach Procedure [ICAO]). "A series of predetermined maneuvers by reference to flight instruments with specified protection from obstacles from the initial approach fix, or where applicable, from the beginning of a defined arrival route to a point from which a landing can be completed and thereafter, if a landing is not completed, to a position at which holding or enroute obstacle clearance criteria apply."

Area Navigation (RNAV). A method of navigation, which permits aircraft operation on any desired flight path within the specified coverage area and is defined as the portion of time during which the system is to be used for navigation during which reliable navigation information is presented to crew, autopilot, or other system managing the flight of the aircraft..

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

Containment Continuity. The probability of annunciated loss of RNP RNAV capability (for a given RNP RNAV type) shall be less than 10^{-3} per flight hour.

Containment Integrity. The probability that the total system error of each aircraft operating in RNP RNAV airspace exceeds the specified cross track containment limit without annunciation shall be less than 10^{-5} per flight hour. The cross track containment limit is twice the RNP RNAV value.

Containment Radius (Rc). A radius of a circle in the horizontal plane, centered on estimated position, such that the probability of the true position lying outside the circle without being detected is 10^{-5}/hour. This uncertainty only includes position estimation uncertainty.

Continuity. The continuity of a system is the capability of the total system (comprising all elements necessary to maintain aircraft position within the defined airspace) to perform its function without nonscheduled interruptions during the intended operation.

Cross-track containment limit. This is the distance that defines the one dimensional containment limit in the cross-track dimension. The resulting containment region is centered on the desired path and is bounded by +/- the cross-track containment limit. There is a required cross-track containment limit associated with a particular RNP RNAV type. (Reference: DO-283A, paragraph 1.9.3)

Enroute. "A phase of navigation covering operations between departure and termination phases. Enroute phase of navigation has two subcategories: enroute domestic/continental and enroute oceanic." (Reference: DO-229C, Appendix O, page O-3)

Estimate of Position Uncertainty (EPU). A measure based on a defined scale in nautical miles or kilometers which conveys the current position estimation performance.

Fix. A fix is a generic name for a geographical position. A fix is referred to as a fix, waypoint, intersection, reporting point, etc.

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.

Integrity. Integrity is a measure of the confidence factor, which can be placed in the correctness of the information supplied by the total system. Integrity includes the ability of a system to provide timely and valid warnings to the user (alerts) when the system is not reliable to be used for the intended operation (or phase of flight).

Navigation performance accuracy. The total system error (TSE) allowed in the individual lateral and longitudinal dimensions. TSE in each dimension must not exceed the specified RNP type for 95 per cent of the flight time on any portion of any single flight.

Oceanic Airspace. "Airspace over the oceans of the world, considered international airspace, where oceanic separation and procedures per the International Civil Aviation Organization are applied. Responsibility for the provisions of air traffic control service in this airspace is delegated to various countries, based generally upon geographic proximity and the availability of the required resources." Reference: Pilot/Controller Glossary (P/CG) (Addendum to FAA 7110.65 Air Traffic Control)

Parallel Offset. The parallel offset path is defined by one or more offset reference points computed by the navigation system that comprise the active flight plan. The magnitude of the offset is defined by the offset distance.

Required navigation performance (RNP). A statement of the navigation performance necessary for operation within a defined airspace. Navigation performance and requirements are defined for a particular RNP type and/or application.

RNP RNAV. The term used to describe an area navigation capability that meets all of the requirements of this document.

Terminal Area. "A general term used to describe airspace in which approach control service or airport traffic control service is provided." (DO-229C Appendix O, page O-8)

Total System Error. In the lateral dimension, a combination of navigation system error, RNAV computation error, display system error and FTE. In the longitudinal dimension, a combination of navigation system error, RNAV computation error, and display system error.

APPENDIX C: VNAV REQUIREMENTS

1.0 References

(a). RTCA/DO-236B, Minimum Aviation System Performance Standards (MASPS): Required Navigation Performance for Area Navigation (RNP RNAV), 28 October 2003

1.1 Track to Fix (TF)

Where required by procedure, altitude, speed constraint and vertical angle will be provided in the navigation database.

Ref: RTCA/DO-236B, Para. 3.2.3.2

1.2 Direct to Fix (DF)

The navigation system shall construct a path to facilitate guidance from current position to a vertically constrained fix.

Ref: RTCA/DO-236B, Para. 3.7.2.2.1.2

1.3 Radius to Fix (RF), If Implemented

Where required by procedure, altitude, speed constraint, and vertical angle will be provided in the navigation database.

Note 1: The navigation system may implement the navigation database vertical angle assuming that there is no difference in atmospheric conditions between the starting and ending fixes and altitudes.
Note 2: RF leg types are optional.

Ref: RTCA/DO-236B, Para. 3.2.3.3, amended.

