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Guidelines for the Implementation of Lateral Separation Minima

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ABBREVIATIONS AND ACRONYMS

AIC	Aeronautical information circular
AIP	Aeronautical information publication
AIRAC	Aeronautical information regulation and control
ANSP	Air navigation service provider
ATC	Air traffic control
ATCO	Air traffic control officer
ATS	Air traffic services
CDI	Course deviation indicator
DCPC	Direct controller-pilot communications
DDE	Double double exponential
DME	Distance measuring equipment
DR	Dead reckoning
FL	Flight level
FMS	Flight management system
FPL	Filed flight plan
GNSS	Global navigation satellite system
GPS	Global positioning system
HPL	Horizontal protection limit
ICAO	International Civil Aviation Organization
IFR	Instrument flight rules
INS	Inertial navigation system
m	metre
NDB	Non-directional radio beacon
NDE	Normal double exponential
NM	Nautical mile
NOPAC	North pacific
PANS-ATM	Procedures for Air Navigation Services – Air Traffic Management
RAIM	Receiver autonomous integrity monitoring
PBN	Performance-based navigation
RGCS	Review of the General Concept of Separation Panel
RNAV	Area navigation
RNP	Required navigation performance
SASP	Separation and Airspace Safety Panel
SASP-WG/WHL	SASP Meeting of the Working Group of the Whole
VHF	Very high frequency
VOR	VHF omnidirectional radio range
WP	Working paper

Chapter 1

INTRODUCTION

1.1 PURPOSE

1.1.1 This circular provides guidance for the implementation of lateral separation minima intended for the separation of aircraft approved for performance-based navigation (PBN) and/or global navigation satellite system (GNSS) operations. It applies to lateral separation of aircraft on intersecting and non-intersecting tracks. The material supports provisions included in Chapter 5 of the *Procedures for Air Navigation Services — Air Traffic Management* (PANS-ATM, Doc 4444) at paragraphs 5.4.1.2.1.6 and 5.4.1.2.1.7 (see Chapter 2).

1.1.2 Implementation guidance is also provided in the *Performance-based Navigation (PBN) Manual* (Doc 9613). The manual identifies the relationship between area navigation (RNAV) and required navigation performance (RNP) applications and the advantages and limitations of choosing one or the other as the navigation specification requirement for an airspace concept. The manual also aims at providing practical guidance to States, air navigation service providers (ANSPs) and airspace users on how to implement RNAV and RNP applications, and how to ensure that the performance requirements are appropriate for the planned application.

Note.— Guidance for the implementation of lateral separation minima in the terminal airspace is provided in Guidelines for Lateral Separation of Arriving and Departing Aircraft on Published Adjacent Instrument Flight Procedures (ICAO Circular 324).

1.1.3 The Separation and Airspace Safety Panel (SASP) developed the separation minima detailed in this circular in response to the ICAO policy of global implementation of PBN, the large number of aircraft equipped with instrument flight rules (IFR) global navigation satellite system (GNSS) systems and the potential for using such equipment for separation of aircraft in a procedural environment.

1.1.4 Two of the separation minima covered in this document under the PBN umbrella were originally developed by the Review of the General Concept of Separation Panel (RGCSP) in the 1990s for use within the RNP concept. The first minimum developed was the 50 NM lateral separation minimum for RNP followed by the 30 NM lateral separation minimum for RNP 4. Both minima were originally published in Annex 11 – *Air Traffic Services*, Attachment B but were transferred from Annex 11 to the PANS-ATM later.

1.1.5 During the transition to full implementation of the PBN concept, there is a need to provide separation minima based on IFR GNSS systems in aircraft that have yet to obtain appropriate PBN operational approvals. To accommodate the widespread availability of such systems, which provide highly accurate navigation capability, the SASP has developed separation minima that may be applied to aircraft indicating GNSS equipage in the filed flight plan (FPL).

1.2 GENERAL

1.2.1 The continuing growth of aviation increases demands on airspace capacity thereby emphasizing the need for optimum use of available airspace. Improved operational efficiency derived from the application of area navigation techniques has resulted in the development of navigation applications in various regions worldwide and for all phases of flight.

1.2.2 Area navigation systems evolved in a manner similar to conventional ground-based routes and procedures. A specific area navigation system was identified and its performance was evaluated through a combination of analysis and flight-testing. For domestic operations, the initial systems used very high frequency omnidirectional radio range (VOR) and distance measuring equipment (DME) for estimating aircraft position; for oceanic operations, inertial navigation systems (INS) were employed. Currently, performance-based navigation, as detailed in the PBN Manual (Doc 9613), introduces alternative methods for defining equipage requirements by specifying the performance requirements.

1.2.3 Requirements for navigation applications on specific routes or within a specific airspace must be defined in a clear and concise manner. This is to ensure that the flight crew and the air traffic controllers (ATCOs) are aware of the on-board RNAV system capabilities in order to determine if the performance of the RNAV system is appropriate for the specific airspace requirements and the applicable separation minima.

