Cir 324
AN/186

# Guidelines for Lateral Separation of Arriving and Departing Aircraft on Published Adjacent Instrument Flight Procedures

Approved by the Secretary General
and published under his authority

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# ACRONYMS AND ABBREVIATIONS

| | |
|---|---|
| ADS-B | Automatic dependent surveillance — broadcast |
| ANSP | Air navigation services provider |
| ATC | Air traffic control |
| ATM | Air traffic management |
| ATS | Air traffic services |
| ATT | Along-track tolerance |
| BV | Buffer value(s) |
| CNS | Communications, navigation and surveillance |
| CRM | Collision risk model |
| DCPC | Direct controller-pilot communications |
| Ft | Foot |
| GNSS | Global navigation satellite system |
| HAZID | Hazard identification |
| IAF | Initial approach fix |
| IAP | Instrument approach procedures |
| IFP | Instrument flight procedure |
| IFR | Instrument flight rules |
| ILS | Instrument landing system |
| Kt | Knot |
| Min | Minute |
| LOCA | Lateral obstacle clearance areas |
| MLAT | Multilateration |
| NM | Nautical mile |
| OAS | Obstacle assessment surface |
| OCH | Obstacle clearance height |
| OR | Operational requirement |
| PBN | Performance-based navigation |
| Ref | Reference |
| RNAV | Area navigation |
| RNP | Required navigation performance |
| RNP APCH | Required navigation performance — approach |
| RNP AR APCH | Required navigation performance — authorization required — approach |
| SASP | Separation and Airspace Safety Panel |
| SID | Standard instrument departure |
| STAR | Standard instrument arrival |
| SUA | Special use airspace |
| TLS | Target level of safety |
| TMA | Terminal airspace |
| VHF | Very high frequency |
| WP | Working paper |

# Chapter 1

# OVERVIEW

## 1.1 INTRODUCTION

1.1.1 This circular presents guidelines and supporting material for the implementation of separation minima developed for arriving and departing aircraft on published adjacent IFPs. This material supports provisions included in the *Procedures for Air Navigation Services — Air Traffic Management* (PANS-ATM, Doc 4444), Chapter 5, 5.4.1.2.1.4. (see Chapter 2 of this circular). It provides for two separation minima:

a) lateral separation between certain PBN-capable aircraft utilizing IFPs (ref. PANS-ATM, 5.4.1.2.1.4.1 a)); and

b) lateral separation between aircraft on IFPs using protected areas (ref. PANS-ATM, 5.4.1.2.1.4.1 b)).

1.1.2 Work on the development of minima to laterally separate aircraft on published adjacent IFPs was initiated during the 12th SASP Working Group of the Whole (SASP-WG/WHL/12) in November 2007 (see ref. 1[*]). The amendment proposed to separate aircraft from other aircraft by requiring that the protected areas to not overlap (ref. *Procedures for Air Navigation Services — Aircraft Operations*, Volume II — *Construction of Visual and Instrument Flight Procedures* (PANS-OPS, Doc 8168)).

1.1.3 Further work on the subject, particularly related to the safety assessment, was presented at the 13th and 14th meetings of SASP (SASP-WG/WHL/13 and SASP-WG/WHL/14) in May and November 2008, respectively, (see refs. 2 to 9). The 14th meeting marked the beginning of extensive work on safety assessment by collision risk modelling for PANS-ATM, proposed paragraph 5.4.1.2.1.4.1 a) (see refs. 10 to 13 for pertinent WPs presented at SASP-WG/WHL/15).

1.1.4 Examples of New Zealand's use of non-overlapping protected areas as a basis for PANS-ATM proposed paragraph 5.4.1.2.1.4.1 b) can be found at Appendix A to this circular.

## 1.2 SCOPE

The material in this circular is limited to the application of:

a) lateral separation minima for arriving and/or departing aircraft being separated on published IFPs;

b) lateral separation minima between aircraft on published adjacent IFPs (SID, STAR, IAP, including holding patterns); and

c) lateral separation minima for use primarily in terminal areas where procedural control is exercised.

* References 1 to 25 can be found in Appendix D of this circular.

## 1.3 DOCUMENT STRUCTURE

The two paragraph provisions, i.e. 5.4.1.2.1.4.1 a) and b), of the proposed PANS-ATM amendment at 5.4.1.2.1.4 are reflected in the document structure in that the single thread of Chapters 1 and 2 splits onto two threads in Chapters 3 and 4 before rejoining in Chapter 5 (see Figure 1-1).

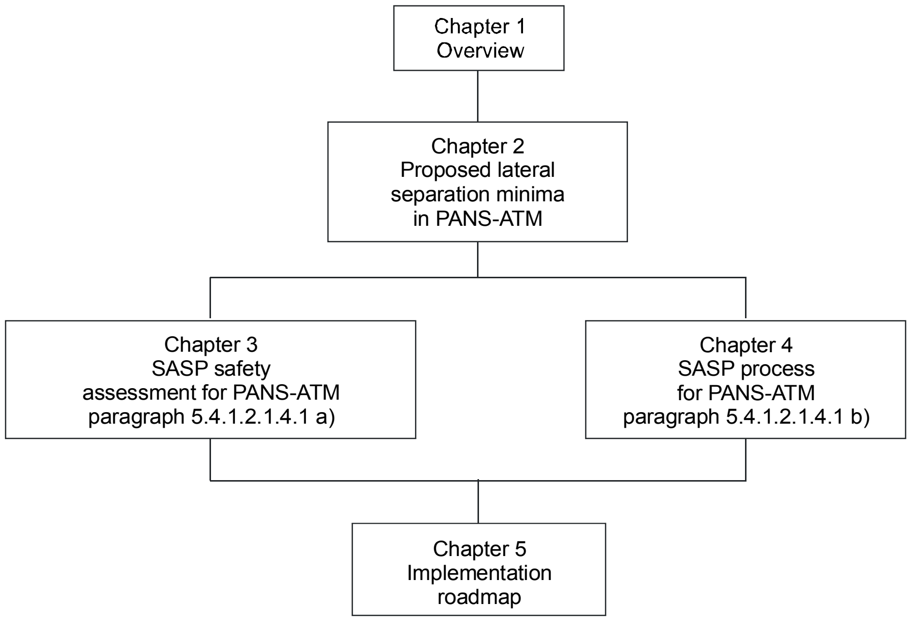


**Figure 1-1. Document structure**

# Chapter 2

# PROPOSED LATERAL SEPARATION MINIMA

## 2.1 INTRODUCTION

This chapter presents an extract of the new PANS-ATM amendment at 5.4.1.2.1.4.

**Chapter 5**

**SEPARATION METHODS AND MINIMA**

. . .

**5.4 HORIZONTAL SEPARATION**

. . .

**5.4.1 Lateral separation**

. . .

5.4.1.2 Lateral separation criteria and minima

5.4.1.2.1 Means by which lateral separation may be applied include the following:

. . .

5.4.1.2.1.4 *Lateral separation of aircraft on published adjacent instrument flight procedures for arrivals and departures*

5.4.1.2.1.4.1 Lateral separation of departing and/or arriving aircraft, using instrument flight procedures, will exist:

a) where the distance between RNAV 1, Basic RNP 1, RNP APCH and/or RNP AR APCH tracks is not less than 13 km (7 NM); or

b) where the protected areas of tracks designed using obstacle clearance criteria do not overlap and provided operational error is considered.

*Note 1.— The 13 km (7 NM) value was determined by collision risk analysis using multiple navigation specifications. Information on this analysis is contained in Circular 324,* Guidelines for Lateral Separation of Arriving and Departing Aircraft on Published Adjacent Instrument Flight Procedures*.*

*Note 2.— Circular 324 also contains information on separation of arrival and departure tracks using non-overlapping protected areas based on obstacle clearance criteria, as provided for in the* Procedures for Air Navigation Services — Aircraft Operations, *Volume II* — Construction of Visual and Instrument Flight Procedures *(PANS-OPS, Doc 8168).*

*Note 3.— Provisions concerning reductions in separation minima are contained in Chapter 2, ATS Safety Management, and Chapter 5, Separation Methods and Minima, Section 5.11.*

*Note 4.— Guidance concerning the navigation specifications is contained in the* Performance-based Navigation (PBN) Manual *(Doc 9613).*

. . .

## 2.2 SUA

2.2.1 SUA may contain a variety of activities hazardous to aviation, such as rocket launches, artillery fire and air combat. Due to this great variation, the separation of the activity inside the SUA from the edge of the SUA could not be peremptorily determined by SASP in order to provide generic guidance. Some types of activities may bring the hazardous operation right against the inside edge of the airspace, while others may utilize a buffer to separate aircraft or activities inside the SUA from the edge. The result of this ambiguity led the SASP to conclude that it is impossible to determine a single separation minimum from a SUA that would work in all cases.