1.4 System Calculated Altitude Data

All system calculated altitude data shall be referenced to the MSL geoid and standard atmospheric pressure model**.**

Ref: RTCA/DO-236B, Para. 3.2.5.1

1.5 Hold to Altitude (HA)

(a). The system shall support Hold to Altitude (HA) leg types.
(b). An HA leg is a holding pattern which must be constructed to meet the requirements defined in Section 3.2.4.1 of RTCA/DO-236B.
(c). An HA leg terminates at the next crossing of the hold fix when the aircraft altitude is at or above the specified altitude.
(d). The altitude is provided by the navigation database.
(e). The source of the magnetic variation needed to convert magnetic courses to true courses is detailed in Section1 3.2.5.4.2 of the FRD for RNP RNAV (Main Section).

Ref: RTCA/DO-236B, Para. 3.2.3.4, 3.2.5.2

1.6 Fix to Altitude (FA)

a. The system shall support Fix to Altitude (FA) leg types.
b. An FA leg is defined by a geodesic path that starts at a fix, with a specified track at the fix, and terminates at a point where the aircraft altitude is at or above a specified altitude.
c. The outbound course from the fix, the fix, and the terminating altitude is provided by the navigation database.
d. The source of the magnetic variation needed to convert magnetic courses to true courses is detailed in Section 3.2.5.4.3 of the FRD for RNP RNAV.
e. Where required by procedure, a speed constraint will be provided in the navigation database.

Note: It must be recognized that an FA leg can be tightly contained only in the cross-track dimension. It is highly variable in the along-track dimension due to the unknown termination point of the FA leg and the resulting following leg in the procedure (typically a DF leg). The FA Leg is intended to be used as the initial segment for specific departure procedures to facilitate more direct courses out of the terminal area for aircraft with a high climb rate.

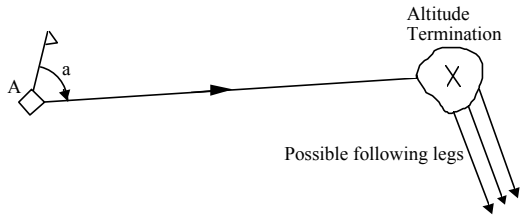


Figure 7. Fix to an Altitude (FA) Leg

Ref: RTCA/DO-236B, Para. 3.2.3.7.

1.7 Course To A Fix (CF)

Where required by procedure, altitude, speed constraint, and vertical angle may be provided in the navigation database.

Ref: RTCA/DO-236B, Paragraphs 3.7.2.2.2, 3.2.3.9

1.8 Altitude/Height Resolution

Systems computing altitude or height for VNAV operations must account for resolution of the data in its vertical path definition error.

Ref: RTCA/DO-236B, Para. 3.2.5.3.5

1.9 Vertical Path Definition

The following sections apply to RNP RNAV systems that incorporate a VNAV capability.

Ref: RTCA/DO-236B, Para. 3.2.8

1.10 Altitude Restrictions

(a). A VNAV system shall support the altitude restrictions "AT", "AT or ABOVE", "AT or BELOW", and "AT or ABOVE and AT or BELOW" (window) during all phases of flight. These altitude restrictions must be available from the Navigation Data Base and via pilot entry into the system.

(b). The navigation system shall support both mean sea level (MSL) and flight level (FL) altitude formats.

Ref: RTCA/DO-236B, Para. 3.2.8.1

1.11 Speed Restrictions

A VNAV system shall support speed restrictions at either an altitude or a waypoint. These speed restrictions may be available from the Navigation Database or may be as required for airspace operations.

Note: For restrictions at a waypoint in departure, the airspeed is expected to remain at or below the restriction prior to sequencing the waypoint from the flight plan. For restrictions at a waypoint in the arrival/approach, the airspeed is expected to remain at or below the restriction after sequencing the waypoint from the flight plan. For restrictions at an altitude, the airspeed is expected to remain at or below the restriction as along as the aircraft altitude is below the speed restriction altitude.

Ref: RTCA/DO-236B, Para. 3.2.8.2

1.12 Descent and Approach

(a). An RNP RNAV system incorporating VNAV shall determine a descent/approach path utilizing the vertical and longitudinal elements associated with the defined lateral flight plan.

Note: A vertical element in conjunction with an associated Latitude/Longitude locations, forms a three dimensional point in space. A descent/approach path "connects" a series of three-dimensional points in space to form a path from "Top of Descent" to "End of Descent".

(b). VNAV paths shall consist of one or more vertical flight plan elements used in defining the intended path over the earth.

