Twenty Ninth Meeting of the
Informal South Pacific ATS Co-ordinating Group
(ISPACG/29)

Santiago, Chile
4-6 March 2015

Agenda Item [*AI 25-2*]

VARIATIONS IN AIRSPEED IN CONTROLLED AIRSPACE

Presented by Federal Aviation Administration (FAA)

SUMMARY

This paper provides an update on implementation of operator notification procedures for unannounced speed changes within the Pacific Oceanic Flight Information Regions

1. INTRODUCTION

1.1. ICAO letter, AN 13/1.8, 13-5/11/07 dated 31 January 2011, requested comments on the proposal for the amendment of Annexes 2 and 11 concerning speed variations and reduced vertical separation minimum (RVSM) monitoring.

1.2. *3.6.2.2(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 2 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.

1.3. The United States concurred that the amendment of the requirement to forward estimate revisions, from in excess of 3 minutes to 2 minutes, would provide some increase in the level of safety associated with the reduced longitudinal separation procedures being applied by an air traffic services unit (ATSU). However, in and of itself, this change will do very little to safeguard against the loss of adequate longitudinal spacing between aircraft.

1.4. ICAO implemented the change to Annex 2 paragraph 3.6.2.2 effective on 15 November 2012. Aircrews are now required to update air traffic service units any time an ETA changes by more than 2 minutes.

1.5. All turbojet aircraft in the NAT are assigned a fixed Mach speed in the oceanic clearance that is issued to aircraft before entry into the NAT area. This practice is governed by the following provision in the NAT section of the Regional Supplementary Procedures (SUPPs, Doc 7030):

6.1.1.7 The ATC-approved true Mach number shall be included in each clearance given to subsonic turbo-jet aircraft operating within Bodo Oceanic, Gander Oceanic, New York Oceanic, Reykjavik, Santa Maria Oceanic and Shanwick Oceanic control areas.

1.6. Iceland recently presented a paper at the NAT ATMG meeting on the Speed Distribution of Aircraft that have an Assigned Mach Speed (see attachment 1).

1.6.1. The paper analyzed the speed information in ADS-C periodic reports and compared them to aircraft assigned fixed Mach Speeds. The paper indicated "Aircraft manufacturers have stated that the reported Mach speed in ADS-C reports is instantaneous speed and not the target speed of the aircraft. It has been stated that because the reported Mach speed is instantaneous it could not be relied on for separation and fix-time calculations since it will show fluctuations from the target speed and may show significant fluctuations in some cases such as when the aircraft encounters turbulence (target speed = the speed that the aircraft is striving to maintain)."

1.6.2. The data set in the Iceland paper was from 12,234 flights and 92,284 periodic ADS-C reports. The data showed that 95% of the ADS-C reports were within plus or minus .01 Mach from the ATC cleared static Mach Speed. Additionally 99.99% of the ADS-C reports were within plus or minus .02 Mach from the ATC cleared static Mach Speed.

1.7. The FAA has presented data on the risks of unannounced speed changes to ICAO, IPACG and ISPACG meetings. The logic that was previously presented defining the risk is included in attachment 2.

2. DISCUSSION

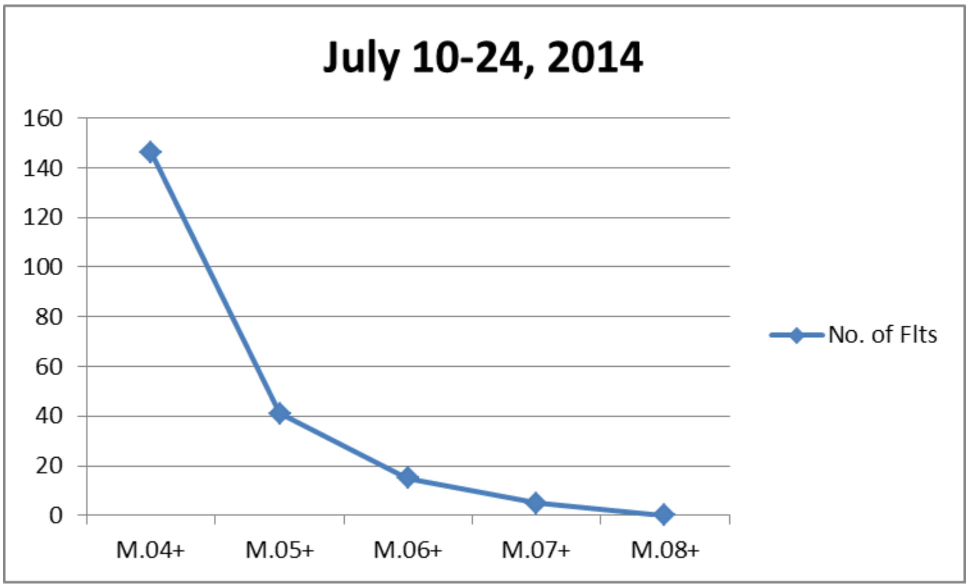
2.1 There are instances where operators flight plan large speed changes in the flight plan. Some examples of these FPLs are included in attachment 3. These extreme speed changes can catch a controller unaware even when the ATC automation system accounts for the speed changes flight planned within field 15 of the FPL. Unannounced speed change problems are not based on the issue of whether the ATC automation system accounts for the speed changes in FPL field 15 or not. ICAO Annex 2 provides the following guidance in paragraph 3.6.2.2.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.

