International Civil Aviation Organization

The Sixteenth Meeting of the Regional Airspace Safety Monitoring Advisory Group (RASMAG/16)

Bangkok, Thailand, 20 – 24 February 2012

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

PROGRESS OF WORK FOR SAFETY ASSESSMENT OF HORIZONTAL SEPARATION MINIMA WITHIN THE FUKUOKA FLIGHT INFORMATION REGION

(Presented by Japan)

SUMMARY

This paper presents the recent work of Japan Airspace Safety Monitoring Agency (JASMA) as an En-route monitoring agency (EMA) within the Fukuoka Flight Information Region (FIR).

This paper relates to –

Strategic Objectives:
*A: **Safety** – Enhance global civil aviation safety*

1. INTRODUCTION

1.1 The Japan Airspace Safety Monitoring Agency (JASMA) has started En-route Monitoring Agency (EMA) works officially with the endorsement of APANPIRG/22 in September, 2011.

1.2 JCAB introduced RNP10/ADS-C/CPDLC-based 50NM longitudinal separation minimum in February 2006 and RNP4/ADS-C/CPDLC-based 30NM longitudinal separation minimum in December 2008 to the whole Pacific Ocean airspace of Fukuoka FIR.

1.3 RNP4/ADS-C/CPDLC-based 30NM longitudinal separation minimum has been applied across FIR boundary between Oakland FIR and Fukuoka FIR as a trial operation since May 2011. According to the reports of IPACG35/FIT22 meeting (Sapporo, Japan, 7-11 November 2011), there were only a couple of cases to use 30NM longitudinal separation minimum across FIR boundary in five months. One of the reasons for the very few utilization of 30NM separation minimum is low population of RNP4 approved aircraft. It is still less than 30 percent of the whole aircraft flying in the Pacific Ocean airspace of Fukuoka FIR. JCAB and FAA, therefore, agreed to continue the trial operation of cross-border 30NM longitudinal separation minimum.

1.4 It is reported that, within the Fukuoka FIR, reduced longitudinal separation is effectively applied especially in the cases in which an aircraft makes a climb/descent through the altitude of succeeding/preceding aircraft. Some tentative calculations estimate that increased number in RNP4 approved aircraft brings further benefits to the effective operation of the ATC.

1.5 Considering the slow increase in application of distance-based reduced longitudinal separation, 10-minute time-based longitudinal separation without Mach Number Technique (MNT) is planned to be introduced to all routes and tracks in Pacific Ocean airspace of Fukuoka FIR on condition that the safety of the operation is confirmed by the pre-introduction assessment.

1.6 As an EMA, JASMA's tasks for the safety monitoring are supposed to focus on PBN-based lateral separation and PBN/Data Link-based longitudinal/lateral separation in Pacific Ocean airspace of Fukuoka FIR. In addition to these PBN related reduced separations, JASMA intends to conduct a safety assessment of non-PBN 10-minute longitudinal separation without MNT, which is not prescribed in ICAO Doc 4444 (PANS ATM).

2. DISCUSSION

2.1 Monitoring of horizontal plane navigation performance

2.1.1 An EMA must be prepared to collect the information necessary to monitor horizontal-plane navigational performance as part of the risk assessment.

2.1.2 RNP10-based 50/50 separations and RNP4-based 30/30 separations have been already introduced in the Pacific Ocean airspace of Fukuoka FIR, and JASMA monitors their safe operations. Large Lateral Deviation (LLD) and Large Longitudinal Error (LLE) occurred are reported to JASMA, which are also reported to FAA's Technical Center (PARMO) in accordance with the bilateral Letter of Agreement between Japan and USA. JASMA received three (3) LLD reports during the period from 1 December 2010 to 30 November 2011.

2.1.3 Based on the information provided from ATC facilities the LLD and LLE reports are categorized. These categories are defined in the ICAO Asia Pacific Region's EMA Handbook. Table 1 and Table 2 show the summary of three (3) LLD reports received by JASMA from 1 December 2010 to 30 November 2011.

Table 1: Summary of LLD occurrence in the Fukuoka FIR

Deviation Code	Cause of Deviation	No. of Occurrences
Operational Errors		
D	ATC system loop error (e.g. ATC issues incorrect clearance, Flight crew misunderstands clearance message etc.);	2
Deviation due to Meteorological Conditions		
G	Turbulence or other weather related causes (other than approved);	1

Table 2: LLD occurred in the oceanic airspace of Fukuoka FIR (December 2010-November 2011)

Event date	Source	Location of deviation	Deviation(NM)	Duration
19-Mar-11	ATMC	TEGOD	unknown	unknown
29-May-11	ATMC	30N160E	unknown	13minutes
31-Oct-11	ATMC	40N155E	23NM	unknown

2.1.4 Two (2) LLD reports categorized as D were caused by the mismatches in the cognition of valid flight plan routes between pilots and air traffic controllers. In these cases flight plan CHG (change route) and/or CX (cancel) messages were not adequately processed.

