Twenty-Third Meeting of the
Informal South Pacific ATC Co-ordinating Group (ISPACG/23)

Santiago, Chile, 26-27 March 2009

Agenda Item 3: Review Relevant Work Conducted Since ISPACG/22

VARIATIONS IN AIRSPEED IN CONTROLLED AIRSPACE

(Presented by Federal Aviation Administration)

SUMMARY

This paper contains a copy of a working paper discussed at the recent 14th meeting of the Separation and Airspace Safety Panel Meeting of The Working Group of The Whole (SASP-WG/WHL/14). The paper provides justification for rewording portions of ICAO Annex 2, Chapter 3, Section 3.6.2.2., "Adherence to flight plan". This paper contains the final wording suggestions for Annex 2 by SASP-WG/WHL/14.

1 INTRODUCTION

1.1 Attachment A contains a working paper (WP/11) discussed at the SASP-WG/WHL/14 meeting which took place 13 – 24 October 2008 in Paris, France. This paper provides justification for rewording portions of the ICAO Annex 2, Chapter 3, Section 3.6.2., "Adherence to flight plan".

2 DISCUSSION

2.1 After discussions during the SASP-WG/WHL/14 meeting, the agreed suggested rewording of ICAO Annex 2, Chapter 3, Section 3.6.2. follows. The syntax used in the suggested rewording is the deleted words are over-struck and the news words are in gray background text. .

3.6.2 Adherence to flight plan

3.6.2.1 Except as provided for in 3.6.2.2 and 3.6.2.4, an aircraft shall adhere to the current flight plan or the applicable portion of a current flight plan submitted for a controlled flight unless a request for a change has been made and clearance obtained from the appropriate air traffic control unit, or unless an emergency situation arises which necessitates immediate action by the aircraft, in which event as soon as circumstances permit, after such emergency authority is exercised, the appropriate air traffic services unit shall be notified of the action taken and that this action has been taken under emergency authority.

3.6.2.1.1 Unless otherwise authorized by the appropriate ATS authority, or directed by the appropriate air traffic control unit, controlled flights shall, in so far as practicable:

a) when on an established ATS route, operate along the defined centre line of that route; or

b) when on any other route, operate directly between the navigation facilities and/or points defining that route.

3.6.2.1.2 Subject to the overriding requirement in 3.6.2.1.1, an aircraft operating along an ATS route segment defined by reference to very high frequency omnidirectional radio ranges shall change over for its primary navigation guidance from the facility behind the aircraft to that ahead of it at, or as close as operationally feasible to, the changeover point, where established.

3.6.2.1.3 Deviation from the requirements in 3.6.2.1.1 shall be notified to the appropriate air traffic services unit.

3.6.2.2 ~~*Inadvertent changes* ~~.*Deviations from flight plan or clearance*. In the event that a controlled flight ~~inadvertently~~ deviates from its current flight plan or air traffic control clearance, the following action shall be taken:

a) *Deviation from track:* if the aircraft is off track, action shall be taken forthwith to adjust the heading of the aircraft to regain track as soon as practicable.

b) *Deviation from any ATC assigned Mach number/true airspeed*: the appropriate air traffic services unit shall be informed immediately.

~~b~~c) ~~*Variation in true airspeed:* if the average true airspeed at cruising level between reporting points varies or is expected to vary by plus or minus 5 per cent of the true airspeed, from that given in the flight plan, the appropriate air traffic services unit shall be so informed.~~ *Deviation from flight planned mach number/true airspeed:* if , for any reason, the Mach number / true airspeed at cruising level varies by plus or minus 0.02 Mach or more, or plus or minus 10 knots or more from the filed Mach number/true airspeed, the appropriate air traffic service unit shall be so informed.

~~c~~d) *Change in time estimate:* if the time estimate for the next applicable reporting point, flight information region boundary or destination aerodrome, whichever comes first, is found to be in error in excess of 3 minutes from that notified to air traffic services, or such other period of time as is prescribed by the appropriate ATS authority or on the basis of air navigation regional agreements, a revised estimated time shall be notified as soon as possible to the appropriate air traffic services unit.

3.6.2.2.1 Additionally, when an ADS agreement is in place, the air traffic services unit (ATSU) shall be informed automatically via data link whenever changes occur beyond the threshold values stipulated by the ADS event contract.

3.6.2.3 *Intended changes.* Requests for flight plan changes shall include information as indicated hereunder:

a) *Change of cruising level:* aircraft identification; requested new cruising level and cruising Mach number/true airspeed at this level, revised time estimates ~~(when applicable)~~ at subsequent reporting points or flight information region boundaries (when applicable).

b) *Change of Mach number/true airspeed:* aircraft identification, requested Mach number/true airspeed.

c) *Change of route:*

1) *Destination unchanged:* aircraft identification; flight rules; description of new route of flight including related flight plan data beginning with the position from which requested change of route is to commence; revised time estimates; any other pertinent information.

