

Cir 331
AN/192



Implementation of Strategic Lateral Offset Procedures

Approved by the Secretary General
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FOREWORD

When reduced vertical separation minimum (RVSM) was implemented and the uptake of global navigation satellite system (GNSS) became apparent, the Oceanic Air Navigation Service Providers (ANSPs) became aware that the risk of mid-air collision was increasing exponentially. RVSM altimetry puts an aircraft within an average of 10 m (33 ft) vertically and GNSS puts that same aircraft within approximately 9 m (30 ft) laterally of where they are supposed to be. The obvious solution to reduce the vertical overlap risk in the system to meet the Target Level of Safety was to reduce the vertical overlap probability by recreating the randomness that RVSM and GNSS had removed from aircraft distribution. The result was the implementation of a lateral offset in increments of one mile of up to 3.7 km (2 NM) to the right. This has been used in the oceans for a decade. One additional benefit is that it provides a wake turbulence avoidance capability.

The risk of mid-air collisions in non-oceanic airspace prompted several organizations to request ICAO to adapt the strategic lateral offset procedure (SLOP) to a surveillance environment. Utilizing the extreme accuracy of GNSS and newer aircraft's ability to offset in tenths of a mile, multiple offsets up to one half mile may be applied safely within route separations as low as 11.1 km (6 NM).

The mitigation of risk that this creates in the air traffic system will allow ANSPs to continue to meet the target levels of safety.

The content of this circular was developed over a period of two years by a group of experts on separation and airspace safety comprising of pilots, air traffic controllers, aircraft operators, air navigation service providers and regulators from different States, international organizations and ICAO regions.

This Circular provides insight into the development of SLOP, including discussion of all the safety analyses.

ACRONYMS AND ABBREVIATIONS

AIC	Aeronautical information circular
AIP	Aeronautical information publication
AIRAC	Aeronautical information regulation and control
AIS	Aeronautical information service
ANSP	Air Navigation Service Provider
AOC	Aircraft offset capability
ASOC	Advanced-strategic offset concept
ASLOP	Advanced-strategic lateral offset procedure
ATC	Air traffic control
ATS	Air traffic services
CPDLC	Controller-pilot data link communications
DCPC	Direct controller-pilot communication
DME	Distance measuring equipment
FAA	Federal Aviation Administration
FD	Fault detection
FDE	Fault detection and exclusion
FL	Flight level
FMS	Flight management system
GAPAN	Guild of air pilots and air navigators
GLONASS	Global navigation satellite system
GNSS	Global navigation satellite system
GPS	Global positioning system
ICAO	International Civil Aviation Organization
IFR	Instrument flight rules
INS	Inertial navigation system
IP	Information paper
NDB	Non-directional beacon
NM	Nautical mile
PANS-ATM	Procedures for air navigation services – air traffic management
PIRG	Planning and implementation regional group
RAIM	Receiver autonomous integrity monitoring
RGCSP	Review of the General Concept of Separation Panel
RNAV	Area navigation
RNP	Required navigation performance
RVSM	Reduced vertical separation minimum
SASP	Separation and Airspace Safety Panel
SBAS	Satellite-based augmentation system
SLOP	Strategic lateral offset procedure
TCAS	Traffic alert and collision avoidance system
WGS-84	World Geodetic System – 1984
WG	Working Group
WG/WHL	Working Group of the Whole
WP	Working paper

Chapter 1

OVERVIEW

1.1 INTRODUCTION

1.1.1 The purpose of this circular is to provide information on the work undertaken by the Review of the General Concept of Separation Panel (RGCSP), the Separation and Airspace Safety Panel (SASP), and planning and implementation regional groups (PIRGs) to establish the offset values and procedures to be used in applying strategic lateral offsets. The purpose of such offsets is to mitigate the increasing collision risk resulting from improved navigation and altimetry performance. This increased risk is a result of the improved accuracy and use of global navigation satellite system (GNSS) and the adoption of reduced vertical separation minimum (RVSM) compliant altimetry systems.

1.1.2 This circular is aimed at a worldwide audience among civil aviation authorities and air navigation service providers responsible for airspace management as well as aircraft operators and aircrew.

1.2 SCOPE

1.2.1 The material in this circular is limited to the application of the strategic lateral offset procedures (SLOP) in the en-route environment.

