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Manual on the Use of Performance-based Navigation (PBN) in Airspace Design

Approved by the Secretary General
and published under his authority

First Edition — 2013

International Civil Aviation Organization

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AMENDMENTS

Amendments are announced in the supplements to the *Catalogue of ICAO Publications*; the Catalogue and its supplements are available on the ICAO website at www.icao.int. The space below is provided to keep a record of such amendments.

RECORD OF AMENDMENTS AND CORRIGENDA

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FOREWORD

The purpose of this manual is to provide step-by-step guidance on the application of performance-based navigation (PBN) in a development of an airspace concept. Originally developed as material to support the ICAO Airspace Concept Workshops for PBN Implementation, this manual can also be used by stakeholders involved in the implementation of PBN.

Airspace planners and designers need to understand the interdependence of the airspace concept with the navigation system capability and to view both in context with other enablers (communications (COM), surveillance (SUR) and air traffic management (ATM) procedures and tools). The benefits derived from the implementation of a PBN in an airspace concept must warrant the cost of aircraft and air traffic control (ATC) system equipage, pilot and ATC training, as well as airspace and procedure design arising from the implementation. This is achieved through careful planning which takes account of the detailed navigation functional requirements called up by the airspace concept and the timing of the implementation since costs are driven by the number of airframes that have to be retrofitted with updated navigation systems to meet the new requirements.

This manual is intended to supplement the existing procedures and guidance material on airspace design and planning found in:

Procedures for Air Navigation Services — Air Traffic Management (PANS-ATM, Doc 4444)

Procedures for Air Navigation Services — Aircraft Operations (PANS-OPS, Doc 8168);

Air Traffic Services Planning Manual (Doc 9426); and

Performance-based Navigation (PBN) Manual (Doc 9613)

Manual on Required Communication Performance (RCP) (Doc 9869).

Quality Assurance Manual for Flight Procedure Design (Doc 9906)

- Volume 1 — *Flight Procedure Design Quality Assurance System*

This manual also serves as an overlying and unifying reference document for the:

Continuous Descent Operations (CDO) Manual (Doc 9931); and

Continuous Climb Operations (CCO) Manual (Doc 9993).

Future developments

Comments on this manual would be appreciated from all parties involved in the development and implementation of airspace concepts for PBN implementation. These comments should be addressed to:

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GLOSSARY

ABBREVIATIONS/ACRONYMS

ACC	Area control centre
AIM	Aeronautical information and mapping
AIRAC	Aeronautical information regulation and control
ANSP	Air navigation service provider
ATC	Air traffic control
ATM	Air traffic management
ATS	Air traffic service
CCO	Continuous climb operations
CDO	Continuous descent operations
CNS	Communications, navigation, surveillance
COM	Communications
DME	Distance measuring equipment
DTG	Distance to go
FDP	Flight data processor
Fpm	Feet per minute
FMS	Flight management system
FTS	Fast time simulation
GA	General aviation
GNSS	Global navigation satellite system
HMI	Human-machine interface
IAP	Instrument approach procedure
IFR	Instrument flight rules
INS	Inertial navigation system
IRS	Inertial reference system
LPV	Localizer performance with vertical guidance
NAV	Navigation
NAVAID	Aid to navigation
PBN	Performance-based navigation
RAIM	Receiver autonomous integrity monitoring
RDP	Radar data processor
RNAV	Area navigation
RNP	Required navigation performance
RT	Radio transmission
RTS	Real time simulation
SARPS	Standards and Recommended Practices
SID	Standard instrument departure
STAR	Standard instrument arrival
SUR	Surveillance
TLS	Target level of safety

(x)

TMA	Terminal control area
VFR	Visual flight rules
VOR	VHF omnidirectional radio range

DEFINITIONS

Airspace concept. An airspace concept provides the outline and intended framework of operations within an airspace. Airspace concepts are developed to satisfy explicit strategic objectives such as improved safety, increased air traffic capacity and mitigation of environmental impact, etc. Airspace concepts can include details of the practical organization of the airspace and its users based on particular CNS/ATM assumptions, e.g. ATS route structure, separation minima, route spacing and obstacle clearance.

Area navigation (RNAV). A method of navigation which permits aircraft operation on any desired flight path within the coverage of station-referenced navigation aids or within the limits of the capability of self-contained aids, or a combination of these.