1.3 SCOPE

This circular is limited to the application of lateral separation of aircraft operating on intersecting or non-intersecting tracks in a procedural control environment applying area navigation.

Chapter 2

LATERAL SEPARATION MINIMA

2.1 This circular addresses the implementation of the lateral separation minima published in PANS-ATM, paragraphs 5.4.1.2.1.6 to 5.4.1.2.1.8, reproduced below.

2.2 For intersecting tracks or ATS routes as described in the PANS-ATM, 5.4.1.2.1.7, smaller separations are possible for both RNP 2 and RNP 4 if a restriction is made to the intersection angle. However applications also exist for angles smaller than 5 degrees or bigger than 175 degrees and the current minima provide the maximum benefit and also remain consistent with the existing RNP 4, 30 NM lateral separation minimum.

5.4.1.2 lateral separation criteria and minima

...

5.4.1.2.1.6 *Lateral separation of aircraft on parallel or non-intersecting tracks or ATS routes.* Within designated airspace or on designated routes, lateral separation between aircraft operating on parallel or non-intersecting tracks or ATS routes shall be established in accordance with the following:

- a) for a minimum spacing between tracks of 93 km (50 NM) a navigational performance of RNAV 10 (RNP 10), RNP 4 or RNP 2 shall be prescribed;
- b) for a minimum spacing between tracks of 55.5 km (30 NM) a navigational performance of RNP 4 or RNP 2 shall be prescribed;
- c) for a minimum spacing between tracks of 27.8 km (15 NM) a navigational performance of RNP 2 or a GNSS equipage shall be prescribed. Direct controller-pilot VHF voice communication shall be maintained while such separation is applied;
- d) for a minimum spacing between tracks of 13 km (7 NM), applied while one aircraft climbs/descends through the level of another aircraft, a navigational performance of RNP 2 or a GNSS equipage shall be prescribed. Direct controller-pilot VHF voice communication shall be maintained while such separation is applied; and
- e) for a minimum spacing between tracks of 37 km (20 NM), applied while one aircraft climbs/descends through the level of another aircraft whilst using other types of communication than specified in d) above, a navigational performance of RNP 2 or a GNSS equipage shall be prescribed.

Note 1.— Guidance material for the implementation of the navigation capability supporting 93 km (50 NM), 55.5 km (30 NM), 37 km (20 NM), 27.8 km (15 NM) and 13 km (7 NM) lateral separation is contained in the Performance-based Navigation (PBN) manual (Doc 9613) and Guidelines for the Implementation of Lateral Separation Minima (Circular 334).

Note 2.— Guidance material for implementation of communication capability supporting 93 km (50 NM) and 55.5 km (30 NM) lateral separation is contained in the Manual on Required Communication Performance (RCP) (Doc 9869). Information regarding RCP allocations for these capabilities is contained in RTCA DO-306/EUROCAE ED-122 Safety and Performance Standard for Air Traffic Data Link Services in Oceanic and Remote Airspace (Oceanic SPR Standard).

Note 3.— Existing implementations of 55.5 km (30 NM) lateral separation minimum require a communication capability of direct controller-pilot voice communications or CPDLC and a surveillance capability by an ADS-C system in which a periodic contract and waypoint change and lateral deviation event contracts are applied.

Note 4. – See Appendix 2, Item 10: Equipment and capabilities, in relation to the GNSS prescribed in c), d) and e) above.

5.4.1.2.1.7 *Lateral separation of aircraft on intersecting tracks or ATS routes.* Lateral separation between aircraft operating on intersecting tracks or ATS routes shall be established in accordance with the following:

- a) an aircraft converging with the track of another aircraft is laterally separated until it reaches a lateral separation point that is located a specified distance measured perpendicularly from the track of the other aircraft (see Figure 5-6); and
- b) an aircraft diverging from the track of another aircraft is laterally separated after passing a lateral separation point that is located a specified distance measured perpendicularly from the track of the other aircraft (see Figure 5-6).

This type of separation may be used for tracks that intersect at any angles using the values for lateral separation points specified in the table below:

<i>Navigation</i>	<i>Separation</i>
RNAV 10 (RNP 10)	93 km (50 NM)
RNP 4	55.5 km (30 NM)
RNP 2	27.8 km (15 NM)

5.4.1.2.1.8 When applying the 27.8 km (15 NM) separation minima specified in the table above, a GNSS, as indicated in the flight plan by the letter G, meets the specified navigation performance.

Note.— Guidance material for the implementation of the navigation capability supporting 93 km (50 NM), 55.5 km (30 NM), and 27.8 km (15 NM) lateral separation is contained in the Performance-based Navigation (PBN) Manual (Doc 9613) and Guidelines for the Implementation of Lateral Separation Minima (Circular 334).