1.3 DEVELOPMENT OF STRATEGIC LATERAL OFFSET PROCEDURES

1.3.1 In November 2000 ICAO published the first of three State letters requesting comments on the Strategic Lateral Offset Procedures. That letter proposed offsets of 1.9 km (1 NM) to the right of track, applied by GNSS aircraft only, and used in systems of parallel routes separated by at least 93 km (50 NM). The offsets could only be applied when authorized by air traffic control (ATC).

1.3.2 This proposal was a start but failed to provide for the alleviation of the effects of wake turbulence. The guidelines were not successful in mitigating the risk of lateral overlap since they merely moved the centre line one mile. There were also other concerns that needed to be addressed.

1.3.3 On receipt of the first State letter, the North Atlantic Mathematicians Working Group formed a committee to develop the improvements they felt were necessary to make lateral offsets achieve the risk mitigations and wake avoidance capabilities that were desired. One problem was the requirement for ATC authorization. The air navigation service providers (ANSPs) did not want the responsibility nor the increased workload that such authorizations would create. After consultation between the NAT SPG and the ICAO Secretariat, it was agreed to propose the amendment of the NAT section of Regional Supplementary Procedures (Doc 7030) to allow pilots to initiate offsets without having to report them, so that use of the procedure would be entirely transparent to controllers.

1.3.4 The second State letter dated May 2002, stated that the authorization required by Annex 2 — Rules of the Air, paragraph 3.6.2.1.1, prior to a pilot's application of a lateral offset, could be achieved by coordinated publication of approved offset procedures, by NOTAMs and by notices in Aeronautical Information Publications (AIP), by all States concerned. Action should also be taken to incorporate the procedures in the Regional Supplementary Procedures (Doc 7030). The NAT SPG proceeded to implement a lateral offset procedure under guidelines in its portion of Doc 7030, resulting in the third State letter.

1.3.5 The third State letter was issued in August 2004. The guidelines published in the State letter were based on safety assessments and procedures developed by SASP. These procedures, which were known as the Strategic Lateral Offset Procedures (SLOP), were subsequently implemented in various oceanic areas throughout the world.

1.3.6 SLOP was subsequently published in the Procedures for Air Navigation Services — Air Traffic Management (PANS-ATM, Doc 4444) and was only applicable in Oceanic and remote continental airspace. The offsets were restricted to 1.9 km (1NM) or 3.7 km (2 NM) right of centre line with maintaining the centre line also remaining as the third option. The application of the procedure was restricted to airspace where the lateral separation was 55.5 km (30 NM) or more.

1.3.7 A mid-air collision in South America in 2006 prompted ICAO to amend the SASP work programme to develop a solution similar to the SLOP for the domestic en-route environment. Guild of Air Pilots and Air Navigators (GAPAN) and International Federation of Airline Pilots Associations (IFALPA) also supported that notion and urged ICAO to act as quickly as possible on this subject.

1.3.8 The idea quickly emerged to employ the capability of some modern aircraft to offset in fractions of a mile for this purpose. Both Boeing and Airbus announced that all their future aircraft would have the capability to offset in tenths of a mile and it was therefore clear that using such “micro-offsets” to mitigate the collision risk would be viable in the future.

1.3.9 SASP subsequently conducted safety assessments to establish that application of micro-offsets as great as 0.9 km (0.5 NM) to the right of centre line would be safe in airspace where lateral separation or route spacing is at least 11.1 km (6 NM).

1.3.10 The extreme accuracies of modern navigation systems reduce the random lateral separations between aircraft aiming to fly on the same route. When a gross error eliminates all planned separation between two aircraft, in the longitudinal or vertical dimension, the reduced probability of random separation in the lateral dimension makes a collision far more likely than it would have been in the past, when an aircraft's lateral deviations from route centre line were far greater. The use of lateral offsets is a means of increasing the random lateral separation between aircraft that aim to fly along the same route.

1.3.11 Errors are rare but they do occur. Aircraft are sometimes flown at flight levels other than those expected by the controller, therefore, allowing aircraft to fly self-selected lateral offsets provides an additional safety margin and mitigates the risk of a mid-air collision when non-normal events such as aircraft navigation errors, height deviation errors and turbulence induced altitude-keeping errors do occur. It has been shown that collision risk is significantly reduced by the application of these offsets.

