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ABBREVIATIONS AND ACRONYMS

AIC	Aeronautical information circular
AIP	Aeronautical information publication
AIRAC	Aeronautical information regulation and control
AIS	Aeronautical information service
ANSP	Air navigation service provider
ATC	Air traffic control
ATS	Air traffic services
CPDLC	Controller-pilot data link communications
DCPC	Direct controller pilot communications
DME	Distance measuring equipment
FAA	Federal Aviation Administration
FD	Fault detection
FDE	Fault detection and exclusion
FL	Flight level
FMS	Flight management system
GLONASS	Global navigation satellite system
GNSS	Global navigation satellite system
GPS	Global positioning system
ICAO	International Civil Aviation Organization
IFR	Instrument flight rules
km	Kilometre
m	Metre
NAVAIDS	Navigation aids
NDB	Non-directional beacon
NM	Nautical mile
PANS-ATM	Procedures for Air Navigation Services – Air Traffic Management
PBN	Performance-based navigation
RAIM	Receiver autonomous integrity monitoring
RLS	Reference level of safety
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
SBAS	Space-based augmentation system
SLOP	Strategic lateral offset procedures
TSO	Technical standard order
VHF	Very high frequency
VOR	VHF omnidirectional radio range
WGS-84	World Geodetic System – 1984

Chapter 1

INTRODUCTION

1.1 PURPOSE

1.1.1 The purpose of this circular is to provide guidance on applying the global navigation satellite system (GNSS) lateral separation minima which is based on the VHF omnidirectional radio range (VOR) lateral separation minima. It is aimed at a worldwide audience within the civil aviation authorities responsible for implementing this and other separation minima.

1.1.2 As a result of the large number of aircraft equipped with instrument flight rules (IFR) GNSS equipment for navigation and its potential use for separation in the procedural environment, the Separation and Airspace Safety Panel (SASP) developed the separation minima detailed in this document for interim use in the transition period to widespread implementation of performance-based navigation (PBN). These separation minima are intended to exploit the capabilities and precision of GNSS equipment that, as a minimum, meet the requirements of ICAO Annex 10 — *Aeronautical Communications*, Volume I — *Radio Navigation Aids*.

1.2 BACKGROUND

1.2.1 In 1996, the International Civil Aviation Organization (ICAO) endorsed the development and use of GNSS as a primary source of future navigation for civil aviation. ICAO noted the increased flight safety, route flexibility and operational efficiencies that could be realized from the move to space-based navigation. Since then, air navigation service providers (ANSPs), airline operators and avionics manufacturers have engaged in an ambitious effort to develop GNSS, their related augmentation systems, airborne receivers and ground infrastructure, and to implement procedures, equip aircraft and train pilots in the use of satellite navigation.

1.2.2 GNSS provides significant improvements when compared to conventional radio navigation installations because of the global availability and accuracy of the GNSS signal. The potential for the use of GNSS for the application of separation was identified in 2002. The first GNSS longitudinal separation was published in November 2007, and the GNSS lateral separation minima introduced in this circular are the second to be published.

1.2.3 This circular is published in support of Amendment No. 6 to the *Procedures for Air Navigation Services — Air Traffic Management* (PANS-ATM) which becomes applicable in November 2014.

Chapter 2

GLOBAL NAVIGATION SATELLITE SYSTEM (GNSS)

2.1 INTRODUCTION

2.1.1 This chapter provides a high-level overview of GNSS positioning in the context of using GNSS as a basis for separation in a procedural environment. The information is primarily based on that published in the ICAO *Global Navigation Satellite System (GNSS) Manual* (Doc 9849).

2.1.2 GNSS is global in scope and fundamentally different from traditional navigation aids (NAVAIDs). It has the potential to support all phases of flight, resulting in a seamless global navigation guidance system. GNSS provides accurate guidance in remote and oceanic areas where it is impractical, too costly, or impossible to install traditional NAVAIDs. It also guarantees that all operations are based on a common navigation reference.

2.2 GNSS CORE CONSTELLATIONS AND POSITIONING

2.2.1 Currently, there are two fully operational global satellite constellations in operation: the global positioning system (GPS) provided by the United States and the Russian Global Navigation Satellites System (GLONASS). The European Galileo system is currently under development. These systems will provide independent capabilities but could be used in combination in the future with specifically designed receivers to improve GNSS robustness.

2.2.2 Satellites in the core constellations broadcast a timing signal and a data message that include their orbital parameters (ephemeris data). The GNSS receiver computes position, velocity, time and possibly other information depending on the application. Measurements from a minimum of four satellites are required to establish three-dimensional position (longitude, latitude and height). Accuracy is dependent on the precision of the time measurements from the satellites and the relative geometry of the satellites used. Once the receiver knows its position, it can provide guidance (navigation) between waypoints selected from a database in the receiver. Guidance to a pilot is typically provided through both traditional course deviation indicators and moving map displays. To meet the performance criteria for aviation, GNSS must be able to ensure integrity, accuracy, availability and continuity to specified levels.

2.3 GNSS ACCURACY

2.3.1 GNSS offers position measurements that are equal to or more accurate than distance measuring equipment (DME), VOR and non-directional radio beacon (NDB). The collision risk calculations done to establish the GNSS lateral separation referred to in this circular assumed the GNSS along-track accuracy to be ±0.124 NM, GNSS cross-track accuracy to be ±1 NM, DME Fix Tolerance to be ±0.25 NM plus 1.25 per cent of the distance to the antenna, VOR accuracy to be ±1 NM and ±5.2 degrees, and NDB accuracy to be ±1 NM and ±6.9 degrees. All of those were assumed to be 95th percentile containment values.

2.3.2 In addition to a high degree of accuracy, GNSS receivers approved for IFR operations offer integrity by providing alerts when the position cannot be guaranteed within a specified degree of certainty. These alert limits are:

a) en-route – 3.7 km (2.0 NM);

b) terminal – 1.85 km (1.0 NM); and

c) approach – 556 m (0.3 NM).

2.3.3 The position information provided by the GNSS to the user is expressed in terms of the World Geodetic System – 1984 (WGS-84) geodetic reference datum.

2.4 GNSS LATERAL SEPARATION MINIMA

This circular addresses the implementation of the following GNSS lateral separation minima published in the *Procedures for Air Navigation Services — Air Traffic Management* (PANS-ATM, Doc 4444), paragraph 5.4.1.2.1.2.

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:

5.4.1.2.1.1 *By reference to the same or different geographic locations*. By position reports which positively indicate the aircraft are over different geographic locations as determined visually or by reference to a navigation aid (see Figure 5-3).

5.4.1.2.1.2 *By use of NDB, VOR and GNSS on intersecting tracks or ATS routes*. By requiring aircraft to fly on specified tracks which are separated by a minimum amount appropriate to the navigation aid employed. Lateral separation between two aircraft exists when:

a) *VOR:* both aircraft are established on radials diverging by at least 15 degrees and at least one aircraft is at a distance of 28 km (15 NM) or more from the facility (see Figure 5-4);

b) *NDB:* both aircraft are established on tracks to or from the NDB which are diverging by at least 30 degrees and at least one aircraft is at a distance of 28 km (15 NM) or more from the facility (see Figure 5-5);

c) *GNSS/GNSS:* each aircraft is confirmed to be established on a track with zero offset between two waypoints and at least one aircraft is at a minimum distance from a common point as specified in Table 5-1; or

d) *VOR/GNSS:* the aircraft using VOR is established on a radial to or from the VOR and the other aircraft using GNSS is confirmed to be established on a track with zero offset between two waypoints and at least one aircraft is at a minimum distance from a common point as specified in Table 5-1.

Table 5-1

	Aircraft 1: VOR or GNSS Aircraft 2: GNSS	
Angular difference between tracks measured at the common point	FL010 — FL190 Distance from a common point	FL200 — FL600 Distance from a common point
15 – 135	27.8 km (15 NM)	43 km (23 NM)
The distances in the table are ground distances. States must take into account the distance (slant range) from the source of a DME signal to the receiving antenna when DME is being utilized to provide range information.		