2) *Destination changed:* aircraft identification; flight rules; description of revised route of flight to revised destination aerodrome including related flight plan data, beginning with the position from which requested change of route is to commence; revised time estimates; alternate aerodrome(s); any other pertinent information.

2.2 As a result of further discussions, which were highlighted by some concerns by the International Federation of Air Line Pilots' Association (IFALPA) representative, the SASP-WG/WHL/14 meeting agreed to hold off on advancing the proposal until the member from the United States had the opportunity to discuss the issues with the representative from IFALPA. The group agreed that this issue would be further discussed at SASP-WG/WHL/15.

3 ACTION BY THE MEETING

3.1 The meeting is invited to note the information provided.

International Civil Aviation Organization

WORKING PAPER

SASP-WG/WHL/14-WP/11
13/10/08

SEPARATION AND AIRSPACE SAFETY PANEL (SASP) MEETING OF THE WORKING GROUP OF THE WHOLE

FOURTEENTH MEETING

Paris, France, 13 to 24 October 2008

Agenda Item 1: En-route separation minima and procedures — horizontal

Variations in Airspeed in Controlled Airspace

(Presented by the United States of America)
(Prepared by Ms Christine Falk and Mr Gene Fortunato)

SUMMARY

Modern air traffic control (ATC) automation systems project the future positions of aircraft using expected airspeed. The resulting ATC decision support functions base future aircraft clearances on these projected positions. Because of the reliance on the expected airspeed and the recent reductions in longitudinal separations, any variation in airspeed can affect the horizontal separation of aircraft in controlled airspace. As horizontal separation minima are reduced, the tolerance for error in the execution of the clearance is limited. Thus, it is important that operators and ATC units understand the effects of such variations and have a mutual understanding of permissible, if any, airspeed variations to ensure the continued safe operation of controlled airspace.

1. INTRODUCTION

1.1. ICAO Annex 2 (reference 1), Chapter 3, Section 3.6.2., "Adherence to flight plan", contains recommended practices concerning adherence to flight plan. Paragraph 3.6.2.2 from ICAO Annex 2 follows, the portion highlighted in gray text is the section of interest for this working paper.

> 3.6.2 Adherence to flight plan
> 3.6.2.1 Except as provided for in 3.6.2.2 and 3.6.2.4, an aircraft shall adhere to the current flight plan or the applicable portion of a current flight plan submitted for a controlled flight unless a request for a change has been made and clearance obtained from the appropriate air traffic control unit, or unless an emergency situation arises which necessitates immediate action by the aircraft, in which event as soon as circumstances permit, after such emergency authority is exercised, the appropriate air traffic services unit shall be notified of the action taken and that this action has been taken under emergency authority.

3.6.2.1.1 Unless otherwise authorized or directed by the appropriate air traffic control unit, controlled flights shall, in so far as practicable:
a) when on an established ATS route, operate along the defined centre line of that route; or
b) when on any other route, operate directly between the navigation facilities and/or points defining that route.
3.6.2.1.2 Subject to the overriding requirement in 3.6.2.1.1, an aircraft operating along an ATS route segment defined by reference to very high frequency omnidirectional radio ranges shall change over for its primary navigation guidance from the facility behind the aircraft to that ahead of it at, or as close as operationally feasible to, the change-over point, where established.
3.6.2.1.3 Deviation from the requirements in 3.6.2.1.1 shall be notified to the appropriate air traffic services unit.
3.6.2.2 *Inadvertent changes.* In the event that a controlled flight inadvertently deviates from its current flight plan, the following action shall be taken:
a) *Deviation from track:* if the aircraft is off track, action shall be taken forthwith to adjust the heading of the aircraft to regain track as soon as practicable.
b) *Variation in true airspeed:* if the average true airspeed at cruising level between reporting points varies or is expected to vary by plus or minus 5 per cent of the true airspeed, from that given in the flight plan, the appropriate air traffic services unit shall be so informed.
c) *Change in time estimate:* if the time estimate for the next applicable reporting point, flight information region boundary or destination aerodrome, whichever comes first, is found to be in error in excess of three minutes from that notified to air traffic services, or such other period of time as is prescribed by the appropriate ATS authority or on the basis of air navigation regional agreements, a revised estimated time shall be notified as soon as possible to the appropriate air traffic services unit.
3.6.2.2.1 Additionally, when an ADS agreement is in place, the air traffic services unit (ATSU) shall be informed automatically via data link whenever changes occur beyond the threshold values stipulated by the ADS event contract.
3.6.2.3 *Intended changes.* Requests for flight plan changes shall include information as indicated hereunder:
a) *Change of cruising level:* aircraft identification; requested new cruising level and cruising speed at this level, revised time estimates (when applicable) at subsequent flight information region boundaries.
b) *Change of route:*
1) *Destination unchanged:* aircraft identification; flight rules; description of new route of flight including related flight plan data beginning with the position from which requested change of route is to commence; revised time estimates; any other pertinent information.
2) *Destination changed:* aircraft identification; flight rules; description of revised route of flight to revised destination aerodrome including related flight plan data, beginning with the position from which requested change of route is to commence; revised time estimates; alternate aerodrome(s); any other pertinent information.
3.6.2.4 *Weather deterioration below the VMC.* When it becomes evident that flight in VMC in accordance with its current flight plan will not be practicable, a VFR flight operated as a controlled flight shall:
a) request an amended clearance enabling the aircraft to continue in VMC to destination or to an alternative aerodrome, or to leave the airspace within which an ATC clearance is required; or