Chapter 2

DESCRIPTION OF THE NEW STRATEGIC LATERAL OFFSET PROCEDURES

2.1 PANS-ATM PROVISIONS

2.1.1 This circular addresses the implementation of the following strategic lateral offset procedures published in the PANS-ATM, Section 16.5.

16.5 STRATEGIC LATERAL OFFSET PROCEDURES (SLOP)

Note 1.— SLOP are approved procedures that allow aircraft to fly on a track parallel to the right of the centre line relative to the direction of flight to mitigate the lateral overlap probability due to increased navigation accuracy, and wake turbulence encounters. Unless specified in the separation standard, an aircraft's use of these procedures does not affect the application of prescribed separation standards.

Note 2.— Annex 2, 3.6.2.1.1, requires authorization for the application of strategic lateral offsets from the appropriate ATS authority responsible for the airspace concerned.

16.5.1 Implementation of strategic lateral offset procedures shall be coordinated among the States involved.

Note.— Information concerning the implementation of strategic lateral offset procedures is contained in the Implementation of Strategic Lateral Offset Procedures (Circ 331).

16.5.2 Strategic lateral offsets shall be authorized only in en-route airspace as follows:

- a) where the lateral separation minima or spacing between route centre lines is 55.5 km (30 NM) or more, offsets to the right of the centre line relative to the direction of flight in tenths of a nautical mile up to a maximum of 3.7 km (2 NM); and
- b) where the lateral separation minima or spacing between route centre lines is 11.1 km (6 NM) or more and less than 55.5 km (30 NM), offsets to the right of the centre line relative to the direction of flight in tenths of a nautical mile up to a maximum of 0.9 km (0.5 NM).

16.5.3 The routes or airspace where application of strategic lateral offsets is authorized, and the procedures to be followed by pilots, shall be promulgated in aeronautical information publications (AIPs). In some instances it may be necessary to impose restrictions on the use of strategic lateral offsets, e.g. where their application may be inappropriate for reasons related to obstacle clearance. Route conformance monitoring systems shall account for the application of SLOP.

16.5.4 The decision to apply a strategic lateral offset shall be the responsibility of the flight crew. The flight crew shall only apply strategic lateral offsets in airspace where such offsets have been authorized by the appropriate ATS authority and when the aircraft is equipped with automatic offset tracking capability.

Note 1.— Pilots may contact other aircraft on the inter-pilot air-to-air frequency 123.45 MHz to coordinate offsets.

Note 2.— The strategic lateral offset procedure has been designed to include offsets to mitigate the effects of wake turbulence of preceding aircraft. If wake turbulence needs to be avoided, an offset to the right within the limits specified in 16.5.2 may be used.

Note 3.— Pilots are not required to inform ATC that a strategic lateral offset is being applied.

2.2 WHY AIRCRAFT SHOULD OFFSET

2.2.1 The extreme accuracy of the global navigation satellite system (GNSS) and today's altimeter systems can result in high collision risk when an error occurs in the system. This may for example happen when an aircraft is flying at a level that is not expected by ATC. Applying an offset to the right of track significantly reduces the collision risk between aircraft on the same or opposite direction tracks in such circumstances because the aircraft obtains lateral spacing from nearby aircraft that are immediately above and below.

2.2.2 An example is a mid-air collision where a Boeing 737 collided head on with an Embraer legacy business jet. Both aircraft were assigned flight level 370, the Embraer transponder was not operating and neither aircraft received a traffic alert and collision avoidance system (TCAS) alert. All 154 passengers and crew aboard the Boeing 737 were killed. An offset to the right by one or both aircraft would have prevented this accident.

2.2.3 The higher the usage of SLOP the greater the resulting collision risk reduction. But even a small uptake of SLOP, has a significant effect. For example, a single offsetting aircraft flying the North Atlantic in a direction opposite to the main traffic flow may be passing a considerable number of opposite direction aircraft. This single aircraft applying SLOP provides a reduced risk, not only for itself, but also for all the other encountered aircraft, even though they were not participating in any form of offset.

