Twenty First Meeting of the
Informal South Pacific ATS Co-ordinating Group (ISPACG/21)

Auckland, New Zealand, 6-8 March 2007

Agenda Item 5: Identify future work programs

RNP
(Presented by NZ Civil Aviation Authority)

SUMMARY

The Protected Airspace Concept has been recently discussed by SASP. It is clear that there are inconsistencies in the ICAO Doc 444 references supporting this concept, which forms the basis of automated conflict probe ATM systems used in the Pacific.

Furthermore, application of the Protected Airspace Concept for RNP horizontal separation standards does not adequately recognise the difference for between strategic planning based on Air Traffic Service (ATS) routes and the tactical capability of automated ATM surveillance systems. Thus, it may be possible for such systems to enable significant reductions in RNP lateral separation without changes to aircraft or ground systems if the technical performance of these systems is acceptable.

1. INTRODUCTION

1.1 The International Civil Aviation Organization (ICAO) recognises in Doc 4444 (PANS ATM – Procedures for Air Navigation Services Air Traffic Management) that aircraft may be separated using specified 'protected airspace'. References to this concept within PANS ATM appear in paragraph 5.4.1.2.1.3, 5.4.1.2.1.4 and 5.4.2.6.4.1(b), which are reproduced later in this Working Paper. There have been recent suggestions to remove reference to protected airspace as a means of establishing separation. This would have a deleterious effect on automated ATM systems as the application of protected airspace in these systems work enable key facilities such as conflict probing.

1.2 The ICAO Separation and Airspace Safety Panel (SASP) discussed the concept of protected airspace as it applies to route systems, tracks and dissimilar navigation systems at the November/December 2006 Panel meeting. During that meeting it became apparent that there may be inconsistencies in some PANS ATM references to protected airspace with respect to the actual application of lateral separation, especially by automated ATM systems.

1.3 It also appears that the assumptions that support the calculation of Required Navigation Performance (RNP) lateral separation standards may not reflect the application of tactical separation between aircraft pairs. The discussion at SASP revealed that it may be possible to derive reduced separation standards using surveillance systems that can apply separation tactically between aircraft pairs, compared to procedural systems.

1.4 The recent emphasis on performance based navigation heralds the advent of an environment where aircraft that satisfying higher levels of performance requirement can receive significant benefits for the expenditure involved. The benefits can include more efficient and flexible tracks, lower meteorological minima and reduced separation standards. However the same ‘higher performance – greater privilege’ formula has not been as evident for ATS ground systems in respect to RNP separation as it has been for traditional tools such as radar (considering 8 NM, 5 NM and 3 NM separation standards).

2. DISCUSSION

Protected Airspace Definition

2.1 PANS ATM contains the following references to protected airspace.

> 5.4.1.2.1.3 *By use of different navigation aids or methods*. Lateral separation between aircraft using different navigation aids, or when one aircraft is using RNAV equipment, shall be established by ensuring that the derived protected airspaces for the navigation aid(s) or RNP do not overlap.
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> 5.4.1.2.1.4 RNAV operations; where RNP is specified on parallel tracks or ATS routes. Within designated airspace or on designated routes, where RNP is specified, lateral separation between RNAV-equipped aircraft may be obtained by requiring aircraft to be established on the centre lines of parallel tracks or ATS routes spaced at a distance which ensures that the protected airspace of the tracks or ATS routes does not overlap.
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> 5.4.2.6.4.1 [Longitudinal] separation based on the use of ADS shall be applied so that the distance between the calculated positions of the aircraft is never less than the prescribed minimum. This distance shall be obtained by one of the following methods:
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> c) when the aircraft are on parallel tracks whose protection areas overlap, the distance shall be measured along the track of one of the aircraft as in a) above using its calculated position and the point abeam the calculated position of the other aircraft (see Figure 5-33).

2.2 While the PANS ATM references indicate that lateral separation is derived by the application of protected airspace, there is a lack of formal definition as to what this concept actually means in practice. In essence, it has been taken to mean the projection of the lateral separation standard in accordance with the navigation performance standards of the system being used and the disposition of the aircraft involved. Given that the standard could vary dependent on factors such as the angle of incidence between crossing tracks, any one aircraft may have protected airspace of several different standards. However this should not preclude a simple description of protected airspace that will explain what it means and cement the concept for continued use.

2.3 In addition, it would appear that current PANS ATM protected airspace references only relate to lateral separation, as the longitudinal separation section only refers to a situation when lateral separation is compromised in a parallel track situation (paragraph 5.4.2.6.4.1).

2.4 Automated ATM systems such as New Zealand's Oceanic Control System (OCS) and the United States' Ocean 21 require a profile to be established for each controlled aircraft based on their known or expected position and concomitant flight plan details. These systems then project the horizontal and vertical separation standards along this profile to establish whether there are any conflicts within this 'protected airspace'. In the case of RNP4, protected airspace would equate to a lateral distance of 30 NM (Nautical Miles), both laterally and longitudinally. Thus the protected

airspace concept should embody separation in the horizontal (lateral and longitudinal) and vertical dimensions.