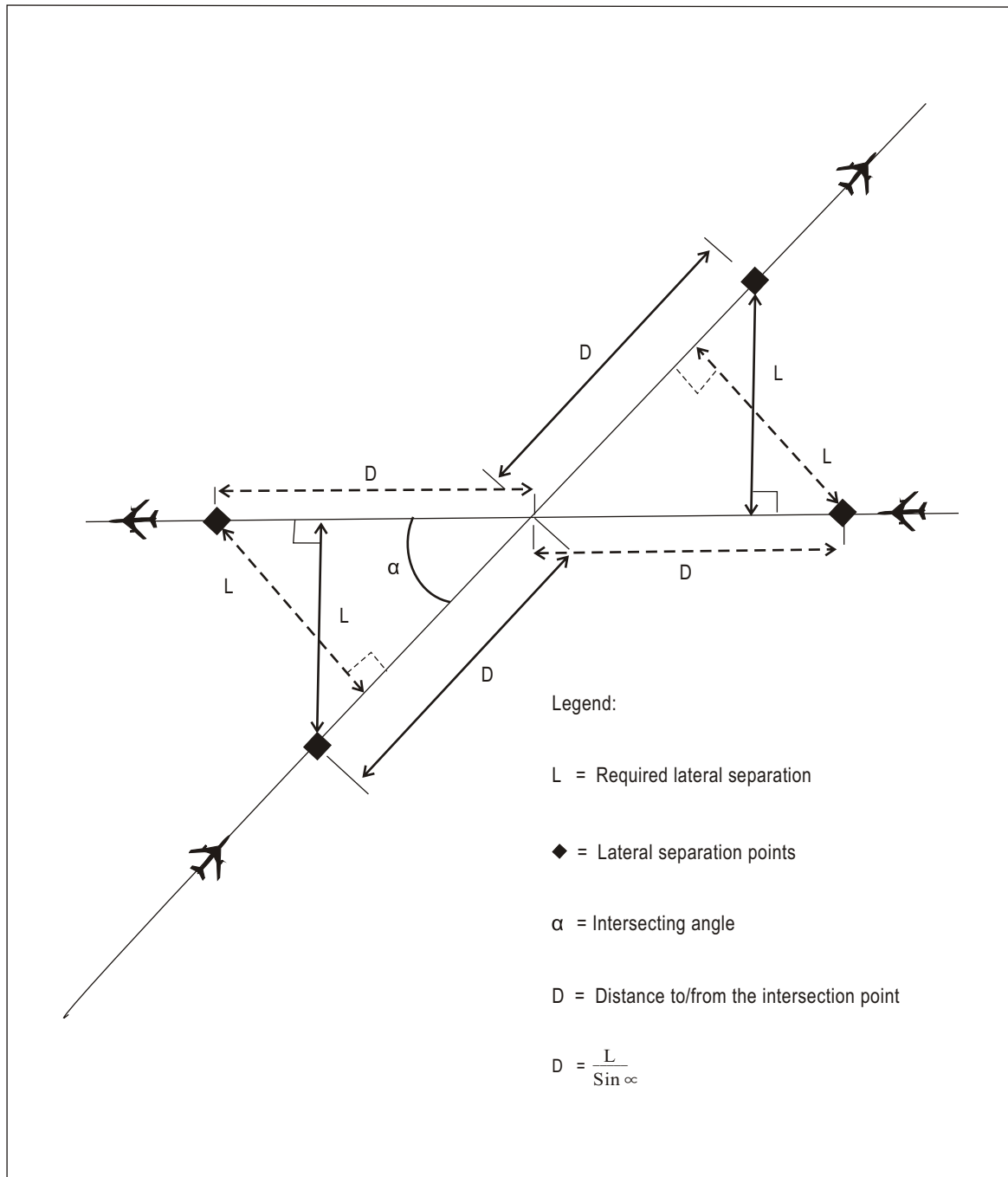


Figure 5-6. Lateral separation points (see 5.4.1.2.1.7)

Chapter 3

SASP SAFETY ASSESSMENT

3.1 INTRODUCTION

This chapter summarizes the safety assessment performed by the SASP to determine the lateral separation minimum, contained in the PANS-ATM, paragraphs 5.4.1.2.1.6 and 5.4.1.2.1.7. In context, this chapter first describes the scope of any SASP safety assessment and then outlines the methodology used to arrive at the lateral separation minima.

3.2 SCOPE OF SASP SAFETY ASSESSMENT

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

3.2.2 The difference in assessment scope is depicted in Figure 3-1; it suggests, for example, that because the local operating environment into which PBN lateral separation is to be integrated may have a significant effect on safety, the full safety assessment can only be completed for each local application. As such, the appropriate ATS authority needs to complement the SASP assessment with an 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.