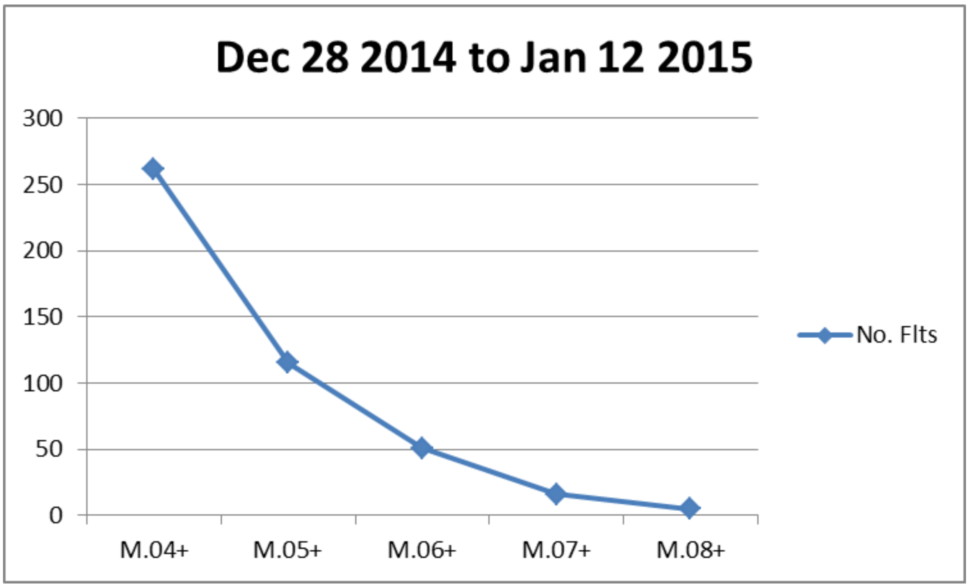
Given this guidance an aircraft flight planned at M.81 or greater may adjust speed by M.08 or about 48 knots without advising ATC. Speed adjustments of this magnitude by just one aircraft can equate a spacing loss of 11nm between two subsequent ADS-C reports. If the ADS-C 30nm longitudinal separation standard is being applied, this would equate to a 36% loss of the separation minima.

2.2 In the Pacific all aircraft are not assigned a fixed Mach Speed to fly. The Iceland NAT ATMG paper indicates that assigning a fixed Mach Speed to all turbojet aircraft would greatly reduce the impact of unannounced speed changes, but it would have an adverse impact on efficiency. To quantify the number of unannounced speed changes from the filed flight plan, the FAA analyzed two 15 day periods of Oakland ARTCC flights. In the collected data, aircraft that were not at cruise flight levels were eliminated. Drastic speed changes pose the most risk to derogating longitudinal separation. The ADS-C reports were filtered to show only aircraft where the Mach Speed in the ADS-C reports changed by M.02 or more between two subsequent ADS-C reports.

2.3 Between July 10-24, 2014, 7,305 ADS-C flights were examined. Of those flights, 2193 flights had speed changes of .02 Mach or more between subsequent ADS-C reports. 146 flights had speed changes M.04 or greater and 5 flights had a change of M.07. A speed change of M.07 equates to a speed change of 45 knots between two ADS-C reports.



2.4 A second 15 day time period with 9,089 ADS-C flights was examined from December 28, 2014 to January 12, 2015. Of those flights 3,008 flights had a speed change of M.02 or greater between subsequent ADS-C reports. 261 flights had one or more speed changes of M.04 or greater. 5 flights had speed changes of M.08 or greater.



2.5 Abrupt Speed changes of M.04 or greater equate to a changes of 26 knots and can cause a 20% degradation of separation between subsequent ADS-C reports. The 261 flights with speed changes of M.04 or more in the second data collection were examined more closely. From the Iceland Paper it can be inferred that while the Mach Speed reported in a periodic ADS-C report is an instantaneous look at the Mach Speed at the time of the report, most aircraft are within .01 Mach number of their cleared speed. The aircraft that are making speed changes of M.04 or more are outside of the normal .01 Mach variance that occurs with instantaneous ADS-C snapshots.

