

RTCA, Inc.  
1150 18th Street, NW, Suite 910  
Washington D.C. 20036

**Minimum Aviation System Performance  
Standards:  
Required Navigation Performance for  
Area Navigation**

RTCA DO-236D  
Supersedes DO-236C & Change 1 to DO-236C  
June 23, 2022

Prepared by SC-227  
©2022, RTCA, Inc.

Copies of this document may be obtained from  
RTCA, Inc.  
Telephone: 202-833-9339  
Facsimile: 202-833-9434  
Internet: [www.rtca.org](http://www.rtca.org)

Please visit the RTCA Online Store for document pricing and ordering information.

## FOREWORD

This report was prepared by RTCA Special Committee 227 (SC-227) and EUROCAE Working Group 85(WG-85) and approved by the RTCA Program Management Committee (PMC) on June 23, 2022 and as ED-75E by the council on June 23, 2022.

RTCA, Incorporated is a not-for-profit corporation formed to advance the art and science of aviation and aviation electronic systems for the benefit of the public. The organization functions as a Standards Development Organization and develops consensus based recommendations on contemporary aviation issues. RTCA's objectives include, but are not limited to:

- coalescing aviation system user and provider technical requirements in a manner that helps government and industry meet their mutual objectives and responsibilities;
- analyzing and recommending solutions to the system technical issues that aviation faces as it continues to pursue increased safety, system capacity, and efficiency;
- developing consensus on the application of pertinent technology to fulfill user and provider requirements, including development of minimum operational performance standards for electronic systems and equipment that support aviation; and
- assisting in developing the appropriate technical material upon which positions for the International Civil Aviation Organization and the International Telecommunication Union and other appropriate international organizations can be based.

The organization's recommendations are often used as the basis for government and private sector decisions as well as the foundation for many Federal Aviation Administration Technical Standard Orders.

Since RTCA is not an official agency of the United States Government, its recommendations may not be regarded as statements of official government policy unless so enunciated by the U.S. government organization or agency having statutory jurisdiction over any matters to which the recommendations relate.

### Disclaimer

This publication is based on material submitted by various participants during the SC approval process. Neither the SC nor RTCA has made any determination whether these materials could be subject to valid claims of patent, copyright or other proprietary rights by third parties, and no representation or warranty, expressed or implied is made in this regard. Any use of or reliance on this document constitutes an acceptance thereof "as is" and is subject to this disclaimer.

This Page Intentionally Left Blank

## TABLE OF CONTENTS

<b>1</b>	<b>PURPOSE AND SCOPE</b> .....	<b>1</b>
<b>1.1</b>	<b>Introduction</b> .....	<b>1</b>
<b>1.2</b>	<b>System Overview</b> .....	<b>2</b>
1.2.1	Position Estimation .....	2
1.2.2	Path Definition .....	3
1.2.3	Path Steering .....	4
1.2.4	User Interface .....	5
1.2.5	Navigation System Controls and Features .....	5
<b>1.3</b>	<b>Operational Goals and Applications</b> .....	<b>5</b>
1.3.1	Path Definition .....	5
1.3.2	Containment Methodology.....	5
1.3.3	Contribution to Increased Capacity .....	6
1.3.4	User-Preferred Trajectories and Trajectory Based Operations.....	6
1.3.5	Future Concepts of Use and Operations.....	6
<b>1.4</b>	<b>Required Navigation Performance (RNP)</b> .....	<b>7</b>
1.4.1	Area Navigation .....	7
1.4.2	PBN and RNP Concept .....	7
1.4.3	Application of the Term RNP .....	7
1.4.4	Navigation Accuracy.....	8
1.4.5	Vertical Navigation (VNAV) .....	8
1.4.6	Advanced RNP.....	8
<b>1.5</b>	<b>Assumptions</b> .....	<b>9</b>
1.5.1	Navigation Infrastructure .....	10
1.5.2	Defining Airspace .....	10
1.5.3	Navigation Error.....	11
1.5.4	Navigation Data.....	11
1.5.5	Reference Earth Model.....	11
1.5.6	Desired Path .....	12
1.5.7	Transitions Between Legs .....	13
1.5.8	Datalink Considerations .....	13
1.5.9	Flight Plan Updates .....	14
1.5.10	Polar Navigation .....	14
1.5.11	Dispatch Assessment .....	14
<b>1.6</b>	<b>Verification Procedures</b> .....	<b>14</b>
<b>1.7</b>	<b>Definitions</b> .....	<b>15</b>
1.7.1	Required Navigation Performance .....	15
1.7.2	Error Terms.....	15
1.7.3	Lateral Containment Concept.....	20
1.7.4	Vertical Performance .....	23