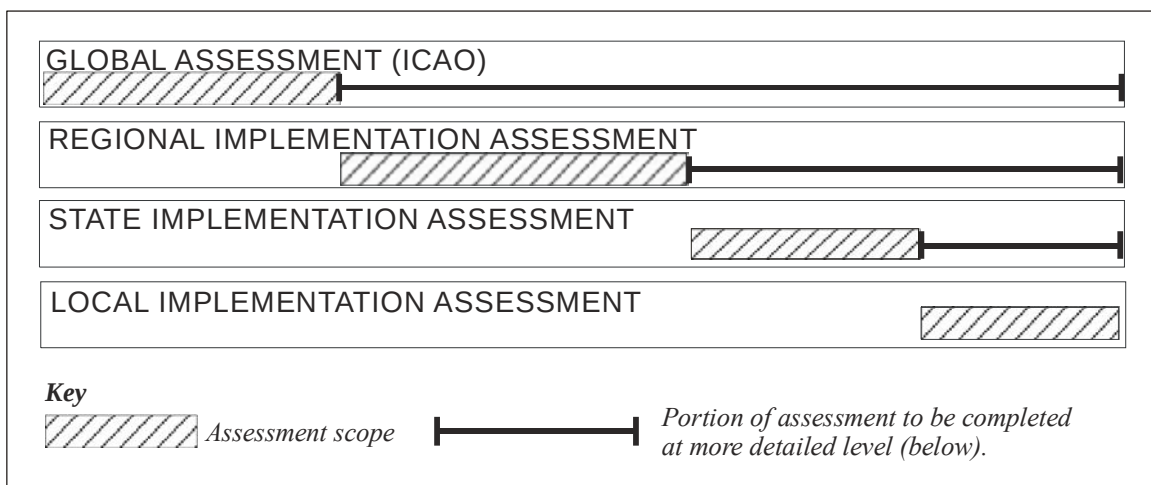


Figure 3-1. Safety Assessment Scope

3.2.3 SASP's assessment is based on a number of assumed characteristics related to either the airspace environment or aircraft performance (see 3.3.11). These characteristics may not necessarily be the same as those relevant to any particular regional, State or local implementation.

3.2.4 An implementation supporting safety assessment should begin with a review of 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 airspace being considered, then the analysis only needs to focus on an assessment of issues related specifically to implementation.

3.3 OBJECTIVES AND DEVELOPMENT OF SASP SAFETY ASSESSMENTS

3.3.1 The objective of the various SASP safety assessments in support of the lateral separation minima referenced in paragraph 3.1 above was to determine:

- a) the minimum safe spacing between parallel tracks for the RNAV 10 (RNP 10), RNP 4, and RNP 2 navigation specifications and also for aircraft equipped with IFR GNSS systems; and
- b) the minimum safe distance of the lateral separation points on an aircraft's track to the intersecting track of another aircraft for RNAV 10 (RNP 10), RNP 4, and RNP 2 navigation specifications and also for aircraft equipped with IFR GNSS systems.

3.3.2 In the context of the assessment of the safety of a separation minimum, a distinction is made between collision risk due to navigation performance and risk due to other hazards.

3.3.3 Collision risk due to navigation performance may be subdivided into:

- a) collision risk due to typical navigation performance; and
- b) collision risk due to atypical navigation performance.

Note.— Depending on the case, the expression “atypical navigation performance” may be used in case of navigation system failure or degradation, and/or operational error.

3.3.4 Typical and atypical navigation performance fall within the general framework of hazards, but are special in the sense that they allow a detailed quantitative evaluation. Collision risk due to both types of navigation performance has been quantified by means of collision risk modelling.

3.3.5 The minimum spacing between parallel tracks and the minimum distance of a lateral separation point are considered to be “safe” when:

- a) the level of aircraft collision risk (made up of the collision risks due to typical and atypical navigation performance) does not exceed a target level of safety (TLS) of 5×10^{-9} fatal aircraft accidents per flight hour¹; AND

1. A different (but related) unit is used for the climb or decent procedure to be described in section 3.7, viz. a maximum tolerable probability of collision in a typical execution of the procedure of 5×10^{-10} .

- b) the risk due to all other hazards is “negligible”.

3.3.6 The assessment of the collision risk due to navigation performance complies with the guidance from the *Manual on Airspace Planning Methodology for the Determination of Separation Minima* (Doc 9689) concerning the “Evaluation of system risk against a threshold” method.

3.4 SAFETY ASSESSMENT FOR 50 NM NON-INTERSECTING TRACKS – RNAV 10 (RNP 10), RNP 4 OR RNP 2

When implementing the separation specified in this section the assumptions, enablers and system performance requirements detailed in the following paragraphs must be taken into account and compared to the characteristics of the airspace where the separation is being implemented. The assumptions and implementation considerations are listed in the table below:

<i>Assumption</i>	<i>Implementation considerations</i>
1. Mean aircraft cross-track performance (weighted by flight hour) must satisfy 95% containment in 6 NM.	Implementation of a lateral separation standard of 50 NM requires appropriate monitoring to ensure the assumptions are met.
2. The rate of lateral deviations larger than 25 NM is less than 1E-5.	The large lateral deviation (LLD) rate can be expressed as the total time aircraft deviate more than half the separation standard divided by the total flight hours.
3. The occupancy must not exceed 0.2 for opposite direction traffic.	The “occupancy” is defined as “the parameter of the collision risk model which is twice the count of aircraft proximate pairs in a single dimension divided by the total number of aircraft flying the candidate paths in the same time interval”.