2.5 Using the OCS as an example, a conflict at the same level does not occur unless another aircraft enters the protected airspace volume. In terms of horizontal separation this equates to the full applicable lateral and longitudinal standards. However this still allows the protected airspace volumes to overlap, as long as an aircraft itself does not enter the overlap (example below in Figure 1). Therefore some adjustment should be made to the PANS ATM protected airspace requirements to take this into account.

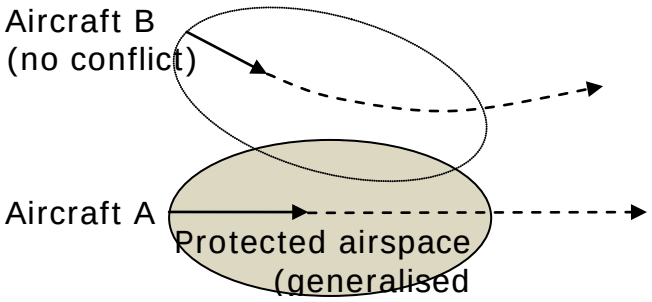

Figure 1: Example of protected airspace overlap with

2.6 PANS ATM references to protected airspace all require that protected airspace must not overlap. Current automated ATM systems in the Pacific do not work in this manner; unless the protected airspace can be considered to be half the normal separation standard. However this is not the case and two dissimilar aircraft capabilities could create a problem if it were. For example, a non-RNP and an RNP4 aircraft with 50 NM (half of 100 NM) plus 15 NM (half of 30 NM) would equal 65 NM but we do not know if the resultant composite standard is safe with regard to the performance of the non-RNP aircraft's performance.

2.7 ATS route systems have been developed in the past using composite separation standards (Doc 7030 authorises this in the Pacific). ATS route planning needs to take into account the worst case performance of any aircraft using the route, so the standard will be conservative by definition. In general, automated ATM systems utilise the larger separation standard of the two when different standards are being applied between two dissimilar aircraft. While this appears to be restrictive, it is not as conservative as route systems penalising better performing aircraft if there is no discrimination between the individual aircraft using the route system. In future, it may be possible for automated ATM systems to establish continually varying composite standards which satisfy an acceptable level of safety but this will involve a complex set of algorithms.

1.1. Strategic Versus Tactical RNP Separation

2.8 Current horizontal separation standards such as RNP4 were devised using a mathematical calculation of safety levels. These calculations included, *inter alia*, data on traffic densities, level occupancies, aircraft speed, aircraft size and a significant allowance for operational errors as the standard was predicated on it being used in a procedural ATS route system. These factors are important in an ATS route system because differences in density and occupancy affect the overall risk level. Significant operational errors must be mitigated by sufficient latitude in order for ATS to intervene if necessary. Hence the separation standard was established as a factor of 5.0 (RNP10) or 7.5 times (RNP4) the aircraft navigational performance requirement. The following PANS ATM standard affirms the requirement for collision risk modelling to take into account the aforementioned factors.

> 5.4.1.2.1.5.2 The distance of the lateral separation points from the track intersection shall be determined by collision risk analysis and will depend on complex factors such as the navigation accuracy of the aircraft, traffic density, and occupancy.

2.9 PANS ATM paragraph 5.4.1.2.1.5.2 states that lateral separation must be determined by collision risk modelling (in order to achieve an acceptable level of safety). It is doubtful whether this can be achieved in a tactical, operational environment with continuously changing variables and it also implies a changing separation to achieve a level of safety standard. Clearly a varying separation standard is not satisfactory for most ATM systems and even with automation this is unsatisfactory with human monitoring. Thus collision modelling of this nature would normally be an analysis of long term historical traffic data against an overall target level of safety and should not be required for the application of tactical separation between aircraft pairs.

2.10 The ICAO RNP Special Operational Requirements Study Group's (RNPSORSG) Performance Based Navigation (PBN) Manual (draft version 4.1) states the following in Section 3.1.

> Separation minima and route spacing can generally be described as being a function of three factors: navigation performance, aircraft's exposure to risk and the mitigation measures which are available to reduce risk. Aircraft-to-aircraft separation and ATS route spacing are not exactly the same. As such, the degree of complexity of the 'equation' depicted graphically in Figure 3-2 and Figure 3-3 depends on whether separation between two aircraft or route spacing criteria are being determined.
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> Aircraft to aircraft separation, for example, is usually applied between two aircraft and as a consequence, the traffic density part of the Risk is usually considered to be a single aircraft pair. For route spacing purposes this is not the case: the traffic density is determined by the volume of air traffic operating along the spaced ATS routes. This means that if aircraft in an airspace are all capable of the same

navigation performance, one could expect the separation minima between a single aircraft pair to be less than the spacing required parallel ATS routes, for example.

2.11 Pacific automated ATM systems apply separation between aircraft pairs in a tactical sense and therefore factors such as the density and occupancy of the route system are not relevant. This is consistent with the previous draft PBN Manual comments. With Automatic Dependent Surveillance (ADS), and automated conformance monitoring and conflict alert functions, the operational error buffer may be able to be reduced to the surveillance response and ATS communication time required for intervention. Therefore, it is arguable that RNP lateral separation standards developed for ATS route systems are conservative when applied in a tactical sense between aircraft pairs and could be significantly reduced without any adverse affect on safety.