<b>2</b>	<b>SYSTEM PERFORMANCE REQUIREMENTS</b>	<b>25</b>
<b>2.1</b>	<b>Accuracy</b>	<b>25</b>
2.1.1	RNP	25
2.1.2	VNAV	25
<b>2.2</b>	<b>Containment Integrity</b>	<b>27</b>
2.2.1	RNP RNAV	27
2.2.2	VNAV	28
<b>2.3</b>	<b>Containment Continuity</b>	<b>28</b>
2.3.1	RNP RNAV	28
2.3.2	VNAV	28
<b>2.4</b>	<b>Estimated Time of Arrival</b>	<b>29</b>
<b>2.5</b>	<b>Time of Arrival Control</b>	<b>29</b>
2.5.1	Accuracy	29
2.5.2	Integrity	30
2.5.3	Continuity	30
<b>2.6</b>	<b>Lateral Control Performance</b>	<b>30</b>
<b>2.7</b>	<b>Speed Control Performance</b>	<b>31</b>
<b>3</b>	<b>FUNCTIONAL REQUIREMENTS</b>	<b>33</b>
<b>3.1</b>	<b>Position Estimation Requirements</b>	<b>33</b>
3.1.1	Estimate of Position	33
3.1.2	Estimate of Position Uncertainty (EPU)	33
3.1.3	Containment Radius	34
3.1.4	Position Estimation Effects on System Compliance	34
<b>3.2</b>	<b>Path Definition Requirements</b>	<b>35</b>
3.2.1	Flight Path Legs Developed from the Navigation Database	35
3.2.2	Flight Path Legs Developed from User-Defined Data	36
3.2.3	Leg Definition	36
3.2.4	Special Operations	40
3.2.5	Error Terms	46
3.2.6	Applicable RNP	55
3.2.7	Leg Types and RNP	55
3.2.8	Vertical Path Definition	56
<b>3.3</b>	<b>Path Steering Requirements</b>	<b>64</b>
3.3.1	RNP RNAV	64
3.3.2	VNAV	65
3.3.3	Continuous Lateral Path Steering	65
<b>3.4</b>	<b>Estimated Time of Arrival</b>	<b>65</b>
3.4.1	Equipment Requirements	65

<b>3.5</b>	<b>Time of Arrival Control</b> .....	<b>66</b>
3.5.1	Equipment Requirements .....	66
<b>3.6</b>	<b>User Interface Requirements</b> .....	<b>69</b>
3.6.1	General .....	69
3.6.2	Displays and Controls .....	69
<b>3.7</b>	<b>System Features and Capabilities</b> .....	<b>71</b>
3.7.1	Initialization Capability.....	71
3.7.2	Path Selection.....	72
3.7.3	Navigation Source (Navaid) Selection.....	78
3.7.4	Path Steering .....	78
3.7.5	Displays/Status .....	79
3.7.6	Alerting .....	84
3.7.7	Estimated Time of Arrival.....	86
3.7.8	Time of Arrival Control .....	86
<b>3.8</b>	<b>Navigation Database Requirements</b> .....	<b>87</b>
3.8.1	Content .....	87
3.8.2	Access .....	87
3.8.3	Database Standard .....	88
<b>3.9</b>	<b>Datalink Interface</b> .....	<b>88</b>
<b>3.10</b>	<b>Navigation Display Interface</b> .....	<b>89</b>
<b>4</b>	<b>NAVIGATION SYSTEM PERFORMANCE EVALUATION</b> .....	<b>91</b>
<b>4.1</b>	<b>General</b> .....	<b>91</b>
4.1.1	Certification and Process Basis .....	91
4.1.2	Navigation Accuracy and Containment Compliance .....	91
<b>4.2</b>	<b>Performance Accuracy Compliance</b> .....	<b>94</b>
4.2.1	Lateral Performance .....	94
4.2.2	Vertical Performance.....	94
4.2.3	Estimated Time of Arrival Performance .....	95
4.2.4	Time of Arrival Control Performance .....	95
<b>4.3</b>	<b>General Containment Compliance</b> .....	<b>97</b>
4.3.1	Containment Integrity .....	97
4.3.2	Containment Continuity .....	97
<b>4.4</b>	<b>Containment Integrity and Continuity Evaluation</b> .....	<b>98</b>
4.4.1	System Development Evaluation and System Monitoring.....	98
4.4.2	Failure Analysis Description.....	99
<b>5</b>	<b>MEMBERSHIP</b> .....	<b>103</b>
<b>APPENDIX A: REFERENCES, GLOSSARY, ACRONYMS AND ABBREVIATIONS</b> .....		<b>A-1</b>