Safety assessment for navigation performance

3.4.1 The safety assessment for 50 NM spacing of parallel routes for RNAV 10 (RNP 10) capable aircraft was presented in Working Paper 4 of the 17th Meeting of Working Group A of the Review of the General Concept of Separation Panel (RGCSP) of ICAO (Ref. 1)². It was based on the “Reich model” formulae for the rates of collision due to the loss of planned lateral separation: one for a pair of co-altitude parallel flight paths whose traffic moves in the same direction, the other for a pair of co-altitude parallel flight paths whose traffic moves in opposite directions:

2. References are numbered 1, 2, 3, ... by section and are listed at the end of each section, 3.4 through 3.8.

$$N_{ay}(\text{same}) = P_y(S_y)P_z(0)\frac{\lambda_x}{S_x}E_y(\text{same})\left\{\frac{|\Delta V|}{2\lambda_x} + \frac{|\dot{y}|}{2\lambda_y} + \frac{|\dot{z}|}{2\lambda_z}\right\} \quad (3.4.1)$$

$$N_{ay}(\text{opp}) = P_y(S_y)P_z(0)\frac{\lambda_x}{S_x}E_y(\text{opp})\left\{\frac{2|\dot{V}|}{2\lambda_x} + \frac{|\dot{y}|}{2\lambda_y} + \frac{|\dot{z}|}{2\lambda_z}\right\} \quad (3.4.2)$$

3.4.2 See Appendix B to Part II, Section 2, Chapter 4, of Ref. 2 or Appendix 4 to Ref. 1. The formulae are nearly identical, differing only in the parameters that are sensitive to the direction of flight. Thus the reasoning behind the assessment is explained once, and then applied with two (slightly) different sets of parameter values.

3.4.3 The route system's estimated rate of accidents due to the loss of planned lateral separation was required not to exceed its maximum tolerable value, the TLS of 5×10^{-9} fatal accidents per flight-hour.

3.4.4 In a system whose adjacent routes are laterally separated by 50 NM, the probability of a lateral deviation whose magnitude is two or more separation standards is considered to be relatively small. A good estimate of lateral risk can be obtained by considering only those deviations that move the errant aeroplane approximately one separation standard away from its intended path in space.

3.4.5 The assessment assumed that aircraft lateral deviations from centreline are well-described by a double double exponential (DDE) probability density function with mean zero and parameters α , λ_1 , and λ_2 , i.e.

$$f(y; \alpha, \lambda_1, \lambda_2) = \frac{1-\alpha}{2\lambda_1} e^{-\frac{|y|}{\lambda_1}} + \frac{\alpha}{2\lambda_2} e^{-\frac{|y|}{\lambda_2}} \quad (3.4.3)$$

This function is a weighted sum of the density function of typical errors and the density function of atypical errors. The parameter λ_1 is $1/\sqrt{2}$ times the standard deviation of typical lateral errors; the parameter λ_2 is $1/\sqrt{2}$ times the standard deviation of atypical lateral errors; $\lambda_2 > \lambda_1 > 0$; and the parameter α ($1 > \alpha > 0$) is the fraction of flying time during which aeroplanes using the route system are committing atypical errors.

3.4.6 The lateral overlap probability $P_y(S_y)$ of aeroplanes assigned to parallel routes spaced nautical miles apart can be derived from the DDE density function as

$$P_y(S_y; \alpha, \lambda_1, \lambda_2) \approx 2\lambda_y \left[\left(\frac{1-\alpha}{2\lambda_1} \right)^2 (\lambda_1 + S_y) e^{-\frac{S_y}{\lambda_1}} + \left(\frac{\alpha}{2\lambda_2} \right)^2 (\lambda_2 + S_y) e^{-\frac{S_y}{\lambda_2}} + \frac{\alpha(1-\alpha)}{2} \left(\frac{e^{-\frac{S_y}{\lambda_1}} + e^{-\frac{S_y}{\lambda_2}}}{\lambda_1 + \lambda_2} + \frac{e^{-\frac{S_y}{\lambda_2}} - e^{-\frac{S_y}{\lambda_1}}}{\lambda_2 - \lambda_1} \right) \right] \quad (3.4.4)$$

$\lambda_1 \neq \lambda_2$

3.4.7 For both same-direction flight and opposite-direction flight the assessment began by deriving the maximum tolerable lateral overlap probability for a pair of randomly chosen aeroplanes, one assigned to each of the co-altitude flight paths. This was done by substituting the maximum tolerable value of 5×10^{-9}

fatal accidents per flight-hour for $N_{ay}(same)$ and $N_{ay}(opp)$ in the left-hand sides of eqs. (3.4.1) and (3.4.2), substituting suitable values for all parameters other than $P_y(S_y; \alpha, \lambda_1, \lambda_2)$ in the right-hand sides of eqs. (3.4.1) and (3.4.2), and then solving for $P_y(S_y; \alpha, \lambda_1, \lambda_2)$. The resulting maximum tolerable probabilities, one for same-direction flight and one for opposite-direction flight, were stated as functions of the route system's occupancy, and all calculations were done for occupancies ranging from 0.1 to 2.0, in steps of 0.1.