Note.— Area navigation includes performance-based navigation as well as other RNAV operations that do not meet the definition of performance-based navigation.

Continuous climb operation (CCO). An operation, enabled by airspace design, procedure design and ATC, in which a departing aircraft climbs without interruption, to the greatest possible extent, by employing optimum climb engine thrust, at climb speeds until reaching the cruise flight level.

Continuous descent operation (CDO). An operation, enabled by airspace design, procedure design and ATC facilitation, in which an arriving aircraft descends continuously, to the greatest possible extent, by employing minimum engine thrust, ideally in a low drag configuration, prior to the final approach fix/final approach point.

Note 1.— An optimum CDO starts from the top of descent and uses descent profiles that reduce segments of level flight, noise, fuel burn, emissions and controller/pilot communications, while increasing predictability to pilots and controllers and flight stability.

Note 2.— A CDO initiated from the highest possible level in the en-route or arrival phases of flight will achieve the maximum reduction in fuel burn, noise and emissions.

Navigation aid (navaid) infrastructure. Navaid infrastructure refers to space-based and or ground-based navigation aids available to meet the requirements in the navigation specification.

Navigation application. The application of a navigation specification and the supporting navaid infrastructure to routes, procedures, and/or defined airspace volume, in accordance with the intended airspace concept.

Note.— The navigation application is one element, along with communications, surveillance and ATM procedures, which meets the strategic objectives in a defined airspace concept.

Navigation function. The detailed capability of the navigation system (such as the execution of leg transitions, parallel offset capabilities, holding patterns, navigation databases) required to meet the airspace concept.

Note.— Navigational functional requirements are one of the drivers for the selection of a particular navigation specification.

Navigation specification. A set of aircraft and aircrew requirements needed to support performance-based navigation operations within a defined airspace. There are two kinds of navigation specification:

RNAV specification. A navigation specification based on area navigation that does not include the requirement for on-board performance monitoring and alerting, designated by the prefix RNAV, e.g. RNAV 5, RNAV 1.

RNP specification. A navigation specification based on area navigation that includes the requirement for on-board performance monitoring and alerting, designated by the prefix RNP, e.g. RNP 4, RNP APCH.

Note.— The Performance-based Navigation (PBN) Manual (Doc 9613), Volume II, contains detailed guidance on navigation specifications.

Performance-based navigation. Area navigation based on performance requirements for aircraft operating along an ATS route, on an instrument approach procedure or in a designated airspace.

Note.— Performance requirements are expressed in navigation specifications in terms of accuracy, integrity, continuity, availability and functionality needed for the proposed operation in the context of a particular airspace concept.

RNAV operations. Aircraft operations using area navigation for RNAV applications. RNAV operations include the use of area navigation for operations which are not developed in accordance with this manual.

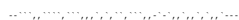
RNAV system. A navigation system which permits aircraft operation on any desired flight path within the coverage of station-referenced navigation aids or within the limits of the capability of self-contained aids, or a combination of these. An RNAV system may be included as part of a flight management system (FMS).

RNP operations. Aircraft operations using an RNP system for RNP navigation applications.

RNP system. An area navigation system which supports on-board performance monitoring and alerting.

Standard instrument arrival (STAR). A designated instrument flight rule (IFR) arrival route linking a significant point, normally on an ATS route, with a point from which a published instrument approach procedure can be commenced.

Standard instrument departure (SID). A designated instrument flight rule (IFR) departure route linking the aerodrome or a specified runway of the aerodrome with a specified significant point, normally on a designated ATS route, at which the en-route phase of a flight commences.



Chapter 1

BACKGROUND

1.1 PERFORMANCE-BASED NAVIGATION (PBN)

1.1.1 The ICAO Performance-based Navigation (PBN) Concept was introduced in 2008 and is detailed in the *Performance-based Navigation (PBN) Manual* (Doc 9613). The PBN concept replaced the required navigation performance (RNP) concept.

1.1.2 PBN introduces airworthiness certification and operational approval requirements for use of an RNAV system in airspace implementations. PBN is one of a number of enablers of airspace concepts, as shown in Figure 1-1.