**Summary of the original report on 19 March 2011.*
ATC got an inquiry from the receiving ATC about the aircraft flying the different route from the original Flight Plan (FP). ATC checked the FP and confirmed that it matched the FP of receiving ATC. It was confirmed that no change message was received. The FP also matched with the ones dispatcher had. The pilot said they will report later to the receiving authority.

**Summary of the original report on 29 May 2011.*

When ATC got the 160E over time and 150E estimate at 0325Z the ATC found that 150E latitude differs from original FP. ATC confirmed the pilot and got the new latitude. ATC re-cleared route clearance at 0338Z. So it was deviating for the period of 13 minutes.

2.1.5 One deviation caused by bad weather without ATC clearance was categorized as G. At the farthest point it deviated 23nm left of the course.

**Summary of the original report on 31 October 2011.*
ATC found a deviation without an ATC approval. When confirmed to the aircraft, the answer was: "We did deviate left of the course for WX but are currently back on course."

2.1.6 In order to reduce any confusion among air traffic controllers over the complex definition of LLE in the EMA Handbook and facilitate their reporting process, JASMA has coordinated with ATC facilities in Japan and defined LLD/LLE as follows.

Table3: Definition of LLD and LLE

Type of Error	Category of Error	Criterion for Reporting
Large Lateral Deviation (LLD)	Individual-aircraft	Any deviation of 15 NM or more to the left or right of the current flight plan track observed on the radar and/or ADS-C display.
Large Longitudinal Error (LLE)	Aircraft-pair (Distance-based separation applied)	Infringement of longitudinal separation standard based on ADS-C.
		Expected distance between an aircraft pair varies by 10 NM or more, even if separation standard based on ADS-C is not infringed.

2.1.7 It is a compromise that JASMA has selected distance-based LLEs only, and discarded time-based LLEs for now. The responsibility of an EMA is to monitor the safe PBN-based reduced separations in the international airspace, that is RNP10-based 50/50 separations and RNP4-based 30/30 separations in the Pacific Ocean airspace. Because they are all distance-based reduced separations and consequently controllers focus on the distance among the two or more PBN aircraft on the same route/track, it is concluded appropriate to simplify the definition of LLE based only on the 'distance' at this time.