Note 1.— The values in the table above are from a larger table of values derived by collision risk analysis. The source table for separation of aircraft navigating by means of GNSS and VOR is contained in Circular 322, Guidelines for the Implementation of GNSS Lateral Separation Minima Based on VOR Separation Minima. *States may refer to Circular 322 for greater detail and other angular differences and separation distances.*

Note 2.— The values in the table above have accounted for distances from the common point encompassed by the theoretical turn area for fly-by turns as specified in the Minimum Aviation System Performance Standard: Required Navigation Performance for Air Navigation *(ED-75B/DO-236B), section 3.2.5.4 and fixed radius transition turns as defined in the* Performance-based Navigation (PBN) Manual *(Doc 9613)*.

Note 3.— Guidance material for the implementation of the GNSS lateral separation is contained in Circular 322.

5.4.1.2.1.2.1 When aircraft are operating on tracks which are separated by considerably more than the minimum figures in 5.4.1.2.1.2 a) and b), States may reduce the distance at which lateral separation is achieved.

5.4.1.2.1.2.2 Before applying GNSS-based track separation the controller shall confirm the following:

a) ensure that the aircraft is navigating using GNSS; and

b) in airspace where strategic lateral offsets are authorized, ensure that a lateral offset is not being applied.

5.4.1.2.1.2.3 In order to minimize the possibility of operational errors, waypoints contained in the navigation database or uplinked to the aircraft flight management system should be used in lieu of manually entered waypoints, when applying GNSS-based track separation. In the event that it is operationally restrictive to use waypoints contained in the navigation database, the use of waypoints that require manual entry by flight crews should be limited to half or whole degree of latitude and longitude.

5.4.1.2.1.2.4 GNSS-based track separation shall not be applied in cases of pilot reported receiver autonomous integrity monitoring (RAIM) outages.

Note.— For the purpose of applying GNSS-based lateral separation minima, distance and track information derived from an integrated navigation system incorporating GNSS input is regarded as equivalent to GNSS distance and track.

5.4.1.2.1.2.5 GNSS receivers used for applying separation shall meet the requirements in Annex 10, Volume I, and be indicated in the flight plan.

2.5 GNSS TERMINOLOGY

2.5.1 **Receiver Autonomous Integrity Monitoring (RAIM)** — RAIM provides integrity monitoring of GPS for aviation applications. In order for a GPS receiver to perform RAIM or fault detection (FD) function, a minimum of five satellites with satisfactory geometry must be visible to it. The RAIM function performs consistency checks between position solutions obtained with various subsets of the visible satellites. The receiver provides an alert to the pilot if the consistency checks fail. Because of geometry and service maintenance RAIM is not always available.

2.5.2 **Fault Detection and Exclusion (FDE)** — An enhanced version of RAIM employed in some receivers is known as fault detection and exclusion (FDE). It uses a minimum of six satellites to not only detect a possibly faulty satellite, but to exclude it from the navigation solution so the navigation function can continue without interruption. The goal of fault detection is to detect the presence of a positioning failure. Upon detection, proper fault exclusion determines and excludes the source of the failure (without necessarily identifying the individual source causing the problem), thereby allowing GNSS navigation to continue without interruption. Availability of RAIM and FDE will be slightly lower for mid-latitude operations and slightly higher for equatorial and high-latitude regions due to the nature of the orbits. The use of satellites from multiple GNSS constellations or the use of space-based augmentation system (SBAS) satellites as additional ranging sources can improve the availability of RAIM and FDE.

2.5.3 **RAIM Prediction** — GNSS differs from traditional navigation systems because the satellites and areas of degraded coverage are in constant motion. Therefore, if a satellite fails or is taken out of service for maintenance, it is not immediately clear which areas of the airspace will be affected, if any. The location and duration of these outages can be predicted with the aid of computer analysis. During the pre-flight planning process, pilots should use a RAIM predictive programme to ensure adequate GNSS coverage along the planned route of flight.

2.6 GNSS IMPLEMENTATION ISSUES

2.6.1 In developing the safety assessment for the VOR-like GNSS standard, SASP recognized the importance of a number of factors that would impact on any implementation of the standards on a global basis. Among these factors, two had specific importance in the SASP safety assessment, namely the areas of applicability and equipment eligibility, and are described in detail in the following paragraphs. To resolve any additional safety issues identified when undertaking their own safety assessment, States could consider adding an additional buffer, for example, when one or both aircraft are inbound to the common point to take account of the effect of increased closure rate on risk.

2.6.2 **Communication and Area of Applicability** — Historically VOR and NDB separation was normally used in areas that were also served with direct controller pilot communication – very high frequency voice communication (DCPC-VHF). Since GNSS provides worldwide coverage, it has the potential to be used where DCPC VHF is not available, such as in oceanic and remote airspace. As part of the implementation process, the appropriate air traffic services (ATS) authority must determine, for each area of application, the communication requirements for the application of the GNSS lateral separation minima.This issue is considered further in Hazard 2 in Attachment B.

2.6.3 **Equipment Eligibility** — The eligibility for allowing the application of GNSS lateral separation minima to aircraft utilizing integrated area navigation (RNAV) systems incorporating GNSS inputs has also been considered. Discussions regarding this issue involved the analysis of how the various types of flight management system (FMS) work, and whether it could be assumed that position information from integrated RNAV systems incorporating GNSS input could be regarded as equivalent to GNSS position. It was agreed that with over 400 varying FMSs, it would be difficult to speculate how each FMS derived its navigation data. However, after thorough discussion the SASP came to the conclusion that any position report derived from an FMS incorporating GNSS would be acceptable, as it would be more accurate than a VOR/DME position report.

2.6.4 **Implementation Safety Assessment** — In order to ensure that the implementation of GNSS lateral separation minima is safe, the appropriate ATS authority must undertake its own implementation safety assessment as outlined in Chapter 2 of the PANS-ATM. This is to complement the SASP safety assessment to account for possible local conditions that may not have been covered by the safety assessment work of SASP. For this reason, the safety assessment work carried out by the SASP is included in Chapter 3 of this circular. Chapter 4 indicates what remains to be done by the appropriate ATS authority as part of its implementation safety assessment.

Chapter 3

SASP SAFETY ASSESSMENT

3.1 INTRODUCTION

This chapter summarizes the safety assessment performed by SASP to determine the GNSS lateral separation minima. The methodology is explained below as are the conclusions drawn from it.

3.2 SCOPE

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 GNSS 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 a regional or local implementation-focussed assessment (Chapter 2 of the PANS-ATM refers). 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.

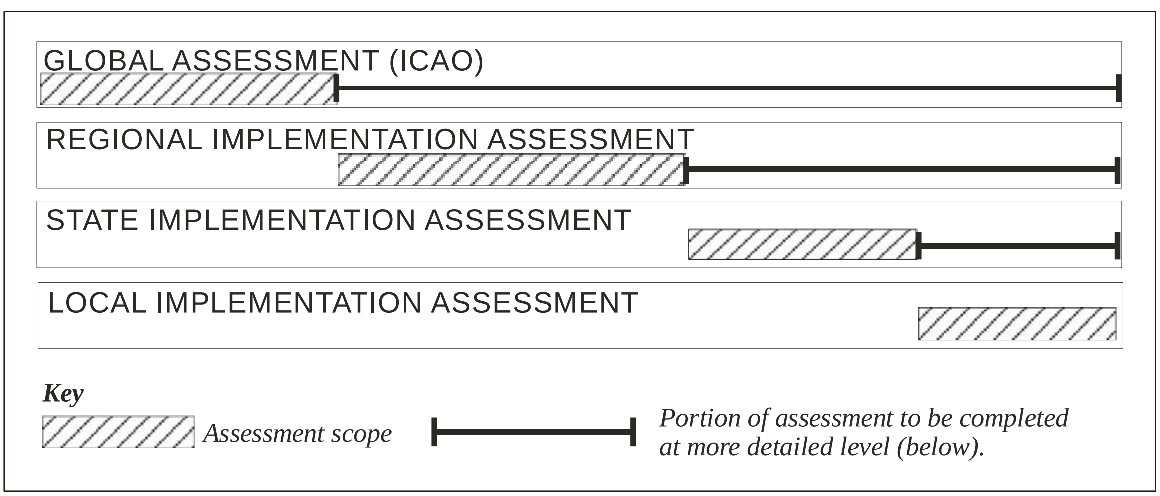

Figure 3-1. Safety Assessment Scope

Note 1.— In undertaking a "global" assessment, SASP is not able to assess all of the factors that might affect safety during implementation. States should note that SASP's assessment is usually based on a number of assumed characteristics related to either the airspace environment or aircraft performance. These characteristics may not necessarily be the same as those relevant to any particular regional, State or local implementation.