(c). The navigation system shall support the following path and constraint definition for establishing the defined vertical path for VNAV:

1. "Geometric" Point to Point Paths
    a. "AT" to an "AT" constraint
    b. System defined altitude to system defined altitude
2. Flight Path Angle Paths
    a. Procedure defined
    b. Pilot defined
3. "Geometric" Point to Point Path Boundaries
    a. "AT" constraint to "WINDOW" constraint (Wedge)

b. “WINDOW” constraint to “WINDOW” constraint (Tube)
c. “WINDOW” constraint to “AT” constraint (Wedge)

Ref: RTCA/DO-236B, Para. 3.2.8.4

1.13 Descent Path Construction

The following general requirements apply to the descent path:

1. The constructed descent path shall pass through AT altitude constraints.
2. The constructed descent path is not required to pass through “AT or ABOVE” or “AT or BELOW” altitude constraints at the “AT” altitude, but the path shall satisfy the restriction.
3. The constructed descent path is required to pass between the “AT or ABOVE” and “AT or BELOW” portions of the “WINDOW”. The path shall also stay between the space described by connecting geometrically (constant barometric gradient) the “AT or ABOVE” portions of “WINDOW” and “AT” constraints, followed by connecting geometrically the “AT or BELOW” portions of “WINDOW” and “AT” constraints.
4. The termination Latitude/Longitude associated with a fly-by waypoint shall be related to the bisector.
5. The defined path shall be referenced to Mean Sea Level altitudes.

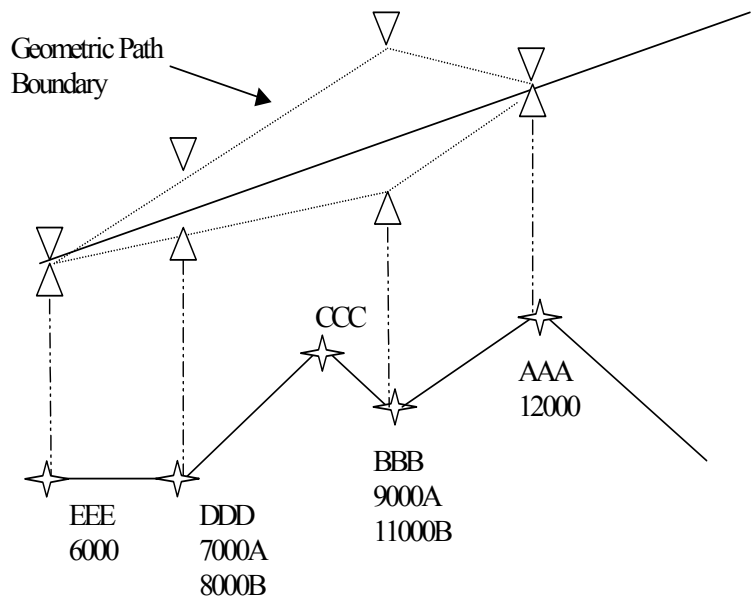


Figure 8. Descent Path

Descent Path Permitted by Two “WINDOW” Constraints, Two “AT” Constraints and Cruise Altitude

Note: The path described above that is defined with “WINDOW” constraints, may include a “Geometric” Point to Point path, a Curvilinear “Optimum” path or a path to accommodate decelerations.

Ref: RTCA/DO-236B, Para. 3.2.8.4.1

1.14 Geometric Point to Point (GPP) Paths

(a). A GPP path shall be defined by a constant barometric altitude gradient between two three dimensional Latitude/Longitude/Barometric Altitude end-points.
(b). The gradient shall be calculated based upon the distance between the two end points and the altitude difference.
(c). The following requirements and considerations apply to GPP paths:

1. GPP paths may incorporate more than one lateral leg in defining the vertical leg. The distance between the lateral legs, as utilized to determine gradient, shall be along track distance.