2.3 WHERE AIRCRAFT SHOULD OFFSET

2.3.1 As stated in the PANS-ATM, Section 16.5, a flight crew should only apply SLOP if the following conditions are satisfied:

- a) the appropriate ATS authority has authorized the application of SLOP in the airspace concerned and promulgated in aeronautical information publications (AIPs);
- b) the aircraft is equipped with automatic offset tracking capability; and

- c) if the maximum allowed lateral offset is 0.5 NM, then only aircraft capable of offsetting in a fraction of a mile should apply SLOP.

2.3.2 When operating in airspace where SLOP has been authorized, the decision to apply SLOP is the responsibility of the flight crew.

Note.— Automatic offset tracking capability is a flight management system (FMS) capability of creating a route parallel to the active route and intercepting and flying that route when executed by the pilot.

2.4 WHEN AIRCRAFT SHOULD OFFSET

2.4.1 Due to the positive effect on collision risk, flight crew of suitably equipped aircraft should apply SLOP as a standard operating procedure in all airspace where the procedure has been approved and promulgated by the appropriate authority. The offset should be applied from the time the aircraft reaches its cruising level until top of descent.

2.4.2 Aircraft not flying a published route or track could also apply SLOP. Even though such aircraft normally present a smaller overlap risk due to the random nature of such operations, the offset would not have any negative impact, but would rather have a positive impact in case the flight experienced proximate same direction or opposite direction random route aircraft.

2.5 HOW AIRCRAFT SHOULD OFFSET

2.5.1 The effect of SLOP is maximized if the traffic is evenly distributed among the available lateral offset options. Therefore pilots should choose a lateral offset position in accordance with the following:

- a) if flying in airspace where a maximum of 0.9 km (0.5 NM) offset is approved:
 - 1) randomly choose an offset position of 0.2 km (0.1 NM), 0.4 km (0.2 NM), 0.6 km (0.3 NM), 0.7 km (0.4 NM) or 0.9 km (0.5 NM) right of track;
- b) if flying in airspace where a maximum of 3.7 km (2 NM) offset is approved:
 - 1) if the aircraft is equipped with a capability to offset in tenths of a nautical mile then randomly choose an offset position of 0.2 km (0.1 NM) or more up to 3.7 km (2 NM) right of track; and
 - 2) if the aircraft is equipped with a capability to offset only in whole nautical miles then randomly choose centreline or an offset position of 1.9 km (1 NM) or 3.7 km (2 NM) right of track.

2.5.2 If pilots are aware of other aircraft immediately above or below they should use whatever means are available (e.g. TCAS, visual acquisition, or communications with other aircraft on an inter-pilot air-to-air frequency) to determine the best offset position.

2.5.3 If there is a need to apply offsets to mitigate the effect of wake turbulence, then the crew should choose the most suitable offset positions of those specified above. An aircraft overtaking another aircraft

should, if capable, offset within the confines specified above so as to create the least amount of wake turbulence for the aircraft being overtaken.

2.5.4 Voice position reports should be based on the waypoints of the current ATC clearance and not the offset positions.

2.5.5 There is no ATC clearance required for the application of SLOP and it is not necessary to inform ATC.

Offsets to the left should NOT be made under any circumstances unless under clearance from ATC.

2.6 CONSIDERATIONS FOR THE APPROPRIATE AUTHORITY

2.6.1 Civil aviation authorities are urged to authorize SLOP as a collision risk mitigation measure wherever it is possible. The following is recommended to be taken into account when authorizing the use of SLOP in a particular airspace:

- a) implementation in coordination between all States involved will improve harmonization and clarity related to area of implementation across FIRs. Fragmented areas of SLOP implementation could create pilot confusion as to whether the procedure is authorized;
- b) SLOP is to be authorized only between top of climb and top of descent;
- c) in airspace where the lateral separation minima or route spacing is 55.5 km (30 NM) or more the maximum allowable offset value is 3.7 km (2 NM);
- d) in airspace where the lateral separation minima or route spacing is 11.1 km (6 NM) or more and less than 55.5 km (30 NM), the maximum allowable offset value is 0.9 km (0.5 NM);
- e) SLOP is not to be applicable in airspace where the lateral separation minima or route spacing is less than 11.1 km (6 NM);
- f) the routes or airspace where application of SLOP is authorized, and the procedures to be followed by pilots, are to be published in aeronautical information publications (AIPs);
- g) air traffic controllers need to be made aware of the airspace where SLOP is authorized;
- h) in some instances it may be necessary to impose restrictions on the use of SLOP, e.g. where their application may be inappropriate for reasons related to obstacle clearance;
- i) route adherence monitoring systems should account for the application of SLOP; and
- j) the location of any prohibited, restricted or danger areas must be taken into account before SLOP are authorized.