2.12 To achieve a goal useful to stakeholders, it is necessary to discuss the issues at fora such as ISPACG and to agree, from an operational perspective, what the stated objective should be. If key stakeholders such as airlines and ATS units hold the view that reduced RNP separation standards for automated ATM systems is practical, then the task will be to build a case that identifies the acceptable:

a) communications system and time performance requirements;

b) aircraft navigational performance buffer;

c) surveillance system capability; and

d) RNP separation standards specifically for automated ATM systems applying tactical separation between aircraft pairs that satisfy the expected safety levels.

2.13 The following suggestions are put forward as a starting point for discussion.

a) The communication system for reduced separation RNP standards should be Direct Controller Pilot Communication, with a return communication capability of 3.0 minutes.

b) The RNP separation standard with respect to the aircraft navigation performance buffer should be 4σ (four sigma) plus a buffer, equating to 16 NM for RNP4 plus the buffer (99% containment of each aircraft if two aircraft are being considered, using 2σ each).

c) The surveillance capability should include:

i. either radar, multilateration or ADS (B or C) systems that allows the detection of aircraft position with sufficient regularity to determine an unexpected departure of no more than 3σ (three sigma) from the approved track, given a deviation of 10 degrees*; and

ii. automated track profile conformance monitoring (variable set parameter 5.0 NM) and conflict alert functions.

*This value needs to be determined – perhaps 95% of blunder deviations or less may be an acceptable parameter after an extensive analysis of observed deviations by ATS units.

2.14 Aircraft navigation and ground system buffer allowances do not need to be added together as the former is an equipment issue, whereas the ATM system intervention capability is mainly there to guard against blunders (human errors). Given an appropriate surveillance detection and communication capability, ATS intervention in the case of a blunder should be no less effective than the navigational performance requirements of the aircraft. Thus it may be possible for RNP aircraft to be separated by the greater of 4σ RNP plus a buffer (0.5 RNP?) or 3σ plus a buffer for ATS intervention.

2.15 The possibility of reduced separation criteria for States with automated ATM systems in particular would be an important deliverable, which would indubitably encourage more States to upgrade so their key stakeholders could benefit through increased efficiency. The reality of modern navigation systems is an actual navigation performance normally in the region of 0.02 to 0.09 NM for most GNSS/IRU based Flight Management System applications (anecdotal advice from Boeing) and if these extreme accuracies can be complimented by modern ATS systems to guard against the inevitable human failures, then there is every reason to suggest that major benefits could be derived from the application of tactical RNP separation standards.

3. ACTION BY THE MEETING

3.1 The meeting is invited to:

a) [**Recommendations**

3.1 ISPACG participants should develop a draft definition of the protected airspace concept for consideration by SASP. A suggested early draft is as follows.

The projection of the minimum horizontal (lateral and longitudinal) and vertical separation standards commensurate with the standards of the communication, navigation, surveillance and ATM system performance being used and the disposition of the aircraft involved.

3.2 ISPACG participants should consider PANS ATM amendments to take into account the application of protected airspace by automated ATM systems for consideration by SASP. A suggested early draft may be as follows.

5.4.1.2.1.3 *By use of different navigation aids or methods*. Lateral separation between aircraft using different navigation aids, or when one aircraft is using RNAV equipment, shall be established by ensuring that the derived protected airspaces for the navigation aid(s) or RNP do not overlap. In the case of two aircraft using RNAV equipment, the protected airspace of one aircraft shall not overlap the other aircraft.

5.4.1.2.1.4 RNAV operations; where RNP is specified on parallel tracks or ATS routes. Within designated airspace or on designated routes, where RNP is specified, lateral separation between RNAV-equipped aircraft may be obtained by requiring aircraft to be established on the centre lines of parallel tracks or ATS routes spaced at a distance which ensures that the protected airspace of the tracks or ATS routes does not overlap the centre line of an adjacent track or route.

5.4.2.6.4.1 [Longitudinal] separation based on the use of ADS shall be applied so that the distance between the calculated positions of the aircraft is never less than the prescribed minimum. This distance shall be obtained by one of the following methods:

c) when the aircraft are on a parallel track~~s~~ whose protection area~~s~~ overlaps the centreline of the adjacent track, the distance shall be measured along the track of one of the aircraft as in a) above using its calculated position and the point abeam the calculated position of the other aircraft (see Figure 5-33).

3.3 ISPACG participants should consider PANS ATM amendments to take into account the differences between procedural route systems and automated ATM systems for consideration by SASP. A suggested early draft is as follows.

5.4.1.2.1.5.2 The distance of the lateral separation points from ~~the~~ an ATS route system track intersection shall be determined by collision risk analysis and will depend on complex factors such as the navigation accuracy of the aircraft, traffic density, and occupancy.

3.4 ISPACG participants should note the content of this paper and progress the work necessary for reduced RNP separation standards using ATM systems capable of tactical separation for SASP consideration if this is considered plausible.

Note/Review etc…]

b) [Any additional actions required?]