2. A GPP path shall support all altitude constraint types listed previously.

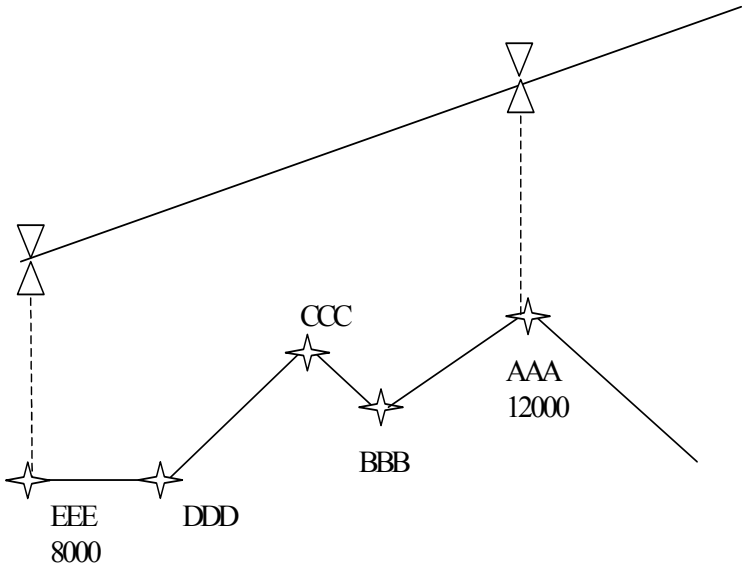


Figure 9. Geometric Point to Point Path

Descent Path defined by AT constraints and a Cruise Altitude

Ref: RTCA/DO-236B, Para. 3.2.8.4.2

1.15 Flight Path Angle Paths

To qualify for VNAV use in RNP RNAV airspace, both the fix and the flight path angle must be defined in the navigation database as part of the intended procedure.
If a Flight Path Angle (FPA) vertical path intersects the altitude of a preceding three-dimensional (AT or AT/ABOVE) fix after the constrained fix, the system shall compute a level segment until intercepting the FPA path.

Ref: RTCA/DO-236B, Para. 3.2.8.4.3

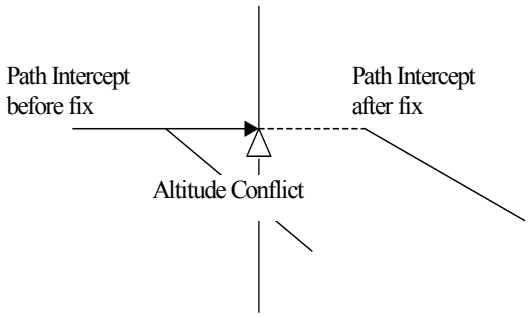


Figure 10. Waypoint with Vertical Constraint

1.16 VNAV Path Transitions

(a). When transitioning between regions with differing limits, the systems shall ensure the selected Vertical Path Performance Limit meets or is more restrictive than the limits defined in Section 2.1 of RTCA/DO-236B.

(b). When a lateral and vertical transition occurs at the same fix, the system shall apply the vertical constraint at the lateral bisector.

(c). Where vertical transitions occur, the aircraft altitude relative to the desired path shall be as follows.

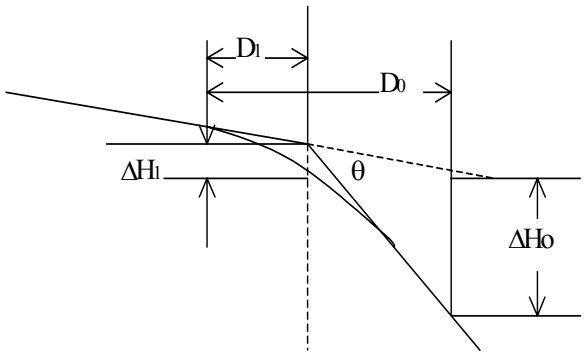


Figure 11. Fly-by Transition

Where:

D1: Distance from start of transition to passage of waypoint.
D0: Distance from start of transition to end of transition.
ΔH1: Altitude below initial vertical path at passage of waypoint.
ΔH0: Altitude below initial vertical path at end of transition.

Ref: RTCA/DO-236B, Para. 3.2.8.5

1.16.1 VNAV Temperature Compensation

Temperature compensation shall be accomplished in accordance with RTCA DO-236B.

Ref: RTCA DO-236B, paragraphs 3.2.8.6, 3.7.2.2.5, and Appendix H, amended.

1.16.2 Path Steering Error Budget for Vertical Performance Requirements
(Formerly 1.15.1)

For the vertical performance requirements, the path steering error budget must reflect altitude reference as well as other factors such as roll compensation and speed protection, as applicable.

Ref: RTCA/DO-236B, Para. 3.3.2

1.16.3 VNAV Flight Progress
(Formerly 1.15.2)

(a). The equipment shall depict deviation from the desired vertical path.
(b). The equipment shall provide a numeric display of vertical path steering error.
(c). The vertical path steering error shall be displayed with a resolution of not less than 10 feet.

Note: System defined vertical flight profiles may include fixes for which an altitude constraint or vertical angle have not been specified. For these fixes, it is desired that the system will provide the capability to estimate the aircraft crossing altitude.

(d). A transition to/from level flight shall be indicated to the flight crew.
(e). The system shall provide the capability to respond to flight crew commands for a vertical maneuver.

Note: It is intended that a system capable of performing a vertical transition provide an indication of the impending maneuver along with a requirement for timely flight crew acknowledgement of the maneuver prior to conducting it. Flight crew use of a separate altitude pre-selector for both altitude selection and subsequent acknowledgement is one method that has been used.

(f). The non-numeric vertical deviation information shall use full-scale deflection suitable for the RNP RNAV environment. Reference should be made to Table 2-1 of RTCA/DO-236B when determining the scaling sensitivity.
(g). The non-numeric vertical deviation value shall be know or available for display to the flight crew.
(h). Non-numeric vertical deviation information shall be displayed in the pilot's primary field of view, during all phases of flight operation where there is a defined path.
(i). All displays of vertical deviation information shall be clear and unambiguous.
(j). The location of numerical vertical deviation information shall be consistent with its intended function during vertical navigation operations.