Chapter 3

SASP SAFETY ASSESSMENT

3.1 INTRODUCTION

3.1.1 This chapter summarizes the safety assessment performed by SASP to determine under which circumstances the application of SLOP would be safe. The methodology is explained below, as is the rationale behind its use and the conclusions drawn from it.

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 can be seen that because the local operating environment into which SLOP 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-focused 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.

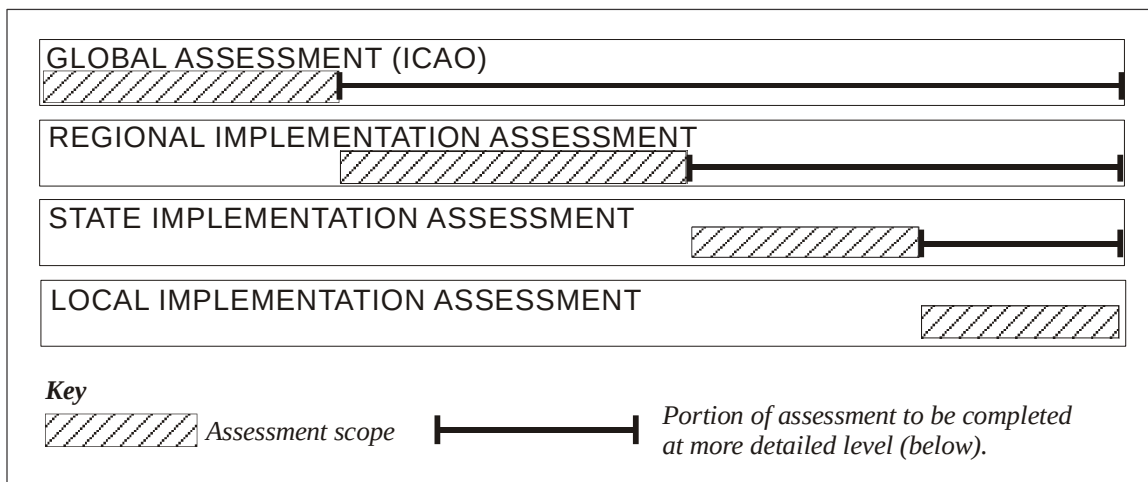


Figure 3-1. Safety assessment scope

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 In undertaking an implementation supporting safety assessment it 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 undertaking an assessment of issues related specifically to implementation.

3.3 OBJECTIVES AND DEVELOPMENT OF SASP SAFETY ASSESSMENTS

3.3.1 Strategic lateral offsets as described in Chapter 2 have a mitigating effect on vertical and longitudinal collision risk. However, depending on the directions of flow, they may lead to some increase in lateral collision risk, both for non-intersecting (parallel) tracks and intersecting tracks.

3.3.2 The objective of the SASP safety assessment in support of the use of SLOP was to determine whether the increases, if any, in lateral collision risk due to the use of SLOP would be tolerable.

3.3.3 Early work on lateral offsets examined the anticipated effects of using several possible procedures, principally in systems of parallel routes. Different procedures offered different reductions in vertical and longitudinal risk, and – depending in some cases on the route configuration or method of application – either increases or decreases in lateral risk. Studies by SASP and its predecessor, the RGCSP, also considered different levels of aircraft equipage with GNSS, different levels of aircraft equipage with offset capability, different navigational capabilities of the non-GNSS part of the fleet, and different probabilities that aircraft equipped to apply offsets would actually do so. Details are given in the summaries provided in section 3.4.

