International Civil Aviation Organization

The Twentieth Meeting of the Regional Airspace Safety Monitoring Advisory Group (RASMAG/20)

Bangkok, Thailand, 26-29 May 2015

Agenda Item 3: Reports from Asia/Pacific RMAs and EMAs

JASMA HORIZONTAL SAFETY ASSESSMENT

(Presented by JASMA)

SUMMARY

This paper presents the results of the horizontal airspace safety assessment of the oceanic airspace of the Fukuoka Flight Information Region (FIR) for the year 2014(1st Jan.2014-31stDec.2014.)

1. INTRODUCTION

1.1 This paper provides the horizontal risk assessment results of Fukuoka FIR oceanic airspace carried out by JASMA. The methods for the calculation are refined or amended couple of times for the past meetings. JASMA has changed Py(x) lateral deviation assess procedure. This is partly because the data screening process takes too much time and workforce. New Py(x) calculation detail is under Attachment A. In this paper we report the risk results of three ATC separations, namely;

a) Time based longitudinal separation. (10 minutes without Mach number technique)

b) Distance based longitudinal separation. (RNP4)

c) 50NM lateral separation.

1.2 For the calculation methods and parameters used, please refer to the Attachment B to this paper.

2. ESTIMATED RISK VALUES

2.1 The report shows that for the oceanic airspace of Fukuoka FIR, all target level of safety were met for the year 2014 except risk estimation for 10 minutes time based longitudinal separation without Mach number technique. This result is mainly attributable to the existence of aberrant data.

2.2 JASMA had been using radar data to assess deviation values. The radar systems was mainly to serve for domestic traffic but the portion of the coverage covers oceanic areas. The data acquired from RDP (Radar Data Processing System) have quite a number of large deviation data mainly because of weather deviations. Also radar vectors are common practice especially within a domestic airspace and those also cause large lateral/longitudinal deviations. In the newly introduced procedure we omitted manual data screening process with an expectation of law of large numbers will eventually prevail and the adverse effect of aberrant data will be nullified. The Electrical Navigation Research Institute (ENRI) has been proposing an algorithm which systematically filter the erroneous data which have the direct and adverse effect on the calculated values. Next time we will apply the algorithm and expected to meet TLS.

<u>10 MINUTES SEPARATION</u>

2.3 **Table 1** shows calculation results of 10 minutes time based longitudinal separation without Mach number technique. Estimated 2014 risk value is slightly above TLS. This is because of the aberrant data. Ever improving navigational accuracy could also a factor.

NOPAC Routes – estimated annual flying hours = 81057 hours ***(note: estimated hours based on 2014 traffic sample data)***			
Risk	**Risk Estimation**	**TLS**	**Remarks**
RASMAG 20 Longitudinal Time Risk	***$9.33x10^{-9}$***	*5.0×10^{-9}*	*Above TLS*
RASMAG 19 Longitudinal Time Risk	*$3.76x10^{-11}$*	*5.0×10^{-9}*	*Below TLS*

Table 1: NOPAC time separation Risk Estimates

<u>30NM LONGITUDINAL SEPARATION FOR RNP4 AIRCRAFT</u>

2.4 **Table 2** shows calculation results of 30NM distance based longitudinal separation collision risk estimates. The calculated values seem varies each year. But this is mainly because of the changes in the algorithm used for calculation of the risk. Risk estimation is below TLS.

NOPAC Routes ADS-C aircraft – estimated annual flying hours = 81057 hours ***(note: estimated hours based on 2014 traffic sample data)***			
Risk	**Risk Estimation**	**TLS**	**Remarks**
RASMAG 20 Longitudinal 30NM Risk	***$5.78x10^{-13}$***	*5.0×10^{-9}*	*Below TLS*
RASMAG 19 Longitudinal 30NM Risk	*$1.28x10^{-10}$*	*5.0×10^{-9}*	*Below TLS*

Table 2: Risk Estimates for RNP4 aircraft with 30NM distance based separation.