Note 2.— In undertaking a regional implementation, a 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 region, then the region only needs to focus on undertaking an assessment of issues related specifically to implementation.

Note 3.— A State implementation assessment need not necessarily follow a regional implementation assessment but could be initiated by a State on its own initiative. In this case, as with the regional implementation assessment, a 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 State, then the State only needs to focus on undertaking an assessment of issues related specifically to implementation.

Note 4.— A local implementation assessment would normally be a supporting activity for a State implementation assessment and focus specifically on implementation issues such as hazard identification. However, there may be circumstances where the service provider may need to review SASP's global assessment and/or the regional assessment, taking particular note of the assumed characteristics used in that assessment.

3.3 OBJECTIVE OF SASP SAFETY ASSESSMENT

The objective of the SASP safety assessment is to demonstrate that the GNSS lateral separation minima are safe for application subject to an appropriate implementation safety assessment being undertaken.

3.4 ASSUMPTIONS

The main assumption was that in applying lateral separation using GNSS in a manner similar to the way lateral separation is applied utilizing VOR, the only change would be the means by which aircraft position was determined.

3.5 DEVELOPMENT OF SASP ASSESSMENT METHODOLOGY

In the context of the assessment of the safety of a separation minimum, a distinction is made between the risk due to navigation performance and the risk due to other hazards. Both safety assessments are described below.

3.5.1 Safety assessment for navigation performance

3.5.1.1 In order to assess the suitability of GNSS for lateral separation, SASP followed the guidance from the *Manual on Airspace Planning Methodology for the Determination of Separation Minima* (Doc 9689). This manual describes two methods for determining whether a proposed system is safe. They are:

a) comparison with a reference system; and

b) evaluation of system risk against a threshold.

3.5.1.2 For the comparison method, the safety of the proposed system is inferred from the safety of the reference system on the condition that the two systems are sufficiently similar (cf. paragraph 3.5.1.5). For the threshold method, the proposed system 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 Since SASP was not seeking to determine new separation minima, but rather to demonstrate that a different technology could be used to allow the application of existing VOR-based separation minima, SASP determined that it would be reasonable to compare GNSS performance with the existing VOR/DME performance in terms of accuracy of position determination.

3.5.1.4 Doc 9689 identifies that the minimum requirements for a proposed system to be considered sufficiently similar to a reference system are:

a) separation minima must not be less in the proposed system than in the reference system;

b) proposed means of communication and surveillance must be no worse in terms of accuracy, reliability, integrity and availability than those in the reference system;

c) frequency and duration of the application of minimum separation between aircraft must not be greater in the proposed system than in the reference system; and

d) navigation performance (typical and non-typical) of the population of aircraft in the proposed system should be no worse in its effect on collision risk in any dimension, than that of the aircraft in the reference system.

3.5.1.5 SASP decided to undertake a technical comparison using a reference VOR/DME system already being used for VOR separation that is judged to be safe. Prior to the amendment, the reference system separation was described in PANS-ATM, paragraph 5.4.1.2.1:

> "Means by which lateral separation may be applied include the following:"*.….5.4.1.2.1.2* "*By use of the same navigation aid or method.* By requiring aircraft to fly on specified tracks which are separated by a minimum amount appropriate to the navigation aid or method employed. Lateral separation between two aircraft exists when: a) *VOR:* both aircraft are established on radials diverging by at least 15 degrees and at least one aircraft is at a distance of 28 km (15 NM) or more from the facility…".

3.5.1.6 The use of GNSS for applying these minima was expected to be possible since GNSS cross-track accuracy is at least as good as VOR accuracy, and GNSS along-track accuracy is at least as good as DME accuracy. The position determination accuracy of GNSS was therefore deemed to be better or at least no worse than VOR/DME.

3.5.1.7 SASP's view was that the requirements in the above listing were met as follows:

a) requirement a) was met as this form of lateral separation is based upon a combination of an angular separation of tracks and distances from a common point, which allows a trade-off between the two components under the constraint that the risk of collision is not larger than that for a 15-degree angle in combination with a 15 NM distance;

b) requirement b) was met as, prior to the amendment, there was no explicit communication requirement in the PANS-ATM for the application of VOR separation. Moreover, communications requirements were not factored into the collision risk calculations because of the various methods of application of lateral separation in a procedural environment;

c) requirement c) applies to safety assessments of entire route systems and does not have an effect on safety assessments of separation minima which consider the collision risk of a pair of aircraft per operation; and

d) requirement d) was met by the fact the lateral navigation performance of GNSS is significantly better than VOR.

3.5.1.8 A safety analysis using the comparative safety assessment method was presented at SASP-WG/WHL/9 with the following strategy: an angle between radial tracks, a flight level (FL), aircraft ground speeds and a combination of aircraft directions (towards or away from the VOR) are chosen. Calculations are done first for a VOR-VOR pair. The first aircraft is started at a trial lateral separation point, such as 15 NM from the VOR. A set of second aircraft are started at a range of distances from the VOR on the other radial track. The aircraft are then flown for ten minutes, and a collision risk for each pair is calculated using the collision risk model in SASP-WG/WHL/7-WP/20 (Ref. 2). An average collision risk over all the second aircraft starting positions is then calculated. If the average collision risk is less than 4 x then the lateral separation point is decreased and the computations are repeated until the collision risk is found to be just under 4 x. (This level of safety is based on 5 x fatal accidents per flight hour converted to collisions and a ten-minute period.) Taking the lateral separation point found from the VOR-VOR calculation, a GNSS aircraft is then substituted for either or both VOR aircraft, and an average collision risk is computed. The working paper also considered NDB aircraft in combination with VOR and GNSS aircraft. The separation table in PANS-ATM, 5.4.1.2.1.2, was generated by making a trade-off between the angular separation of tracks and distances from a common point (the two components making up the lateral separation minima) under the constraint that the risk of collision is not larger than that for a 15-degree angle in combination with a 15 NM distance.

3.5.1.9 The navigational accuracies were set as:

a) VOR cross-track: minimum of ±1 NM and ±5.2 degrees;

b) NDB cross-track; minimum of ±1 NM and ±6.9 degrees;

c) DME along-track: 0.25 NM plus 1.25 per cent of the slant range; and

d) GNSS: ±1 NM (cross-track) and ±0.124 NM (along-track).

These are 95th percentile values. Results were calculated using both Gaussian and Double Exponential distributions and then shown separately in tables.

3.5.1.10 These tables showed results for a range of track intersection angles, flight levels and combinations of ground speed and flight direction. To two decimal places the results showed a lower or equal collision risk when a GNSS aircraft was substituted for a VOR (or NDB) aircraft on intersecting tracks at a VOR (NDB). It was also shown that the lateral separation point at angles higher than 15 degrees could be safely less than 15 NM.

3.5.1.11 The modelling was extended to:

a) have initial positions for the second aircraft every 0.1 NM rather than the previous 0.25 NM;

b) include lower altitudes; and

c) include more aircraft ground speed combinations.

Very fast aircraft were not paired with very slow aircraft. Also aircraft speeds greater than 300 kts were excluded below FL150, and speeds slower than 300 kts were excluded above FL150.

3.5.1.12 Reference levels of safety (RLS) were calculated using both Gaussian and Double Exponential distributions. These were the maximum collision risks obtained with the 15 degree-15 NM VOR-VOR case, maximized over all the flight level – speed combinations for diverging, converging and passing cases. Calculations were repeated for 13- and 14-degree angles between tracks with the lateral separation distance being adjusted outwards until both the Gaussian and Double Exponential collision risks were just equal to or below the RLS values. Calculations were also repeated for 16-90 degree angles between tracks with the lateral separation distance being decreased as far as possible for the collision risks to stay within the RLS values. In this way a table of lateral separation values for a range of angles and flight levels was built up for a VOR-VOR pair. Most of the values were less than 15 NM.