3.3.4 Later work on lateral offsets also examined their possible effect on intersecting-tracks collision risk. Apart from the traditional lateral separation minima for VHF omnidirectional radio range (VOR), and non-directional radio beacon (NDB), dead reckoning, and area navigation (RNAV) operations, the PANS-ATM provided a method of applying lateral separation for “RNAV operations (where RNP is specified) on intersecting tracks or air traffic services (ATS) routes” based on the concept of a defined area of conflict around an intersection (Ref. 53). This method of applying lateral separation was superseded by an alternative method of applying lateral separation on intersecting tracks based on a “protected” region of airspace on either side of the track of a reference aircraft (ref. 55). The reason for the replacement was that the SASP saw several operational advantages of the alternative method over the area of conflict method. SLOP risk assessments have been performed for both methods of applying intersecting-tracks lateral separation and are included below. Details of the lateral offset work for both the area of conflict method and the protected region method are provided in 3.5.

3.3.5 In the context of the safety assessment of existing separation minima combined with SLOP, a distinction is made between collision risk due to navigation performance and risk due to other hazards.

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

3.3.7 Typical and atypical navigation performance falls 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.

3.3.8 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.

3.3.9 Existing lateral separation minima for parallel tracks and intersecting tracks 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 hour; and
- b) the risk due to all other hazards not considered in the modelling is “negligible”.

3.3.10 The use of lateral offsets may increase the lateral collision risk for an existing safe separation minimum, even to a level greater than the TLS. It is necessary, therefore, to define additional criteria to judge whether such increases are tolerable. Ideally, such criteria should also take into account the corresponding reductions in the vertical and longitudinal collision risks. These additional criteria will be presented as a part of each individual assessment in Section 3.4 and 3.5 below.

3.3.11 Several assumptions were made during the safety assessment by SASP:

- a) an aircraft employing a lateral offset would be equipped with GNSS for positioning and a FMS capable of offsetting laterally from the aircraft’s cleared routing;
- b) internationally applied collision-risk methodology is appropriate to assess the increase or decrease in collision risk in the various dimensions when the offset procedure is applied; and
- c) a significant reduction in collision risk in one dimension (for example, the vertical) attributable to application of the procedure is desirable even if application of the procedure leads to a small increase in collision risk in another dimension (for example, the lateral).

3.3.12 A significant enabler for the implementation of SLOP is the development and equipping of aircraft with a flight management system capable of providing automatic offsets in either one NM increments or, for some modern aircraft, in increments of tenths of a nautical mile. A full level of equipage, while significant as an end-state goal, is not required, as any aircraft applying SLOP adds to the safety of the system.

3.4 SAFETY ASSESSMENT FOR SLOP AND NON-INTERSECTING TRACKS

RGCSP-WG/B Meeting, October 1998

3.4.1 The RGCSP began quantitative work on lateral-offset procedures at its meeting in October 1998. The panel conducted its business in two working-group meetings: that of WG/A, which concentrated on matters of horizontal separation, and that of WG/B, which concentrated on vertical separation. The use of lateral offsets was seen as a means of mitigating increases in risk arising from two trends: 1) the implementation of RVSM above FL290 in airspaces around the world; and 2) the increasing use of the highly accurate GNSS. The panel recognized that if two aircraft, assigned to the same route, lose their planned vertical separation, they avoid a collision only if they have random longitudinal separation or random lateral separation. The increased use of GNSS drastically reduces the probability that two such aircraft will have random lateral separation. Thus the use of lateral offsets was seen as a means of restoring some lateral dispersion (about the route centre line) to the traffic assigned to any particular route. Since the implementation of RVSM provided the impetus for the use of lateral offsets, the topic was considered in the meeting of WG/B.

3.4.2 The October 1998 meeting of RGCSP WG/B, suggested a plan for random lateral offsets (ref. 3)¹. It was first shown that the probability of a collision, in the event of a loss of planned vertical separation, varies directly with the lateral overlap probability of the aircraft involved in the encounter. Thus the benefit of implementing an offset scheme can be assessed by the extent to which it reduces the lateral overlap probability of a pair of aircraft assigned to the same route. It was later shown that it is technically feasible to use random offsets limited by any finite distance. A typical scientific calculator, costing very little, includes a random number generator. By generating a random number between 0 and 1, and then using the calculator to apply a simple linear transformation, a pilot could easily determine the direction and extent of his random offset. Since the random numbers are uniformly distributed between 0 and 1, the resulting offsets would also be uniformly distributed on some chosen interval.

