Doc 9905
AN/471

Required Navigation Performance Authorization Required (RNP AR) Procedure Design Manual

Approved by the Secretary General
and published under his authority

First Edition — 2009

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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.

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FOREWORD

Required navigation performance (RNP) was initially envisaged by the International Civil Aviation Organization (ICAO) as a means to facilitate change in airspace operation. ICAO recognized that global navigation satellite systems, the navigation infrastructure, operations, and aircraft systems were undergoing change faster than could be supported by their traditional technical standards processes. RNP was developed to allow the specification of airspace and operation requirements without the constraints of the slow process for specifying equipment and systems.

Initially, in order to support RNP operations, RNP procedure design criteria were developed and incorporated in the *Procedures for Air Navigation Services — Aircraft Operations* (PANS-OPS) (Doc 8168). However, lacking demand and general familiarity with the change in operations and implementation paradigm possible with RNP, the initial criteria were conservative in nature and specification. Consequently, as specific locations were identified where demanding RNP solutions were needed, ICAO criteria were found to be insufficient and lacking in the necessary support guidance for approving operations.

At the same time, one State in collaboration with industry and a key airline operator undertook the task to develop criteria that permitted the usage of RNP-capable aircraft to address a significant problem with airport access in obstacle-rich environments or terrain, under limiting weather conditions. These criteria for RNP procedures were documented in regulatory guidance, as part of the United States Federal Aviation Administration (FAA) Advisory Circular (AC) 120-29A.

The AC 120-29A RNP criteria permit a significant degree of flexibility and customization in procedure design. It extends beyond traditional procedure design guidance in its provision of criteria addressing relevant aspects of operational requirements that must be considered in the implementation of such special flight operations e.g. visual segment assessment, engine loss, extraction, tailored climb gradient and balked landing. However, such criteria can be very demanding and time-consuming as it must be evaluated and approved for every application. As a result, it was determined that a degree of standardization in lieu of maximum variability would facilitate not only procedure development but implementation as well.

The same State, consistent with its aviation community, derived a separate set of procedure design criteria that retained many key areas of flexibility but also set specific standards in others, so as to simplify the procedure design implementation effort while retaining the means to achieve significant operational benefits. These criteria were documented in United States FAA Order 8250.52, which was initially used in that State, but was also embraced by others needing such criteria to address operational problems in their regions. ICAO has reviewed these criteria and developed equivalent criteria contained herein that was harmonized with PANS-OPS with regard to terminology, units of measurement and certain design parameters. As the concepts behind the criteria contained in this manual are relatively new, it was decided not to include the criteria in PANS-OPS at this stage.

In order to rationalize and support the implementation of RNP operations, ICAO established the Required Navigation Performance and Special Operational Requirements Study Group (RNPSORSG) which developed the *Performance-Based Navigation (PBN) Manual* (Doc 9613). The PBN Manual provides two types of navigation specifications for approach operations: RNP approach (RNP APCH) and RNP authorization required approach (RNP AR APCH). The RNP APCH navigation specification is intended to satisfy general RNP operational requirements and permit participation by aircraft with a basic level of RNP capability without a requirement for operational authorization. The other navigation specification, RNP AR APCH, which enables a higher level of navigation performance better able to address issues of airport access, such as obstacle-rich environments, and facilitate advances in air traffic management (ATM), requires the operator to meet additional aircraft and aircrew requirements and obtain operational authorization from the State regulatory authority.

RNP AR procedures can provide significant operational and safety advantages over other area navigation (RNAV) procedures by incorporating additional navigational accuracy, integrity and functional capabilities to permit operations using reduced obstacle clearance tolerances that enable approach and departure procedures to be implemented in circumstances where other types of approach and departure procedures are not operationally possible or satisfactory. Procedures implemented in accordance with this manual allow the exploitation of high-quality, managed lateral and vertical navigation (VNAV) capabilities that provide improvements in operational safety and reduced controlled flight into terrain (CFIT) risks.

This manual is intended for use by aircraft operators and procedure designers of instrument approaches based on RNP using RNAV avionics systems, where authorization is required (AR).

The manual includes design criteria to aid States in the implementation of RNP AR approach procedures in accordance with the PBN Manual, Volume II, Part C, Chapter 6, Implementing RNP AR APCH. Similar criteria for departure procedures will be incorporated when developed.

DEFINITIONS

Aircraft-based augmentation system (ABAS). An augmentation system that augments and/or integrates the information obtained from the other GNSS elements with information available on board the aircraft.

Note.— The most common form of ABAS is receiver autonomous integrity monitoring (RAIM).