3.5.1.13 A second table in the working paper applied to cases where GNSS aircraft were substituted for one or both VOR aircraft. Previous calculations were repeated with the GNSS aircraft present until the maximum collision risks were either no more than five per cent greater than the corresponding VOR-VOR value or negligible (less than 4 x). Some lateral separation values had to be increased but only minor changes were apparent from the VOR-VOR table. The working paper did not show results for NDB aircraft.

3.5.1.14 SASP-WG/WHL/10 made four main recommendations:

a) to model tracking tolerance abeam a VOR or NDB assuming a cone of ambiguity (ICAO *Procedures for Air Navigation Services — Aircraft Operations*, Volume I — *Flight Procedures* (PANS-OPS, Doc 8168) Volume II, Figures I-2-2-3 and I-2-2-4). Cone angles from the vertical were 50 degrees (VOR) and 40 degrees (NDB);

b) to use reference levels of safety (RLS) based on the maximum collision risk of all VOR-VOR pairs at altitudes only up to FL100;

c) to extend the calculations up to a track intersection angle of 135 degrees; and

d) to show similar results for NDB aircraft substituting for one or both aircraft.

These recommendations were addressed at SASP-WG/WHL/11.

3.5.1.15 The safety analysis was completed at SASP-WG/WHL/11. The effect of the cone of ambiguity and the removal of high altitudes from the RLS calculations led to some lateral separation distances being larger than in the previous documentation. Results were also shown for the case where VOR-VOR RLS values were calculated to FL150 rather than FL100.

3.5.1.16 The tables discussed at SASP-WG/WHL/11 gave theoretical minimum lateral separation values for all combinations of aircraft navigating by means of VOR or NDB or GNSS. The values were obtained through a chain of comparisons against the collision risk for a 15 degree–15 NM pair of aircraft navigating by means of VOR.

3.5.1.17 The results from the calculations concerning NDB type separations indicated that improvements could be made from the 30 degree–15 NM separation minimum. In theory this would allow separation at smaller angular differences. Furthermore, similar separation values could also be applied between a mix of aircraft navigating by means of GNSS and NDB. In practice, however, it was felt that the data did not support reducing the minimum separation distance below 15 NM. As a result of this, SASP created two tables for inclusion in PANS-ATM for NDB separation: one table for a mix of GNSS and NDB and one table for the separation of two aircraft navigating by means of NDB. Those tables were, however, subsequently reviewed by the Air Navigation Commission, which elected not to use them and to keep the PANS-ATM NDB separation unchanged.

3.5.1.18 Table 3-1 was selected by SASP as the basis for the PANS-ATM, VOR/GNSS separation values as it was considered to be most representative of the operational environment:

Table 3-1. VOR/GNSS separation values from SASP

	GNSS/VOR — GNSS/VOR	
Angular difference	*F010 – F280 (NM)*	*F290 – F600 (NM)*
13	170	170
14	60	61
15	15	22
16	11	20
17	11	19
18	11	18
19	11	18
20	11	17
21	11	16
22	11	16
23-24	11	15
25	11	15
26-27	11	14
28	11	14
29	10	13
30	10	13
31-32	10	13
33-34	10	13
35-36	10	12
37	9	12
38	9	12
39-41	9	12
42	8	12
43	8	12
44-45	8	11

	GNSS/VOR — GNSS/VOR	
Angular difference	*F010 – F280 (NM)*	*F290 – F600 (NM)*
46-48	8	11
49-53	7	11
54-58	7	11
59	6	11
60-135	6	11

Note.— All distances are ground distances. Slant range correction must be added whenever the distance values in this table are used as a basis for separation of aircraft navigating by means of VOR/DME.

3.5.1.19 In respect of Table 3-1, lateral separation distances were calculated for large angles between tracks resulting in distances that were found to be as small as 6 NM. However, it was recognized by SASP that these were theoretical values which could not be utilized operationally in some cases, for example, between aircraft operating on converging or opposite direction tracks.

3.5.1.20 The hazard identification process conducted by SASP subsequently identified that the effect of fly-by turns could in some circumstances have an effect on the application of the separation. A conservative effect of the fly-by turns was calculated using assumptions and formulas provided in Document ED-75B/DO-236B *MASPS Required Navigation Performance for Area Navigation* (issued in December 2003). The calculations revealed that aircraft utilizing area navigation may under certain circumstances be expected to initiate and complete a fly-by turn up to 15 NM from the fly-by waypoint in low-level airspace and up to 20 NM from fly-by waypoint in high-level airspace (refer to Hazard 12 in Attachment B of this circular). In order to be able to issue a general separation standard, this information required the separation distances to be restricted to 15 NM below FL195 and 20 NM above FL195.

3.5.1.21 If there is an operational requirement to use values in Table 3-1 in paragraph 3.5.1.18 that are not represented in the PANS-ATM GNSS/VOR table, the pertinent ATS authority may use those values as a basis for deriving different separation minima, provided a safety assessment is carried out.

3.5.2 Hazard assessment

3.5.2.1 As was stated in paragraph 3.5.1, the SASP safety assessment comprises two parts, namely the risk due to navigation performance and the risk due to other hazards. With the description of the safety assessment for navigation performance having been completed in the previous paragraphs, the following paragraphs deal briefly with the safety assessment for the other hazards.

3.5.2.2 In an effort to identify hazards that may affect the implementation and use of published separation minima and to develop effective controls for these hazards, SASP undertook a process of hazard identification. The intent of this activity was to bring operational experience and issues into the development of a separation minimum. The identified hazards are documented in the Implementation Hazard Log in Attachment B.

Note.— SASP hazard identification is limited in its scope and is intended to identify significant globally applicable hazards and to develop specific controls that shall be considered in separation minima development. This activity should ***not*** *be considered as a formal hazard identification process that would normally include the determination of severity and estimates of likelihood and requires complementary regional, State or local implementation safety assessment action.*

3.6 REFERENCE MATERIAL

The following SASP WPs demonstrate the safety assessment described in Section 3.5.

Reference	*Meeting*	*Working Paper*	*Title*
1	*SASP/WG/WHL/9*	*19*	*A Comparative Analysis to Support the Use of GNSS in Lieu of VOR/DME for Lateral Separation*
2	*SASP/WG/WHL/7*	*20*	*A Collision Risk Model Based on Reliability Theory That Allows for Unequal RNP Navigational Accuracy*
3	*SASP/WG/WHL/10*	*19*	*Lateral Separation Tables*
4	*SASP/WG/WHL/11*	*21*	*Lateral Separation Tables (revised).*

3.7 CONCLUSIONS

3.7.1 The application of the SASP process demonstrated that the separation minima developed and detailed in this circular have been determined as being safe. SASP also identified a number of hazards together with appropriate mitigations and controls.

3.7.2 Notwithstanding the above, there is a requirement for a region or State to undertake an implementation safety assessment. In principle, this comprises two parts, namely a safety assessment for navigation performance and a hazard assessment. In practice, only a hazard assessment needs to be performed for any local implementation since the safety assessment for GNSS navigation performance is valid for any implementation. The hazard analysis is to identify hazards and related mitigation measures that are specific to the local situation.

3.7.3 To assist regions and States with their implementation safety assessment, a State implementation plan is provided in the next chapter. This plan will be seen to rely upon the various outputs from the application of the SASP safety assessment.

Chapter 4

IMPLEMENTATION CONSIDERATIONS

4.1 INTRODUCTION

4.1.1 The successful implementation of the proposed separation minima is not possible at the regional, State or local level without completing an implementation safety assessment (see Chapter 3). When undertaking this activity, reference should be made to the requirements detailed in Annex 11 — *Air Traffic Services* (Section 2.27), PANS-ATM (Chapter 2, Section 2.6), and the guidance material contained in the *Safety Management Manual (SMM)* (Doc 9859) including the development of hazard identification, risk management and mitigation procedures tables.

