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

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Prepared by SC-227
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## FOREWORD

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# 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).

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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 Doc 9613() 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 Manual's information and guidance was the RTCA Minimum Aviation System Performance Standards (MASPS) for RNP and the Minimum Operational Performance Standards (MOPS) for RNP.

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. This 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 definition of RNP developed by the ICAO PBN SG and enable PBN-based operational applications. This MASPS uses the term RNP 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 Doc 9613() PBN Manual. This 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

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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 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 aircraft types, this MASPS only addresses vertical path definition requirements for level flight and descent.

The ETA and TOAC requirements and guidance were derived from material provided by EUROCAE WG-85 and are based upon projects in the European SESAR program.

Runway position monitoring requirements are defined for RNP systems that include this optional non-RNP capability.

Compliance with these standards is one means of ensuring that the system and each subsystem will perform its intended function(s) satisfactorily under conditions normally encountered in aeronautical operations. This MASPS, when invoked by regulatory authorities, are expected to provide the benefits of the listed applications in section 1.3.

Section 1.0 of this document describes minimum navigation performance functions, operational goals, and applications needed for RNP operations. It also includes the assumptions made within this MASPS for defining the airborne requirements.

RNP may be considered to apply to a route, procedure or operation. The functions are described for position estimation, path definition and steering, and user interface.

Section 2.0 describes the minimum system performance requirements.

Section 3.0 describes minimum performance standards for each subsystem/function that is a required element of minimum system performance.

Section 4.0 describes an acceptable method for demonstrating system performance compliance and subsystem performance to meet the minimum standards in Section 2.0.

Section 5.0 describes the membership list.

The appendices in this MASPS include:

Appendix A, references, a glossary of terms, acronyms and abbreviations

Appendix B, a discussion of system compliance analysis.

Appendix C, navigation system requirements and infrastructure characteristics.

Appendix D, reserved

Appendix E, examples of holding pattern entries.

Appendix F, CNS-ATM System Considerations.

Appendix G, a table to identify where RNP, VNAV, and Time of Arrival requirements exist.

Appendix H, additional information supporting the recommendation for temperature compensation.

Appendix I, additional guidance on the application of a MASPS RNP system in operations where the lateral navigation accuracy is less than 0.3 NM.

Appendix J, an example of a system compliance analysis for Time Of Arrival Control.

Appendix K, descent path illustrations.

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Appendix L, an example for the application of statistical hypothesis testing to fault detection in ground-based navaids

## 1.2 System Overview

A navigation system as addressed in this MASPS provides the functions of position estimation, path definition, path steering, and situation indications and alerting to the flight crew. The system may also provide the optional speed control function to support Vertical Navigation and Time of Arrival Control. These functions and the operational interface to the system affect the level of navigation performance that can be achieved. This section provides a general description of functions and explains the relationship between the various elements of the navigation system. See Figure 1-1.

### 1.2.1 Position Estimation

Position estimation is a means of determining the aircraft's position over the surface of the earth. Data is used, either from radio sensors (with signals from ground-based Navaids or from satellites) or from onboard autonomous navigation sensors, to derive an estimated position. The position estimation function obtains information concerning any ground-based Navaids that are being used from a navigation database. The function also provides position data for display of parameters such as estimated position, estimate of position uncertainty, ground speed and track angle, based on the sensor data being processed.

The method by which the position estimation function may process the different types of sensor data is not provided in this MASPS. The document provides overall requirements for system performance which in itself may constrain the methods to be used through specifications of accuracy, integrity, continuity and availability of the data.

Where the system provides functions for the vertical dimension, the system may use crew entered and sensor information to derive altitude/height information for display, time estimates, etc.