Airspace concept. An airspace concept provides the outline and intended framework of operations within an airspace. An airspace concept is essentially a high-level statement of an airspace plan. Airspace concepts are developed to satisfy explicit strategic objectives such as improved safety, increased air traffic capacity and mitigation of environmental impact. Airspace concepts include details of the practical organization of the airspace and its users based on particular communications, navigation and surveillance/air traffic management (CNS/ATM) assumptions, e.g. air traffic services (ATS) route structure, separation minima, route spacing and obstacle clearance.

Approach procedure with vertical guidance (APV). An instrument procedure which utilizes lateral and vertical guidance but does not meet the requirements established for precision approach and landing operations.

Area navigation (RNAV). A method of navigation which permits aircraft operation on any desired flight path within the coverage of ground-based or spaced-based 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 operations that do not meet the definition of performance-based navigation.

Area navigation route. An ATS route established for the use of aircraft capable of employing area navigation.

ATS surveillance service. Term used to indicate a service provided directly by means of an ATS surveillance system.

ATS surveillance system. A generic term meaning variously, ADS-B, PSR, SSR or any comparable ground-based system that enables the identification of aircraft.

Note.— A comparable ground-based system is one that has been demonstrated, by comparative assessment or other methodology, to have a level of safety and performance equal to or better than monopulse SSR.

Cyclic redundancy checking (CRC). *A mathematical algorithm applied to the digital expression of data that provides a level of assurance against loss or alteration of data.*

Decision altitude (DA) or decision height (DH). A specified altitude or height in the precision approach or approach with vertical guidance at which a missed approach must be initiated if the required visual reference to continue the approach has not been established.

Note 1.— DA is referenced to mean sea level and DH is referenced to the threshold elevation.

Note 2.— The required visual reference means that section of the visual aids or of the approach area which should have been in view for sufficient time for the pilot to have made an assessment of the aircraft position and rate of change of position, in relation to the desired flight path. In Category III operations with a decision height the required visual reference is that specified for the particular procedure and operation.

Note 3.— For convenience where both expressions are used they may be written in the form "decision altitude/height" and abbreviated "DA/H".

Glide path. A flight path defined in the vertical axis that passes through the DCP/RDH on the final approach segment of an APV or PA.

Mixed navigation environment. An environment where different navigation specifications may be applied within the same airspace (e.g. RNP 10 routes and RNP 4 routes in the same airspace) or where operations using conventional navigation are allowed together with RNAV or RNP applications.

Navigation aid (NAVAID) infrastructure. Navaid infrastructure refers to space-based and or ground-based navigation aids available to meet the requirements in a 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 communication, surveillance and ATM procedures meeting 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 selection of a particular navigation specification. Navigation functionalities (functional requirements) for each navigation specification can be found in the Performance-Based Navigation (PBN) Manual (Doc 9613), *Volume II, Parts B and C.*

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

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

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

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

Obstacle clearance surface (OCS). An obstacle evaluation surface used to determine the minimum obstacle clearance altitude at any point.

Performance-based navigation (PBN). 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.

Procedural control. Air traffic control service provided by using information derived from sources other than an ATS surveillance system.

RNAV operations. Aircraft operations using an area navigation system for RNAV applications. RNAV operations include the use of area navigation for operations which are not developed in accordance with the *Performance-Based Navigation (PBN) Manual (*Doc 9613).

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 applications.

RNP route. An ATS route established for the use of aircraft adhering to a prescribed RNP specification.

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

Satellite based augmentation system (SBAS). A wide coverage augmentation system in which the user receives augmentation from a satellite-based transmitter.

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.

ABBREVIATIONS AND ACRONYMS

AC	Advisory circular
ADS-B	Automatic dependent surveillance broadcast
AGL	Above ground level
anpe	Actual navigation performance error
APCH	Approach
APV	Approach procedure with vertical guidance
AR	Authorization required
*ase	Altimetry system error
ASI	Airspeed indicator
ATC	Air traffic control
*atis	Automatic terminal information service
ATM	Air traffic management
ATS	Air traffic services
ATT	Along track tolerance
BARO-VNAV	Barometric vertical navigation
BG	Body geometry
CAT	Category
CDA	Continuous descent approach
CFIT	Controlled flight into terrain
Cot	Cotangent
CNS/ATM	Communications, navigation and surveillance/air traffic management
DA/H	Decision altitude/height
DER	Departure end of runway
D_{FAP}	Distance from threshold to FAP
D_{FROP}	Distance to final approach roll-out point
DR	Descent rate
DTA	Distance of turn anticipation
FAA	Federal Aviation Administration
FAF	Final approach fix
FAP	Final approach point
FAS	Final approach segment
FCC	Flight control computer
FOSA	Flight operations safety assessment
FROP	Final approach roll-out point
ft	Feet
*fte	Flight technical error
FTP	Fictitious threshold point
GNSS	Global navigation satellite system
GP	Glide path
GPI	Ground point of intercept
GPS	Global positioning system
H	Altitude

* Lower case is used for those abbreviations and acronyms that come from the *Performance-Based Navigation (PBN) Manua*l (Doc 9613).