3.4.3 It was assumed that a typical aeroplane's lateral distance from its intended path, at any arbitrarily chosen moment, is a normally distributed random variable having mean 0 and standard deviation equal to the aeroplane's required navigation performance (RNP) value divided by 1.96 (this assumption was based on the original definition of RNP values as distances that provide 95 per cent containment). An aeroplane's signed distance from its route centre line is the algebraic sum of its intended lateral offset and its deviation from its intended path. The difference between two such sums represents the lateral distance between the centres of two aircraft assigned to a given path. The meeting provided a formula for the probability density function of this difference. When the absolute value of the difference is less than the wingspan of an aeroplane, the two aircraft have laterally overlapping positions.

3.4.4 The formula for the density function was used to produce three graphs. In one of them aircraft were assumed to meet RNP 10; in another they were assumed to meet RNP 4; and in the third they were assumed to meet RNP 1. The horizontal axis of each graph showed values of the maximum allowable offset distance, ranging from 0.9 km (0.5 NM) to 5.5 km (3 NM). The vertical axis showed (for each point on the graph) the ratio of the lateral overlap probability when offsets are used, to the lateral overlap probability when offsets are not used. Thus each graph showed (for one of the three RNP values) the extent to which the

1 The reference material at the end of this circular provides a (nearly) complete, chronologically ordered, bibliography of all the material considered by SASP in developing the procedure and safety assessment detailed in Circular 331. Only a limited number of documents are explicitly referenced in sections 3.4 and 3.5.

use of offsets would reduce lateral overlap probability. In each graph, the reduction in overlap probability varied directly with the maximum allowable offset distance, so that the greatest reduction was achieved when the maximum offset could be as great as 5.5 km (3 NM).

3.4.5 For aircraft that met RNP 10, the maximum reduction in lateral overlap probability was only slightly greater than 5 per cent. This is because these aircraft already exhibit a wide dispersion about the route centre line; and so the use of offsets would yield only a slight increase in dispersion, and a slight decrease in lateral overlap probability. Aircraft that met the classical definition of RNP 4 (i.e. 95 per cent containment within 7.4 km (4 NM) of the intended path) could achieve a reduction of 25 per cent in lateral overlap probability if the maximum allowable offset distance were 5.5 km (3 NM). Aircraft that met the classical definition of RNP 1 would benefit the most from the offset scheme, as their lateral overlap probabilities would decrease by more than 70 per cent if they used uniformly distributed offsets with a maximum distance of 5.5 km (3 NM).

3.4.6 RGCSP WG/B recognized that the offset capabilities available in much of the commercial fleet allow aircraft to fly on paths offset from a programmed route by whole numbers (i.e., integer values) of nautical miles. Though it would still be technically possible to apply uniformly distributed offsets – e.g. by programming offset way-points into a flight management system – the working group found the use of uniformly distributed offsets to be impractical. Until 2009, when SASP began technical studies of “micro-offsets”, all further RGCSP and SASP documents dealing with offsets assumed that they would be specified in integer numbers of nautical miles.

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3.4.7 The RGCSP recognized that the use of lateral offsets could give rise to increases in lateral risk. Before endorsing any particular scheme for applying offsets, the panel asked its (newly created) mathematicians’ subgroup to examine the change in lateral risk that might result from the use of offsets of 1.9 km (1 NM), 3.7 km (2 NM) or 5.5 km (3 NM). Documents for the meeting, examined several scenarios specified by the panel, in order to estimate the changes in lateral risk caused by the use of offsets (ref. 6).

3.4.8 The first three scenarios considered by the meeting assumed a pair of parallel routes, spaced 50 NM apart, carrying same-direction traffic. In one scenario the aircraft satisfied RNP 10; in another they satisfied RNP 4; and in the third they satisfied RNP 1. Aircraft assigned to a pair of parallel routes decrease their lateral risk by using offsets that increase their intended lateral separation. Therefore all cases in the first three scenarios in which aircraft offsets increase, their intended separation were ignored. To avoid unnecessary complications, it examined only those (hypothetical) cases in which the offsets are of the same magnitude, and move the aircraft toward each other. To limit the number of cases under consideration, the paper showed computations only for pairs of aircraft that meet the same RNP level. All computations assumed that aircraft lateral deviations from their intended paths (at any arbitrarily chosen moment) are random signed distances that can be described by a double exponential (DDE) distribution. The parameter of the DDE’s “core distribution” was derived from the RNP value of the aircraft being considered; the parameter of the DDE’s “tail distribution” was (conservatively) taken to be the spacing between the routes; and the “mixing parameter” was derived from studies of North Atlantic traffic in the mid-1990s.