Ref: RTCA/DO-236B, Para. 3.7.5.1.2

1.17 Navigation Modes and Performance

(a). The equipment shall provide basic climb, cruise and descent modes.

(b). The system shall compute and display a top-of-descent (TOD).
(c). The system may also compute top-of-climb (TOC).
(d). The VNAV guidance provided by the system shall be valid for all groundspeeds up to a maximum value to be set by the equipment designer and for all ascent and descent rates up to a maximum value determined by the equipment designer.
(e). Where a system provides for vertical navigation, the system shall include the display of appropriate navigation data.
(f). If there is a specified navigation database approach procedure with a flight path angle associated with any flight plan leg, the equipment shall display the flight path angle for that leg.

Ref: RTCA/DO-236B, (a)-(d) Para. 3.7.5.3, (e) Para. 3.7.5.2, (f) Para. 3.7.5.2.2

1.18 VNAV Flight Planning

(a). The system shall provide a means for the flight crew to confirm the correctness of input data prior to the utilization of the new data by the system.
(b). It shall be possible to define a vertical path by specifying altitude constraints at two fixes in the flight plan. Fix altitude constraints shall be defined as one of the following:
   1. An "AT or ABOVE" altitude constraint, e.g. 2400A
   2. An "AT or BELOW" altitude constraint, e.g. 4800B
   3. An "AT" altitude constraint, e.g. 5200
   4. An "WINDOW" constraint, e.g. 2400A3400B

Note: Constraint types (1) and (2) above may be appropriate for situations where bounding the vertical path is not required. However, these types of constraints are not characteristic of a VNAV path.

(c). It shall be possible to define a vertical path to an along-track fix.
(d). The system shall allow flight crew inputs of altitude and speed associated with a fix in accordance with the table listed in the Display and Controls section (Table 3-4 of RTCA/DO-236B).
(e). Altitudes and/or speeds associated with published terminal procedures (SIDs/DPs, STARs, and approaches) shall be extracted from the navigation database.
(f). Systems that specify flight path angles shall be able to define a vertical path by specifying a fix and a selected Flight Path Angle (FPA) from that fix.
(g). Flight crew input of angles shall be in accordance with the table listed in the Display and Controls section (Table 3-4 of RTCA/DO-236B).
(h). The system shall also provide sufficient information e.g. FPA, vertical speed, etc, for the pilot to determine the flyability of the planned vertical path.

Ref: RTCA/DO-236B, Para. 3.7.2.1.1

1.19 VNAV Alerts

(a). The equipment shall provide a visual indication of impending vertical fix crossing.
(b). Alert of vertical turns to and from level flight level flight shall be provided approximately 1 minute, but not later than 30 seconds prior to the required vertical path change.
(c). Top of descent shall be indicated with vertical turn anticipation cues.
(d). When the pre-set altitude has not been set to a lower altitude, the pilot shall be prompted to re-set the target altitude to accommodate the desired descent profile.
(e). The system shall provide an alert to the flight crew when it is not possible, from a performance standpoint, to fly the defined vertical profile.

Ref: RTCA/DO-236B, Para. 3.7.6

1.20 Terminal Requirements

1.20.1 Navigational Database Flight Plan Legs for Terminal Area Procedures

The minimum leg types for the definitions of the RNP RNAV flight paths for all navigation database procedures (e.g SIDs, STARS, Approaches, Missed Approaches), are as follows:

Minimum Leg Types	ARINC 424 Leg Type
- Track to Fix leg	TF
- Initial Fix	IF
- Fix to Altitude leg	FA
- Direct to Fix leg	DF
- Course to Fix leg	CF

Ref: RTCA/DO-236B, Para. 3.2.1.1, amended.

APPENDIX D: BRNAV REQUIREMENTS

1.0 References

(a). FAA AC 90-96, Approval of U.S. Operators and Aircraft to Operate Under Instrument Flight Rules (IFR) in European Airspace Designated for Basic Area Navigation (BRNAV/RNP-5), 20 March 1998

1.1 Purpose of this Appendix

This Appendix addresses BRNAV requirements for aircraft that are unable to meet the requirements contained in the body of this FRD for RNP RNAV but for which BRNAV capability (European Enroute capability) is sought. Systems that meet the requirements of RNP-5 or better in accordance with the body of the FRD (i.e., the FRD without appendices) are BRNAV capable and do not need to address the requirements of this Appendix.

1.2 Flight Plans into European Airspace

U.S. registered aircraft filing flight plans into European BRNAV designated airspace are expected to meet the European BRNAV airspace requirements.