HATh	Height above threshold
HL	Height loss
IAF	Initial approach fix
IAS	Indicated airspeed
IF	Intermediate fix
IRU	Inertial reference unit
ISA	International standard atmosphere
isad	International standard atmosphere temperature deviation
km	Kilometre
kt	Knot
LNAV	Lateral navigation
LTP	Landing threshold point
LTP_{ELEV}	Landing threshold point elevation
m	Metre
MA	Missed approach
MAS	Missed approach segment(s)
MEL	Minimum equipment list
MOC	Minimum obstacle clearance
NM	Nautical mile
OAS	Obstacle assessment surface(s)
OCA/H	Obstacle clearance altitude/height
OCS	Obstacle clearance surface
PANS-OPS	Procedures for Air Navigation Services — Aircraft Operations
PBN	Performance-based navigation
PSR	Primary surveillance radar
R	Rate of turn
r	Radius
RA	Radio altimeter
RDH	Reference datum height
RF	Radius to fix (ARINC leg type)
RNAV	Area navigation
RNP	Required navigation performance
RNP AR	Required navigation performance authorization required
RNPSORSG	Required Navigation Performance and Special Operational Requirements Study Group
RSS	Root sum square
RWY	Runway
SI	International system of units
SOC	Start of climb
SSR	Secondary surveillance radar
TAS	True airspeed
TCH	Threshold crossing height
TF	Track to fix (ARINC leg type)
TP	Turning point
TrD	Transition distance
TWC	Tailwind component
V	Speed
VA	Heading to altitude (ARINC leg type)
vae	Vertical angle error
V_{at}	Speed at threshold
VEB	Vertical error budget
VGSI	Visual glide slope indicator
VNAV	Vertical navigation

VPA	Vertical path angle
V_{slg}	Stall speed in landing configuration at maximum landing mass
V_{so}	Stall speed
WGS	World geodetic system
wpr	Waypoint precision error

Chapter 1

DESCRIPTION OF REQUIRED NAVIGATION PERFORMANCE AUTHORIZATION REQUIRED (RNP AR)

1.1 PURPOSE OF THE MANUAL

1.1.1 This manual is intended for use by aircraft operators and procedure designers of instrument approaches based on required navigation performance (RNP) using area navigation (RNAV) avionics systems, where authorization is required (AR).

1.1.2 The manual includes design criteria to aid States in the implementation of RNP AR approach (APCH) procedures in accordance with *Performance-Based Navigation (PBN) Manual* (Doc 9613) (hereafter referred to as the PBN Manual), Volume II, Part C, Chapter 6, Implementing *RNP AR APCH*.

1.2 APPLICATION

1.2.1 Implementation of RNP AR procedures extends beyond procedure design in that an authorization process for aircraft operators is necessary to ensure that other critical dependencies and associated airworthiness and operational procedure approvals are complete prior to implementation. Guidance on implementation and operational approval is provided in the PBN Manual.

1.2.2 The PBN Manual contains navigation specifications applicable to two RNP approach applications: RNP APCH and RNP AR APCH.

1.2.3 RNP AR APCH operations are classified as approach procedures with vertical guidance (APVs) in accordance with Annex 6 — *Operation of Aircraft*. This type of operation requires a positive vertical navigation (VNAV) guidance system for the final approach segment (FAS). Current RNP AR APCH implementations utilize a barometric vertical navigation system (BARO-VNAV) meeting specified airworthiness requirements. Obstacle clearance is based on a statistical assessment of all the component errors referred to as a vertical error budget (VEB). Other suitably accurate vertical guidance may be implemented provided equivalent accuracy, integrity and containment can be assured.

1.2.4 RNP AR APCH procedures may be designed to support multiple minima for various appropriate RNP, e.g. RNP 0.3, RNP 0.2, down to RNP 0.1. However, designers should not promulgate procedures with RNP less than 0.3 unless there is an operational benefit. Reductions in RNP reduce the alert limits and increase the possibility of an alert and a consequent go-around; therefore, the minimum RNP published should not be smaller than necessary to provide the required operational capability.