4.1.2 This chapter provides an overview of the minimum steps that SASP considers necessary for a regional, State or local authority to undertake a safety assessment.

4.2 IMPLEMENTATION CONSIDERATIONS

When undertaking a regional, State or local safety assessment, the following process is 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 being implemented will fit the current airspace system and regional or State airspace planning strategy.

Step 3 — Review this circular.

Step 4 — The region or State must undertake safety management activities including:

a) formal hazard and consequence(s) identification and safety risk analysis activities including identification of controls and mitigators;

b) implementation plan;

c) techniques for hazard identification/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 risk management techniques as set out in the ICAO *Safety Management Manual (SMM)* (Doc 9859);

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

e) simulation, where appropriate;

f) operational training; and

g) regulatory approvals.

Step 5 — Develop suitable safety assessment documentation including a safety plan and associated safety cases.

Step 6 — Implementation activities should include:

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) development of an appropriate backup plan to enable reversion, if necessary; and

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

Step 7 — Develop suitable post-implementation monitoring and review processes.

Attachment A

EXPLANATION OF TERMS

Accuracy. A measure of the difference between the true aircraft position and a measured/reported/estimated aircraft position. Accuracy may be defined as a bias (offset) and noise. The noise is usually characterized by a standard deviation and may have either a Gaussian or a different type of probability distribution. Accuracy may also be defined as a 95th percentile value.

Availability. The ability of a system to perform its required function at the initiation of the intended operation. It is quantified as the proportion of time the system is available to the time the system is planned to be available. Periods of planned maintenance are discounted from the availability figures. Overall availability is composed of:

a) the availability of functions affecting all aircraft (a/c) (e.g. external positioning function, ground data acquisition function); and

b) the availability of systems affecting only one a/c (e.g. transponder function): expressed per flight hour.

Continuity. The probability of a system performing its required function without unscheduled interruption, assuming that the system is available when the procedure is initiated. Overall, continuity is composed of:

a) the continuity of functions affecting all a/c (e.g. satellite function, ground data acquisition function): expressed in a number of disruptions per year; and

b) the continuity of systems affecting only one a/c (e.g. transponder function): expressed per flight hour.

Integrity. The level of trust that errors will be correctly detected. Integrity risk is the probability that an error in the information larger than a given threshold is undetected for longer than a time to alert.

Attachment B

IMPLEMENTATION HAZARD LOG

This section lists some hazards that were considered by the SASP when developing the GNSS lateral separation minima. The pertinent ATS authority must, in its implementation safety assessment, review these hazards and reflect how they may affect its local implementation and additionally identify if there are other regional, State or local hazards that need to be considered (Section 3.5.2 refers).

Subject 1 — Application of Separation
Hazard Loss of separation.
Unsafe event (cause) A failure of GNSS track and distance reports for the purpose of lateral separation will result on tracks assigned to the aircraft, position reports, pilot reported distances from waypoints/fixes and climb/descend clearances with restrictions. Those methods are designed to ensure that, when applying lateral separation, aircraft are never separated by less than the specified minimum.
Analysis The track angles and distances specified in PANS-ATM, paragraph 5.4.1.2.1.2 are minimum separation values. In reality aircraft are often (most of the time) spaced by larger values when applying this separation. The angular difference between tracks depends on local airspace design. Minima close to the distance standard could effectively be used in association with altitude restrictions such as "*maintain an altitude until a certain distance*" or "*reach an altitude by a certain distance*". Controllers apply the GNSS lateral separation based on: a) a track that is assigned to the aircraft; and b) reported distances from a waypoint or a fix; and, when required c) a climb/descent clearance with a restriction. It is important to note that controllers are not required to determine the actual ground distance between any two aircraft when applying this type of lateral separation, but rather ensure that the angular distance between the tracks is adequate and that at least one of the aircraft is more than a minimum distance from the point of intersection while vertical separation does not exist. In many (or most) cases, in normal operations, aircraft will be separated by more than the required minimum separation.

SASP global controls and/or mitigators

1) SASP has done a collision risk assessment that demonstrates that:

   a) the estimated collision risk based on the use of GNSS is sufficiently small; or

   b) the estimated collision risk based on the use of GNSS is less than that estimated when VOR or NDB is used.

(Refer to Chapter 3 for a description of the collision risk assessment done by the SASP.)

2) The PANS-ATM amendment specifies that controllers must ask the pilot to confirm that the aircraft is established on the assigned track before applying the separation.

Regional and local controls and/or mitigators required

1) All instances of loss of separation related to this separation minima must be reported and investigated.

2) The ATS authority intending to apply this separation must ensure that the airspace and route design is such that the application of this separation is practicable.

3) The ATS authority intending to apply this separation must ensure that the amount of traffic is not more than can be safely handled by this type of separation.

Subject 2 — Communication

Hazard

Loss of separation.

Unsafe event (cause)

Use of inappropriate communication media.

Analysis

The applicability of VOR/NDB separation is limited by virtue of the VOR/NDB service range. Typically, separation can only be applied within a 200-mile radius of a VOR/NDB facility. Subsequently, VOR/NDB separation is limited to continental airspace. However, PANS-ATM has never specified what type of communications should be used to apply the VOR/NDB-based separation.

The GNSS signal is available globally, and its accuracy is uniform regardless of airspace category. Given sufficient communication equipment, this will allow controllers to apply the new GNSS lateral separation in all categories of airspace including oceanic and remote airspace.

The procedures associated with applying this type of lateral separation are such that it is not efficient to use it without direct controller pilot communication. The controller has to obtain reports from pilots that they are established on the required tracks before the separation can be applied. The appropriate distance values must also be obtained before the separation can be applied or could alternatively be issued in a restricted clearance. It is nevertheless clear that the separation can be safely effected in various situations without the use of direct controller pilot VHF voice communications, but in this case the efficiency may be less. An example of this is an altitude change between two aircraft that are established on diverging tracks outbound from a significant point.

The possible permutations in the application of this type of lateral separation are many, and the SASP does not consider it feasible to prescribe on a globally applicable base the communication to be used in each case. This task is left to the appropriate ATS authority to determine.

SASP global controls and/or mitigators

None.

Regional and local controls and/or mitigators required

1) The appropriate ATS authority must in the implementation safety assessment determine, for each area of application, the communication requirements for the application of the GNSS lateral separation minima.

2) Provide appropriate training to controllers regarding communication procedures and communication performance.

Subject 3 — Area Navigation

Hazard

Loss of separation.

Unsafe event (cause)

A lack of awareness of the specifics of the difference between “TO-TO” and “TO-FROM” may result in a controller applying intersecting track lateral separation incorrectly.

Analysis

The GNSS receiver functions differently compared to conventional avionics receivers.

a) The GNSS receiver presents data in reference to the waypoint the aircraft is approaching. Once an aircraft passes this waypoint, the GPS receiver again sequences the next waypoint as the “active” waypoint, and all information displayed is in reference to this new waypoint. This is referred to as “TO-TO” navigation.

b) Some aircraft navigating using GNSS are not capable of flying an outbound track from a waypoint. Those aircraft always have to track towards a waypoint.

c) In some cases, after passing fly-over waypoints, the aircraft will not join a track from the fly-over waypoint but rather join a track direct towards the next waypoint.

While the concept of “TO-TO” navigation may pose a potential hazard, the safety analysis shows that technical risks are limited. The change from the old TO-FROM navigation to the new TO-TO navigation introduces changes to the pilot’s perspective in regard to his tools, tasks, and associated procedures, and this also applies to how the controller must apply the separation. Those issues need to be addressed by means of training and awareness initiatives.

SASP global controls and/or mitigators

1) Paragraph 5.4.1.1.4 has been added to the PANS-ATM amendment stating that “when an aircraft turns onto an ATS route via a flyover waypoint, a separation other than the normally prescribed lateral separation shall be applied”.

Regional and local controls and/or mitigators required

1) Any risk associated with the different behaviour of the GNSS system as opposed to conventional VOR/NDB/DME systems should be mitigated by means of training and awareness initiatives. This is the responsibility of the appropriate ATS authority.