Ref: AC 90-96, Para. 10

1.3 Aircraft Equipage

(a). An aircraft may be considered eligible for BRNAV approval if it is equipped with one or more RNAV systems approved and installed in accordance with the guidance contained in this Appendix.

(b). The minimum level of availability and integrity required for BRNAV systems for use in designated European airspace can be met by a single installed system comprising one or more sensors, RNAV computer, control display unit, and navigation display(s) (e.g., HSI, or CDI), provided that the system is monitored by the flight crew and that in the event of a system failure, the aircraft retains the capability to navigate relative to ground based navigation aids (e.g., VOR, DME, TACAN and NDB).

(c). Aircraft not suitable equipped will not be permitted to operate in the designated BRNAV airspace.

Ref: AC 90-96, para. 7.a

1.4 Minimum Required System Functions

The following system functions are the minimum required to conduct BRNAV/RNP-5 operations:

1. Continuous indication of aircraft position relative to track to be displayed to the pilot flying on a navigation display situated in his primary field of view;
   Note: In addition, where the aircraft type certificate requires more than one pilot, information to verify aircraft position must be displayed in the non-flying pilot's primary field of view.

2. Display of distance and bearing to the active (To) waypoint;
3. Display of ground speed or time to the active (To) waypoint;
4. Storage of waypoints; minimum of 4; and
5. Appropriate failure indication of the RNAV system, including the sensors.

Ref: AC 90-96, Appendix 2

1.5 Limitations on the Design and/or Use of Navigation Systems

Although the following navigation systems have RNAV capability, limitations are required for their use when conducting operations in designated RNAV airspace.

Ref : AC 90-96, Para. 7.d

1.5.1 Inertial Navigation Systems (INS) Limitations

(a). Approved INS system installations that meet the requirements of paragraph 1.4 but either do not have automatic radio navigation updating, are not coupled with RAIM compliant GPS, or do not use supplemental RAIM compliant GPS, are limited to a maximum 2-hour time limit for operation in designated BRNAV airspace from the time that the system is placed in the navigation mode (NAV SELECT).

(b). CNO or his designated representative will give consideration to extending the 2-hour time limit for specific INS configurations.

Note: Certain INS's perform automatic radio navigation aid updating after the pilot makes a manual selection of navigation aids. Such systems are not limited to the 2-hour time limit previously discussed provided that the squadron has established procedures for pilots to follow.

Ref : AC 90-96,Para. 7.d.1

1.5.2 GPS

1.5.2.1 GPS Implementation

(a). GPS installed shall provide pseudorange step detection and health word checking functions or the requirements of subparagraph (b). below.

(b). GPS equipment which does not satisfy the step detection and health word checking may be utilized but are limited to BRNAV operations where Receiver Autonomous Integrity Monitoring (RAIM) outages do not exceed 5 minutes.

(c). The maximum RAIM outage shall not be extended beyond 5 minutes.

Ref: AC 90-96, Para. 7.d.3 --(a), TSO C-129a. (Wording is revised.)

1.5.2.2 Flight Planning Restrictions for GPS

(a). During pre-flight planning, if 24 satellites (23 if barometric aiding is incorporated into the GPS installation) are projected to be operational for the flight, then the aircraft can depart without further action. (Note: This is only an operational requirement.)

(b). If 23 or fewer satellites (22 if barometric aiding incorporated), are to projected to be operational, then the availability of GPS integrity (RAIM) should be confirmed for the

intended flight (route and time). (Note: This is only an operational requirement.)

Ref: AC 90-96, Para. 7.d.3 --(b)

1.5.3 GPS INTEGRITY MONITORING (RAIM) PREDICTION PROGRAM

Where a GPS Integrity Monitoring (RAIM) Prediction Program is used as a means of compliance with Appendix D Para. 1.5.2.2 (Flight Planning Restrictions for GPS) it should meet the following criteria:

1. The program should provide prediction of availability of the integrity monitoring (RAIM) function of the GPS equipment, suitable for conducting RNP-5 (BRNAV) operations in designated European airspace.
2. The program should use either a RAIM algorithm identical to that used in the airborne equipment, or an algorithm based on assumptions for RAIM prediction that give a more conservative result.
3. The program should calculate RAIM availability based on a satellite mask angle of not less than 5 degrees.
4. The program should have the capability to manually designate GPS satellites that have been notified as being out-of-service for the intended flight.
5. The program should allow the user to select:
   a. The intended route and declared alternates;
   b. The time and duration of the intended flight.

Ref: AC 90-96, APPENDIX 1

1.5.4 Availability of VOR, DME, TACAN or ADF

VOR, DME, TACAN or ADF capability should be installed and operative consistent with the applicable operating rules and intended route-of-flight to ensure availability of a suitable alternative means of navigation in the event of GPS/RNAV system failure.