1.2.5 The design criteria in this manual are applicable to a range of aircraft types and cannot; therefore, take into account the full capability of some aircraft types. Consequently, procedures designed in accordance with this manual will provide an acceptable operational solution in many but not all circumstances. Where an operationally acceptable solution is not available through the application of these criteria, development of detailed procedures may be needed to satisfy local conditions. Alternative design solutions may be derived which specify aircraft type or specific performance parameters, special operating conditions or limitations, crew training, operational evaluation or other requirements that can be demonstrated to provide an equivalent level of safety. Such solutions are not the subject of this manual and require a case-by-case flight operations safety assessment (FOSA) and operational approval.

1.2.6 RNP AR APCH operations utilize high levels of RNAV capability, and all aspects of the operation must meet the relevant requirements specified in the PBN Manual.

1.2.7 The safety of RNP AR APCH procedures is dependent upon the proper inter-relationship between aircraft capability, operating procedures and procedure design. Users of this manual should understand this critical difference in the design of RNP AR procedures.

1.3 AIRCRAFT QUALIFICATION

1.3.1 Aircraft qualification is integral to the process of authorization for RNP AR operations. For an RNP AR instrument flight procedure, only aircraft that have demonstrated performance, capability and functionality can be authorized to conduct RNP AR APCH operations.

1.3.2 Aircraft must meet the requirements of the RNP AR APCH navigation specification given in the PBN Manual. Aircraft manufacturers must demonstrate and document aircraft performance and capability, and any special procedures or limitations associated with the aircraft and systems as part of either an aircraft certification programme or aircraft compliance assessment.

1.3.3 The demonstration of aircraft capability allows all qualified aircraft to use the instrument flight procedure, relieving the designer of the need to consider individual aircraft types or performance capabilities.

1.3.4 As aircraft performance, integrity and functionality are demonstrated, documented and approved as part of the demonstration of RNP AR capability, the conduct of special or extensive flight trials and simulations to gather statistical evidence of the aircraft performance is not required to support the implementation of RNP AR operations.

1.4 OPERATIONAL QUALIFICATION

1.4.1 The authorization process for RNP AR APCH operations includes the approval of operating procedures and crew training in accordance with the RNP AR APCH navigation specification given in the PBN Manual.

1.4.2 Operating procedures must conform to any conditions in the aircraft RNP AR capability approval and any additional requirement such as a minimum equipment list (MEL), flight crew operations manuals, aircraft flight manuals and maintenance guidance.

1.4.3 Operating procedures must also take into account any limitations or requirements specified by the procedure designer. Specified equipment or capabilities may be required to conduct an RNP AR APCH procedure in certain cases.

1.4.4 Individual RNP AR APCH procedures are validated in accordance with the PBN Manual and other relevant guidance prior to publication. However, as variations may occur in functionality, equipment and flyability, operators are required to conduct an operational validation of each of the procedures applicable to the type of aircraft operated.

1.4.5 Prior to authorization for the conduct of RNP AR APCH operations, an operator must demonstrate to the State regulator that all appropriate elements of the RNP AR APCH operations have been appropriately addressed including:

a) determination of aircraft qualification;

b) training e.g. flight crews, dispatch;

c) MEL, continuing airworthiness;

d) requirements for operational procedures;

e) dispatch procedures;

f) maintenance procedures;

g) conditions or limitations for approval;

h) procedure operational validation for each aircraft type; and

i) conduct of a FOSA.

1.4.6 The specific considerations and issues for these areas are as described in detail in the PBN Manual.

1.5 FLIGHT OPERATIONS INFORMATION

1.5.1 The conduct of RNP AR instrument procedures requires that the aircraft operator examine its crew information, flight procedures and training to ensure that they are sufficient to enable operator qualification and operational approval.

1.5.2 Crew information, flight procedures and training must be suitable for the RNP AR APCH instrument approach procedures, aircraft type(s) or variants, crew positions, airborne systems, navaids and ground systems to be used. Training topics will be tailored to suit their application to initial qualification, recurrent qualification, requalification, command training upgrade or differences qualification, as applicable. Crew training requirements are detailed in the PBN Manual.

1.6 FLIGHT PROCEDURES

Users of this manual must be familiar with the following aspects associated with RNP AR APCH operations.

a) *RNP capability.* Crews must be aware of the aircraft RNP capability documented in the RNP AR authorization appropriate to the aircraft configuration or operational procedures (e.g. global positioning system (GPS) inoperative, use of flight director instead of autopilot).

b) *RNP availability check*. Prior to the commencement of an approach, the crew is responsible for ensuring that the appropriate RNP is selected. The highest RNP consistent with the operating conditions should be selected to reduce the possibility of alerts and consequent missed approaches. Crews will ensure prior to commencement of a procedure that the required navigation system performance is available and can be expected to be available through the conduct of the procedure. RNP should not be changed after commencement of the procedure.