2.2.2 For this reason, the new amendment proposal was for application between "aircraft on published adjacent instrument flight procedures in terminal areas". SASP strongly suggests that States wishing to determine the separation between PBN aircraft generally in terminal areas and the edge of SUAs carry out an individual safety assessment for each related SUA. States may elect to use *as reference only* the separation minima in PANS-ATM, 5.4.1.2.1.4.1 a) and/or 5.4.1.2.1.4.1 b). Depending on the results of the safety assessment, an additional buffer may or may not be used from the edge of the SUA.

# Chapter 3

# SASP SAFETY ASSESSMENT FOR PANS-ATM PARAGRAPH 5.4.1.2.1.4.1 a)

## 3.1 INTRODUCTION

This chapter summarizes the safety assessment performed by the SASP to determine the lateral separation minimum, contained in 5.4.1.2.1.4.1 a) of PANS-ATM Amendment No. 3. In this context, this chapter first describes the scope of any SASP safety assessment and then outlines the methodology used to arrive at the lateral separation minimum in 5.4.1.2.1.4.1 a).

## 3.2 SCOPE OF SASP SAFETY ASSESSMENT

3.2.1 It is useful and necessary to distinguish between assessments undertaken by States for purposes of implementation at the local or regional level and those undertaken by SASP from a global perspective. An assessment undertaken for global purposes does not always contain the information required to address specific local implementation requirements.

3.2.2 This difference in assessment scope is depicted in Figure 3-1; it suggests, for example, that as it is the local operational environment into which an ICAO Standard is to be integrated, which largely determines safety considerations, the full safety assessment can only be completed for each local implementation. As such, in this case airspace planners need to complement the SASP assessment with a regional or local implementation-focussed assessment. It should be noted that a local implementation assessment may not necessarily require a regional assessment but may be initiated by an ANSP on a case-by-case basis.

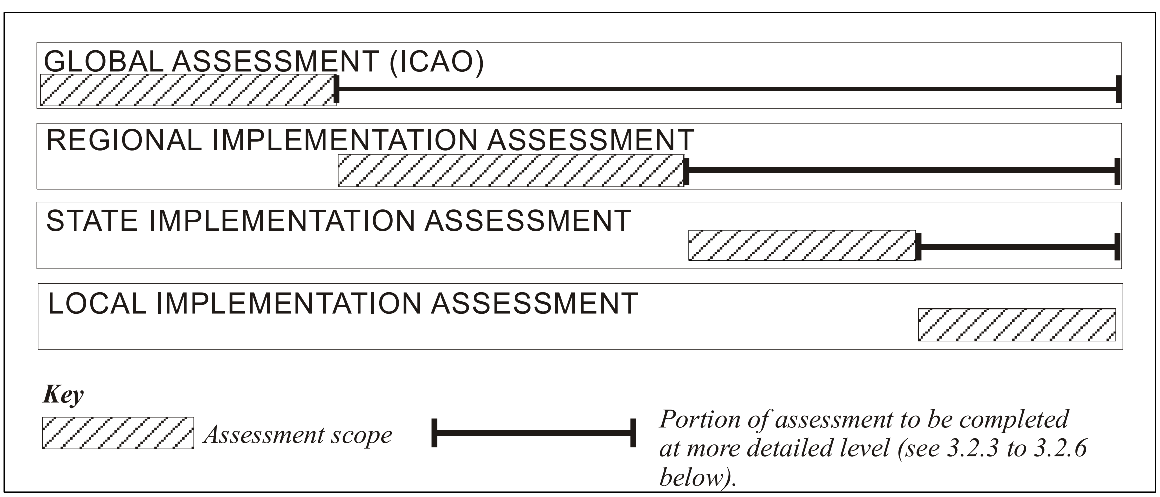


**Figure 3-1. Safety assessment scope**

3.2.3 States should note that the SASP's assessment was usually based on a number of assumed characteristics related to either the airspace environment or aircraft performance. These characteristics may not necessarily have been the same as those relevant to any particular regional, State or local implementation.

3.2.4 In undertaking regional implementation, a supporting safety assessment should begin with a review of the SASP's global assessment, taking particular note of the assumed characteristics used in that assessment. Where these characteristics are the same or more stringent than those within the region, the region only needs to focus on undertaking an assessment of issues related specifically to regional implementation.

3.2.5 A State assessment need not necessarily follow a regional assessment but could be initiated by a State on its own initiative. In this case, as with the regional assessment, a supporting safety assessment should begin with a review of the SASP's global assessment, taking particular note of the assumed characteristics used in that assessment. Where these characteristics are the same or more stringent than those within the State, then the State only needs to focus on undertaking an assessment of issues related specifically to State implementation.

3.2.6 A local implementation assessment would normally be a supporting activity for a State assessment and would focus specifically on implementation issues such as HAZID. However, there may be circumstances where the ANSP may need to review the SASP's global assessment and/or the regional assessment, taking particular note of the assumed characteristics used in that assessment.

## 3.3 OBJECTIVE OF THE SAFETY ASSESSMENT

3.3.1 The general objective of the SASP safety assessment was to determine the minimum safe separation between published adjacent IFPs based on any combination of the following operational approvals: RNAV 1, Basic-RNP 1, RNP APCH and RNP AR APCH.

3.3.2 A minimum distance between published adjacent IFPs is considered "safe" when the level of aircraft collision risk does not exceed a TLS of $5 \times 10^{-10}$ collisions per arrival-departure pair. The resultant separation is considered safe subject to a safety assessment (ref. Annex 11 — *Air Traffic Services*) being undertaken for implementation into a local environment.

## 3.4 ASSUMPTIONS

3.4.1 Several assumptions were made during the safety assessment by SASP with regard to the operational scenario and CRM.

3.4.2 The first assumption concerned the geometry of the published adjacent IFPs. This is shown in Figure 3-2 where it is assumed that the turn angle for intercepting the intermediate/final approach segment is between 15 and 90 degrees. The departing aircraft flies a certain distance beyond the end of the runway before turning and flying back parallel to the approach segment.

3.4.3 TMA operating aircraft speeds were assumed given that the published adjacent IFPs would be located quite close to the airport where aircraft would climb and descend on published adjacent tracks.

3.4.4 A terminal environment was envisaged assuming 400 air traffic movements per day (200 arriving and 200 departing flights per day).

3.4.5 The aircraft, either arriving or departing, are assumed to be approved for either RNAV 1, Basic-RNP 1, RNP APCH and/or RNP AR APCH operations.

3.4.6 Procedural ATC without radar, ADS-B or MLAT-based surveillance was assumed.

## 3.5 DEVELOPMENT OF SASP SAFETY ASSESSMENT

In the context of the assessment of the safety of a separation minimum, only the safety risk due to navigation performance was taken into account and is described below. A HAZID was not undertaken and would need to be undertaken for implementation, as per 3.2.1 and 3.2.2 above.

### 3.5.1 Safety assessment for navigation performance

3.5.1.1 Following the guidance provided in the *Manual on Airspace Planning Methodology for the Determination of Separation Minima* (Doc 9689), SASP agreed at SASP-WG/WHL/14 to use the "Evaluation of system risk against a threshold" method for the safety assessment for navigation performance.

3.5.1.2 For the threshold method, the proposed system, as portrayed in 3.3.1 above, is considered to be safe when a quantitative estimate of the risk in the proposed system is less than the prevailing threshold value.

3.5.1.3 During SASP-WG/WHL/14, SASP started the development of a CRM to obtain a quantitative estimate of the risk and completed this work during SASP-WG/WHL/15 (see refs. 9 and 11 to 13). In the absence of an existing threshold for the proposed system, SASP agreed on a TLS of $5 \times 10^{-10}$ collisions per arrival-departure pair at SASP-WG/WHL/15 (see refs. 14 and 17).