b) if no clearance in accordance with a) can be obtained, continue to operate in VMC and notify the appropriate ATC unit of the action being taken either to leave the airspace concerned or to land at the nearest suitable aerodrome; or
c) if operated within a control zone, request authorization to operate as a special VFR flight; or
d) request clearance to operate in accordance with the instrument flight rules.

1.2. Air operators have interpreted the language as "permissive" allowing an aircrew to voluntarily increase or decrease airspeed up to 5% without the requirement to inform air traffic service units. Air traffic service units plan and execute horizontal aircraft separation based on flight crew adherence to the cruise airspeed contained in the active flight plan.

1.3. This is the only reference in ICAO documentation that relates to speed variation for a particular flight that has not been assigned a cruise Mach number. Based on discussions among operators and air traffic service units, it has become evident that a misunderstanding of the change in airspeed language exists. This misunderstanding can increase the risk to continuing safe operation of controlled airspace.

1.4. This issue was first introduced to the Separation and Airspace Safety Panel, by the representative from New Zealand, during its 11th meeting as a Working Group of the Whole in Working Paper SASP-WG/WHL/11-WP/10, (reference 2) and SASP-WG/WHL/12-WP/29 (reference 3), showing the potential for misinterpretations. Subsequent work on this issue was conducted by the Federal Aviation Administration (FAA) and presented at SASP-WG/WHL/11-WP/26 (reference 4) and SASP-WG/WHL/13-WP/09 (reference 5), demonstrating the evidence of deviations in speed by some aircraft.

2. Background

2.1. On 22 December 2005, the FAA implemented 30-nm lateral and longitudinal separation standards on an operational trial basis in a portion of the Oakland Oceanic FIR. In June 2007, the operational-trial-use of the 30-nm lateral and longitudinal separation standards was expanded to the entire Oakland Oceanic FIR.

2.2. As part of the operational trial, the FAA formed a group of experts to evaluate performance of the various components of the system supporting the reduced separation minima. This group has been termed the "30-30 Scrutiny Group", more simply known as the scrutiny group. The scrutiny group reviews pertinent data related to the operational trial. In an effort to understand the factors affecting the reduced horizontal separation minima, the scrutiny group has examined variations in aircraft true airspeed or Mach number evidenced in the periodic ADS reports received at the Oakland Oceanic Area Center (OAC). Initial results of these analyses were presented in references 4 and 5. The intention of references 4 and 5 were to highlight variations in airspeed observed in traffic data. The speed variations observed in the Pacific appear to be planned, most likely the result of operators utilizing an economic cruise mode available on Boeing and Airbus aircraft. These cruise modes base airspeed on calculations set by the operator dependent variables, such as fuel burn, to achieve best economic cruise. The experience is that as the aircraft becomes lighter, the cruise speed decreases (reference 6, paragraph 2.14).

2.3. Reference 4 provided a comparison of filed airspeeds versus actual airspeeds of Automatic Dependent Surveillance-Contract (ADS-C) operations in Oakland Oceanic airspace. Reference 5 identified flight operations with an observed change in airspeed. These operations were further examined to check if the reduced longitudinal separation standard was applied and, whether the change in airspeed affected the longitudinal separation between the airplane pairs.