c) *Radius to fix (RF) legs*. The use of RF legs provides more flexibility in the design of the procedure track. RF legs may be present in all phases of the procedure including the final segment, and the requirement for RF leg capability, if applicable, will be annotated on the approach chart. As the use of RF legs in the design of procedures is optional, capability to fly procedures incorporating RF legs must be specifically identified in the operator authorization.

d) *Minimum equipment*. Minimum equipment provisions are detailed in the PBN Manual. At some locations, the airspace or obstacle environment will require RNP capability during a missed approach from anywhere on the procedure. At these locations redundant equipment may be required.

e) *Non-standard speeds or climb gradients*. RNP AR approaches are developed based on standard approach speeds and specified a nominal climb gradient in the missed approach. Any exceptions to these standards must be indicated on the approach procedure, and the operator must ensure they can comply with any published restrictions before conducting the operation.

f) *Non-normal operations*. Crews must be competent to contain the aircraft position within tracking tolerances consistent with the selected RNP during all normal and non-normal operations. (Flight technical tolerances are specified in the navigation specifications given in the PBN Manual, Volume II, Chapter 6.)

g) *Vertical flight path tolerances*. In the FAS, crews will monitor any vertical deviation from the VNAV path to ensure that the aircraft remains within the tolerances specified in the navigation specifications given in the PBN Manual, Volume II, Chapter 6.

h) *Coupled autopilot.* Use of coupled autopilot is recommended. Operator procedures must specify the conditions for operations without autopilot.

Chapter 2

RNP AR APPROACH PROCEDURE DESIGN

2.1 UNDERLYING PRINCIPLES

RNP APCH versus RNP AR APCH

2.1.1 RNP APCH is defined as an RNP approach procedure that requires a lateral TSE of +/-1 NM in the initial, intermediate and missed approach segments (MAS) and a lateral TSE of ±0.3 NM in the FAS. Guidance on implementing RNP APCH operations can be found in the PBN Manual, Volume II, Chapter 5, Implementing RNP APCH.

2.1.2 RNP AR APCH is defined as an RNP approach procedure that requires a lateral TSE as low as ±0.1 NM on any segment of the approach procedure. RNP AR APCH procedures also require that a specific vertical accuracy be maintained as detailed in the PBN Manual, Volume II, Chapter 6. The vertical datum for RNP AR procedures is the landing threshold point (LTP). The RNP AR APCH criteria apply only to those aircraft and operators complying with specified additional certification, approval and training requirements. RNP AR APCH procedures are only published where significant operational advantages can be achieved while preserving or improving safety of operation. The RNP AR certification and approval requirements are contained in the PBN Manual. For the purposes of applying the criteria contained in this manual, RNP levels address obstacle protection associated with RNP values. The RNP level is used to determine the area semi-width value (in NM) of a protection area associated with a segment of an instrument procedure.

2.2 OBSTACLE CLEARANCE ALTITUDE/HEIGHT (OCA/H) AND DECISION ALTITUDE/HEIGHT (DA/H)

2.2.1 An OCA/H is published for RNP AR procedures on the chart; however, for procedures involving an MAS with RNP values less than RNP 1.0, DA/H is published instead, and the appropriate notation is entered on the chart. In this case, the approval process ensures that the missed approach is not executed before the along-track point where the nominal DA/H occurs.

DA/H lower limit — aerodrome environment

A lower limit is applied to OCA/H as follows:

a) 75 m (246 ft) provided that the inner approach, inner transitional and balked landing surfaces of Annex 14 — *Aerodromes*, Volume I, Chapter 4, have been assessed and have not been penetrated; and

b) 90 m (295 ft) in all other cases.

Procedure complexity and OCA/H values below 75 m (246 ft)

2.2.3 If an OCH of 75 m (246 ft) is obtained using a straight-in approach, the procedure should not be further complicated by adding RF turns or reducing RNP solely to obtain lower OCH values.

2.3 STANDARD CONDITIONS

OCA/H is promulgated for those categories of aircraft for which the procedure is designed. The OCH values shall be based on the following standard conditions:

a) final approach vertical guidance and DA/H are based on pressure altimeter;

b) procedure is flown using flight director or autopilot;

c) aircraft dimensions are considered in certification (no additional procedure design action is required);

d) early go-around or missed approach is safeguarded by the certification and approval process; and

e) aircraft are appropriately certificated and approved by the appropriate authority for RNP AR operations.

2.4 TERRAIN EFFECTS

The application of the VEB for obstacle protection relies on accurate altimetry. Rapidly rising terrain, significant ridgelines or cliffs, steep valley walls and deep canyons may be associated with Bernoulli/Venturi/orographic lifting effects that can impact vertical performance. Areas where significant variations in pressure may occur must be identified during the design process, and their effect on the proposed procedure must be considered during the design process and validated in the safety assessment.