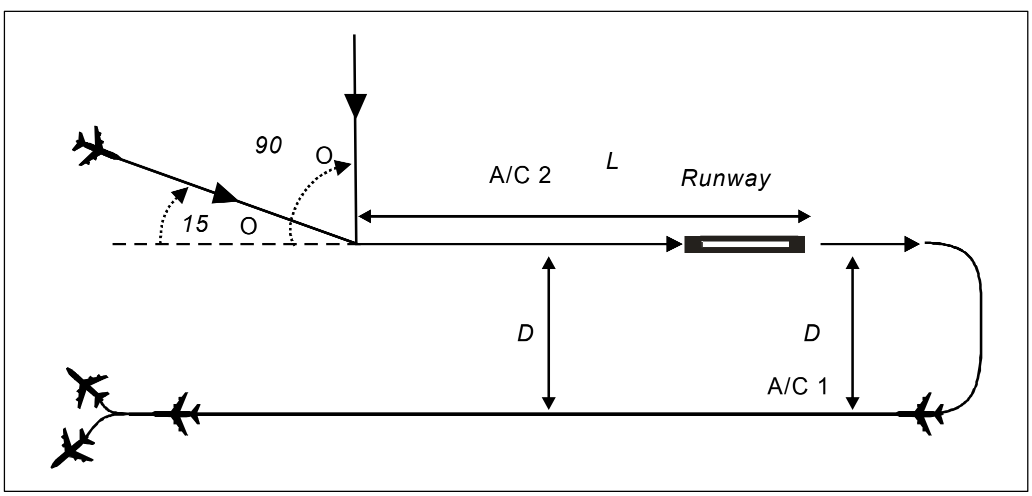


**Figure 3-2. Horizontal view of the operational scenario**

### 3.5.2 TLS

3.5.2.1 The subject of a TLS for lateral separation of aircraft on published adjacent IFPs in terminal areas was discussed by SASP at SASP-WG/WHL/15. It was noted that in the absence of such a TLS, there were various methods that might be used to determine one. One method could be to take the TLS that the SASP has used for en route of $5 \times 10^{-9}$ fatal accidents per flight hour and translating that into fatal accidents per operation, i.e. arrival-departure aircraft pair. Another method would be to base the required TLS on safety targets utilized in the PANS-OPS for ILS operations in the terminal area.

3.5.2.2 Three methods of calculating obstacle clearance altitude/height are described in PANS-OPS, Volume II, Part II, 1.1.5 (see ref. 25). In order to carry out its work, SASP selected the method based on a set of OAS. This method was best documented in the Second edition — 1982, PANS-OPS, Volume II (see ref. 26), where in Part III, Attachment A, 1.2 and 1.3, the basic geometry of the OAS was defined by the approach surfaces, which were developed using a data-matched mathematical model. The data-matched model produced lateral and vertical distributions at selected ranges in the final approach which were combined to produce isoprobability contours at those ranges. A major factor used to define the selection of an isoprobability contour for practical application was that the total risk summed over all ranges in the final approach was specified to lie within the overall safety target of $1 \times 10^{-7}$. Consequently, the collision probability resulting from the use of PANS-OPS OAS for ILS approaches is believed to be approximately $10^{-9}$. This means that the expected number of hull losses due to an arriving aircraft colliding against terrain or some other obstacle equals approximately $10^{-9}$ per arrival.

3.5.2.3 SASP opted for the threshold value determined by the second method for the determination of a TLS for aircraft-to-aircraft separation described in 3.5.3.1 below. Since a midair collision between an arriving aircraft and a departing aircraft involves the loss of two aircraft, TLS for aircraft-to-aircraft separation of $5 \times 10^{-10}$ collisions per arrival-departure pair was adopted.

### 3.5.3 Collision risk methodology

3.5.3.1 In line with previous SASP safety assessments, SASP addressed two components of collision risk due to navigation performance, namely:

a) collision risk due to typical navigation performance; and

b) collision risk due to atypical navigation performance.

The sum of the two components of risk was to be compared against the agreed TLS.

3.5.3.2 Collision risk due to typical navigation performance, also referred to as technical risk, addresses the risk due solely to typical navigation errors of aircraft approved for the navigation specifications listed in 3.3.1 above.

3.5.3.3 For the current assessment, collision risk due to atypical navigation performance was taken as the risk due to one particular type of operational error, or blunder, namely, the arriving aircraft missing the turn.

### 3.5.4 Collision risk due to typical navigation performance

3.5.4.1 Consider the collision risk due to typical navigation performance. Based on the general CRM given in Appendix D, reference 24, the following specific model for the proposed system described in 3.3.1 was developed and used (see refs. 11 and 13):

$$CR(t_0, t_1) = 2 \times \int_{-\infty}^{\infty} \int_{-\infty}^{\infty} \int_{\tau_{\min}}^{\tau_{\max}} \int_{t_0}^{t_1} HOP(t \mid V_1, V_2, \tau) \times \left[ \frac{2V_{rel}}{\pi \lambda_{xy}} + \frac{|\dot{z}|}{2\lambda_z} \right] g(\tau) f_1(V_1) f_2(V_2) dt d\tau dV_1 dV_2 \quad (1)$$

The model calculates the collision risk $CR(t_0, t_1)$, expressed in collisions per arrival-departure pair, over a time interval $[t_0, t_1]$ where $t_0$ denotes the beginning of the initial approach, and $t_1$ denotes the time of touchdown.

3.5.4.2 Most of the parameters in equation (1) above have their usual meaning, e.g. aircraft speeds and dimensions ($V_1$, $V_2$, $V_{rel}$, $|\dot{z}|$, $\lambda_{xy}$, $\lambda_z$), aircraft speed error probability densities ($f_1(V_1)$, ($f_2(V_2)$), and the probability of vertical overlap ($P_z(h_z)$) (see ref. 24).

3.5.4.3 One of the specificities of the model of equation (1) concerns the dependence of the probability of horizontal overlap at time $t$, $HOP(t \mid V_1, V_2, \tau)$, on the duration $\tau$ of the turn from initial approach to intermediate/final approach. The duration $\tau$ of the turn itself is modelled as a random variable with a rectangular probability distribution over a time interval $[\tau_{min}, \tau_{max}]$.

3.5.4.4 Another specificity concerns the dependence of the probability of horizontal overlap $HOP(t \mid V_1, V_2, \tau)$ on the geometry of the proposed system in Figure 3-2 and the typical navigation performance of the envisaged aircraft population specified in 3.3.1.

3.5.4.5 As regards the dependence of $HOP(t \mid V_1, V_2, \tau)$ on the geometry, a particular element concerns the location of the departing aircraft at the initial time $t_0$. The height of the departing aircraft at the initial time $t_0$ plays a similar part with respect to the probability of vertical overlap $P_z(h_z)$. The dependence of the probabilities of horizontal and vertical overlap on the initial location and height, assuming $x_{10}$ and $h_{10}$, of the departing aircraft has been accounted for by maximizing the estimate of the collision risk over all possible values $x_{10}$ and $h_{10}$, and comparing the resulting maximum risk against the TLS.

3.5.4.6 The final element to be mentioned here is the role of the navigation specifications. The navigation specifications have been used to infer values for the parameters of the navigation error probability distributions. It should be noted that the navigation specifications do not specify the type of navigation error probability distribution. Therefore, both Gaussian and double exponential probability distributions have been used for the typical along-track and cross-track navigation error distributions. For RNP aircraft, the standard deviations were based on the RNP integrity (2 × *accuracy*) requirement. For RNAV aircraft the standard deviations were based on the containment requirement (1 × *accuracy*).

3.5.4.7 Tables 3-1 and 3-2 show SASP CRM results for Basic-RNP 1 aircraft pairs and RNAV 1 pairs, respectively. The risk values shown are the maximum collision risks, in collisions per arrival-departure pair, over all starting positions and starting heights of the departing aircraft as set out in 3.5.4.5 above. Results were obtained for a number of track spacings *D*, with a shallow turn angle (15 degrees) and also with sharper turn angles (45 and 90 degrees).

3.5.4.8 The case of a departing Basic-RNP 1 aircraft and an arriving RNP 0.3 aircraft is covered by the Basic-RNP 1 pair case (see Table 3-1). The initial and intermediate approaches are flown as Basic-RNP 1 before the arriving aircraft switches to RNP 0.3 for the final approach. The maximum collision risk will occur while both aircraft are flying with Basic-RNP 1 navigational accuracy.

3.5.4.9 Maximum collision risk values for RNAV 1 aircraft in Table 3-2 are higher than the corresponding Basic-RNP 1 values. The separation distance $D$ = 7 NM results in all collision values falling under the TLS of $5 \times 10^{-10}$ collisions per arrival-departure pair for all turn angles. It should be remembered that the values in the tables are **maximum** collision risks over all starting positions and heights for the departing aircraft. As such they are very conservative risk estimates. An average risk is more appropriate and a fairer measure of the risk experienced by aircraft under the scenario shown in Figure 3-2. Averaging would reduce the CR by a factor of approximately 10 and would bring the risk estimates under the TLS, e.g. a smaller separation distance of $D$ = 6 NM.