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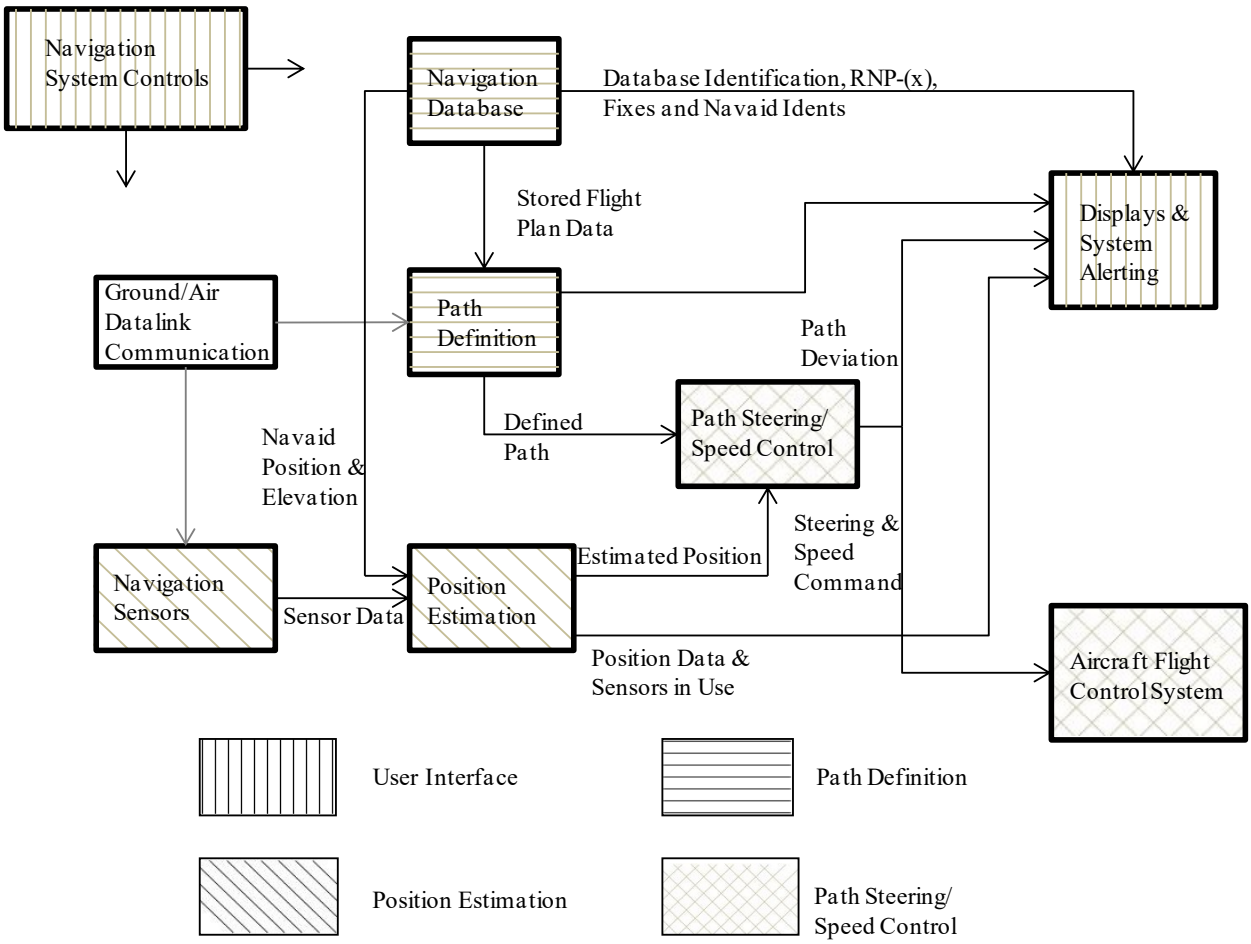



**Figure 1-1: Navigation System Block Diagram**

### 1.2.2 Path Definition

The path definition function computes the defined path to be flown in relation to the vertical, horizontal, and time dimensions. The elements of a defined path include fixes, path constraints (altitude, speed, location), and leg types, such that a seamless horizontal and vertical path between the start and end of the planned flight can be achieved.

*Note 1: This MASPS uses the term constraints where specific factors (altitude, speed and location) affect the definition and specification of a path. In the case of speed, it is also specified by the term "restriction" where it is applied to ensure the safe and appropriate aircraft performance and behavior in a flight operation.*

The lateral aspects of path definition determine a geographically fixed ground track from origin to destination, whether derived from an airborne database, pilot entry or data uplink. The sub-functions involved are:

***1.*** Fix definition;

***2.*** Leg type definition;

***3.*** Leg transition definition, e.g., turns;

***4.*** Tactical operations, e.g. direct-to, lateral offsets and holds.

The vertical aspects of path definition determine a path profile from origin to destination. The vertical aspects are extensions to the sub-functions prescribed for the lateral path:

***1.*** altitude/flight level constraints, associated with fix definition

***2.*** vertical angle, associated with leg definition

***3.*** speed constraints, associated with fix definition

*Note 2: Path definition should include an accurate lateral and vertical path, with a best estimate of times of arrival associated with each lateral and some vertical fixes.*

Reporting by either voice or digital air/ground datalink interface has become an important part of path definition through clearances for pre-defined procedures to be used from the airborne navigation database or fixes that the system must use to create a route or procedure.