<b>APPENDIX B:</b>	<b>EXAMPLE OF SYSTEM COMPLIANCE ANALYSIS .....</b>	<b>B-1</b>
<b>APPENDIX C:</b>	<b>NAVIGATION SYSTEM REQUIREMENTS AND INFRASTRUCTURE CHARACTERISTICS .....</b>	<b>C-1</b>
<b>APPENDIX D:</b>	<b>RESERVED .....</b>	<b>D-1</b>
<b>APPENDIX E:</b>	<b>HOLDING PATTERN ENTRY EXAMPLE.....</b>	<b>E-1</b>
<b>APPENDIX F:</b>	<b>CNS-ATM SYSTEM CONSIDERATIONS .....</b>	<b>F-1</b>
<b>APPENDIX G:</b>	<b>RNP RNAV / VNAV / TOAC REQUIREMENTS CROSS REFERENCE .....</b>	<b>G-1</b>
<b>APPENDIX H:</b>	<b>TEMPERATURE COMPENSATION.....</b>	<b>H-1</b>
<b>APPENDIX I:</b>	<b>RNP LESS THAN 0.3 NM.....</b>	<b>I-1</b>
<b>APPENDIX J:</b>	<b>EXAMPLE OF ETA AND TOAC COMPLIANCE ANALYSIS .....</b>	<b>J-1</b>
<b>APPENDIX K:</b>	<b>DESCENT PATH ILLUSTRATIONS .....</b>	<b>K-1</b>

## TABLE OF FIGURES

Figure 1-1: Navigation System Block Diagram .....	3
Figure 1-2: Lateral Components of Navigation Error Terms .....	15
Figure 1-3: Vertical Components of Navigation Error Terms.....	17
Figure 1-4: TOAC Definitions.....	19
Figure 1-5: Cross-Track Containment Parameters .....	20
Figure 1-6: Navigation System Operational States.....	21
Figure 1-7: Position Estimation Performance Measures .....	22
Figure 1-8: Vertical Path Performance Limit .....	23
Figure 2-1: Illustration of VPPL Along Vertical Profile .....	26
Figure 3-1: Track to Fix (TF) Leg .....	36
Figure 3-2: Radius to Fix (RF) Leg .....	37
Figure 3-3: Fix to Altitude (FA) Leg.....	38
Figure 3-4: Direct to Fix (DF) Leg .....	39
Figure 3-5: Course to Fix (CF) Leg.....	39
Figure 3-6: Course from Fix (FM).....	40
Figure 3-7: Heading Vectors (VM) .....	40
Figure 3-8: Holding Pattern Definition.....	42
Figure 3-9: Offset Path Definition.....	46
Figure 3-10: Fly-By Theoretical Transition Area.....	52
Figure 3-11: Fixed Radius Transition.....	53
Figure 3-12: Example of Fly-Over Transition Area .....	54

