INTERAGENCY GROUP ON INTERNATIONAL AFFAIRS
Department of Transportation
Federal Aviation Administration
Washington, DC 20591

July 29, 2011

Presented by:
Principal Staff Officer

IGIA 150/4.228A
FINAL ACTION

Title: Regional Supplementary Procedures – U.S. Proposal to Amend the ASIA PAC Regional Supplementary Procedures (SUPPS) (Doc 7030)

The IGIA member agencies by informal action completed July 29, 2011, approved IGIA 150/4.228 dated July 15, 2011.

The approval of IGIA 150/4.228 was forwarded ICAO Bangkok on July 29, 2011.

Victoria Williams

PROPOSAL FOR AMENDMENT OF THE REGIONAL SUPPLEMENTARY PROCEDURES PACIFIC (PAC) REGION (Doc. 7030/5)

(Serial No.: XXX – ASIA/PAC 6-2)

a) **Regional Supplementary Procedures:**

ASIA/PAC

b) **Proposed by:**

United States

c) **Proposed amendment:**

Editorial Note: Amendments are arranged to show deleted text using strikeout (~~text to be deleted~~), and added text with grey shading (text to be inserted).

Amend the following in the ASIA/PAC SUPPS, Chapter 6.

Chapter 2. FLIGHT PLANS

2.1 CONTENT – GENERAL

(A-2, Chapter 3; P-ATM – Chapter 4 and Appendix 2)

2.1.11 Mach Number

2.1.11.1 For turbo-jet aircraft intending to operate within the Anchorage Oceanic and Oakland Oceanic FIRs, the planned true Mach number shall be specified in Item 15 of the flight plan.

2.1.11.2 For turbo-jet aircraft intending to operate within the Anchorage Oceanic and Oakland Oceanic FIRs, if for any reason, the Mach number/true airspeed at cruising level varies by plus or minus 0.02 Mach/10 knots or more *from the first filed speed entry in flight plan form Item 15*, the appropriate air traffic service unit shall be so informed immediately.

d) **Date when proposal received:**

XXX

e) **Proposers reason for amendment:**

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 $S(t)$.

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

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

$$\Delta V = V_1 - V_2 \tag{2}$$

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

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

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:

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

Rearranging terms in equation (4):

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

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 $\lambda_1 = 15.73$ sec, $\lambda_2 = 240.01$ sec and, $\rho = 0.015$.

$$f(x{=}\rho.\lambda_3.\lambda_4) = \frac{3-\rho}{\lambda_3} e^{\frac{-|x|}{\lambda_3}} + \frac{\rho}{\lambda_4} e^{\frac{-|x|}{\lambda_4}} \qquad \text{where } 0 < \rho < 1, \text{ and } 0 < \lambda_1 < \lambda_2$$

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

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[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

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

$$\begin{aligned} S(t_m) &= S(t_o) + \Delta V\,(t_m - t_o) \\ &= 30\ nm + \Delta V\,(14\ min) \\ &= 52nm + \Delta V\left(36\,\mathrm{o\ kp} \times \frac{3hour}{82\,\mathrm{o\ kp}}\right) \end{aligned} \tag{6}$$

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 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 $t_b > t_m > t_o$.

$$\begin{aligned} S(t_b) &= D_1(t_b) - D_2(t_b) \qquad \text{where } t_b > t_m \\ &= S(t_m) + V_1(t_b - t_m) - V_2(t_b - t_m) \\ &= S(t_m) + (V_1 - V_2)\,(t_b - t_m) \\ &= S(t_m) + \Delta V\,(t_b - t_m) \end{aligned} \tag{7}$$

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.

$$\begin{aligned} S(t_b) &= S(t_m) + \Delta V\,(t_b - t_m) \\ 0 &= S(t_m) + \Delta V\,(t_b - t_m) \end{aligned}$$

$$\frac{-S{*}t_m{+}}{\Delta V} = {*}t_b - t_m{+} \tag{8}$$

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:

$$N_{ax} = P_y(0) P_z(0) \frac{4\lambda_x}{\overline{\left|\overset{0}{x}\right|}} \left[\frac{\overline{\left|\overset{0}{x}\right|}}{4\lambda_x} + \frac{\overline{\left|\overset{0}{y}(0)\right|}}{4\lambda_y} + \frac{\overline{\left|\overset{0}{z}(0)\right|}}{4\lambda_z} \right] \cdot \mathrm{P}\left\{ overtake \quad occurs \right\} \qquad (9)$$

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 Estimate
λ_z	Average aircraft height (nm)	0.0101 nm	Value used in Pacific Vertical Risk Estimate
$\overline{\left\|\overset{0}{x}\right\|}$	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

Parameter	Description	Value	Source
$\left|\overline{\overset{0}{y*2+}}\right|$	Average relative speed at which airplanes assigned to the same route laterally wander past each other (kts)	20 kts	Value used in Ref 10
$\left|\overline{\overset{0}{z*2+}}\right|$	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}
-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.

f) **Proposed implementation date of the amendment:**

Upon approval by the Council.

g) **Action by the Secretary General:**

The proposal has been circulated to the following States and international organizations.

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h) **Secretariat’s comments:**