### 1.2.3 Path Steering

The defined path is used by the path steering function, where it is combined with the estimated position and time to determine parameters of path deviation and steering commands. These parameters are used for correcting errors relative to the defined path in terms of lateral, vertical and time of arrival.

#### 1.2.3.1 Lateral Steering

Typical of the parameters for lateral control are the computation of cross-track error and track angle error. Having determined the lateral path steering errors, the lateral steering sub-function computes a steering command for the aircraft flight control system (autopilot, flight director), and a path deviation for display to the flight crew on the flight instruments. Both types of commands, the latter in combination with the pilot, attempt to correct the errors and hold the aircraft to the defined path. The overall navigation performance achieved will depend upon the type of steering command selected, i.e. automatic or manual.

#### 1.2.3.2 Vertical Steering

Typical of the parameters for vertical control are the computation of speed, thrust, altitude, vertical track error, flight path angle, and vertical track angle. Having determined the vertical path errors, the vertical steering and control sub-function computes commands and indications, a steering command that may be used by an aircraft flight control system (autopilot, flight director), and path guidance/deviation data for display to the flight crew on the flight instruments. These commands, where the steering management and display may be in combination with the pilot, attempt to correct the errors and hold the aircraft to the defined vertical path. The overall navigation performance achieved will depend upon the type of steering command selected, i.e. automatic or manual, and aircraft flight performance.

### 1.2.4 User Interface

#### 1.2.4.1 Controls, Displays and System Alerting

The user interface is achieved through system controls, displays and alerting functions. These functions provide the means for system initialization, flight planning and progress monitoring, active guidance control and presentation of navigation data for flight crew situational awareness. System alerting and the means by which navigation information is displayed or made accessible to the flight crew, needs to be compatible with the overall

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flight deck philosophy for the aircraft. Similarly, the means of flight crew interface with the navigation system needs to be user-friendly and the overall design will need to consider flight crew workload.

#### 1.2.4.2 Reporting

As the Air Traffic Management (ATM) system evolves, reporting by either voice or digital air/ground datalink, has become an important and required function. Examples of reporting are present position, current flight path and fixes plus other items required by Air Traffic Control to maintain the safe separation of aircraft.

### 1.2.5 Navigation System Controls and Features

In addition to the basic subfunctions, the navigation system will need to provide the necessary features and capabilities required to support aircraft RNP operations. The requirements associated with controls and features vary depending upon the RNP. Section 3.7 of this document contains details of system features and capabilities, and their applicability to each RNP.

## 1.3 Operational Goals and Applications

This MASPS establishes requirements for the airborne navigation component of the CNS/ATM operating environment. Benefits will be achieved through coordinated efforts of the service providers and users, and may be used to varying degrees depending on the operating environment.

### 1.3.1 Path Definition

RNP operations, especially at lower RNP's, are characterized by reliable, predictable and repeatable ground tracks. This is achieved by aircraft systems and operating environments that utilize the same path definitions. Additionally, the aircraft systems and operating environment support the conduct of operations where a vertical descent profile or time of arrival is specified, including arrival and approach procedures with displayed guidance and path keeping control, as appropriate.

### 1.3.2 Containment Methodology

An aircraft meeting the required navigation performance will remain within the limits defined by the RNP with a predefined level of confidence. Application of this MASPS will enable assignment of a value to that level of confidence and provide a methodology to demonstrate that the system meets the specified RNP. Following consideration of typical performance of existing navigation systems and evaluating what was necessary to obtain operational benefit, a lateral containment limit of two times the RNP (2xRNP) has been chosen (See Figure 1-5). The lateral containment limit is also an enabling element for the ICAO RNP navigation specification requirement for on-board performance monitoring and alerting.

An aircraft meeting vertical navigation performance will remain in proximity to the vertical path and its constraints with a predefined level of confidence. Application of this MASPS will enable assignment of a value to that level of confidence. Following consideration of typical performance of existing systems, a vertical path performance limit (VPPL) that represents 99.7% (3 sigma) performance has been chosen (See Figure 1-8). The VPPL is defined to be independent of the lateral containment limit.

These limits and their corresponding assurance levels should be used to support the development of optimal airspace with RNP routes and procedures.