2) Pilots should be advised by means of AICs or State AIPs, that position reports from other than "TO" waypoints may be requested by ATC for the purpose of track and distance-based separation. To this end, pilots should be reminded to be familiar with their avionics equipment so that this information can be provided as soon as practicable. It is the responsibility of the appropriate ATS authority to issue the appropriate guidance material to pilots. Following is an example of a suitable text for this purpose.

> GNSS avionics typically display the distance to the next waypoint. To ensure proper separation between aircraft a controller may request the distance from a waypoint that is not the currently-active waypoint in the avionics; it may even be behind the aircraft. Pilots should be able to obtain this information from the avionics. Techniques vary by manufacturer, so pilots should ensure familiarity with this function.

Subject 4 – Database Integrity

Hazard

Loss of separation.

Unsafe event (cause)

A lack of database integrity may result in incorrect waypoint information in the aircraft and ATM system database.

Analysis

Database integrity issues are common to all aspects of area navigation and to the application of all separation minima that employ area navigation. This issue is therefore not specific to the application of GNSS lateral separation.

With the implementation of area navigation procedures, the handling of navigation data is a significant aspect of safe operations. Its importance increases as operations move away from traditional procedures and routes based on flying "to and from" ground-based NAVAIDs. Database integrity relies on minimizing errors throughout the entire data chain, commencing with surveying, through procedure design, data processing and publication, data selection, coding, packing processes and up to the replacement of onboard data. The latter occurs as often as every 28-day AIRAC cycle, and in the future may become a near real-time activity.

Modern ATM systems also employ navigation databases. Database errors may result in incorrect results from conflict probes and could therefore lead to loss of separation.

International efforts are currently in progress to ensure database integrity by the introduction of new database quality control procedures. Refer to the following documents for information about this issue:

- Annex 15 — *Aeronautical Information Services*,
- RTCA document DO-200A.

SASP global controls and/or mitigators

None.

Regional and local controls and/or mitigators required

The appropriate ATS authority must ensure that applicable quality control procedures are followed at all levels of the data chain to ensure database integrity in aircraft and ATM systems.

Subject 5 — Incorrect Waypoint

Hazard

Loss of separation.

Unsafe event (cause)

Pilots providing distance and track information with reference to the “wrong” waypoint.

Analysis

With the multitude of waypoints stored in the navigation system database, there is a possibility that a pilot will provide distance in reference to an incorrectly selected waypoint or fly a track to an incorrectly selected waypoint. The resulting position information will be erroneous and could result in loss of separation. The possibility of such errors is not as likely when using VOR/DME/NDB, because there is no database associated with VOR/DME/NDB receivers.

This risk exists with the application of any RNAV type procedure. There are numerous procedures that require pilots to navigate to waypoints and report distances or progress in regard to waypoints imbedded in their databases. When GNSS lateral separation is used between any two RNAV aircraft, the separation can be erroneous when one or both aircraft report the distance or track in regard to the wrong waypoint. With respect to providing distance information by means of DME equipment, it has been pointed out that several new aircraft types select the DME automatically, and unless pilots verify the channel of the DME manually, the resulting distance may also be erroneous. This identifies the issue that pilots must be vigilant of procedures with any type of equipment.

Database issues are common to any RNAV operation. They do not pose any greater risk to GNSS lateral separation than to other separation, which is based on deriving position reports from waypoints.

It is important that controllers and pilots use standard phraseology when obtaining and giving track and distance reports. This helps in minimizing the possibility of errors.

SASP global controls and/or mitigators

SASP has created specific phraseology for obtaining and reporting GNSS tracks and distances and those are published in the PANS-ATM.

Regional and local controls and/or mitigators required

1) Pilots and controllers should be advised by means of respective directives, circulars, manuals and training the importance of including the name of the waypoint when reporting the distance to/from that waypoint.

2) Appropriate ATC training is required to make controllers appreciate the significance of using distances with reference to incorrect waypoints. To this end, the training curriculum should include the definition of “Common Point”.

Subject 6 — Incorrect Waypoint Entry in En-route Mode
Hazard Loss of separation.
Unsafe event (cause) A manual waypoint entry error results in navigation to an incorrect waypoint.
Analysis Navigation systems allow pilots to create waypoints manually in the en-route mode. This presents the possibility that pilots may enter waypoint coordinates incorrectly. CPDLC enables ATC to uplink route information into the area navigation system. This presents the possibility that ATC may uplink an incorrect waypoint. Pilots and ATC sometimes have to create ad hoc latitude/longitude waypoints in the absence of predefined waypoints or air routes. The risk of entering such waypoints incorrectly into the navigation system increases as the number of digits defining the waypoint increases. The risk of manually entering very complex waypoints such as 6521.9N013.6W may be too high in the context of applying GNSS lateral separation. There may be a high risk of misunderstanding when communicating such waypoints between controller and pilot.
SASP global controls and/or mitigators The following paragraph 5.4.1.2.1.2.3 has been added to the PANS-ATM: *In order to minimize the possibility of operational errors, waypoints contained in the navigation database or uplinked to the aircraft flight management system should be used in lieu of manually entered waypoints, when applying GNSS-based track separation. In the event that it is operationally restrictive to use waypoints contained in the navigation database, the use of waypoints that require manual entry by flight crews should be limited to half or whole degree of latitude and longitude.*
Regional and local controls and/or mitigators required The appropriate ATS authority should design the airspace in such a way that the requirement to use manually created latitude/longitude waypoints is avoided. This can be done by creating predefined waypoints and airways/routes in a manner that aids the application of GNSS lateral separation.

Subject 7 — Equipment Eligibility
Hazard Loss of separation.
Unsafe event (cause) Controllers use RNAV position reports, instead of GNSS position reports for the application of GNSS lateral separation.

Analysis

The safety analysis used for determining GNSS lateral separation used a comparative assessment between GNSS and VOR/NDB/DME sensors, not RNAV and VOR/NDB/DME. Since RNAV navigation accuracy was not assessed by this comparative assessment, it is not known what type of errors could be introduced by such reports and subsequently whether lateral separation could be compromised.

Previous discussions in SASP regarding this issue involved the analysis of how the various types of FMSs work, and whether it could be assumed that navigation and position information from integrated RNAV systems incorporating GNSS input could be regarded as equivalent to GNSS navigation and distance. It was agreed that with over 400 varying FMSs, it would be impossible to speculate how each FMS derives its navigation data. After thorough discussion, the SASP came to the conclusion that any navigation and position information derived from an FMS incorporating GNSS input would be more accurate than VOR/NDB/DME navigation and position information.

The feedback from human factors experts was unanimous that it could not be expected that all pilots involved would adhere to the requirement to use only GNSS-derived distance for the application of GNSS lateral and longitudinal separation, even after careful training and with sufficient operational experience. Therefore it would be realistic to expect that less accurate RNAV or FMS distances would sometimes be reported.

SASP global controls and/or mitigators

1) The following note was added to paragraph 5.4.1.2.1.2.4 to clarify what navigation system could be regarded as equivalent to GNSS position accuracy:

   "For the purpose of applying GNSS-based lateral separation minimum, distance and track information derived from an integrated navigation system incorporating GNSS input is regarded as equivalent to GNSS distance and track."

2) Paragraph 5.4.1.2.1.2.2 states: Before applying GNSS-based track separation the controller shall confirm the following: a) ensure that the aircraft is navigating using GNSS….

3) Phraseology has been added to the PANS-ATM where the controller specifically requests "GNSS distance" when obtaining a GNSS-derived distance report.

Regional and local controls and/or mitigators required

The appropriate ATS authority should include the foregoing mitigations in flight crew and controller training programmes.

Subject 8 — Potential Difference Between the Coordinates of a VOR/NDB/DME Navigation Aid and a Collocated Waypoint

Hazard

Loss of separation.

Unsafe event (cause)

During separation of a mix of VOR- and GNSS-equipped aircraft, the RNAV waypoint is not exact overlay on the position of the VOR/DME navigation aid.