2.4. A small number of these aircraft pairs were observed to have reduced longitudinal separation standards applied, due to the current limited application of the reduced separation standards in Oakland Oceanic airspace. The limited application of the reduced separation standards means the initial clearances are not given with the reduced separation standards applied. Air traffic control (ATC) may apply the reduced separation standards when a re-clearance is issued during flight operations. For example, an aircraft, which is eligible for the reduced separation standards, requests an altitude change and the clearance results in an application of the reduced longitudinal separation standard because there is another suitably equipped aircraft operating on the same track at the new altitude. Therefore, the number of longitudinally separated aircraft pairs affected by airspeed changes was small as presented in reference 5. Future applications of the reduced separation standards in Oakland Oceanic airspace will allow ATC to grant clearances involving reduced separations to suitably equipped aircraft on entry into oceanic airspace. It is anticipated that this will provide the opportunity for many more eligible aircraft pairs to be observed at the reduced separations.

3. Discussion

3.1. The requirements for the application of a 30-nm longitudinal separation standard using ADS are listed in Section 5.4.2.6.4 of reference 7. Among other items, this Section requires that aircraft be approved to RNP 4, and specifies the need for ADS with a maximum periodic reporting interval of 14 minutes. Given this periodic reporting interval, 14 minutes is the maximum expected time between consecutive ADS position reports for flights eligible for the 30 nm longitudinal separation standard. This maximum expected time between consecutive position reports occurs when the reporting times of both aircraft are synchronized in time.

3.2. The actual position of aircraft between consecutive position reports is unknown to ATC. Aircraft performance and weather affect the speed of the airplane. The collision risk model which supported the 30 nm longitudinal separation change assumed aircraft operate at constant speed during the time interval in which risk is estimated (reference 8). The collision risk model included along-track and across-track errors to account for the difference between the nominal and actual position of the aircraft. The along-track and cross-track errors were also assumed to be constant during the time interval in which risk is estimated. In most cases these are valid assumptions. However, given the observed use of economic cruise modes and the expected increase in the application of the reduced separation standards in the Pacific (references 4 and 5), it is important to consider the effect on the probability of an overtake when airspeed change occurs.

3.3. Useful Definitions

3.3.1. The distance based longitudinal model developed in reference 9 provides a relationship for computing the longitudinal distance between a pair of airplanes. However, this model and the model developed in reference 8 assume constant airspeed during the interval for which risk is estimated.

3.3.2. Let A_1 and A_2 be two airplanes that fly along the same route, in the same direction, and at the same flight level. Let A_1 denote the leading airplane, and A_2, the trailing airplane. A_1 and A_2 are already flying on the same track and flight level. Let t_o be the time at the start of the 14 minute reporting interval.

3.3.3. At a time t, $t \geq t_o$, during the 14 minute time interval between consecutive ADS reports, in which A_1 and A_2 are operating on the same route and flight level, the separation distance between A_1 and A_2 is denoted as $S(t)$. The distance of A_1 from the position of A_2 at t_o is denoted by $D_1(t)$. Additionally, $D_2(t)$ is the distance of A_2 from the position of A_2 at time t_o. At time t_o, the start of the interval over which risk is estimated, $D_2(t_o)$ is equal to zero, and the separation, $S(t_o)$, between A_1 and A_2 is simply equal to $D_1(t_o)$. Equation 1 provides a general form for estimating $S(t)$.

$$S(t) = D_1(t) - D_2(t) \quad \text{for } t \geq t_o \qquad (1)$$

3.3.4. At some time t, where $t > t_o$, a change of speed occurs for one or both airplanes. It is assumed that this change in speed occurs almost immediately after time t_o. Let V_1 and V_2 denote new speed for A_1 and A_2, respectively. The new speed for each airplane is the initial speed plus the change in speed.

Therefore

$$\Delta V = V_1 - V_2 \qquad (2)$$

3.3.5. Using equations 1 and 2, the new separation distance at time t_m, $S(t_m)$, is given by

$$\begin{aligned} S(t) &= D_1(t) - D_2(t) \quad \text{where } t > t_o \\ &= S(t_o) + V_1(t - t_o) - V_2(t - t_o) \\ &= S(t_o) + (V_1 - V_2)(t - t_o) \\ &= S(t_o) + \Delta V (t - t_o) \end{aligned} \qquad (3)$$

3.3.6. For each increment of speed difference, ΔV, it takes $\frac{S(t_o)}{\Delta V}$ *hours* to erode the initial separation, $S(t_o)$. Therefore, for an overtake to occur by some time t, where $t > t_o$, the time to erode the initial separation must be less than or equal to the time interval between consecutive position reports and the ATC intervention buffer;

$$\frac{S(t_o)}{\Delta V} \leq \left(ADS \quad report \quad interval \right) + \left(ATC \quad resolution \quad buffer \right)$$