2.5.1 Of the 261 M.04 speed change flights, there were 333 speed change events of M.04 or more. Of the 333 speed events, ATC was advised of the change only 20 times, which left 313 unannounced large speed changes to ATC. One aircraft had a speed change of M.10 without advising ATC; that equates to an unannounced 65 knot speed change.

2.6 It is clear from this data that action must be taken by the ANSPs to manage unannounced speed changes. Discussions at SASP meetings to revise Annex 2 paragraph 3.6.2.2 has met with resistance. It was suggested at SASP, that Mach Speed assignments, like the NAT, should be used to manage unannounced speed changes. Considering the Iceland NAT ATMP paper, fixed Mach Speed assignments have closely controlled aircraft speeds.

2.7 While fixed Mach Speed assignments do greatly reduce unannounced speed changes, they are inefficient and do not support Cost Index speeds which save fuel burn. The IPACG and ISPACG PT have been discussing this issue. The challenge is to develop a procedure which is not work intensive and manages aircraft speed changes in a safe and efficient manner. Based on these guidelines, the following proposed procedure has been developed:

IN ORDER TO PREVENT UNANNOUNCED SPEED CHANGES AIRCREWS ARE REQUIRED TO USE THE FOLLOWING PROCEDURES IN THE KZAK FIR. UPON CROSSING THE KZAK FIR BOUNDARY, AIRCRAFT ARE REQUIRED TO REPORT THEIR SPEED VIA CPDLC OR HF VOICE. TURBOJET AIRCRAFT ARE TO

REPORT THEIR MACH NUMBER (AND NON-TURBOJET AIRCRAFT ARE TO REPORT A TRUE AIRSPEED.)
A PILOT MUST INFORM ATS EACH TIME THE CRUISING (SPEED, EITHER TAS OR) MACH NUMBER (WHICHEVER IS APPLICABLE) VARIES OR IS EXPECTED TO VARY BY A VALUE EQUAL TO OR GREATER THAN:
(A. 10 KNOTS TAS FROM THE PREVIOUSLY REPORTED SPEED - Non-Turbojet)
B. 0.02 MACH FROM THE PREVIOUSLY REPORTED SPEED (- Turbojet.)

The yellow highlighted text is optional for those ANSPs that want to apply the procedure to non-turbjet aircraft.

2.8 This procedure has gone through many iterations and has been refined to this version. Discussions with aircrews have revealed that many aircrews do not monitor their flown airspeed versus the FPL speed. By requiring a Mach Speed report at the boundary, a baseline speed has been set for the aircrew. They now have a reported speed and have to advise ATC when the aircraft speed will be changing by M.02 or greater. In the Pacific, FANS 1/A aircraft must provide one CPDLC position report at the boundary, a Mach Speed may be included with that report. HF aircraft can include the Mach Speed with their FIR position report/HF check-on. The ultimate goal is to have all the Pacific FIRs utilize the same procedure above and publish it via AIP or NOTAM.

2.9 This procedure will allow for the continued use of Cost Index Speeds in Pacific and increase safety.

3. ACTION BY THE MEETING

3.1 The meeting is requested to:

a) Support the Implementation of the procedure on June 25, 2015 in the Pacific FIRs where possible.

b) Keep ATC informed of speed changes of M.02 or greater.

Attachment 1

Attachment 2

e) **Risks associated with unannounced speed changes:**

1) 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.

2) Separation assurance involves the application of separation standards to ensure aircraft remain an appropriate minimum distance or altitude from other known aircraft. Air Traffic Service Units in a procedural control environment must be aware of the speed an aircraft is flying in order to maintain separation assurance. Air Traffic Controllers utilize the first filed speed entry in the aircraft flight plan when making control decisions. Aircraft must fly at the flight planned speed or advise ATC of any deviations from that speed. This allows controllers to have more assurance in applying longitudinal separation thereby allowing flights to operate more efficiently without compromising safety.

3) Just as an aircraft makes a request to ATC to change altitude, even though the planned altitude change is within Item 15 route of flight, an aircraft must request a change of speed from ATC also. ATSUs are implementing ICAO approved reduced separation minima such as ADS 30nm longitudinal separation. With the implementation of reduced separation minima, known aircraft speed becomes even more critical to ensure there is no loss of planned longitudinal separation.

4) There is significant safety risk associated with allowing speed changes without first notifying the air traffic service unit. The following data prepared by the Federal Aviation Administration Air Transportation System Evaluation Group, Separation Standards Analysis Team, is presented as supporting evidence.