2.5 LATERAL PROTECTION

For RNP AR procedures, the semi-width of the primary area is defined as 2 × RNP. There are no buffer or secondary areas. Table 2-1 lists RNP values applicable to the specific instrument procedure segments.

Table 2-1. RNP values

Segment	*RNP AR*		
	Maximum	*Standard*	*Minimum*
Arrival	2	2	1.0
Initial	1	1	0.1
Intermediate	1	1	0.1
Final	0.5	0.3	0.1
Missed approach	1.0	1.0	0.1*
*See section 4.6 for limitations associated with MAS minimum values.			

2.6 VERTICAL PROTECTION

2.6.1 In the final approach and MAS, obstacle clearance is provided by two obstacle assessment surfaces (OAS):

a) a final approach surface based on the VEB of the barometric altimeter system; and

b) a horizontal surface based on a transition distance (TrD) (see 4.6.9), and a missed approach (Z) surface.

2.6.2 The certification, approval and training processes are designed to ensure barometric altimeter and crew performance are adequate to remain within this vertical profile.

Chapter 3

GENERAL CRITERIA

3.1 AIRCRAFT SPEED CATEGORIES

3.1.1 Aircraft performance differences have a direct effect on the airspace and visibility required for manoeuvres such as circling approach, turning missed approach, final approach descent and manoeuvering to land (including base and procedure turns). The most significant factor in performance is speed. Accordingly, five categories of typical aircraft have been established to provide a standardized basis for relating aircraft manoeuvrability to specific instrument approach procedures.

3.1.2 The landing configuration which is to be taken into consideration shall be defined by the operator or by the airplane manufacturer.

3.1.3 Aircraft categories will be referred to throughout this document by their letter designations as follows:

- Category A — less than 169 km/h (91 kt) indicated airspeed (IAS)
- Category B — 169 km/h (91 kt) or more but less than 224 km/h (121 kt) IAS
- Category C — 224 km/h (121 kt) or more but less than 261 km/h (141 kt) IAS
- Category D — 261 km/h (141 kt) or more but less than 307 km/h (166 kt) IAS
- Category E — 307 km/h (166 kt) or more but less than 391 km/h (211 kt) IAS

3.1.4 The criterion taken into consideration for the classification of aeroplanes by categories is the IAS at threshold (V_{at}) which is equal to the stall speed (V_{so}) multiplied by 1.3 or stall speed, in landing configuration at maximum certificated landing mass (V_{so}) multiplied by 1.23. If both V_{so} and V_{slg} are available, the higher resulting speed at threshold (V_{at}) is used. The ranges of speeds (IAS) in Tables 3-1 a) and 3-1 b) are to be used in calculating procedures. For conversion of these speeds to TAS, see 3.1.7.

Restriction on aircraft category and IAS

3.1.5 Where airspace requirements are critical for a specific category of aircraft, procedures may be based on lower speed category aircraft, provided use of the procedure is restricted to those categories. Alternatively, the procedure may be designated as limited to a specific maximum IAS for a particular segment without reference to category. True airspeed (TAS) should be calculated using the procedure speeds given in Tables 3-1 a) and 3-1 b).

Permanent change of category (maximum landing mass)

3.1.6 An operator may impose a permanent, lower landing mass, and use of this mass for determining V_{at} if approved by the State of the Operator. The category defined for a given aeroplane shall be a permanent value and thus independent of changing day-to-day operations.

Table 3-1 a). IAS (km/h)

Segment		*IAS by aircraft category (CAT)*				
		CAT A	*CAT B*	*CAT C*	*CAT D*	*CAT E*
Initial, intermediate		280	335	445	465	467
Final		185	240	295	345	As specified
Missed approach		205	280	445	490	As specified
Minimum airspeed restriction	Initial	204	259	389	389	As specified
	Final	185	222	259	306	As specified
	Intermediate	204	259	333	333	As specified
	Missed	185	241	306	343	As specified

Table 3-1 b). IAS (kt)

Segment		*IAS by aircraft category (CAT)*				
		CAT A	*CAT B*	*CAT C*	*CAT D*	*CAT E*
Initial, intermediate		150	180	240	250	250
Final		100	130	160	185	As specified
Missed approach		110	150	240	265	As specified
Minimum airspeed restriction	Initial	110	140	210	210	As specified
	Final	100	120	140	165	As specified
	Intermediate	110	140	180	180	As specified
	Missed	100	130	165	185	As specified

Note.— The speeds given in Table 3-1 b) are converted and rounded to the nearest multiple of five for operational reasons and from the standpoint of operational safety are considered to be equivalent.