Analysis

If the RNAV waypoint is not collocated with the position of the VOR/DME, then the aircraft would not be measuring distance and track from a common point as is required for this separation. The resulting distance between the aircraft might therefore be less than the required separation.

Where the airborne database "overlays" a waypoint on top of a ground-based navigation aid, the database encoders have no other choice than to use the official AIRAC coordinates for that navigation aid. When the Aeronautical Information Service (AIS) establishes a waypoint in the same location as a NAVAID, the process necessitates the use of the navigation aid's defined coordinates. It is therefore highly unlikely that there would be any intentional discrepancies.

While it cannot be guaranteed that waypoints and navigation aids are collocated in all instances, it is believed that this issue does not pose a significant risk to lateral separation between a mix of VOR and GNSS aircraft, as the errors between the waypoints and fixes formed by ground-based NAVAIDs, for example, are typically very small. Procedures to minimize this risk are well outlined in Annex 15 as well as in RTCA DO 200 (processing of aeronautical data) and RTCA DO 201 (processing aeronautical information).

SASP global controls and/or mitigators

None.

Regional and local controls and/or mitigators required

1) The appropriate ATS authority must define and document for the controller's use which RNAV waypoints and navigation aids are to be considered a common point.

2) ICAO documentation contains information regarding the steps to be followed to ensure the collocation of waypoints and existing navigation aid's coordinates. The process of publishing waypoints undergoes a scrupulous integrity checking.

Subject 9 — GNSS Outage

Hazard

Loss of GNSS navigation capability.

Unsafe event (cause)

GNSS failure affecting multiple aircraft or a failure of individual GNSS receivers.

Analysis

The effect of a failure of an individual GNSS receiver or a failure affecting multiple aircraft will have different impacts on the ATM system.

GNSS outages are detected by RAIM equipment. If an individual GNSS receiver fails, the pilot shall advise ATC that the aircraft can no longer navigate using the GNSS signal, and controllers will apply other forms of separation. This is no different from a traditional avionics equipment failure.

Local GNSS outages are possible, for example, during periods of GNSS signal interference. Pilots cannot distinguish interference from loss of GNSS integrity, so again they would simply advise ATC that they are receiving a RAIM warning, and ATC would again apply a different form of separation. Following further RAIM warning reports from other pilots in the area, controllers should suspect that interference may be occurring and shall not use GNSS for separation.

Total GNSS failure is very unlikely. Since 1993, when GNSS was approved for IFR navigation, there has only been one occurrence of a faulty satellite (July 2001, PRN 22). All aircraft with FDE were able to continue navigation using GNSS, while those without FDE could no longer use GNSS for navigation. Again ATC was advised and appropriate measures applied. No other failures or outages have been reported; therefore a total failure of the GNSS is extremely rare.

SASP global controls and/or mitigators

The following paragraph has been added to PANS-ATM, 5.4.1.2.1.2.4:

GNSS-based track separation shall not be applied in cases of pilot reported RAIM outages.

Regional and local controls and/or mitigators required

The appropriate ATS authority must consider the effect of GNSS outages in its contingency plans.

Subject 10 — An Aircraft Fails to Meet a Restriction

Hazard

Loss of separation.

Unsafe event (cause)

A pilot does not comply with an ATC clearance.

Analysis

When applying lateral separation, controllers may instruct pilots to climb/descend after passing a specific position or may instruct pilots to climb/descend to reach a flight level/altitude before passing a certain position or distance from a fix. It is the responsibility of the pilot to judge whether such a clearance can be met and to advise ATC if unable to comply.

In applying this type of lateral separation, controllers must use some of the following means to establish that aircraft are separated:

a) instruct aircraft to maintain a certain track or radial;

b) obtain position (distance) reports to establish that at least one of the aircraft is more than the minimum distance away from the common point;

c) clear aircraft to reach a certain level before a certain distance from the common point; and

d) clear aircraft to descend/climb to a certain level after passing a certain distance from the common point.

There may be several reasons that a pilot fails to meet a restriction:

a) pilot overestimates the rate-of-climb/descend capability of the aircraft;

b) the aircraft is not able to reach a certain altitude because of temperature, turbulence, etc.;

c) the pilot forgets to initiate a climb/descent at the correct time/position; and

d) the pilot misunderstands the clearance/instruction/restriction.

Ultimately it is the responsibility of the pilot to judge if he can safely comply with a clearance/instruction/restriction.

All those issues are common to the application of any separation minima. This issue is therefore not specific to the application of GNSS lateral separation.

SASP global controls and/or mitigators

Additional buffers were added to the minimum distance separation values for the cases of converging and opposite direction tracks.

Regional and local controls and/or mitigators required

The appropriate ATS authority should include the appropriate application methods of GNSS lateral separation in controller training programmes.

Subject 11 — Misunderstanding in Communicating the Clearance to the Aircraft

Hazard

Loss of separation.

Unsafe event (cause)

Pilot misunderstands the clearance.

Analysis

There is a possibility that a pilot could misunderstand a clearance and therefore fly a different flight profile than was intended by the controller to effect proper separation. This can result in loss of separation.

Air traffic controllers must communicate clearances to aircraft. Some clearances are simple while other clearances are complex. There are various means of communication: VHF, UHF, HF, data link, telephones. The quality of communications varies, and language barriers exist between pilots and controllers with different native tongues. All of these and more issues can influence the likelihood of a misunderstanding in communicating a clearance to the aircraft.

There are many things that can lead to misunderstanding and mishearing in ATC communications. Examples are:

a) bad quality of communications (static, noise, etc.);

b) lack of English language proficiency;

c) bad radiotelephony procedures; and

d) non-standard phraseologies.

All those issues are common to any ATC communications and application of any separation minima. No communication issue seems to be specific to the application of GNSS lateral separation.

SASP global controls and/or mitigators

SASP has created standard phraseologies for the application of GNSS-based separation. Those phraseologies are published in the PANS-ATM.

Regional and local controls and/or mitigators required

The appropriate ATS authority should enforce the use of standard phraseologies in pilot-controller communications.

Subject 12 — Fly-by Turns

Hazard

Loss of separation.

Unsafe event (cause)

The separation being applied does not accommodate the expected variability in the performance of area navigation systems executing fly-by turns.

Analysis

Most waypoints in area navigation are fly-by waypoints. By design this involves the aircraft turning before reaching the waypoint and completing the turn without ever flying over the waypoint. The distance from the fly-by waypoint at which an aircraft commences and/or terminates the fly-by turn depends on many factors, e.g., the magnitude of the turn, aircraft speed, altitude, wind velocity.

Because GNSS lateral separation is based on aircraft being established on tracks that diverge/converge by a specified number of degrees, an early turning aircraft could result in loss of separation.

Controllers must be aware of this behaviour of RNAV aircraft and instruct the aircraft to maintain a specific track while the track separation is being applied.

Document ED-75B/DO-236B “MASPS Required Navigation Performance for Area Navigation” issued in December 2003 deals with fly-by turns. This document contains requirements for navigation systems operating in an RNAV environment and provides guidance for the development of airspace and operational procedures. In paragraph 3.2.5.4 the document deals with the issue of fly-by transitions (turns) and provides formulas for deriving conservative fly-by transition areas based on conservative assumptions of ground speed and roll angle. Fly-by theoretical transition (turn) areas can only be derived for turns up to 120 degrees for low-altitude transitions and turns up to 70 degrees for high-altitude transitions.

The values in the following table were calculated based on the formulas and assumptions documented in ED-75B, paragraph 3.2.5.4.1. The table lists the distance from a fly-by waypoint at which an aircraft may be expected to initiate and complete a turn and the distance the aircraft may be expected to be displaced from a fly-by waypoint when it passes abeam the waypoint.