3.3.7. The ATC resolution buffer is denoted as τ. Therefore, the probability of an overtake is the probability that τ is greater than or equal to the time for the remaining separation to be eroded at the end of the 14 minute reporting interval:

$$Prob(Overtake) = Prob\left\{ \frac{S(t_o)}{\Delta V} - \left(ADS \quad report \quad interval \right) \leq \tau \right\} \qquad (4)$$

Rearranging terms in equation (4):

$$Prob(Overtake) = Prob\left\{ \tau \geq \left[\frac{S(t_o)}{\Delta V} - \left(ADS \quad report \quad interval \right) \right] \right\} \qquad (5)$$

3.3.8. The components for the ATC resolution buffer, τ, are provided in reference 8. Under normal ADS operation, an allowance of 4 minutes is assumed for the value of τ. In the case where the periodic ADS reports are received and a response to the CPDLC uplink is not received in 3 minutes, an allowance of 10 ½ minutes is assumed for the value of τ. Reference 8 also provides components for τ when the ADS periodic report is lost or takes longer than 3 minutes, these components are listed in Table 2. The total allowance provided for the ATC resolution buffer in this case is 810 seconds or 13 ½ minutes.

Component	**Value (seconds)**
Controller wait for ADS report	180
Controller message composition	15
CPDLC uplink and wait for response	90 + α
HF communication	300
Pilot reaction	30
Aircraft inertia plus climb	75
Extra allowance	30
Total	720 + α

Table 2. Components of τ when ADS periodic report takes longer than 3 minutes

3.3.9. Three minutes after an ADS position report is overdue, a request for a position report will be sent by ATC via ADS or CPDLC. Reference 8 makes a conservative assumption that this request will always fail, the original time allowance for this request in reference 8 is 180 seconds for the CPDLC uplink and wait for response. The time allotted for the CPDLC uplink was 90 seconds, the remaining 90 seconds was the time allotted for the controller to wait for the response. The controller will re-attempt to contact the aircraft via HF, a 300 second allowance is provided for this in Table 2.

3.3.10. Transit time data for uplink CPDLC messages were collected from the Oakland OAC over the eight month period of February through July 2008. These data show a large range for CPDLC uplink transit times. A total of 290,178 data values were available during this time period. The maximum delay time observed was over 45 minutes (45:32 minutes). These data were fit to a mixture of two exponential distributions, with parameters λ_1= 15.73 sec, λ_2 = 240.01 sec and, ρ = 0.015.

$$f(x;\rho,\lambda_1,\lambda_2)=\frac{1-\rho}{\lambda_1}e^{\frac{-|x|}{\lambda_1}}+\frac{\rho}{\lambda_2}e^{\frac{-|x|}{\lambda_2}}$$

where $0 < \rho < 1$, and $0 < \lambda_1 < \lambda_2$

3.3.11. The CPDLC uplink time is modeled to the fitted data, in a similar manner as in reference 10. The α value in Table 2 represents the transit time for CPDLC uplink messages observed in the Oakland OAC data.

3.4. It is desired to compute the maximum change in longitudinal distance between the aircraft pair if one or both of the aircraft change their airspeed. To do this, the worst case scenario is examined. Here, the initial longitudinal distance, $S(t_o)$, between A_1 and A_2 is close to the minimum of 30 nm, and ATC expects the aircraft to maintain the same Mach number, although for this scenario a Mach number assignment has not been given to either aircraft. The ADS periodic reporting interval is 14 minutes.

3.5. There are nine possible scenarios to consider for the change in airspeed, in some cases the magnitude of the airspeed change by aircraft A_1 and/or A_2 determines whether an overtake is possible or not. Table 1 contains the nine possible speed change scenarios.

	Aircraft A_1 Increases Speed	**Aircraft A_1 Decreases Speed**	**Aircraft A_1 Maintains Constant Speed**
Aircraft A_2 Increases Speed	Possible Risk of Overtake[1]	Risk of Overtake	Risk of Overtake
Aircraft A_2 Decreases Speed	No Risk of Overtake	Possible Risk of Overtake[2]	No Risk of Overtake
Aircraft A_2 Maintains Constant Speed	No Risk of Overtake	Risk of Overtake	No Risk of Overtake

Table 1. Speed Change Scenarios for the Lead Airplane, A_1, and the Trailing Aircraft, A_2, Over a 14 Minute Interval

3.6. In the worst case scenario, the lead aircraft, A_1, experiences a decrease in airspeed, while the trailing aircraft, A_2, experiences an increase in airspeed.