3.5.4.10 Based on RNAV 1 versus RNAV 1 CRM results for turns up to 90 degrees presented in Table 3-2, SASP agreed to the 7 NM lateral separation minimum for any mix of RNAV 1, Basic-RNP 1, RNP APCH and/or RNP AR APCH. It should be emphasized that the collision risk addressed in Tables 3-1 and 3-2 is that due to typical navigation performance for the pertinent navigation specifications. SASP also considered collision risk due to atypical navigation performance. (see 3.5.5.1 below).

**Table 3-1. Maximum collision risk (in collisions per arrival-departure pair) for Basic-RNP 1 aircraft over all starting positions and starting heights for the departing aircraft (based on nominal aircraft speeds of $\hat{V}_1 = 150$ kt and $\hat{V}_2 = 120$ kt for the departing and arriving aircraft, respectively; climb and descent rates of 380 ft/min and 397 ft/min; 10 NM initial approach segment, 20.25 NM from turning point to touchdown)**

| *Basic-RNP 1 pairs* | | | |
|---|---|---|---|
| *Turn angle (degrees)* | *Distance between tracks D (NM)* | *Collision risk with Gaussian position errors σ = 0.33843* | *Collision risk with double exponential position errors λ = 0.162602* |
| 15 | 6 | 2.3E-21 | 9.0E-18 |
| 15 | 5 | 6.0E-16 | 3.9E-15 |
| 15 | 4 | 1.5E-11 | 1.5E-12 |
| 15 | 3 | 3.2E-08 | 6.0E-10 |
| | | | |
| 45 | 6 | 1.1E-16 | 3.7E-16 |
| 45 | 5 | 3.0E-12 | 1.8E-13 |
| 45 | 4 | 7.5E-09 | 8.0E-11 |
| 45 | 3 | 1.9E-06 | 3.7E-08 |
| | | | |
| 90 | 6 | 5.0E-14 | 3.7E-14 |
| 90 | 5 | 3.4E-10 | 1.3E-11 |
| 90 | 4 | 2.0E-07 | 4.3E-09 |
| 90 | 3 | 1.2E-05 | 1.1E-06 |

3.5.4.11 The collision risk values in Tables 3-1 and 3-2 were based on nominal aircraft speeds of $\hat{V}_1$ = 150 kt and $\hat{V}_2$ = 120 kt for the departing and arriving aircraft, respectively. These values are related to the initial collision risk modelling work at SASP-WG/WHL/14 (see ref. 9). Three more sets of nominal aircraft speeds related to different aircraft operating experience are described in reference 12 of Appendix D. These sets are $\hat{V}_1$ = 145 kt and $\hat{V}_2$ = 235 kt, $\hat{V}_1$ = 215 kt and $\hat{V}_2$ = 230 kt; and $\hat{V}_1$ = 145 kt and $\hat{V}_2$ = 225 kt. The main difference between the initial values of the nominal aircraft speeds and those in reference 12 concerns the speed of the arriving aircraft, which is much higher in the case of reference 12. A second difference concerns the nominal speed of the departing aircraft under the second set of reference values, namely, 215 kt as opposed to 150 kt.

**Table 3-2. Maximum collision risk (in collisions per arrival-departure pair) for RNAV 1 aircraft over all starting positions and starting heights for the departing aircraft (based on nominal aircraft speeds of $\hat{V}_1 = 150$ kt and $\hat{V}_2 = 120$ kt for the departing and arriving aircraft, respectively; climb and descent rates of 380 ft/min and 397 ft/min; 10 NM initial approach segment, 20.25 NM from turning point to touchdown)**

| *RNAV 1 pairs* | | |
|---|---|---|
| *Turn angle (degrees)* | *Distance between tracks D (NM)* | *Collision risk with double exponential position errors λ = 0.333333* |
| 15 | 7 | 9.0E-12 |
| 15 | 6 | 1.5E-10 |
| 15 | 5 | 2.7E-09 |
| 15 | 4 | 4.6E-08 |
| | | |
| 45 | 7 | 2.6E-11 |
| 45 | 6 | 5.0E-10 |
| 45 | 5 | 1.0E-08 |
| 45 | 4 | 2.0E-08 |
| | | |
| 90 | 7 | 2.7E-10 |
| 90 | 6 | 4.4E-09 |
| 90 | 5 | 7.0E-08 |
| 90 | 4 | 1.0E-06 |

3.5.4.12 Taking the four sets of nominal aircraft speeds into account, the collision risk calculations have been repeated for the following two combinations of nominal aircraft speeds for the departing and arriving aircraft (see ref. 16):

a) $\hat{V}_1$ = 150 kt and $\hat{V}_2$ = 230 kt; and
b) $\hat{V}_1$ = 215 kt and $\hat{V}_2$ = 230 kt.

3.5.4.13 The collision risk values in Tables 3-1 and 3-2 were also based on nominal climb and descent rates of 380 ft/min and 397 ft/min for the departing and arriving aircraft, respectively. These values are related to the initial collision risk modelling work at SASP-WG/WHL/14 (see ref. 9). Three more sets of nominal climb and descent rates related to different aircraft operating experience are described in reference 12, namely, 1 500 ft/min and 1 250 ft/min; 2 250 ft/min and 1 250 ft/min; and 1 750 ft/min and 1 250 ft/min. Note that the descent rate was the same for each set.

3.5.4.14 Taking these additional sets into account, the collision risk calculations have been repeated for the following combinations of climb and descent rates for the departing and arriving aircraft (see ref. 16):

a) climb rate 1 250 ft/min, descent rate 1 250 ft/min;

b) climb rate 1 700 ft/min, descent rate 1 250 ft/min; and

c) climb rate 2 250 ft/min, descent rate 1 250 ft/min.

3.5.4.15 The results of the additional calculations for the aircraft speeds, climb and descent rates, and combinations thereof confirmed the safety of the 7 NM separation minimum.

### 3.5.5 Collision risk due to atypical navigation performance

3.5.5.1 In relation to collision risk due to atypical navigation performance, a single type of operational error or blunder has been examined (see 3.5.3.3 above). Specifically, the arriving aircraft missing the turn from the initial approach segment to the intermediate approach segment, continuing flying along its original heading, and crossing through the departure path (see Figure 3-3). Collision risk for this blunder scenario has been modelled in two different ways (see refs. 11 and 12). Both models calculate an estimate of the collision risk given that a blunder has occurred. These risk estimates then need to be multiplied by the probability of a blunder occurring to obtain an estimate of the collision risk due to atypical navigation performance.

3.5.5.2 The first approach used the same type of CRM as given in equation (1) but with the probability of horizontal overlap $HOP(t \mid V_1, V_2)$ now based on the straight track of the blundering arriving aircraft and no longer dependent on the turn duration (see ref. 11). The approach also assumed that the blunder would not be detected until OCH, after which an instantaneous climb out would start with a 2.5 per cent climb gradient.

3.5.5.3 The second approach comprised two parts and can be summarized as follows (see ref. 12). The first part began with determining, for a blundering arriving aircraft, the times of entering and exiting a “lateral overlap band” $[-\lambda_{xy}/2, \lambda_{xy}/2]$ about the nominal departure path. It was then determined during which time interval a departing aircraft has to pass an arbitrary reference point (e.g. the projection of the departure end of the runway on the parallel departure path) to be actually in horizontal overlap with a blundering arriving aircraft. On the assumption that the aircraft departures follow a Poisson process, it is then possible to calculate the probability that a blundering arriving aircraft will be in horizontal overlap with a departing aircraft. Note that the Poisson departure process provides a means for accounting for traffic density.

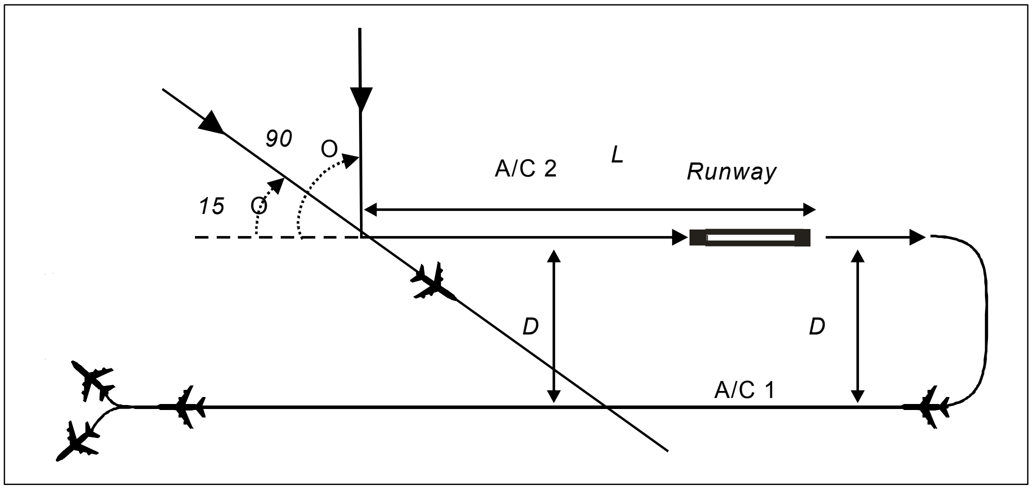


**Figure 3-3. Horizontal view of the blunder scenario**

3.5.5.4 The second part of the (second) approach concerns the probability of vertical overlap between a blundering arriving aircraft and a departing aircraft given that they are in horizontal overlap. The first step of this part was to calculate the height band occupied by the blundering aircraft during the period of time of horizontal overlap. Similarly, the height band occupied by a departing aircraft during a horizontal overlap was calculated. A vertical overlap was defined to occur when there was any overlap between the two height bands. To cast this into probabilistic terms, a "Monte Carlo" simulation was used. The probability of vertical overlap given horizontal overlap was estimated as the proportion of the total number of runs in which a vertical overlap occurred.