<u>50NM LATERAL SEPARATION</u>

2.5 **Table 3** shows collision risk for laterally separated aircraft in the NOPAC system. The risk value might increase as the traffic volume increases, but for the duration the value will remain below TLS.

NOPAC Routes(EXCEPT G344) – estimated annual flying hours = 81057hours ***(note: estimated hours based on 2014 traffic sample data)***			
Risk	**Risk Estimation**	**TLS**	**Remarks**
RASMAG 20 Lateral Risk	$\mathbf{7.51 \times 10^{-10}}$	2.5×10^{-9}	*Below TLS*
MAWG 2 Lateral Risk	0.80×10^{-9}	2.5×10^{-9}	*Below TLS*

Table 3: Lateral separation Risk Estimates for NOPAC.

<u>LLD consideration from RNP/RNAV DEVIATION REPORTs</u>

2.6 There were only one report which is categorized as B, “flight crew incorrect operation or interpretation of airborne equipment” according to the EMA HANDBOOK classification of navigation errors. This event occurred on eastbound flight on G344. After the last waypoint in Fukuoka FIR, the flight entered into Oakland FIR instead of Anchorage FIR (After KALIG the flight went to 44N170E, 46N180E). Cause of the event came from different flight plan of cockpit and control room. Duration of deviation was 62 minutes. But it was not in the congested airspace and no lack of ATC separation.

2.7 **Figure 1** shows airway NOPAC routes under consideration for this estimation. And the red line shows the deviated course which has occurred on eastbound flight on G344.