Ref: AC 90-96, Para. 7.d.3--(e)

APPENDIX E: PRNAV REQUIREMENTS

1.1 References

(a). JAA Temporary Guidance Leaflet (TGL) No. 10, *Airworthiness and Operational Approval for Precision RNAV Operations in Designated European Airspace*, 1 November 2000
(b). RTCA/DO-236B, Minimum Aviation System Performance Standards (MASPS): Required Navigation Performance for Area Navigation (RNP RNAV), 28 October 2003

1.2 Accuracy

(a). During operations on routes or in areas notified exclusively for PRNAV equipped aircraft, the lateral track keeping accuracy shall be equal to or better than ± 1 nm for 95% of the flight time (RNP-1).
(b). This value shall include signal source error, airborne receiver error, display system error, and flight technical error. This navigation performance assumes the necessary coverage provided by satellite or ground based navigation aids is available for the intended route to be flown.

Ref: (a). JAA TGL-10, Para. 6.1, (b). AC 90-96A (draft)

1.3 Visibility of Display Elements

Display elements, e.g. CDI, (E)HSI, shall be instrumented with a lateral deviation display, To/From flag and failure indicator, for use as primary flight instruments for navigation of the aircraft, for maneuver anticipation, and for failure/status/integrity indication, visible to the pilot and located in the primary field of view when looking forward along the flight path.

Ref: JAA TGL-10, Para. 7.1, Item 1

1.4 Course Selector of the Deviation Display

The course selector of the deviation display shall be automatically slaved to the RNAV computed path.

Ref: JAA TGL-10, Para. 7.1, Item 1

1.5 Deviation Display Deflection and Scaling

The deviation display shall have a full-scale deflection suitable for the phase of flight and based on the required track keeping accuracy. Scaling may be set automatically by default logic or to a value obtained from a navigation database.

Ref: JAA TGL-10, Para. 7.1, Item 1

1.6 Full Scale Deflection Value

For PRNAV operations, a value of ±1 nm shall be acceptable.

Ref: JAA TGL-10, Para. 7.1, Item 1

1.7 Display requirements to the Pilot Not Flying the Aircraft

The RNAV computed Desired Track (DTK) and aircraft position relative to the path shall be capable of being continuously displayed to the pilot not flying, on the primary flight instruments for navigation of the aircraft.

Ref: JAA TGL-10, Para. 7.1, Item 2

1.8 Pilot Verification by Pilot Not Flying the Aircraft

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

Ref: JAA TGL-10, Para. 7.1, Item 3

1.9 Navigation Database

(a). The navigation database shall contain current official NGS promulgated navigation data from which terminal airspace procedures can be retrieved and loaded into the RNAV system.
(b). The resolution to which the data is stored shall be sufficient to achieve the required track keeping accuracy.
(c). The database shall be protected against flight crew modification of the stored data.

Note: When a procedure is loaded from the database, the RNAV system is required to fly it as published. This does not preclude the flight crew from having the means to modify a procedure or route already loaded into the RNAV system as permitted by JAA TGL-10, Section 10. However, the procedure stored in the database must not be modified and must remain intact within the database for future use and reference.

Ref: JAA TGL-10, Para. 7.1, Item 4, amended.

1.9.1 Display of Validity Period of Database

The means to display the validity period of the navigation database shall be available to the flight crew.

Ref: JAA TGL-10, Para. 7.1, Item 5

1.9.2 Means of Verify Procedure to Be Flown

The system shall provide the means to retrieve and display data stored in the navigation database relating to individual waypoints and navigation aids to enable the verification of the procedure to be flown.

Ref: JAA TGL-10, Para. 7.1, Item 6

1.9.3 Capacity to Load Whole Terminal Procedure

The system shall have sufficient capacity to load the entire terminal procedure(s) to be flown from the database into the RNAV system.
Ref: JAA TGL-10, Para. 7.1, Item 7

1.9.4 Display of Active Navigation Sensor Type

The system shall have the capability to display the active navigation sensor type, either in the pilot's primary field of view, or on a readily accessible page on a CDNU type display as well as a means of determining navigation system performance.

Ref: JAA TGL-10, Para. 7.1, Item 8

1.9.5 Display of The Identification Of The Active Waypoint

The system shall have the capability to display the identification of the active waypoint, either in the pilot's primary field of view, or on a readily accessible page on a CDNU type display, readily visible to the flight crew.

Ref: JAA TGL-10, Para. 7.1, Item 9

1.9.6 Display of Distance And Bearing To The Active Waypoint

The system shall have the capability to display distance and bearing to the active waypoint in the pilot's primary field of view. Where impracticable, the data may be displayed on a readily accessible page on a CDNU type display, provided that it is readily visible to the flight crew.