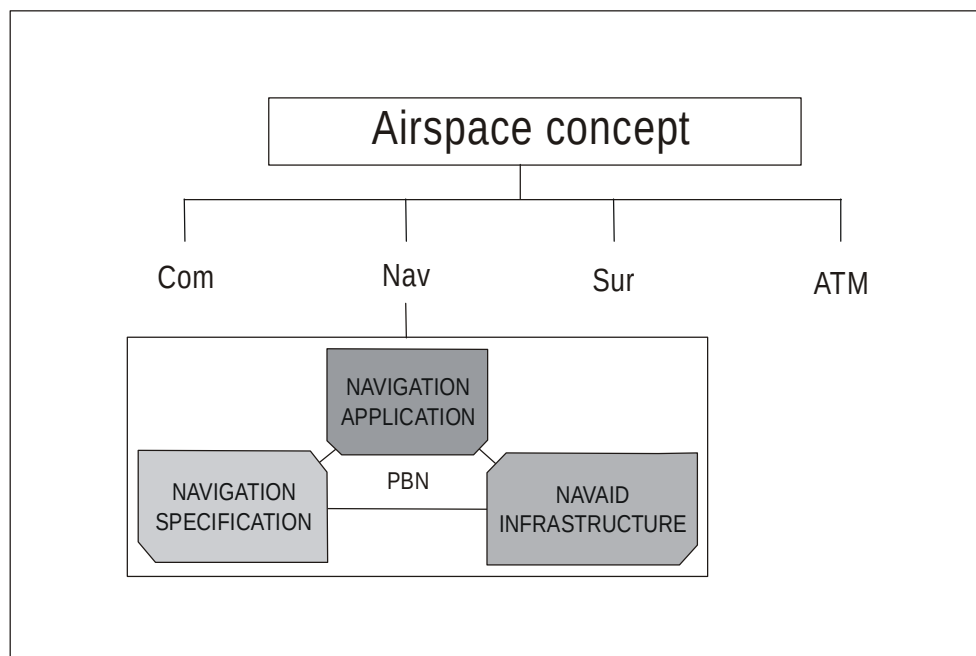


Figure 1-1 Airspace concept and PBN

1.1.3 The PBN concept relies on the use of area navigation. PBN consists of the following components:

- a) navigation aid (navaid) infrastructure;
- b) navigation specification; and

applying the above components in the context of the airspace concept to ATS routes and instrument procedures results in a third component:

- c) navigation application.

The navigation application is key to the development of the airspace concept. The NAVAID infrastructure details the space or ground-based navaids required by the navigation specification used to support the navigation application. The navigation specification is a technical and operational specification that details the performance required of the RNAV or RNP system in terms of accuracy, integrity and continuity. On-board functionality, required navigation sensors, as well as the associated training and operating requirements are also spelled out. The navigation specifications are used by States as a basis for developing national regulations for PBN certification and operational approval.

1.2 THE AIRSPACE CONCEPT

1.2.1 The airspace concept describes the intended operations within an airspace and the organization of airspace to enable those operations. It includes many components of the ATM operational concept, including airspace organization and management, demand and capacity balancing, traffic synchronization, airspace user operations and conflict management. Airspace concepts are developed to satisfy explicit and implicit strategic objectives such as:

- a) improved or maintained safety;
- b) increased air traffic capacity;
- c) improved efficiency;
- d) more accurate flight paths; and
- e) mitigation of environmental impact.

Airspace concepts can include details of the practical organization of the airspace and its users, based on particular communications, navigation, surveillance/air traffic management (CNS/ATM) assumptions; for 2.3.2.33ff service (ATS) route structure, separation minima, route spacing and obstacle clearance. Good airspace design and collaboration with all stakeholders (airspace planners, procedure designers, airlines, general aviation (GA), military, airport authorities, etc.) are critical to the effective implementation of an airspace concept (see Figure 1-2).

1.2.2 Once fully developed, an airspace concept describes in detail the target airspace organization and the operations within that airspace. It addresses all of the strategic objectives and identifies all the CNS-ATM enablers, as well as any operational and technical assumptions. An airspace concept is a master plan of the intended airspace design and its operation.

1.3 PBN BENEFITS

1.3.1 PBN offers many advantages over the historic, conventional navigation methods where instrument flight procedures and air routes were based upon specific ground-based navaids and their associated obstacle clearance criteria. Some advantages of PBN are:

- a) it reduces the need to maintain sensor-specific routes and procedures and their associated costs;