3.7. Between FL250 and FL450, the ratio of Mach number to knots is approximately 0.01 to 6 knots. This assumption was validated using the ICAO Standard Atmosphere (reference 11) for FL250 through FL450. The ratio of Mach number to true airspeed at higher flight levels is also noted in reference 7, paragraph 4.6.1.5., Note 1.

3.8. It is also assumed that the aircraft report simultaneously because this increases the interval of uncertainty in the positions, thus increasing the amount of potential separation change between the aircraft pair. Therefore, the change in longitudinal distance over the 14 minute periodic interval is examined.

3.9. If both airplanes share a common initial speed, then ΔV in equation (2) is equal to the difference in the change of speed between the two airplanes. Let time t_m be the time of the end of the 14 minute reporting interval. Then the new separation distance at time t_m, $S(t_m)$, is given by equation (3). The initial separation distance, $S(t_o)$, is equal to the minimum allowed, 30 nm. The difference between the end time and the start time, $(t_m - t_o)$, is the ADS periodic reporting interval of 14 minutes. It is assumed the reporting times are synchronized in the worst case scenario. Therefore $S(t_m)$ becomes

$$S(t_m) = S(t_o) + \Delta V\,(t_m - t_o)$$

$$= 30\ nm + \Delta V\ (14\ min)$$

$$= 30nm + \Delta V\left(14\min \times \frac{1hour}{60\min}\right) \qquad (6)$$

3.10. Assuming the airplanes hold the new speed, equation (6) gives the longitudinal separation between the airplanes at the end of the 14 minutes reporting interval. Let t_b be the time at the end of the ATC resolution buffer. Then, the amount of time before an overtake occurs is the amount of ATC resolution buffer time before the longitudinal separation equals 0 nm. Let $S(t_b)$ be the separation at time t_b, where $t_b > t_m > t_o$.

[1] If the magnitude of the speed increase of airplane A_1 is less than the magnitude of the speed increase of airplane A_2 there is a risk of overtake, otherwise no risk of overtake
[2] If the magnitude of the speed decrease of airplane A_1 is greater than the magnitude of the speed decrease of airplane A_2 there is a risk of overtake, otherwise no risk of overtake

$$S(t_b) = D_1(t_b) - D_2(t_b) \quad \text{where } t_b > t_m$$
$$= S(t_m) + V_1(t_b - t_m) - V_2(t_b - t_m)$$
$$= S(t_m) + (V_1 - V_2)(t_b - t_m)$$
$$= S(t_m) + \Delta V (t_b - t_m) \qquad (7)$$

3.11. An overtake occured when the longitudinal distance between the airplanes at the end of the ATC resolution buffer, $S(t_b)$, is 0 nm. The amount of ATC resolution buffer time available before an overtake occurs is found by setting $S(t_b)$ = 0 nm.

$$S(t_b) = S(t_m) + \Delta V (t_b - t_m)$$
$$0 = S(t_m) + \Delta V (t_b - t_m)$$
$$\frac{-S(t_m)}{\Delta V} = (t_b - t_m) \qquad (8)$$

3.12. Assuming the worst case scenario, at least one of the ADS periodic reports will be lost. Using the τ when an ADS periodic report takes longer than 3 minutes, Table 3 presents the longitudinal distances after the 14 minute periodic report interval using equation (3) in column 2. Given the speed changes indicated in column1, column 3 of Table 3 presents the separation distance still to be eroded for an overtake to occur using equation. The 4th column of Table 3 uses equation (8) to determine the size of the ATC resolution buffer needed for an overtake to occur. After removing the static portions of the ATC resolution buffer contained in Table 2, the last column in Table 3 contains the probability that the ATC resolution buffer time would equal or exceed the minimum τ needed for an overtake. This value is given by the data fitted to a mixture of two exponential distributions observed for CPDLC uplink messages in Oakland OAC.

Combined Speed Difference ΔV (Mach)	Separation Decrease After 14 Minutes (nm)	Distance Still to Be Eroded After 14 Minutes Elapsed for an Overtake to Occur (nm)	Min τ Needed for an Overtake to Occur (minutes)	P(ATC Resolution Buffer ≥ Min τ Needed for an Overtake)
-0.08	11.2	18.8	23.50	8.463×10^{-4}
-0.07	9.8	20.2	28.86	2.218×10^{-4}
-0.06	8.4	21.6	36.00	3.719×10^{-5}
-0.05	7.0	23.0	46.00	3.053×10^{-6}
-0.04	5.6	24.4	61.00	7.181×10^{-8}
-0.03	4.2	25.8	86.00	1.387×10^{-10}