3.5.5.5 Finally, the probabilities of horizontal overlap and vertical overlap given the occurrence of horizontal overlap were multiplied to obtain the probability of collision between the blundering arriving aircraft and the departing aircraft. The resulting probability of collision was multiplied by the probability of a blunder occurring for comparison against the applicable risk threshold.

3.5.5.6 Both modelling methods were verified by estimating the collision risk between a blundering arriving aircraft and departing aircraft. This provided similar results under similar assumptions (see ref. 15). In this context, it should be remarked that both approaches dealt with the case of the blundering aircraft's track crossing the straight part of the departure track. In addition, in reference 12 the case of a blundering aircraft's track crossing the circular part of the departure track was also analysed. This case occurred for the smaller turn angles given by tan(*turn angle*) $\leq D/L$, where $D$ denotes the spacing between the parallel approach and departure segments, and $L$ denotes the distance from the turning point to the departure end of the runway (see Figure 3-3).

3.5.5.7 Based on the second modelling approach to the blundering aircraft, the SASP has derived maximum tolerable blunder rates for the following combinations of turn angle and vertical profile (see ref. 12):

a) 30-degree turn angle, and arriving aircraft descending;

b) 30-degree turn angle, and arriving aircraft in level flight;

c) 15-degree turn angle, and arriving aircraft descending; and

d) 15-degree turn angle, and arriving aircraft in level flight.

3.5.5.8 Tables 3-3 to 3-6 show the calculated maximum tolerable rates of blunders. The maxima vary with the parameter sets $S_{M,}$, $S_F$, $S_A$ or $S_W$ defined in reference 12 and the departing aircraft flow rate *f*. Each parameter set defines a specific set of random speeds and climb and descent rates for the aircraft and also an initial altitude for the arriving aircraft (see ref. 12 for further details).

3.5.5.9 The maximum tolerable blunder rates in Tables 3-3 to 3-6 were obtained by dividing the available risk budget (TLS) by the (conditional) probabilities of collision given that a blunder occurred, except for the cases where the table values are equal to 1. For those cases, the (conditional) probabilities of collision were effectively zero, meaning, theoretically, that a blunder could be tolerated on each approach.

3.5.5.10 The entries in the Tables 3-3 to 3-6 are based on a TLS of $5 \times 10^{-10}$ midair collisions per arrival-departure pair. Maximum tolerable blunder rates for different risk budgets may be obtained by multiplying the table entries (other than 1) by the ratio of the available budget and the TLS value of $5 \times 10^{-10}$.

3.5.5.11 The tables show that there are only five columns in which the maximum tolerable rates of blunder are sufficiently small to be of any practical relevance, namely, the columns for parameter sets $S_F$ and $S_A$ in Table 3-4, and the columns for parameter sets $S_F$, $S_A$, and $S_W$ in Table 3-6. These are both tables for which the blundering aircraft is assumed to maintain its altitude after failing to turn onto the intermediate/final approach. The largest of the values, $4.6524 \times 10^{-5}$, shown in Table 3-4, is equivalent to one blunder per 21 494 arrivals. The smallest of the values, $3.0645 \times 10^{-7}$, shown in Table 3-6, is equivalent to one blunder per 3 263 175 arrivals.

3.5.5.12 The appropriate ATS authority should consider the material contained in this chapter when implementing and monitoring the lateral separation minimum in PANS-ATM, 5.4.1.2.1.4.1 a).

**Table 3-3. Maximum tolerable rate of blunders (blunders/arrival) for 30-degree turn angle and descending arriving aircraft**

| | *Parameter set* | | | |
|---|---|---|---|---|
| *f* (take-offs/hr) | $S_M$ | $S_F$ | $S_A$ | $S_W$ |
| 6 | 1.0000E+00 | 1.0206E-01 | 3.2571E-01 | 1.0000E+00 |
| 9 | 1.0000E+00 | 6.8205E-02 | 2.1756E-01 | 1.0000E+00 |
| 12 | 1.0000E+00 | 5.1279E-02 | 1.6348E-01 | 1.0000E+00 |
| 15 | 1.0000E+00 | 4.1124E-02 | 1.3104E-01 | 1.0000E+00 |
| 18 | 1.0000E+00 | 3.4354E-02 | 1.0941E-01 | 1.0000E+00 |
| 21 | 1.0000E+00 | 2.9519E-02 | 9.3959E-02 | 1.0000E+00 |

**Table 3-4. Maximum tolerable rate of blunders (blunders/arrival) for 30-degree turn angle and arriving aircraft in level flight**

| | *Parameter set* | | | |
|---|---|---|---|---|
| *f* (take-offs/hr) | $S_M$ | $S_F$ | $S_A$ | $S_W$ |
| 6 | 4.0069E-01 | 4.6524E-05 | 3.2000E-05 | 5.5928E-02 |
| 9 | 2.6797E-01 | 3.1093E-05 | 2.1375E-05 | 3.7378E-02 |
| 12 | 2.0160E-01 | 2.3377E-05 | 1.6062E-05 | 2.8104E-02 |
| 15 | 1.6179E-01 | 1.8747E-05 | 1.2874E-05 | 2.2539E-02 |
| 18 | 1.3524E-01 | 1.5661E-05 | 1.0749E-05 | 1.8829E-02 |
| 21 | 1.1629E-01 | 1.3457E-05 | 9.2312E-06 | 1.6179E-02 |

**Table 3-5. Maximum tolerable rate of blunders (blunders/arrival) for 15-degree turn angle and descending arriving aircraft**

| | *Parameter set* | | | |
|---|---|---|---|---|
| *f* (take-offs/hr) | $S_M$ | $S_F$ | $S_A$ | $S_W$ |
| 6 | 1.0000E+00 | 3.5569E-01 | 1.0000E+00 | 1.0000E+00 |
| 9 | 1.0000E+00 | 2.3741E-01 | 1.0000E+00 | 1.0000E+00 |
| 12 | 1.0000E+00 | 1.7826E-01 | 1.0000E+00 | 1.0000E+00 |
| 15 | 1.0000E+00 | 1.4278E-01 | 1.0000E+00 | 1.0000E+00 |
| 18 | 1.0000E+00 | 1.1912E-01 | 1.0000E+00 | 1.0000E+00 |
| 21 | 1.0000E+00 | 1.0222E-01 | 1.0000E+00 | 1.0000E+00 |

**Table 3-6. Maximum tolerable rate of blunders (blunders/arrival) for 15-degree turn angle and arriving aircraft in level flight.**

| | *Parameter set* | | | |
|---|---|---|---|---|
| *f* (take-offs/hr) | $S_M$ | $S_F$ | $S_A$ | $S_W$ |
| 6 | 1.0000E+00 | 1.1639E-06 | 3.0307E-06 | 1.0662E-06 |
| 9 | 1.0000E+00 | 7.7686E-07 | 2.0223E-06 | 7.1165E-07 |
| 12 | 1.0000E+00 | 5.8333E-07 | 1.5182E-06 | 5.3438E-07 |
| 15 | 1.0000E+00 | 4.6721E-07 | 1.2157E-06 | 4.2801E-07 |
| 18 | 1.0000E+00 | 3.8980E-07 | 1.0140E-06 | 3.5710E-07 |
| 21 | 1.0000E+00 | 3.3451E-07 | 8.6995E-07 | 3.0645E-07 |

# Chapter 4

# SASP PROCESS FOR PANS-ATM PARAGRAPH 5.4.1.2.1.4.1 b)

## 4.1 INTRODUCTION

4.1.1 This chapter outlines a process that may be performed by States in order to determine that the local application of the lateral separation minima in PANS-ATM, 5.4.1.2.1.4.1 b), can be implemented safely.