3.4.9 If RNP 1 aircraft on both routes apply offsets of 1.9 km (1 NM), 3.7 km (2 NM) or 5.5 km (3 NM) toward each other – thereby reducing their intended lateral separation to 48, 46 or 44 NM – the increase in lateral overlap probability is relatively small. Each 2 NM decrease of intended separation increases the lateral overlap probability (and lateral risk) by approximately 4 per cent. The same result holds if the aircraft meet RNP 4. However, when the aircraft meet RNP 10, the increases in risk are far greater.

Each decrease of 2 NM in intended lateral separation increases lateral risk by an amount between 30 and 50 per cent. The effect of a 6 NM reduction in intended separation, from 93 km (50 NM) to 81.5 km (44 NM), is to increase lateral risk by 172 per cent.

3.4.10 The next three scenarios considered by the meeting again assumed a pair of parallel routes spaced 93 km (50 NM) apart, and aircraft that satisfied RNP 1, RNP 4 and RNP 10. The routes were unidirectional, but their flows were in opposite directions. Therefore, the computed values of absolute risk were approximately an order of magnitude greater (for the same level of occupancy) than those of the first three scenarios. Since lateral overlap probabilities did not depend on the directions of traffic flow, the percentage changes in risk for these scenarios were identical to those of the first three scenarios.

3.4.11 The seventh scenario considered had four unidirectional parallel routes, all spaced 93 km (50 NM) apart, and all carrying RNP 10 aircraft in the same direction. Since each of the two inner routes was adjacent to the other, and was also adjacent to one of the two outer routes, an offset executed by an aeroplane assigned to an inner route increased its intended lateral separation from one of the adjacent routes, but decreased its intended lateral separation from the other. Moreover, the risk computations depended on the distribution of traffic over the routes and flight levels in the system, and could, therefore, become extremely complex. Documentation for the meeting also provided, by examples, that if the traffic is appropriately distributed, it is even possible for the use of offsets to cause a decrease in the estimated rate of accidents due to the loss of planned lateral separation. Such decreases could occur, for example, if aircraft assigned to heavily loaded inner routes offset away from each other, toward lightly loaded outer routes.

3.4.12 The eighth, ninth and tenth scenarios also had four unidirectional parallel routes, spaced 93 km (50 NM) apart, carrying RNP 10 aircraft; but some pairs of adjacent routes had opposite-direction flows. In the eighth scenario, each pair of adjacent routes had traffic moving in opposite directions. In the ninth scenario, the two inner routes carried same-direction traffic, while each outer route carried traffic in the direction opposite that of the inner routes. In the tenth scenario the two inner routes carried traffic moving in opposite directions, and each outer route carried traffic moving in the same direction as its adjacent inner route.

3.4.13 Since all pairs of adjacent routes in the eighth scenario had opposite-direction traffic, the risk estimates were analogous to those for the seventh scenario, with the only difference being the use, in the Reich model, of the kinematic factor $k(opp)$ for opposite-direction traffic, rather than $k(same)$, the analogous factor for same-direction traffic. Since $k(opp)$ is approximately an order of magnitude greater than $k(same)$, the absolute risk estimates for the eighth scenario were an order of magnitude greater than those for the seventh scenario; but the percentage changes in risk caused by the use of lateral offsets were identical.

3.4.14 The ninth and tenth scenarios again offered opportunities to show, by example, that the use of lateral offsets has the potential to actually reduce lateral risk. The basic strategy for doing so is to apply offsets that increase the intended lateral separation between aircraft assigned to pairs of opposite-direction routes, while decreasing the intended lateral separation between aircraft assigned to pairs of same-direction routes. (Though the examples were theoretically interesting, it was noted that they might not be fully realistic, in that the occupancy values used for opposite-direction traffic were the same as those used for same-direction traffic. In practice, the same spacing would be used for same-direction route pairs and opposite-direction route pairs only if the opposite-direction occupancies were quite low.)

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3.4.15 After the March 1997 implementation of a reduced vertical separation minimum (RVSM) of