Table 3. Probability that the ATC Resolution Buffer ≥ the Minimum τ Needed for an Overtake to Occur

3.13. Reference 9, provides an estimate of collision risk as:

P{pair collides} = P{pair collides | overtake occurs} x P{overtake occurs}

3.14. A partial form of the collision risk model from reference 9 is:

$$N_{ax} = P_y(0) \cdot P_z(0) \cdot \frac{2\lambda_x}{\left|\overline{\dot{x}}\right|}\left[\frac{\left|\overline{\dot{x}}\right|}{2\lambda_x} + \frac{\left|\overline{\dot{y}(0)}\right|}{2\lambda_y} + \frac{\left|\overline{\dot{z}(0)}\right|}{2\lambda_z}\right] \cdot \mathrm{P}\left\{overtake \quad occurs\right\} \qquad (9)$$

3.15. The P{$\tau \geq$ Minimum τ needed for an overtake} is substituted for the P{overtake occurs} in equation (9) for this worst case scenario. The estimate of the probability of an overtake comes from the given change in airspeed, the remaining separation distance to be eroded for an overtake to occur, the CPDLC performance data, and the length of the ATC resolution buffer time needed for an overtake to occur.

3.16. Table 4 contains the parameter definitions and values assumed for risk estimation using equation (9).

Parameter	Description	Value	Source
N_{ax}	Collision risk of an aircraft pair on the same route at the same flight level whose nominal separation is x (NM).		
$P_y(0)$	Lateral overlap probability. Probability that airplanes assigned to the same route have laterally overlapping positions.	0.669	Value estimated for pairs of GPS-GPS aircraft (Ref 10)
$P_z(0)$	Vertical overlap probability. Probability that airplanes assigned to the same flight level have vertically overlapping positions.	0.538	Value used in Pacific Vertical Risk Estimate
T	Reporting interval of ADS position report.	14 minutes	Requirement for ADS-based separation (Ref 7)
λ_x	Average aircraft length (nm)	0.0364 nm	Value used in Pacific Vertical Risk Estimate
λ_y	Average aircraft width (wingspan) (nm)	0.0321 nm	Value used in Pacific Vertical Risk Estimate
λ_z	Average aircraft height (nm)	0.0101 nm	Value used in Pacific Vertical Risk Estimate
$\overline{\lvert \dot{x} \rvert}$	Average relative speed at which an airplane overtakes and passes another airplane assigned to the same route and flight level (kts)	Varies by scenario	=ΔV in Table 3 converted to kts
$\overline{\lvert \dot{y}(0) \rvert}$	Average relative speed at which airplanes assigned to the same route laterally wander past each other (kts)	20 kts	Value used in Ref 10
$\overline{\lvert \dot{z}(0) \rvert}$	Average relative speed at which airplanes assigned to the same flight level vertically wander past each other (kts)	1.5 kts	Value used in Ref 10

Table 4. Collision Risk Model Parameter Definitions and Estimates

3.17. Reference 8 used a weighted risk for the collision risk estimation for same track longitudinal separation. The weight given to the ATC resolution buffer corresponding to the components given in Table 2 was 0.05, this means it was assumed that 5 percent of the time the ADS periodic position report would take longer than 3 minutes and the controller would eventually resort to HF communication. Table 5 provides the collision risk estimates for each scenario presented in Table 3. Table 5 also provides the "weighted" collision risk values assumed for this worst case scenario as it would apply to the overall risk of the system.

Combined Speed Difference ΔV (Mach)	**Combined Speed Difference |ΔV| (kts)**	**P(ATC Resolution Buffer ≥ Min τ Needed for an Overtake)**	**Collision Risk Estimate (Where τ = Minimum τ Needed for an Overtake to Occur)**	**Weighted Collision risk = 5% of Collision Risk Estimate**
-0.08	48	8.463×10^{-4}	3.057×10^{-4}	1.529×10^{-5}
-0.07	42	2.218×10^{-4}	8.015×10^{-5}	4.008×10^{-6}
-0.06	36	3.719×10^{-5}	1.345×10^{-5}	6.725×10^{-7}
-0.05	30	3.053×10^{-6}	1.105×10^{-6}	5.526×10^{-8}
-0.04	24	7.181×10^{-8}	2.603×10^{-8}	1.302×10^{-9}
-0.03	18	1.387×10^{-10}	5.039×10^{-11}	2.519×10^{-12}

Table 5. Effect on the Weighted Portion of Risk for RNP 4 ADS Separation

3.18. The combined difference in airspeed, ΔV, presented in columns 1 and 2 of Table 5, represents the difference in airspeed of A_1 and A_2. The smallest combined speed difference, ΔV, with a collision risk estimate below the Target Level of Safety (TLS) is 0.04 Mach or 24 knots.