3.4.8 The next step was to require the standard deviation of typical errors (or, equivalently, λ_1) to be kept so small that the lateral overlap probability would be almost entirely due to large atypical errors that move an aeroplane to the vicinity of an adjacent route, where it has a significant probability of being in lateral overlap with an aeroplane assigned to that route. The lateral overlap probability due to large atypical errors was then approximated by a function of λ_2 and α only; and it was shown that, as a function of λ_2 , the approximation reached its maximum when λ_2 equalled the spacing S_y between adjacent routes. Setting this maximum value of the approximation equal to the maximum tolerable lateral overlap probability then yielded a solution for the minimal (most conservative) value of α .

3.4.9 Having assumed a conservative value for λ_2 , and having derived a conservative value for α , the assessment returned to λ_1 by finding a maximum tolerable value for it. To this end, the lateral overlap probability due to typical errors was approximated and required to be less than or equal to 1 per cent of the (approximation to the) lateral overlap probability due to atypical errors. It was then shown that the only way to decrease the lateral overlap probability due to typical errors was to decrease λ_1 ; and the largest value of λ_1 was found which satisfied the 1 per cent requirement.

3.4.10 With the above process, all three parameters α , λ_1 , and λ_2 of the DDE probability density function of the lateral errors were determined such that the TLS would not be exceeded and the risk due to typical errors would be less than or equal to 1 per cent of the (approximation to the) risk due to atypical errors.

3.4.11 The final step was to translate the probability density function parameter λ_1 into a performance requirement. This was achieved by multiplying the theoretic value of λ_1 (cf. paragraph 3.4.9) by the constant $-\ln(0.05)$ (which is approximately equal to 3) to obtain the 95 per cent containment distance for typical lateral errors. Rounding that number to the next lower integer gave the RNP value that should be imposed on users of the route system (dividing this RNP value by $-\ln(0.05)$ then gave the effective value of λ_1).

3.4.12 The assessment found that at most levels of lateral occupancy, same-direction route systems would need to impose RNP 7 in order to meet the TLS, and opposite-direction route systems would need to impose RNP 6 in order to meet the TLS. However, the RGCSP and its successor, the SASP, both declined to consider the development of standards for either RNP 7 or RNP 6.

3.4.13 In a note dealing with the history of 50 NM route spacing, Ref. 1 observed that an earlier RGCSP study, using a less stringent TLS of 2×10^{-8} fatal accidents per flight-hour, had derived a 95 per cent containment distance of 8 NM for typical lateral errors (Ref. 4). The study pertained to the North Pacific (NOPAC) route system and used occupancy values extrapolated to the year 1995. However, the authorities responsible for flights on the NOPAC route system imposed a less demanding containment distance of 10 NM, i.e., RNP 10. It had been suggested that they did so because of concerns as to the ability of the NOPAC fleet to satisfy RNP 8. It was also suggested that some aeroplanes that were nominally "RNP 10" were likely to navigate with 95 per cent containment distances far smaller than 8 NM, thereby producing a "fleet average" performance that would meet the 8 NM requirement.

3.4.14 As a part of the safety assessment, formulae were also provided for two additional parameters that are more easily observed by ANSPs than are the parameters λ_2 and α : the rate of gross lateral errors, usually called η , and the rate of high-risk gross lateral errors, usually called ζ . Using the maximum

tolerable values of α and λ_1 , and the conservative choice of λ_2 , Ref. 1 derived the maximum tolerable values for η and ζ corresponding to each level of occupancy.

3.4.15 Tables 3.4.1 and 3.4.2 show the calculated maximum tolerable values for the rates of gross lateral errors and high-risk gross lateral errors for same-direction flight and opposite-direction flight, respectively. Each of the tables shows the maximum tolerable values for η and ζ as a function of occupancy.

3.4.16 Some additional work related to the safety assessment for 50 NM spacing of parallel routes for RNAV 10 (RNP 10) aircraft is documented in Refs. 4 – 11.

Hazard assessment

3.4.17 Refer to section 3.9 and Attachment A for a description of the SASP hazard assessment.

Table 3-4-1. Maximum acceptable values of parameters describing navigational performance, for a system of same-direction parallel routes with 50 NM between adjacent routes, for a target level of safety (TLS) of 5×10^{-9} fatal accidents per flight-hour, for the parameter values given in table 1 of Ref. 1, for core-core interaction limited to 1% of core-tail interaction, and for the given values of same-direction occupancy, $E_y(\text{same})$