Calculating TAS

3.1.7 IAS to TAS conversion for RNP AR procedures uses the following standard equations:

Non-SI units:

$$TAS = IAS * 171233 * [(288 + VAR) – 0.00198 * H]^{0.5}/(288 – 0.00198 * H)^{2.628}$$

SI units:

$$TAS = IAS * 171233 * [(288 + VAR) – 0.006496 * H]^{0.5}/(288 – 0.006496 * H)^{2.628}$$

where

IAS = indicated airspeed (kt or km/h, as appropriate)
TAS = true airspeed (kt or km/h, as appropriate)
VAR = variation from international standard atmosphere (ISA) (standard value +15) or local data for 95 per cent high temperature, if available
H = altitude (ft or m, as appropriate)

The above equations are incorporated in a Microsoft Excel spreadsheet, which is available together with the electronic version of the manual on the ICAO public website (www.icao.int) under "Publications".

3.2 CALCULATING TURN RADIUS AND BANK ANGLE

Speeds for turn calculations

3.2.1 For RNP AR procedures, the turn radius for fly-by and RF turns is calculated using a speed V = TAS + an assumed tailwind.

3.2.2 Determine the TAS for the turn using formulas in 3.1.7, and the airspeed for the highest aircraft category from Table 3-1 a) or 3-1 b) for which the procedure is designed.

3.2.3 A speed restriction may be applied to reduce turn radius; however, the maximum speed must be operationally acceptable for the aircraft intended for the operation. Only one speed restriction per approach segment is permitted, and the fastest airspeed appropriate for the highest speed category of aircraft for which the procedure is authorized shall be used to determine that speed.

Calculating the turn radius for fly-by turns

3.2.4 The turn radius applied at fly-by fixes is based on a standard bank angle of 18 degrees at a TAS plus assumed tailwind. Locate the highest speed aircraft category that will be published on the approach procedure and use the appropriate IAS in Table 3-1 a) (international system of units (SI)) or Table 3-1 b) (non-SI units), using the highest altitude allowed in the turn, calculate the TAS using the appropriate formulas in 3.1.7. For initial and intermediate segments, use the minimum altitude for the fix prior to the turn fix. Use the tailwind component (TWC) from Table 3-2 a) (SI units) or Table 3-2 b) (non-SI units) for the highest altitude within the turn. (For turns initiated at an altitude located between values in the table, a new TWC may be interpolated for that turn. If an interpolated wind value is ever used below 150 m (492 ft), then the 0 ft value for wind begins with 28 km/h (15 kt.))

3.2.5 For the MAS, use the altitude based on a seven per cent gradient with origin at OCA/H – HL (height loss: nominally 15 m (49 ft)).

3.2.6 Other tailwind gradients, or specific values, may be used after a site-specific determination of wind has been carried out based on that location's meteorological history (using available information from other sources). The source and values used should be documented.

Table 3-2 a). TWC and altitude (SI units)

TWC (km/h) for turn calculations	
Turn height above aerodrome (m)	*Standard tailwind component (kph)*
100	40
500	92
1 000	100
1 500	130
2 000	157
2 500	185
3 000	220
≥3 500	242

3.2.7 Select the appropriate TWC from Table 3-2 a) or 3-2 b) for the highest altitude within the turn and add the value to TAS. Determine the radius of turn (r).

1) Calculate the rate of turn (R) in degrees/second as follows:

$R = (6\ 355 \tan \alpha)/(\pi * V)$

where

V = (TAS + wind speed) in km/h;
α = bank angle

or

$R = (3\ 431 \tan \alpha)/(\pi * V)$

where

V = (TAS + wind speed) in kt;
α = bank angle

up to a maximum value of three degrees/second.

2) Calculate the turn radius (r) for a given value of R as follows:

$r = V/(20 * \pi * R)$

where

V = (TAS + wind speed)

Table 3-2 b). TWC and altitude (non-SI units)

TWC (kt) for turn calculations	
Turn height above aerodrome (ft)	*Standard tailwind component (kt)*
500	25
1 000	38
1 500	50
2 000	50
2 500	50
3 000	50
3 500	55
4 000	60
4 500	65
5 000	70
5 500	75
6 000	80
6 500	85
7 000	90
7 500	95
8 000	100
8 500	105
9 000	110
9 500	115
10 000	120
10 500	125
≥11 000	130

Turn radii based on non-standard bank angles

3.2.8 The standard design bank angle is 18 degrees. Lower or higher bank angles are allowed for smooth transitions, maintaining stabilized approaches, lower minima or to achieve specific leg lengths. Non-standard bank angles must fall in the window of values listed in Table 3-3.