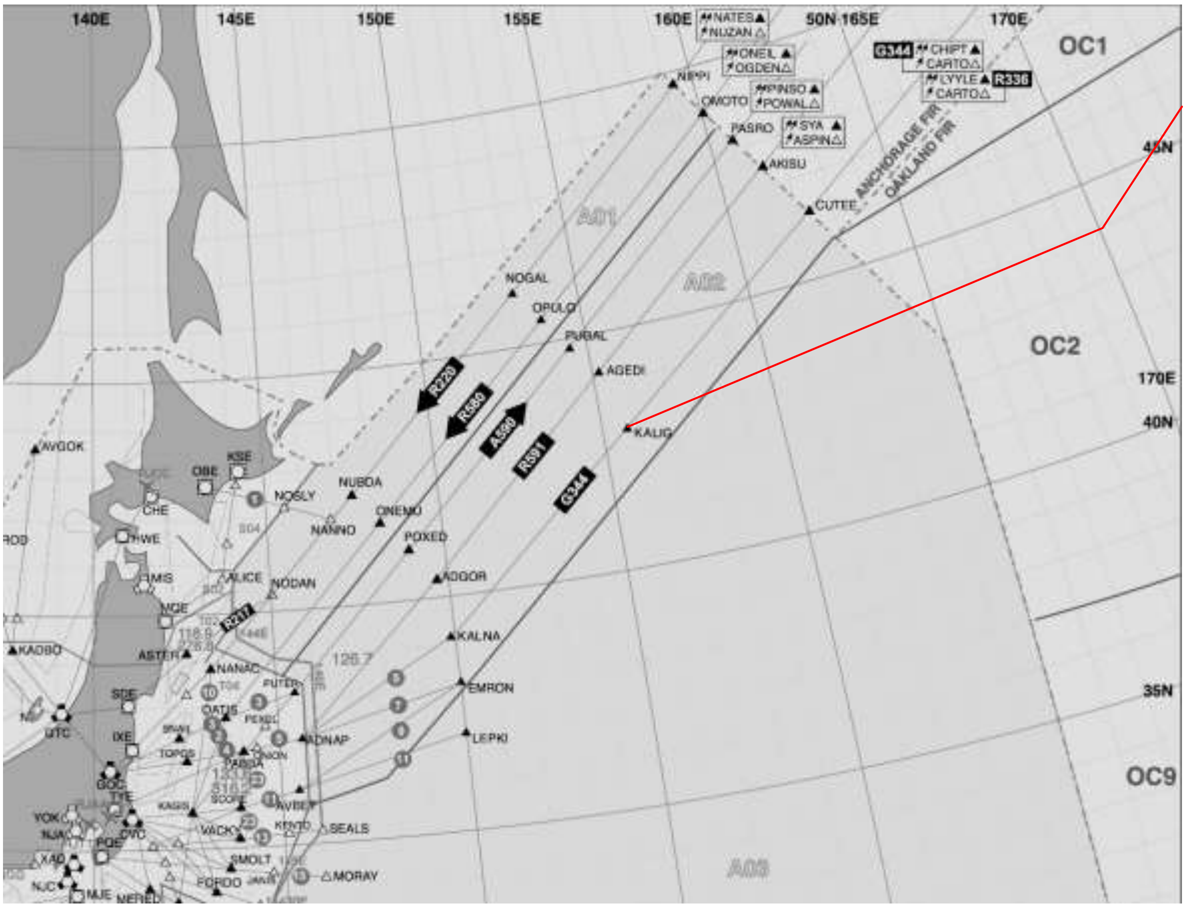

Figure 1: The NOPAC routes system and a course of LLD report

3. ACTION BY THE MEETING

3.1 The meeting is invited to:

a) note the information contained in this paper; and

b) Discuss the results of the airspace safety oversight presented in this working paper and the attached documentation.

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Attachment A

This appendix provides the details of the calculation of $P_y(S_y)$.

JASMA has been using the radar data to calculate $P_y(S_y)$, i.e. the lateral deviation. However,

the radar data includes large noise, so here, ADS-C data is used to estimate the lateral risk of collision. The calculation flow is summarized as follows:

1) Estimation of the route an aircraft is flying.
   Although the closest route of the current aircraft position is mostly the route the aircraft wants to fly, ADS-C data includes the data of the next waypoint. The route which includes the next waypoint via ADS-C data is assumed to be the route the aircraft is flying.

2) Modeling of lateral deviation.
   According to the obtained data, a single probability density function (PDF) is insufficient to model the lateral deviation. A single aircraft is assumed to follow the following PDF (combination of two double exponential distributions).
   $$f(x;\mu_1,\mu_2,\lambda_1,\lambda_2,\alpha)=(1-\alpha)\frac{\exp\left(-|x-\mu_1|/\lambda_1\right)}{2\lambda_1}+\alpha\frac{\exp\left(-|x-\mu_2|/\lambda_2\right)}{2\lambda_2} \quad (1)$$
   where x denotes the lateral deviation. The first term represents the core part and the second term represents the tail part. (i.e. $\lambda_1<\lambda_2$) However, some aircraft apply 1 NM or 2NM SLOP. The following PDF can represent the SLOP effect.
   $$\begin{aligned}g(x;\mu_1,\mu_2,\lambda_1,\lambda_2,\alpha,\gamma_1,\gamma_2)&=(1-\gamma_1-\gamma_2)f(x;\mu_1,\mu_2,\lambda_1,\lambda_2,\alpha)\\&+\gamma_1 f(x;\mu_1+1,\mu_2+1,\lambda_1,\lambda_2,\alpha)++\gamma_2 f(x;\mu_1+2,\mu_2+2,\lambda_1,\lambda_2,\alpha)\end{aligned} \quad (2)$$
   where γ_1 and γ_2 indicate the ratio of aircraft applying 1NM or 2NM SLOP.

3) Parameter estimation (1)
   There are seven parameters in Eq. (2), so these are optimized via Excel solver function. Maximum likelihood estimation (MLE) algorithm is used, and the following log likelihood is maximized.
   $$lik=\sum_{i=1}^{n}\log(\Delta t_i g(x_i;\mu_1,\mu_2,\lambda_1,\lambda_2,\alpha,\gamma_1,\gamma_2)) \quad (3)$$
   where i denotes each sample. Δt_i indicates the position report interval since the last position report. As the position report interval is not constant, it is assumed that the current lateral deviation is observed since the last position report.