$E_y(\text{same})$	$P_y(S_y)$	α	theoretic λ_1	RNP	applied λ_1	η	ζ
0.1	$2.33 \cdot 10^{-7}$	$5.11 \cdot 10^{-4}$	2.8528	8	2.67	$3.96 \cdot 10^{-4}$	$7.59 \cdot 10^{-5}$
0.2	$1.16 \cdot 10^{-7}$	$2.55 \cdot 10^{-4}$	2.7312	8	2.67	$2.41 \cdot 10^{-4}$	$3.81 \cdot 10^{-5}$
0.3	$7.76 \cdot 10^{-8}$	$1.70 \cdot 10^{-4}$	2.6651	7	2.34	$1.26 \cdot 10^{-4}$	$2.52 \cdot 10^{-5}$
0.4	$5.82 \cdot 10^{-8}$	$1.28 \cdot 10^{-4}$	2.6202	7	2.34	$1.00 \cdot 10^{-4}$	$1.89 \cdot 10^{-5}$
0.5	$4.66 \cdot 10^{-8}$	$1.02 \cdot 10^{-4}$	2.5864	7	2.34	$8.45 \cdot 10^{-5}$	$1.52 \cdot 10^{-5}$
0.6	$3.88 \cdot 10^{-8}$	$8.51 \cdot 10^{-5}$	2.5595	7	2.34	$7.42 \cdot 10^{-5}$	$1.26 \cdot 10^{-5}$
0.7	$3.33 \cdot 10^{-8}$	$7.29 \cdot 10^{-5}$	2.5372	7	2.34	$6.68 \cdot 10^{-5}$	$1.08 \cdot 10^{-5}$
0.8	$2.91 \cdot 10^{-8}$	$6.38 \cdot 10^{-5}$	2.5182	7	2.34	$6.13 \cdot 10^{-5}$	$9.49 \cdot 10^{-6}$
0.9	$2.59 \cdot 10^{-8}$	$5.67 \cdot 10^{-5}$	2.5017	7	2.34	$5.70 \cdot 10^{-5}$	$8.44 \cdot 10^{-6}$
1.0	$2.33 \cdot 10^{-8}$	$5.11 \cdot 10^{-5}$	2.4871	7	2.34	$5.35 \cdot 10^{-5}$	$7.60 \cdot 10^{-6}$
1.1	$2.12 \cdot 10^{-8}$	$4.64 \cdot 10^{-5}$	2.4741	7	2.34	$5.07 \cdot 10^{-5}$	$6.91 \cdot 10^{-6}$
1.2	$1.94 \cdot 10^{-8}$	$4.25 \cdot 10^{-5}$	2.4624	7	2.34	$4.84 \cdot 10^{-5}$	$6.34 \cdot 10^{-6}$
1.3	$1.79 \cdot 10^{-8}$	$3.93 \cdot 10^{-5}$	2.4516	7	2.34	$4.64 \cdot 10^{-5}$	$5.85 \cdot 10^{-6}$
1.4	$1.66 \cdot 10^{-8}$	$3.65 \cdot 10^{-5}$	2.4418	7	2.34	$4.47 \cdot 10^{-5}$	$5.44 \cdot 10^{-6}$
1.5	$1.55 \cdot 10^{-8}$	$3.40 \cdot 10^{-5}$	2.4327	7	2.34	$4.32 \cdot 10^{-5}$	$5.08 \cdot 10^{-6}$
1.6	$1.46 \cdot 10^{-8}$	$3.19 \cdot 10^{-5}$	2.4243	7	2.34	$4.19 \cdot 10^{-5}$	$4.76 \cdot 10^{-6}$
1.7	$1.37 \cdot 10^{-8}$	$3.00 \cdot 10^{-5}$	2.4164	7	2.34	$4.08 \cdot 10^{-5}$	$4.49 \cdot 10^{-6}$
1.8	$1.29 \cdot 10^{-8}$	$2.84 \cdot 10^{-5}$	2.4091	7	2.34	$3.98 \cdot 10^{-5}$	$4.24 \cdot 10^{-6}$
1.9	$1.23 \cdot 10^{-8}$	$2.69 \cdot 10^{-5}$	2.4021	7	2.34	$3.89 \cdot 10^{-5}$	$4.02 \cdot 10^{-6}$
2.0	$1.16 \cdot 10^{-8}$	$2.55 \cdot 10^{-5}$	2.3956	7	2.34	$3.80 \cdot 10^{-5}$	$3.82 \cdot 10^{-6}$

Table 3-4-2. Maximum acceptable values of parameters describing navigational performance, for a system of parallel flight paths with 50 NM between adjacent paths and opposite direction traffic on adjacent paths, for a target level of safety (TLS) of 5×10^{-9} fatal accidents per flight-hour, for the parameter values given in table 1 of Ref. 1, for core-core interaction limited to 1% of core-tail interaction, and for the given values of opposite-direction occupancy, $E_y(opp)$