4.1.2 The process outlined herein is based on safety management systems principles as outlined in the *Safety Management Manual (SMM)* (Doc 9859) for the implementation of system changes. This includes requirements for States or ANSPs to carry out local implementation safety assessments taking into account the local particularities as well as system operational error.

## 4.2 DISCUSSION

4.2.1 PANS-ATM, 5.4.1.2.1.4.1 b), introduces a practical method of applying separation in the TMA using the concept of the non-overlapping of protected areas. The provision allows for the use of obstacle clearance areas for aircraft-to-aircraft separation provided operational error is taken into account. In practice, if considered necessary, operational error could be accounted for by the addition of a separation buffer between the protected areas for each aircraft and/or other risk controls such as surveillance and procedures. It should be noted that this separation buffer, if deemed necessary, is in addition to the buffers included in the PANS-OPS obstacle clearance criteria.

*Note.— In this context, a separation buffer refers to a distance between two protected areas to account for operational error, if deemed necessary.*

4.2.2 This method of separation is based on the assumption that obstacle clearance areas are safe for the application of separation between aircraft and obstacles. The basic principle for determination of lateral separation of two IFR procedures, holding patterns or tracks is to separate the obstacle clearance protection areas. Risk controls such as a separation buffer, procedural controls, surveillance, training or other measures to account for operational error may be applied.

4.2.3 Appendix A contains a State's example of using obstacle clearance areas to determine separation between IFPs, which was used by SASP to make its determination for the use of non-overlapping PANS-OPS lateral obstruction clearance areas. Appendix B outlines the process by which SASP assessed the use of PANS-OPS separation application in the State (see ref. 22). Appendix C contains an example for the determination of separation buffers when deemed necessary for PBN operations.

# Chapter 5

# IMPLEMENTATION ROADMAP

## 5.1 INTRODUCTION

5.1.1 The successful implementation of the proposed separation minima is not possible at the regional, State or local level without undertaking an implementation safety assessment (see Chapters 3 and 4 of this circular). When undertaking this assessment, reference should be made to the requirements detailed in Annex 11 (Chapter 2, 2.26), PANS-ATM (Chapter 2, section 2.6), and the guidance material contained in Doc 9859, including the development of HAZID, risk management and mitigation procedures tables.

5.1.2 This chapter provides an overview of the minimum steps that SASP considers necessary for a region or State or ANSP to undertake a safety assessment.

## 5.2 IMPLEMENTATION CONSIDERATIONS

When undertaking a regional or State safety assessment, the following steps are provided as guidance:

**Step 1** — Undertake widespread regional consultation with all possible stakeholders and other interested parties.

**Step 2** — Develop an airspace design concept or ensure that the proposed separation minima being implemented will fit the current airspace system and regional or State airspace planning strategy.

**Step 3** — Review this circular noting specific assumptions, constraints, enablers and system performance requirements.

**Step 4** — Compare assumptions, enablers and system performance requirements in this circular with the regional or State's operational environment, infrastructure and capability.

**Step 5** — If a region or State or ANSP has determined that the change proposal for that region or State is equal to or better than the reference, requirements and system performance in this circular, then the region or State must undertake safety management activities including:

a) formal hazard and consequences identification and safety risk analysis activities including identification of controls and mitigators;

b) implementation plan;

c) techniques for HAZID/safety risk assessment which may include:

1) the use of data or experience with similar services/changes;

2) quantitative modelling based on sufficient data, a validated model of the change and analysed assumptions;

3) the application and documentation of expert knowledge, experience and objective judgement by specialist staff; and

4) a formal analysis in accordance with appropriate safety risk management techniques set out in the Doc 9859;

d) identification and analysis of Human Factors issues identified with the implementation including those associated with human machine interface matters;

e) simulation, where appropriate;

f) operational training; and

g) regulatory approvals.

**Step 6** — If a region or State has determined that the change proposal for that region or State is not equal to the requirements and system performance in this circular, then the region or State must:

a) consider alternative safety risk controls to achieve the technical and safety performance that matches the reference in this circular; or

b) conduct an appropriate quantitative risk analysis for the development of a local standard in accordance with Doc 9689.

**Step 7** — Develop suitable safety assessment documentation including a safety plan and associated safety cases.

**Step 8** — Implementation activities should include:

a) a trial under appropriate conditions;

b) a panel of experts to undertake scrutiny of proposals and development of identified improvements to the implementation plan;

c) an appropriate backup plan developed to enable reversion if necessary; and

d) continuous reporting and monitoring results of incidents, events and observations.

**Step 9** — Develop a suitable post-implementation monitoring and review processes.

# Appendix A

# METHODOLOGIES APPLIED BY NEW ZEALAND

1. Historically New Zealand has accepted a buffer of 1 NM between the track tolerance areas of the route or track pair. With respect to instrument approach procedures, the New Zealand standard has been that the procedure primary areas are separated by either 1 NM or the secondary area of one of the procedures, whichever is the lesser (see Figure APP A-1).

2. Methodologies applied by New Zealand on this matter are as follows:

### 3. Lateral separation of IFR procedures

3.1 The basic principle for determination of lateral separation of two IFR procedures, holding patterns or tracks is to separate the applicable PANS-OPS primary protection areas by an appropriate buffer.

3.2 The maximum value for this lateral separation buffer is 1 NM from the edge of the PANS-OPS primary protection area applicable to the procedure.

3.3 If the applicable PANS-OPS secondary protection area for a procedure is less than 1 NM, then the applicable separation buffer equals the lateral extent of the secondary area.

3.4 When separating two tracks or procedures of unequal separation buffer requirement, the more stringent lateral separation BV applies.

3.5 For holding patterns, the primary area of holding is considered to be the basic holding area, i.e. the portion of the protection area which excludes the holding buffer area. The appropriate lateral separation buffer is considered to be 1NM.

3.6 For RNP RNAV procedures, the applicable separation BV depends on the phase of flight and equals the values in PANS-OPS, Volume II, Table III-1-7-1, shown below.

3.7 When assessing the lateral separation of RNP tracks and procedures, primary protection areas are assumed to be constructed in accordance with PANS-OPS, Volume II, Part III, Section 1, Chapter 7. This also applies to RNP AR procedures with RNP values below the current PANS-OPS minimum of 0.3 NM which may be designed in accordance with other criteria.

3.8 Determination of separation points along the procedural track will take into account the applicable PANS-OPS ATT associated with the navigation system used to determine along-track position.

**Table APP A-1. RNP BV**
(extract of Table III-1-7-1 from PANS-OPS, Volume II)

| *Segment* | *Buffer value (BV)* |
|---|---|
| Departure | 566 m (0.30 NM) |
| Arrival[1]/initial/intermediate approach | 926 m (0.50 NM) |
| Final | 370 m (0.20 NM) |
| Missed approach | 566 m (0.30 NM) |
| Holding[2] | |

1. Arrival closer than 56 km ( 30 NM) to the ARP.
2. Holding areas use different principles.

*Note.— The buffer values in Table III-1-7-1 are derived from an assessment of the worst case maximum excursion beyond the ANP alarm limits generated by the RNP system.*