3.19. This result supports the recommendation for pilots to notify ATC when an airspeed change of 0.02 Mach or more is expected.

4. Conclusion

4.1. The FAA has examined data and recommends the following changes to Annex 2, *Rules of the Air*, Chapter 3, *General Rules*, Section 3.6.2., *Adherence to flight plan*, Para. 3.6.2.2., *Inadvertent changes* as follows. The syntax used in this recommendation is the deleted words are over-struck and the news words are in gray background text:

> 3.6.2 Adherence to flight plan
> 3.6.2.1 Except as provided for in 3.6.2.2 and 3.6.2.4, an aircraft shall adhere to the current flight plan or the applicable portion of a current flight plan submitted for a controlled flight unless a request for a change has been made and clearance obtained from the appropriate air traffic control unit, or unless an emergency situation arises which necessitates immediate action by the aircraft, in which event as soon as circumstances permit, after such emergency authority is exercised, the appropriate air traffic services unit shall be notified of the action taken and that this action has been taken under emergency authority.
> 3.6.2.1.1 Unless otherwise authorized by the appropriate ATS authority, or directed by the appropriate air traffic control unit, controlled flights shall, in so far as practicable:
>
> a) when on an established ATS route, operate along the defined centre line of that route; or
>
> b) when on any other route, operate directly between the navigation facilities and/or points defining that route.
>
> 3.6.2.1.2 Subject to the overriding requirement in 3.6.2.1.1, an aircraft operating along an ATS route segment defined by reference to very high frequency omnidirectional radio ranges shall change over for its primary navigation guidance from the facility behind the aircraft to that ahead of it at, or as close as operationally feasible to, the changeover point, where established.
> 3.6.2.1.3 Deviation from the requirements in 3.6.2.1.1 shall be notified to the appropriate air traffic services unit.

3.6.2.2 ~~*Inadvertent changes*~~ .*Deviations from clearances* in the event that a controlled flight ~~inadvertently~~ deviates from its current flight plan, the following action shall be taken:

a) *Deviation from track:* if the aircraft is off track, action shall be taken forthwith to adjust the heading of the aircraft to regain track as soon as practicable.

b) ~~*Variation in true airspeed:* if the average true airspeed at cruising level between reporting points varies or is expected to vary by plus or minus 5 per cent of the true airspeed, from that given in the flight plan, the appropriate air traffic services unit shall be so informed.~~ *Deviation in mach number/true airspeed:* if , for any reason, the Mach number / true airspeed at cruising level varies by plus or minus 0.02 Mach or plus or minus 10 knots from the cleared/assigned/filed Mach number/true airspeed, the appropriate air traffic service unit shall be so informed.

c) *Change in time estimate:* if the time estimate for the next applicable reporting point, flight information region boundary or destination aerodrome, whichever comes first, is found to be in error in excess of 3 minutes from that notified to air traffic services, or such other period of time as is prescribed by the appropriate ATS authority or on the basis of air navigation regional agreements, a revised estimated time shall be notified as soon as possible to the appropriate air traffic services unit.

3.6.2.2.1 Additionally, when an ADS agreement is in place, the air traffic services unit (ATSU) shall be informed automatically via data link whenever changes occur beyond the threshold values stipulated by the ADS event contract.

3.6.2.3 *Intended changes.* Requests for flight plan changes shall include information as indicated hereunder:

a) *Change of cruising level:* aircraft identification; requested new cruising level and cruising Mach number/true airspeed at this level, revised time estimates ~~(when applicable)~~ at subsequent reporting points or flight information region boundaries (when applicable).

b) *Change of Mach number/true airspeed:* aircraft identification, requested Mach number/true airspeed.

b) *Change of route:*

1) *Destination unchanged:* aircraft identification; flight rules; description of new route of flight including related flight plan data beginning with the position from which requested change of route is to commence; revised time estimates; any other pertinent information.

2) *Destination changed:* aircraft identification; flight rules; description of revised route of flight to revised destination aerodrome including related flight plan data, beginning with the position from which requested change of route is to commence; revised time estimates; alternate aerodrome(s); any other pertinent information.

4.2. The use of economic cruise modes is not discouraged; however, pilots need to provide speed change information to ATC so that separation between aircraft can be maintained.

5. Recommendation

5.1. The Meeting is invited to note the information provided in this paper

5.2. The Meeting is further invited to discuss and recommend the language as an amendment to Annex 2, *Rules of the Air,* Chapter 3, *General Rules,* Section 3.6.2., *Adherence to flight plan.*

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