$E_y(opp)$	$P_y(S_y)$	α	theoretic λ_1	RNP	applied λ_1	η	ζ
0.1	$2.29 \cdot 10^{-8}$	$5.01 \cdot 10^{-5}$	2.4846	7	2.34	$5.30 \cdot 10^{-5}$	$7.46 \cdot 10^{-6}$
0.2	$1.14 \cdot 10^{-8}$	$2.51 \cdot 10^{-5}$	2.3932	7	2.34	$3.78 \cdot 10^{-5}$	$3.75 \cdot 10^{-6}$
0.3	$7.62 \cdot 10^{-9}$	$1.67 \cdot 10^{-5}$	2.3430	7	2.34	$3.27 \cdot 10^{-5}$	$2.51 \cdot 10^{-6}$
0.4	$5.71 \cdot 10^{-9}$	$1.25 \cdot 10^{-5}$	2.3087	6	2.00	$1.14 \cdot 10^{-5}$	$1.86 \cdot 10^{-6}$
0.5	$4.57 \cdot 10^{-9}$	$1.00 \cdot 10^{-5}$	2.2828	6	2.00	$9.87 \cdot 10^{-6}$	$1.49 \cdot 10^{-6}$
0.6	$3.81 \cdot 10^{-9}$	$8.35 \cdot 10^{-6}$	2.2621	6	2.00	$8.86 \cdot 10^{-6}$	$1.24 \cdot 10^{-6}$
0.7	$3.27 \cdot 10^{-9}$	$7.16 \cdot 10^{-6}$	2.2449	6	2.00	$8.13 \cdot 10^{-6}$	$1.06 \cdot 10^{-6}$
0.8	$2.86 \cdot 10^{-9}$	$6.26 \cdot 10^{-6}$	2.2302	6	2.00	$7.59 \cdot 10^{-6}$	$9.30 \cdot 10^{-7}$
0.9	$2.54 \cdot 10^{-9}$	$5.57 \cdot 10^{-6}$	2.2174	6	2.00	$7.17 \cdot 10^{-6}$	$8.27 \cdot 10^{-7}$
1.0	$2.29 \cdot 10^{-9}$	$5.01 \cdot 10^{-6}$	2.2061	6	2.00	$6.83 \cdot 10^{-6}$	$7.44 \cdot 10^{-7}$
1.1	$2.08 \cdot 10^{-9}$	$4.55 \cdot 10^{-6}$	2.1958	6	2.00	$6.56 \cdot 10^{-6}$	$6.77 \cdot 10^{-7}$
1.2	$1.90 \cdot 10^{-9}$	$4.18 \cdot 10^{-6}$	2.1867	6	2.00	$6.33 \cdot 10^{-6}$	$6.21 \cdot 10^{-7}$
1.3	$1.76 \cdot 10^{-9}$	$3.85 \cdot 10^{-6}$	2.1784	6	2.00	$6.13 \cdot 10^{-6}$	$5.73 \cdot 10^{-7}$
1.4	$1.63 \cdot 10^{-9}$	$3.58 \cdot 10^{-6}$	2.1707	6	2.00	$5.96 \cdot 10^{-6}$	$5.32 \cdot 10^{-7}$
1.5	$1.52 \cdot 10^{-9}$	$3.34 \cdot 10^{-6}$	2.1636	6	2.00	$5.82 \cdot 10^{-6}$	$4.97 \cdot 10^{-7}$
1.6	$1.43 \cdot 10^{-9}$	$3.13 \cdot 10^{-6}$	2.1570	6	2.00	$5.69 \cdot 10^{-6}$	$4.66 \cdot 10^{-7}$
1.7	$1.34 \cdot 10^{-9}$	$2.95 \cdot 10^{-6}$	2.1509	6	2.00	$5.58 \cdot 10^{-6}$	$4.39 \cdot 10^{-7}$
1.8	$1.27 \cdot 10^{-9}$	$2.78 \cdot 10^{-6}$	2.1451	6	2.00	$5.48 \cdot 10^{-6}$	$4.14 \cdot 10^{-7}$
1.9	$1.20 \cdot 10^{-9}$	$2.64 \cdot 10^{-6}$	2.1397	6	2.00	$5.39 \cdot 10^{-6}$	$3.93 \cdot 10^{-7}$
2.0	$1.14 \cdot 10^{-9}$	$2.51 \cdot 10^{-6}$	2.1346	6	2.00	$5.31 \cdot 10^{-6}$	$3.73 \cdot 10^{-7}$

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3.5 SAFETY ASSESSMENT FOR 30 NM NON-INTERSECTING TRACKS – RNP 4 or RNP 2

When implementing the separation specified in this section the assumptions, enablers and system performance requirements detailed in the following paragraphs must be taken into account and compared to the characteristics of the airspace where the separation is being implemented. The assumptions and implementation considerations are listed in the table below:

<i>Assumption</i>	<i>Implementation considerations</i>
Implementation of a lateral separation standard of 30 NM requires appropriate monitoring to ensure the rate of lateral deviations larger than 15 NM is less than $1E-5$ and occupancy does not exceed 0.5 for opposite direction traffic.	The LLD rate can be expressed as the total time aircraft deviate more than half the separation standard divided by the total flight hours. The “occupancy” is defined as “the parameter of the collision risk model which is twice the count of aircraft proximate pairs in a single dimension divided by the total number of aircraft flying the candidate paths in the same time interval”.