Table 3-3. Bank angle window

Lowest above ground level (AGL) height in RF segment	*Maximum bank angle (degrees)*
<150 m (492 ft)*	≤3
≥150 m (492 ft)*	≤20

* Height above threshold

3.2.9 These criteria apply to construction at or below FL 190. Where turns above FL 190 are required, a bank angle of five degrees should be used. If five degrees results in a distance of turn anticipation (DTA) value greater than 20 NM, then:

r = 37 tan(0.5 * track change in degrees) km

r = 20 tan(0.5 * track change in degrees) NM

Note.— Aircraft using these procedures may be from States using SI units and with SI-unit airspeed indicators (ASIs). However, the standard non-SI unit aircraft category speeds are not exact conversions, they are rounded. The largest difference is for Category C, where the typical difference in turn radius can be 50 m. This is significant at low values of RNP (RNP 0.1 with a semi-width of only 370 m) and should be considered in turn boundary construction.

Fly-by turns — Distance of turn anticipation (DTA)

3.2.10 The DTA is the distance measured from the turn fix to the start and end points of a fly-by turn. The minimum length of a segment cannot be less than the sum of the DTAs associated with the start and end fix of the segment (see Figure 3-1).

$$DTA = r \tan(A/2)$$

where

r = radius of turn for the TAS for the fastest aircraft speed category for which the procedure is designed, calculated in accordance with 3.2.4

A = turn angle

Note 1.— These criteria differ from the formulas in Doc 8168 — Procedures for Air Navigation Services — Aircraft Operations (PANS-OPS)*, Volume II, Tables III-2-1-1 through III-2-1-20, because the roll-in/ roll-out distance is covered in RNP certification*.

Note 2.— The nominal distances for calculations of descent gradients are measured along the arc from the turn point to the bisector for the inbound leg component and along the arc length from the bisector to the roll-out point for the outbound leg component.

Calculation of bank angle for specific RF leg radius

3.2.11 Where RF legs are necessary, the bank angle required for a given TAS, tailwind speed and turn radius is:

SI units:

$\alpha = \arctan (TAS + W)^2/(127094 * r)$ given $R \leq (6355 * \tan \alpha)/[\pi*(TAS + W)] \leq 3°/sec$

Non-SI units:

$\alpha = \arctan (TAS + W)^2/(68625 * r)$ given $R \leq (3431 * \tan \alpha)/[(\pi*(TAS + W)] \leq 3°/sec$

where

W = tailwind speed
r = turn radius

3.2.12 To ensure that the maximum number of aircraft can fly the procedure, the required radius must result in a bank angle requirement within the window specified in Table 3-3.

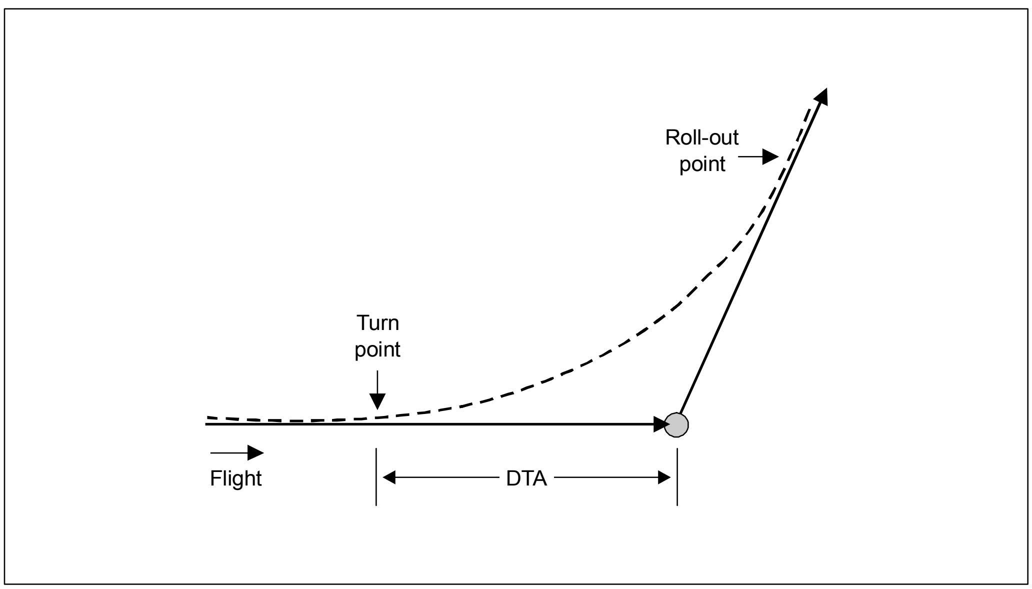

Figure 3-1. Distance of turn anticipation (DTA)