4) Modeling of large lateral deviation
   Eq. (2) does not model the large deviation (more than 15 NM deviation). Therefore, the following expression is used to model the unintended large lateral deviation.
   $$h(x;\mu_1,\mu_2,\lambda_1,\lambda_2,\alpha,\gamma_1,\gamma_2,\beta,\lambda_3)=(1-\beta)g(x;\mu_1,\mu_2,\lambda_1,\lambda_2,\alpha,\gamma_1,\gamma_2)+\beta\frac{\exp\left(-|x|/\lambda_3\right)}{2\lambda_3} \quad (4)$$

5) Parameter estimation (2)

Eq. (4) includes nine parameters, but seven parameters are obtained in "Parameter estimation (1)", so here only two parameters (β, λ_3) should be optimized. Although the actual data includes the data with large deviation, this large deviation is mostly caused by weather effects. The pilot usually requests the weather deviation, and the ATC approves it. This approved deviation is safe, and this should not be included in the unintended deviation. Therefore, the unintentional large lateral deviation is modeled by the LLD report.

The total duration of LLD is denoted by t_{LLD} and the total flight time in the considered FIR is denoted by t_{total} . To match the LLD duration and the LLD in Eq. (4), the following condition should be met.

$$1-\int_{-15}^{15} h(x;\mu_1,\mu_2,\lambda_1,\lambda_2,\alpha,\gamma_1,\gamma_2,\beta,\lambda_3)dx=\frac{t_{LLD}}{t_{total}} \tag{5}$$

LLD report includes the duration of LLD, but it does not include the time histories of deviation during the LLD. Here, the lateral risk of collision is maximized approximately when the following condition is met[1].

$$\lambda_3 = S_y \tag{6}$$

Eq. (6) can avoid the under-estimation of the risk. Based on two conditions (Eq. (5) and (6)) two parameters are obtained.

6) Calculation of $P_y(S_y)$

$P_y(S_y)$ is calculated by the following expressions.

$$P_y(S_y)=\int_{S_y-l_y}^{S_y+l_y}\int_{-\infty}^{\infty} h(u)h(u+v)dudv \tag{7}$$

where l_y denotes the average aircraft span.

References

[1] PARMO, "Safety Assessment to Support Use of 30NM Lateral and 30NM Longitudinal Separation Standards in Anchorage Oceanic and Offshore Airspace," ICAO RASMAG/16, WP/24, (2012).

Attachment B

This appendix provides the calculation methods and parameters used.

1) Using the longitudinal overlapping probability, the collision risk is estimated by the following formula (2)

$$N_{ax} = P_y(0)\cdot P_z(0)\cdot \frac{2\lambda_x}{|\dot{x}|T}\left(\frac{\overline{|\dot{x}|}}{2\lambda_x} + \frac{\overline{|\dot{y}(0)|}}{2\lambda_y} + \frac{\overline{|z(0)|}}{2\lambda_z}\right)\sum E_x(t)P_x(t) \qquad (1)$$

The individual parameters for the equation (1) and their definitions are given in **Table 1**.

Parameter Symbol	Parameter Definition	Parameter Value	Source for Value
Py(0)	Probability that two aircraft on the same track are in lateral overlap	0.669	SASP-WG/WHL/13-IP/08
Pz(0)	Probability of vertical overlap in operational risk estimation for the aircraft flying as a same flight level	0.5380	ICAO SASP safety assessment
$\overline{\lvert\dot{y}(0)\rvert}$	The average relative speed between two aircraft, across track.	1 kt	EMA handbook
$\overline{\lvert\dot{z}(0)\rvert}$	Average vertical speed of aircraft pairs	1.5 kt	ICAO SASP safety assessment
λx	Average aircraft length	0.0270 nm	JASMA(2014Dec)
λy	Average aircraft width	0.00248 nm	JASMA(2014Dec)
λz	Average aircraft height	0.0079nm	JASMA(2014Dec)
T	The average time to fly the segment.	0.69h	FDPS data (NOPAC)
$E_x(t)$	The proportion of aircraft initial separation		
$P_x(t)$	The probability of the loss of longitudinal separation.		