The requirements for the application of a 30NM longitudinal separation standard using ADS-C are listed in Section 5.4.2.6.4 of ICAO Document 4444, Air Traffic Management. 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 30NM longitudinal separation standard. This maximum expected time between consecutive position reports occurs when the reporting times of both aircraft are synchronized in time.

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. 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, it is important to consider the effect on the probability of an overtake when airspeed change occurs.

The distance-based longitudinal model developed when initially assessing the risk for this procedure provides a relationship for computing the longitudinal distance between a pair of airplanes. However, this model and the model developed in a later study assume constant airspeed during the interval for which risk is estimated.

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.

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 $S(t)$.

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

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

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

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

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

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;

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

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:

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

Rearranging terms in equation (4):

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

The components for the ATC resolution buffer, τ, are provided in a study titled "Collision Risk Model Based on Reliability Theory that Allows for Unequal RNP Navigation Accuracy." 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 10½ minutes is assumed for the value of τ. The study referenced above also provides components for τ when the ADS periodic report is lost or takes longer than 3 minutes, these components are listed in Table 1. The total allowance provided for the ATC resolution buffer in this case is 810 seconds or 13½ 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 1. Components of τ when ADS periodic report takes longer than 3 minutes

Three minutes after an ADS position report is overdue, a request for a position report will be sent by ATC via ADS or CPDLC. The study makes a conservative assumption that this request will always fail, the original time allowance for this request 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.

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 $0 < \lambda_1 < \lambda_2$

The CPDLC uplink time is modeled to the fitted data. The α value in Table 1 represents the transit time for CPDLC uplink messages observed in the Oakland OAC data.

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.

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

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.

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 for FL250 through FL450.

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.

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

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

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

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

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

[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

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 $t_b > t_m > t_o$.

$$S(t_b) = D_1(t_b) - D_2(t_b) \quad \text{where } t_b > t_m$$

$$= S(t_m) + V_1(t_b - t_m) - V_2(t_b - t_m)$$

$$= S(t_m) + (V_1 - V_2)(t_b - t_m)$$

$$= S(t_m) + \Delta V (t_b - t_m) \quad (7)$$

An overtake occurred 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.

$$S(t_b) = S(t_m) + \Delta V (t_b - t_m)$$

$$0 = S(t_m) + \Delta V (t_b - t_m)$$

$$\frac{-S(t_m)}{\Delta V} = (t_b - t_m) \quad (8)$$

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

A study entitled "The Rate of Collisions Due to the Loss of Distance-Based Longitudinal Separations" provides an estimate of collision risk as:

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

A partial form of the collision risk model is:

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

The P{τ ≥ 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.

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

Parameter	Description	Value	Source
			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

The Collision Risk Model Based on Reliability Theory that Allows for Unequal RNP Navigation Accuracy study 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 1 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}

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**
-0.05	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

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.

This result supports the recommendation for pilots to notify ATC when an airspeed change of 0.02 Mach or more is expected from the first speed entry in Item 15 of the FPL.

Attachment 3

(FPL-XXXX-IS
-B753/M-SDE2E3FGHIRWXYZ/S
-KSEA0035
-N0396F300 HAROB4 HQM C1418 SEDAR A331 ZINNO/N0463F340 A331 ZIGIE MAGGI3
-PHNL0541
-PBN/A1B1C1D1O1S1T1 NAV/RNVD1E2A1 REG/XXXXX
EET/KZAK0039
SEL/XXXX
RMK/TCAS AGCS EQUIPPED NRP USA)

(FPL-XXXX-IS
-B744/H-SDE3FGHIJ3J5M1RWXY/LB2D1
-RJAA1025
-M073F290 DCT CUPID Y808 ALLEN/M072F290 Y812 SCORE OTR11 LEPKI DCT 37N160E/M071F290 DCT 35N170E/M084F390 DCT 32N180E DCT 27N170W DCT CANON V15 LILIA/M083F390 DCT KLANI KLANI2
-PHNL0633 PHJR
-PBN/A1L1B1C1D1O1S2 DOF/140508 REG/XXXXX EET/KZAK0227 PHZH0542 SEL/FGJP CODE/XXXX RVR/75 OPR/XXX PER/D RALT/RJCK PMDY RMK/TCAS)

XXXXXX IS B788 SADE2FGHIJ2J4J5J6M1M2RWXYZ LB1D1SH
RJAA KSEAP270270N0446XXXXX TR 1
N0446F270 CUPID Y808 ONION OTR5 KALNA/M069F270 DCT 44N160E/M084F390 47N170E
49N180E/M085F410 50N170W 51N160W 52N150W 51N140W DCT ORNAI/N0488F410 DCT
SIMLU DCT KEPKO DCT TOU MARNR3