	Fly-by turns below FL195		*Fly-by turns above FL195*	
Track change in degrees	*Start/end of turn in NM from fly-by waypoint*	*Track distance abeam the waypoint in NM*	*Start/end of turn in NM from fly-by waypoint*	*Track distance abeam the waypoint in NM*
5	3.6	0.1	4.1	0.1
10	3.6	0.2	8.2	0.4
15	3.6	0.2	12.3	0.8
20	3.6	0.3	16.5	1.4
25	3.6	0.4	20.0	2.2
30	3.6	0.5	20.0	2.6
35	3.6	0.6	20.0	3.1
40	3.6	0.6	20.0	3.5
45	3.6	0.7	20.0	4.0
50	4.0	0.9	20.0	4.4
55	4.5	1.1	20.0	4.9
60	5.0	1.3	20.0	5.4
65	5.5	1.6	20.0	5.8
70	6.0	1.9	20.0	6.3
75	6.6	2.2	N/A	N/A
80	7.2	2.6	N/A	N/A
85	7.9	3.1	N/A	N/A
90	8.6	3.6	N/A	N/A
95	9.4	4.1	N/A	N/A
100	10.2	4.8	N/A	N/A
105	11.2	5.5	N/A	N/A

110	12.3	6.4	N/A	N/A
115	13.5	7.4	N/A	N/A
120	14.9	8.6	N/A	N/A

In addition to the above, the SASP considered the possible use of fixed radius transition (FRT) turns (refer to the *Performance-based Navigation (PBN) Manual* (Doc 9613)). Low-level (below F195) FRT turns contain a radius of 15 NM while high-level (above F195) FRT turns contain a radius of 22.5 NM.

SASP global controls and/or mitigators

Separation distances in the PANS-ATM, paragraph 5.4.1.2.1.2 c) and d) were restricted to 15 NM for altitudes below F195 and 23 NM for altitudes above F195 to account for the worst case fly-by.

Regional and local controls and/or mitigators required

1) The turning behaviour of RNAV aircraft must be included in the training curriculum of air traffic controllers when training them to apply GNSS track separation.

2) The training curriculum must also make it clear to controllers that they must instruct aircraft to **maintain** a specific track while this type of lateral separation is being applied.

Subject 13 — One Track is Defined in True Degrees While the Other is Defined in Magnetic Degrees

Hazard

Loss of separation.

Unsafe event (cause)

One aircraft reports a track in true degrees while the other aircraft reports its track in magnetic degrees resulting in real track divergence being less than that indicated to the controller.

Analysis

In the case of application of this separation between aircraft navigating using VOR versus aircraft using GNSS the following may occur:

VOR (conventional) route radial/track is published in magnetic (and true) while the GNSS route might be published only in true track.

Example:

Magnetic variation 10° east, VOR route published track 070° magnetic (=radial 070) and GNSS route published track 090° true.

The resulting effect is that the difference between tracks is actually only 10° because 070° magnetic track is actually 080° in true track.

When this separation is used on published routes this is not a problem because the controller will know the angular difference between published tracks.

If, however, using this separation on tracks that are not a part of a published route system, it must be known if the track that is being reported by the aircraft is a true or magnetic track.

Difference of tracks for the application of this kind of separation must always be calculated using the same reference (true or magnetic north).

SASP global controls and/or mitigators

None.

Regional and local controls and/or mitigators required

When approving the use of GNSS lateral separation the appropriate ATS authority must ensure that controllers use the same track reference (magnetic or true) to establish the angular difference between aircraft.

Subject 14 — Spherical Navigation

Hazard

Loss of separation.

Unsafe event (cause)

The controller incorrectly determines the angular difference between the tracks of the two aircraft being separated.

Analysis

The application of GNSS track separation depends on determining the angular difference between the tracks of the two aircraft being separated. This process is however complicated by the fact that aircraft flying a great circle RNAV track do not have a constant track direction. The rate of the change of the track direction depends on the latitude of the aircraft position, the higher the latitude the greater the rate of the track direction change.

When applying a track separation based on VOR, the controller instructs the pilot to maintain a specific VOR radial while the separation is being applied. While the aircraft flies the radial inbound to, or outbound from, the VOR it is not relevant that the track direction is constantly changing as the aircraft maintains “on course” using a cross-deviation pointer or a radio magnetic indicator (RMI) and thereby follows the VOR’s signal-in-space that defines the correct track.

When track separation based on GNSS is being applied, the pilot does not have the support of the VOR radial. As the track direction indicated to pilots depends on the location of the aircraft along its path (“great circle track”), this information is not useful for using this separation method. The rate of the change of the track direction depends on the latitude of the aircraft position, the higher the latitude and the closer the track is to 090 or 270° TRUE, the greater the rate of the track direction change.

Some aircraft have the capability to determine the bearing from a common point, which is referenced to TRUE (or MAGNETIC) NORTH at the common point. While this information could be used for establishing the required separation, the multitude of different navigation systems and the presentation of this information as well as the number of manipulations required to retrieve this information makes it hazardous and impracticable.

Using (great circle) tracks between the common point and two other significant points that are separated by the applicable angle is a practicable way of establishing GNSS-based track separation. This restriction also mitigates the risk of rounding errors that might occur with the use of “track to/from a significant point”, where aircraft installations can only indicate tracks in full numbers.

SASP global controls and/or mitigators

The separation method has been limited to (great circle) tracks between a common point and two other significant points (or a track between two significant points and a VOR radial).

Regional and local controls and/or mitigators required

The appropriate ATS authority should provide the controller with information about the (great circle) track angles between tracks from a common point and other significant points where it is intended that this separation method is to be used.

Subject 15 — Lateral Offsets

Hazard

Loss of separation.

Unsafe event (cause)

One or both aircraft are applying a lateral offset.

Analysis

The application of GNSS track separation is dependent on the aircraft being established on the assigned great circle RNAV track or VOR radial. The separation may be eroded if lateral offset is used by either aircraft close to the common point.

The actual lateral separation between the aircraft in a minimum angular/distance separation situation can potentially be very small. As an example, if aircraft are separated by 15 degrees at 15 NM from the common point, the actual lateral separation between the aircraft is approximately 4 NM.

If one or both aircraft apply a lateral offset in the direction of the other aircraft in such a situation, the result could be significant erosion of the actual separation between the aircraft.

When applying this type of separation using VOR, the pilot is instructed to report established on a specific VOR radial, which removes the possibility of a lateral offset. When applying the separation to GNSS RNAV aircraft, the pilot is instructed to report established on the track between the applicable waypoints. There is a possibility that the pilot will report established on the track between the waypoints even though he is applying an offset.

When applying this type of separation in airspace where strategic lateral offset procedures (SLOP) are authorized, it is imperative to establish that the pilot is not applying an offset before separation is applied. This can be achieved by asking the pilot directly if he is applying an offset. Since SLOP is a risk mitigation procedure it is, however, not considered appropriate to instruct a pilot to cancel an offset. Therefore, this separation cannot be applied as defined in the PANS-ATM, paragraph 5.4.1.2.1.2 if the pilot informs the controller that he is applying an offset.

SASP global controls and/or mitigators

The SASP has specified in the separation standard in the PANS-ATM, paragraph 5.4.1.2.1.2, that the aircraft must not be applying an offset when this separation is applied:

a) GNSS/GNSS: each aircraft is confirmed to be established on a track, with zero offset, between two waypoints and at least one aircraft is at a minimum distance from a common point as specified in Table 5-1; or

b) VOR/GNSS: the aircraft using VOR is established on a radial to or from the VOR, and the other aircraft using GNSS is confirmed to be established on a track, with zero offset, between two waypoints and at least one aircraft is at a minimum distance from a common point as specific in Table 5-1.

PANS-ATM, paragraph 5.4.1.2.1.2.2 specifies that, where lateral offsets are authorized, the controller shall ensure that lateral offset is not being applied:

5.4.1.2.1.2.2 Before applying GNSS-based track separation the controller shall confirm the following:

. . .

b) in airspace where strategic lateral offsets are authorized, ensure that a lateral offset is not being applied.

Standard phraseology published in the PANS-ATM specifies that the controller must request the pilot to report **established** on the specified track before the separation can be applied.

CONFIRM ESTABLISHED ON THE TRACK BETWEEN *(significant point)* AND *(significant point)* [WITH ZERO OFFSET];

Regional and local controls and/or mitigators required

The effect of lateral offsets on this type of separation must be included in the training curriculum of air traffic controllers when training them to apply GNSS track separation.

— END —

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