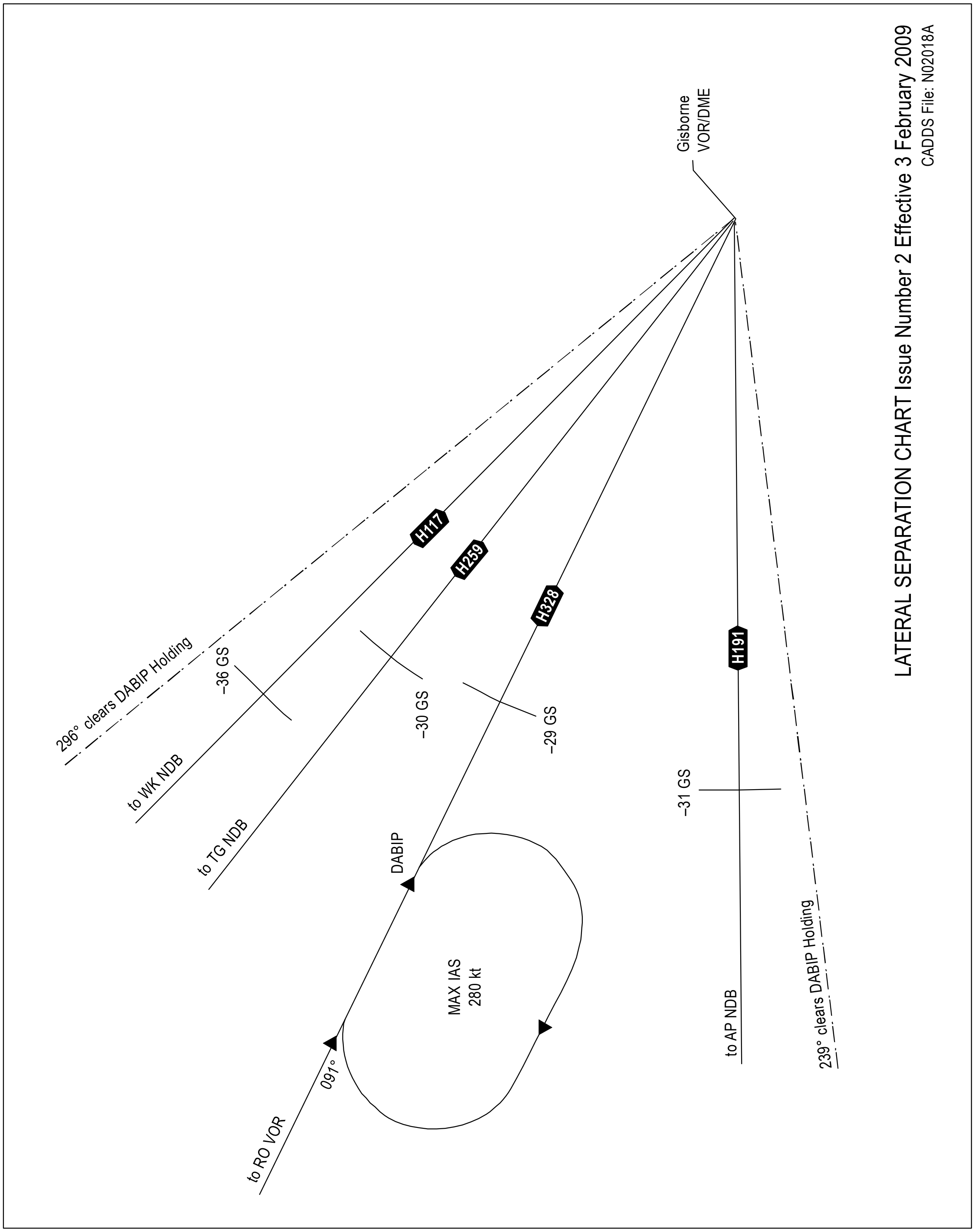


**Figure APP A-1. Gisborne Tower DABIP holding vs VOR routes valid up to and including FL200**

# Appendix B

## EXAMPLE OF USE OF PROTECTED AIRSPACE

1. **SASP Project Team 8 — OR 27:** Separation using PANS-OPS protected surfaces — holding pattern versus ATS routes, version 1, 28 May 2009.

1.1 Develop criteria under which airspace designers and controllers will be able to utilize standards currently contained in the PANS-OPS, Volume II, for aircraft to obstacle purposes, as separation standards for aircraft or special use airspace separation.

2. **Anticipated benefit (justification):**

— New separation standards for instrument procedures near aerodromes
— Increased efficiency and noise abatement alternatives.

3. **OR relationship to current ICAO provisions and ATM procedures:**

— PANS-OPS, Volume II
— PANS-ATM, 5.4.1.2
— *Performance-based Navigation (PBN) Manual* (Doc 9613).

4. **Assumptions (facts) to be included:**

4.1 Airspace characteristics:

— Applied in TMA for the purposes of this OR.

4.2 CNS:

— COMMUNICATIONS: DCPC
— NAVIGATION: GNSS — or as defined by PBN requirements for terminal operations (e.g. RNP 1, 0.3)
— SURVEILLANCE: Nil.

4.3 ATM:

— Nil.

4.4 Aircraft characteristics/performance:

— Aircraft speeds: approach configuration (250 kt and below)
— TMA.

5. **Constraints**

- Aircraft assumed to be in level flight or descending for the arrival and climbing for the departure
- Aircraft on approach manoeuvres to the limit of its containment area.

6. **Assessment methodology**

6.1 The brief description includes a statement of reference system if a comparative analysis is used; and metric/TLS is used if the absolute method is used.

6.2 Determine the collision risk per operation for an aircraft operating at the same level on an arrival or departure procedure based on a VOR radial (the 239 radial or the 296 radial) conflicting with an aircraft operating within a holding pattern (see Figure APP B-1).

7. **High-level hazard and mitigation log**

Anticipated hazards and mitigation (where both hazards/mitigation relate to people, equipment, airborne and ground-based procedures).

8. **Enablers**

8.1 CNS:

- COMMUNICATIONS: DCPC (VHF voice)
- NAVIGATION: GNSS – or as defined by PBN requirements for terminal operations (e.g. RNP 0.3)
- SURVEILLANCE: Assume no surveillance capability (worst case).

8.2 ATM:

- Aircraft handled by single sector.

8.3 ATM procedures:

- Nil.

8.4 Required functionalities for the enabling navigation standard:

- Depends on assumption of approval from PBN.

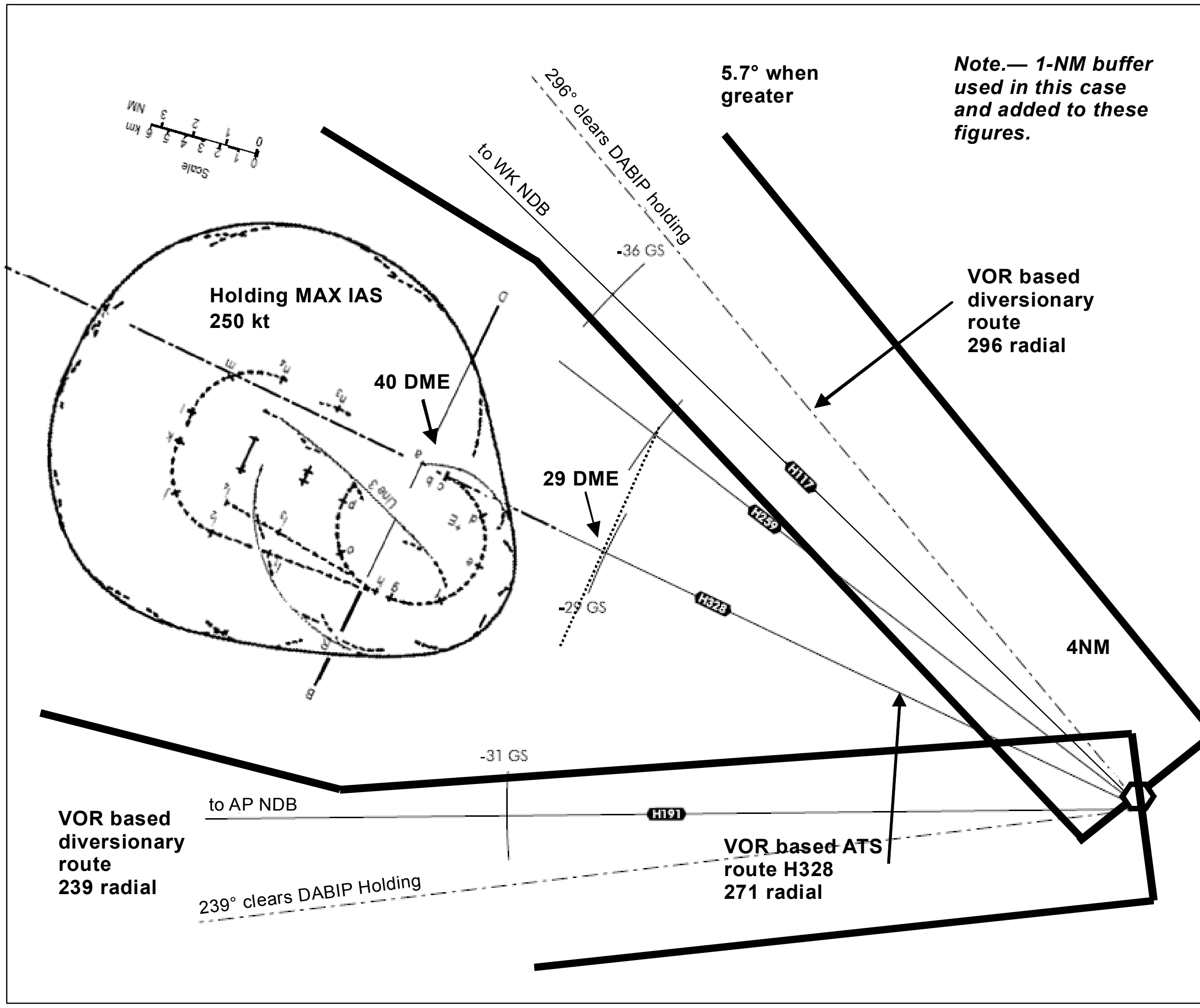


**Figure APP B-1. Holding pattern protected airspace versus ATS routes**

# Appendix C

## SEPARATION BUFFER APPLICATION

1. The basic principle for determination of the *procedural* lateral separation of IFPs is to separate the non-overlapping LOCA with a separation buffer which accounts for *operational error*.