Ref: JAA TGL-10, Para. 7.1, Item 10

1.9.7 Display of Ground Speed Or Time To The Active Waypoint

The system shall have the capability to display ground speed or time to the active waypoint, either in the pilot's primary field of view, or on a readily accessible page on a CDNU type display, readily visible to the flight crew.

Ref: JAA TGL-10, Para. 7.1, Item 11

1.9.8 Resolution of Lateral Deviation

The system shall have the capability to display lateral deviation with a resolution of 0.1 nm.

Ref: JAA TGL-10, Para. 7.1, Item 12

1.9.9 Tuning of VOR & DME Navigation Aids & Inhibiting Individual Navigation Aids

The system shall provide automatic tuning of VOR and DME/TACAN navigation aids used for position updating together with the capability to inhibit individual navigation aids from the automatic selection process.

Ref: JAA TGL-10, Para. 7.1, Item 13.

Note: Further guidance may be found in RTCA DO-236B, section 3.7.3.1.

1.9.10 Nav Source Selection, Reasonableness/Integrity Checks, & Manual Capability

The system shall have the capability to perform automatic selection (or de-selection) of navigation sources, a reasonableness check, an integrity check, and a manual override or deselect.

Ref: JAA TGL-10, Para. 7.1, Item 14.

Note: Further guidance may be found in ED-75A/DO-236B, section 3.7.3.1.

1.9.11 "Direct To" Function.

The system shall have the capability for the "Direct To" function.

Ref: JAA TGL-10, Para. 7.1, Item 15

1.9.12 Automatic Leg Sequencing

The system shall have the capability for automatic leg sequencing with display of sequencing to the flight crew.

Ref: JAA TGL-10, Para. 7.1, Item 16

1.9.13 Capability For Database Procedures

The system shall have the capability to execute database procedures including fly-over and fly-by turns.

Ref: JAA TGL-10, Para. 7.1, Item 17

1.9.14 Leg Transitions And Tracks

The system shall have the capability to execute leg transitions and maintain tracks consistent with the following path terminators, or their equivalent:

1. Initial Fix (IF)
2. Track between Two Fixes (TF)
3. Course to a Fix (CF)
4. Direct to a Fix (DF)

Ref: JAA TGL-10, Para. 7.1, Item 18. Path terminators are defined in ARINC 424.

1.9.15 Manual Intervention

The execution of all leg types (in particular when intercepting a CF leg) shall be shown to be possible without the need for manual intervention, i.e., without disengaging the RNAV mode, and then a manual course selection. This does not preclude means for manual intervention when needed.

Ref: JAA TGL-10, Para. 8.1.1(f)

1.9.16 RNAV System Failure Indication

The system shall provide the capability to display RNAV system failure, (including the associated sensor(s) failure), in the pilot's primary field of view.

Ref: JAA TGL-10, Para. 7.1, Item 19

1.9.17 Reversion To An Alternative RNAV Sensor

For multi-sensor systems, the system shall be capable of automatic reversion to an alternative RNAV sensor if the primary RNAV sensor fails.

Note: This does not preclude providing a means for manual navigation source selection.
Ref: JAA TGL-10, Para. 7.1, Item 20

1.9.18 PRNAV Equipment Requirements

The use of GPS to perform PRNAV operations shall be limited to equipment approved by CNO. Receiver Autonomous Integrity Monitoring (RAIM), or an equivalent means of integrity monitoring as part of a multi-sensor navigation system, shall be provided.

Ref: JAA TGL-10, Para. 8.3.1

1.9.19 Satellite Fault Detection And Exclusion (FDE)

To improve Continuity of Function, GPS with the capability for satellite Fault Detection and Exclusion (FDE) shall be required. *Ref: JAA TGL-10, Para. 8.3.3*

1.9.20 Manual Creation of New Waypoints Prohibited

The creation of new waypoints by manual entry during departure operations into the RNAV system by the flight crew shall not be permitted, as it would invalidate the affected PRNAV procedure. However, since route modifications in the terminal area may take the form of radar headings or 'direct-to' clearances and the flight crew must be capable of reacting in a timely fashion, the system shall have the capability to insert waypoints loaded from the database into the flight plan.

Note: This is an operational requirement not an equipment requirement.
Ref: JAA TGL-10, Para. 10.2.2.2

1.9.21 Route Modifications In The Terminal Area

Since route modifications in the terminal area may take the form of radar headings or 'direct to' clearances and the flight crew must be capable of reacting in a timely fashion, the system shall provide the capability to insert tactical waypoints loaded from the database. However, manual entry or modification by the flight crew of the loaded procedure, using temporary waypoints or fixes not provided in the database, shall not be permitted.

Note: This is an operational requirement not an equipment requirement. Ref: JAA TGL-10, Para. 10.2.3.6