Table 1：parameters in Equation

2) The formulas of the lateral collision risk model used in assessing the safety of operation on NOPAC routes are:

$$N_{ay}(same) = P_z(0)P_y(S_y)\frac{2\lambda_x}{\overline{|\Delta V|}}N_x^y(same)\left[\frac{\overline{|\Delta V|}}{2\lambda_x} + \frac{\overline{|\dot{y}|}}{2\lambda_y} + \frac{\overline{|\dot{z}|}}{2\lambda_z}\right] \qquad (2)$$

$$N_{ay}(opposite) = P_z(0)P_y(S_y)\frac{2\lambda_x}{2\overline{|V|}}N_x^y(opp)\left[\frac{2\overline{|V|}}{2\lambda_x} + \frac{\overline{|\dot{y}|}}{2\lambda_y} + \frac{\overline{|\dot{z}|}}{2\lambda_z}\right] \qquad (3)$$

$$N_{ay} = N_{ay}(same) + N_{ay}(opposite) \qquad (4)$$

3) **Table 2** summarizes the value and source material for estimating the parameter values of the following Collision Risk Model (CRM) used to conduct safety oversight for the RNP-10 based 50NM lateral separation minimum of NOPAC routes.

Parameter Symbol	Parameter Definition	Parameter Value	Source for Value
$\overline{\lvert V \rvert}$	Individual-aircraft along track speed	480 kt	Value often used
$\overline{\lvert \Delta V \rvert}$	Average along track speed of aircraft pairs	28.9 kt	Kushiro Air Route Surveillance Radar data (R220 route, NOPAC,Apr. 1994)
$\overline{\lvert \dot{y} \rvert}$	Average cross track speed of aircraft pairs	42.22 kt	Doc.9689 1st eds. Appendix 13
$\overline{\lvert \dot{z} \rvert}$	Average vertical speed of aircraft pairs	1.5 kt	Value often used
λx	Average aircraft length	0.0270 nm	JASMA(2014Dec)
λy	Average aircraft width	0.0248nm	JASMA(2014Dec)
λz	Average aircraft height	0.0079nm	JASMA(2014Dec)
N_x(same)	The passing frequency of aircraft pair assigned to the adjacent flight levels under the same direction traffic	1.27×10^{-2}	FDPS data (NOPAC, Dec, 2014)
N_x(opp)	The passing frequency of aircraft pair assigned to the adjacent flight levels under the opposite direction traffic	1.84×10^{-1}	FDPS data (NOPAC, Dec, 2014)
$P_z(0)$	Probability of vertical overlap in operational risk estimation for the aircraft flying as a same flight level	0.54	Value often used (shown in RVSM/TF-9-IP/2)
$P_y(50)$	Probability that two aircraft on the same track are in lateral overlap	6.07×10^{-9}	DDE Normal model

Table 2: Estimates of the parameters in the CRM

4) Collision risk for 50NM ATC lateral separation

The total number of Flight hours and Passing frequencies are shown in **Table 3**. Note that passing frequencies between airway R220 and R580 is relatively small. Because R220 and R580 are both westbound only for all the time. So passing occurs only when catching up occurs. On the other hand passing frequencies between R580 and A590 is larger because R580 is used for westbound while A590 is used east bound. The R591 is eastbound only unless designated as westbound PACOTS track.

	Flight Hours		Passing Frequencies		
	East Bounds	West Bounds	Same E-Bounds	Same W-Bounds	Opposite Direction
R220	7.11333	34881.5			
			0	440	1
R580	14.8	14904.4			
			16.5	0	7034.5
A590	26599.3	2.37333			
			58.5	0	424
R591	3381.1	1266.01			
			0	0	0

Table 3： Flight Hours and Passing Frequencies

Table 4 shows lateral collision risk estimation on NOPAC routes. Total risk estimation is below TSL.

Source of Risk	Risk Estimation
N_{ay} (same)	1.15×10^{-10}
N_{ay} (opposite)	6.35×10^{-10}
N_{ay} (total)	7.51×10^{-10}

Table 4： NOPAC Lateral collision risk estimation