2. *Procedural* separation can be established for PBN IFPs by constructing PBN routes using criteria contained in PANS-OPS, Volume II, and separating the closest point of the proximate route centrelines by a distance not less than the sum of the non-overlapping LOCA of the respective PBN IFPs and the applicable separation buffer taken from Table APP C-1 below.

3. The risk analysis methodology used to develop the separation buffers in Table APP C-1 is the same as that used in Chapter 3 of this circular to derive the 7-NM PBN separation standard. The steps for calculating the separation buffer are outlined in 4 below.

4. The separation buffer width is calculated as the difference between the minimum safety distance, D, and the sum of the area semi-widths of the approach and departure procedures:

a) select PBN approach procedure for aircraft 2;

b) select PBN departure procedure for aircraft 1;

c) determine approach procedure area semi-width (1/2 A/W) using PANS-OPS, Volume II;

d) similarly, determine departure procedure area semi-width (1/2 A/W);

e) using the risk analysis methodology based on Chapter 3 of this circular and the approach and departure specifications, determine the minimum distance between approach and departure tracks, D, whose risk meets the TLS used in the circular;

**Table APP C-1. Separation BV for PANS-OPS PBN terminal routes**

| PBN approach specification | PBN departure specification | D, safe distance* (NM) | PANS-OPS semi-width approach (NM) | PANS-OPS semi-width departure (NM | Separation buffer (NM) |
|---|---|---|---|---|---|
| RNAV 1 | RNAV 1 | 7.0 | 2.5 | 2.0 | 2.5 |
| RNP APCH | RNAV 1 | 6.4 | 2.5 | 2.0 | 1.9 |
| RNP APCH | Basic-RNP 1 | 5.0 | 2.5 | 2.0 | 0.5 |

* D is the minimum distance, such that the probability of collision between the pair is less than the 5.0E-10 TLS.

f) if D is larger than the sum, S, of the approach and departure half-widths, subtract S from D giving the required separation buffer for the approach/departure procedure pair (see Figure APP C-1). Otherwise, there should be no separation buffer. This means that the PANS-OPS separation (without buffer) would be the minimum separation.

5. The results of the separation buffer calculations for the three PBN approach/departure pairs are shown in Table APP C-1. The table displays the PBN specifications used, the minimum safe distance, D, computed from the risk analyses, the area semi-widths (1/2 A/W) selected from three PBN specifications, and the separation BV.

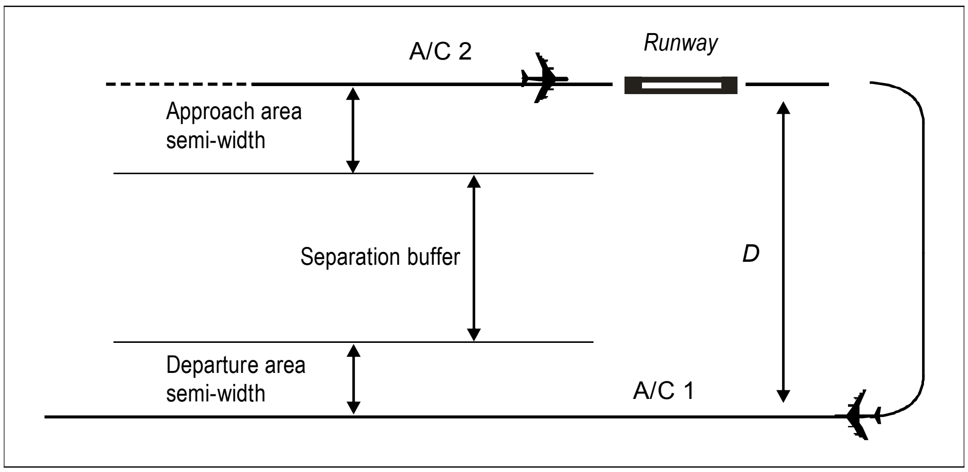


**Figure APP C-1. Separation buffers**

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# Appendix D

# REFERENCES

| *Ref.* | *Meeting* | *Working paper (WP)* | *Title* |
|---|---|---|---|
| 1. | SASP-WG/WHL/12 | WP/15 | Application of PANS-OPS criteria for route spacing. |
| 2. | SASP-WG/WHL/13 | WP/10 | Initial draft circular for application of PANS-OPS criteria. |
| 3. | SASP-WG/WHL/13 | WP/12 | Proposed amendment to the PANS-ATM on application of PANS-OPS criteria for separation in terminal airspace. |
| 4. | SASP-WG/WHL/13 | WP/35 | Collision risk modelling using PANS-OPS criteria for parallel route spacing and aircraft-to-aircraft separation in the TMA. |
| 5. | SASP-WG/WHL/14 | WP/32 | Draft circular for application of PANS-OPS criteria. |
| 6. | SASP-WG/WHL/14 | WP/22 | Review of PANS-OPS obstacle clearance criteria from a safety perspective. |
| 7. | SASP-WG/WHL/14 | WP/27 | Furthering the proposed PANS-ATM amendment concerning the use of PANS-OPS criteria for aircraft separation. |
| 8. | SASP-WG/WHL/14 | WP/38 | Considerations in applying PANS-OPS obstacle clearance areas to air traffic terminal separation standards. |
| 9. | SASP-WG/WHL/14 | | Summary of discussions, Appendix K, report of the mathematicians subgroup meeting at the SASP-WG/WHL/14 Meeting, Paris, France, 13-24 October 2008. |
| 10. | SASP-WG/WHL/15 | WP/18 | Draft circular (as of 1 May 2009) for application of PANS-OPS criteria. |
| 11. | SASP-WG/WHL/15 | WP/13 | Collision risk modelling for an arriving and departing aircraft pair with separation based on protected areas (PT 8 – OR 21). |
| 12. | SASP-WG/WHL/15 | WP/8 | The probability of a collision resulting from a blunder in the execution of the operation described by SASP operational requirement 21. |
| 13. | SASP-WG/WHL/15 | WP/30 | Further collision risk calculations regarding an arriving and departing aircraft pair with separation based on protected areas (PT 8 – OR 21). |
| 14. | SASP-WG/WHL/15 | | Summary of discussions of SASP-WG/WHL/15 Meeting, Montreal, Canada, 25 May – 5 June 2009. |

| *Ref.* | *Meeting* | *Working paper (WP)* | *Title* |
|---|---|---|---|
| 15. | SASP-WG/WHL/15 | | Summary of discussions, Appendix I, report of the mathematicians subgroup meeting at the SASP-WG/WHL/15 Meeting, Montreal, Canada, 25 May – 5 June 2009. |
| 16. | SASP-WG/WHL/16 | WP/27 | Initial Analyses of Australian RNAV Track Data. |
| 17. | SASP-WG/WHL/17 | | Summary of discussions, Appendix I, report of the mathematicians subgroup meeting at the SASP-WG/WHL/17 Meeting, Montreal, Canada 10 to 21 May 2009. |
| 18. | SASP-WG/WHL/16 | WP/11 | PANS-OPS collision risk assessment. |
| 19. | SASP-WG/WHL/17 | WP/7 | Considerations for determining a PANS-OPS separation buffer. |
| 20. | SASP-WG/WHL/17 | WP/8 | Example PANS-OPS separation buffer calculations. |
| 21. | SASP-WG/WHL/17 | WP/14 | PANS-OPS separation buffer proposal for Circular 324-AN/186. |
| 22. | SASP-WG/WHL/17 | WP/19 | Average collision risk for OR 27. |
| 23. | SASP-WG/WHL/17 | WP/22 | Action required of SASP in relation to the circular to support the proposed amendment on lateral separation minima in terminal areas. |
| 24. | SASP-WG/WHL/7 | WP/20 | A collision risk model based on reliability theory that allows for unequal RNP navigational accuracy. |
| 25. | *Procedures for Air Navigation Services — Aircraft Operations*, Volume II — *Construction of Visual and Instrument Flight Procedures*, Fifth Edition — 2006 (Doc 8168). | | |
| 26. | *Procedures for Air Navigation Services — Aircraft Operations*, Volume II — *Construction of Visual and Instrument Flight Procedures*, Second Edition — 1982 (Doc 8168). | | |

**— END —**

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