Figure 3-13: Descent Path Permitted by Two "WINDOW" Constraints, Two "AT" Constraints and Cruise Altitude .....	60
Figure 3-14: Descent Path defined by AT constraints and a Cruise Altitude .....	61
Figure 3-15: Waypoint with Vertical Constraint .....	62
Figure 3-16: Fly-By Transition.....	62
Figure 3-17: Application of TOAC Accuracy to Time Constraint Types .....	67
Figure 4-1: System Development and Safety Assessment Processes .....	92
Figure 4-2: System Validation Processes .....	93
Figure 4-3: Top Level Navigation Fault Tree.....	101
Figure C-1: DME Multipath Error Envelope.....	2
Figure E-1: Holding Entry Sectors .....	2
Figure E-2: Sector 1 Entry Procedure.....	2
Figure E-3: Sector 2 Entry Procedure.....	3
Figure E-4: Sector 3 Entry Procedure.....	3
Figure E-5: Sector 4 Entry Procedure.....	4
Figure H-1: Temperature Effects on Altimetry .....	1
Figure H-2: Temperature Effects on Conventional Non-Precision Approach with Overlaid VNAV Path .....	2
Figure H-3: General Example of Temperature Compensation .....	4
Figure K-1: Geometric Path Boundaries Between Constraints .....	2
Figure K-2: Point-to-Point Altitude Constraints.....	2

## TABLE OF TABLES

Table 1-1: RNP Applicability Range.....	8
Table 1-2: Advanced RNP Functions .....	9
Table 2-1: Vertical Path Performance Limit for Vertical Navigation .....	25
Table 3-1: Maximum Holding Airspeeds (KIAS) .....	43
Table 3-2: Error Terms .....	46
Table 3-3: Operational Applicability of Speed Restrictions.....	58
Table 3-4: Example of Vertical Height Loss for Fly-By .....	63
Table 3-5: Display/Entry Resolutions.....	70
Table 3-6: Non-Numeric Display Requirements .....	80
Table 4-1: Containment Characterization of Navigation System .....	102
Table C-1: Summary of Bounding Capabilities .....	C-4
Table G-1: Requirements Cross Reference .....	G-1

This Page Intentionally Left Blank

# 1 PURPOSE AND SCOPE

## 1.1 Introduction

The International Civil Aviation Organization (ICAO) recognized a need for dramatic improvements to the existing air navigation system. The 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). It was intended to be an evolutionary means of achieving improvements in the global air navigation system. To obtain the benefits of the CNS/ATM concept, aircraft need to achieve accurate, repeatable and predictable navigation performance. This is referred to as Required Navigation Performance (RNP).

The FANS concept evolved further into specific ATM modernization programs in the United States, Europe and other countries. All of these programs relied on both RNAV and RNP to enable the operational improvements needed for improved capacity, efficiency, safety, environment and global interoperability. However, the implementations led to differences in the operational applications, aircraft requirements and associated authorizations, causing confusion in the aviation community e.g. the designation of RNP 10 which through its own terms could be seen as RNAV 10.

The ICAO Performance Based Navigation (PBN) Study Group (SG) was formed after increasing misunderstanding, confusion and feedback resulted from States implementing RNAV and RNP operations in ways that differed from the original applications. The differences were significant in terms of the operational assumptions, mitigation of operational issues, management and assurance of the aircraft capabilities, etc., that could impede global interoperability and safety. The PBN SG's primary task was to create information to clarify RNAV and RNP, provide guidance to aid implementation, and harmonize and better specify area navigation and RNP, all in the development of the ICAO PBN Manual. The navigation specifications and other material in the manual are the result of the PBN SG efforts. One of the strong influences on the PBN Manuals information and guidance was the RTCA RNP RNAV Minimum Aviation System Performance Standards (MASPS) and Minimum Operational Performance Standards (MOPS).

This document contains MASPS for area navigation systems operating in an RNP environment. These standards are intended for designers, manufacturers, and installers of avionics equipment, service providers and users of these systems for world-wide operations. The MASPS provides guidance to aid in the development of airspace and operational procedures needed to obtain the benefits of improved navigation capability.

The requirements of this MASPS are intended to be consistent with the definitions of RNP developed by the ICAO PBN SG and enable PBN-based operational applications. The MASPS uses the term RNP RNAV for the aircraft system because it encompasses a more complete set of technical standards, definitions, considerations and minimum requirements than is contained in any one of the individual specifications for RNP systems in the ICAO Manual. The MASPS represents a comprehensive collection of features and capabilities that can be applied in total or as a feature set tailored to specific needs e.g. as in a single PBN navigation specification, but where the features all follow the common standard established by this MASPS.

Barometric vertical navigation (VNAV) requirements are defined for aircraft that provide this optional capability to ensure accurate and predictable vertical paths. The VNAV requirements in this document are consistent with instrument approach procedures with vertical guidance (APV). Due to the wide disparity of climb performance of different