2.1.8 The intended airspace to collect LLD/LLE corresponds with the data-link airspace (Figure 1).

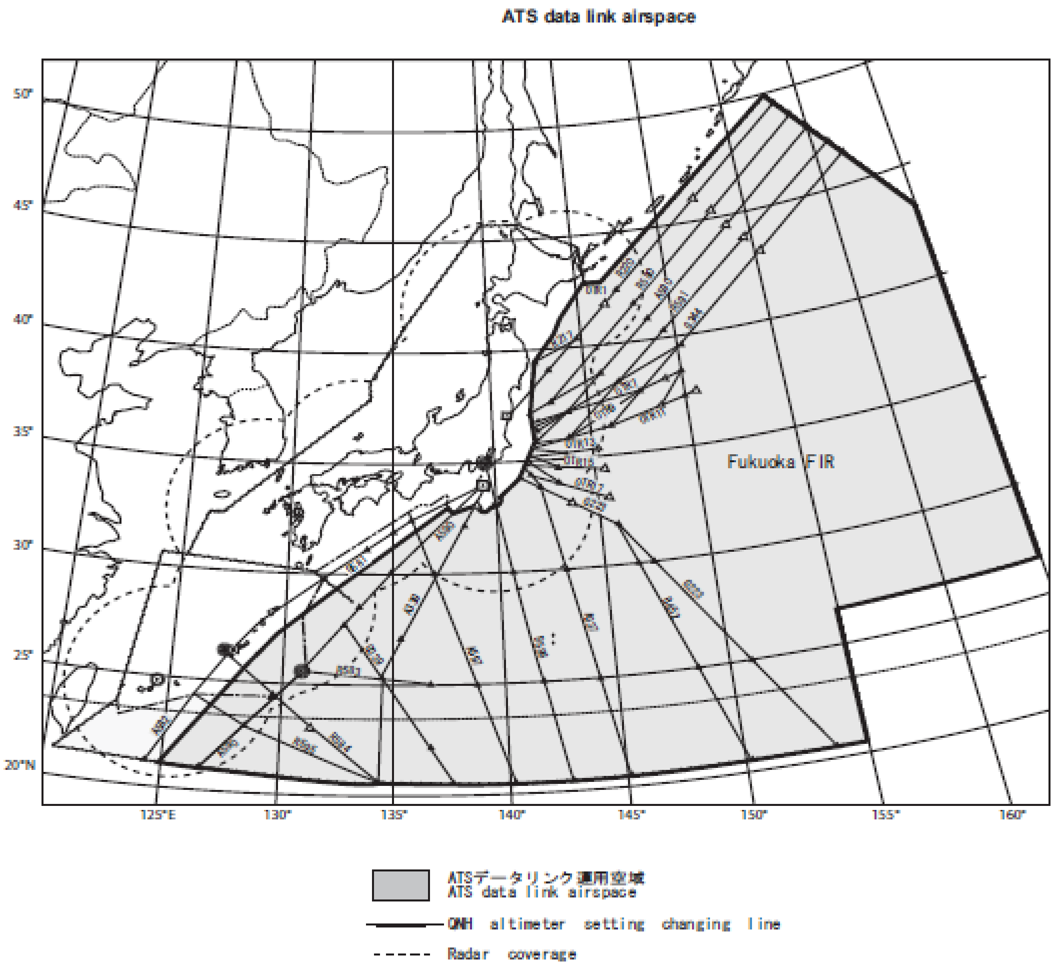

Figure 1: Airspace to collect LLD/LLE in Fukuoka FIR

2.2 Data link performance Monitoring

2.2.1 JASMA has reviewed the data link performance analyzed by Japan Central Reporting Agency (CRA), which is important as these performances are the basis for the reduced separation minima.

2.2.2 Table 4 shows the result of CPDLC downlink performance and Table 5 shows the result of CPDLC uplink performance observed by Japan CRA between July and December 2011. Average success rate during the observation period is 99.16%.

Downlink : 95 %(99%) of whole messages were completed within 1min. (3min.)
Uplink : 95 %(99%) of whole messages were completed within 2min. (6min.)

Table 4: CPDLC Downlink performance from July to December, 2011

	Jul.2011	Aug.2011	Sep.2011	Oct.2011	Nov.2011	Dec.2011
No. of message	47,523	49,634	45,344	43,429	35,418	31,517
Mean	0:00:15	0:00:15	0:00:15	0:00:16	0:00:16	0:00:17
Maximum	1:10:28	1:37:03	2:13:41	5:13:10	1:02:18	3:35:36
Minimum	0:00:01	0:00:01	0:00:01	0:00:01	0:00:01	0:00:01
95Percentile	0:00:30	0:00:35	0:00:30	0:00:30	0:00:30	0:00:35
99Percentile	0:01:25	0:01:20	0:01:25	0:01:30	0:01:30	0:01:50

Table 5: CPDLC Uplink performance from July to December, 2011

	Jul.2011	Aug.2011	Sep.2011	Oct.2011	Nov.2011	Dec.2011
No. of message	38,519	38,944	36,039	34,803	29,953	27,707
Mean	0:00:10	0:00:11	0:00:10	0:00:10	0:00:11	0:00:11
Maximum	0:07:29	0:06:03	0:04:36	0:05:05	0:05:55	0:05:15
Minimum	0:00:01	0:00:01	0:00:01	0:00:01	0:00:01	0:00:01
95Percentile	0:00:25	0:00:30	0:00:25	0:00:25	0:00:25	0:00:30
99Percentile	0:01:25	0:01:25	0:01:15	0:01:15	0:01:15	0:01:20

2.2.3 Table 6 shows the result of ADS report performance.

ADS report : 95 %(99%) of whole messages were completed within 1min. (3min.)

Table 6: ADS report performance from July to December, 2011

	Jul.2011	Aug.2011	Sep.2011	Oct.2011	Nov.2011	Dec.2011
No. of message	222,637	226,768	203,629	198,529	183,255	171,812
Mean	0:00:17	0:00:18	0:00:18	0:00:17	0:00:17	0:00:18
Maximum	0:58:40	0:54:36	0:59:08	0:58:23	0:58:17	0:58:34
Minimum	0:00:01	0:00:01	0:00:01	0:00:01	0:00:01	0:00:01
95Percentile	0:00:45	0:00:45	0:00:40	0:00:40	0:00:45	0:00:45
99Percentile	0:01:45	0:01:55	0:01:55	0:02:00	0:02:00	0:02:15

2.3 Risk assessment procedure

2.3.1 At RASMAG/15, JASMA presented the information that the risk calculation of the distance-based reduced longitudinal separation in the oceanic airspace of Fukuoka FIR would be reported at RASMAG/16 meeting. But we could not make it in time for this meeting. This is mainly because of the delay in developing the ADS-C message processing programs. The program will be completed by the end of March this year. So, hopefully we will be able to present the risk calculation results at RASMAG/17 meeting. Here is the brief outline of the calculation methodology.

2.3.2 The philosophies of many collision risk models are the same. The actual position of aircraft may not be identical to the position estimated by ATC because of the limited information available on the ground. The discrepancy between them may cause a collision of aircraft. It is modeled as probability distribution in CRM. This distribution is often estimated statistically from the data. The data required for the estimation of this distribution are not identical in different separation minima. We need to analyze ADS-C messages in the PBN/ADS-C/CPDLC-based longitudinal separation case. We are now developing the tool for processing the ADS-C messages.

2.3.3 Risk Calculation for distance-based longitudinal separation under ADS-C environment

At RASMAG/15, we presented the result of safety assessment of the longitudinal separation within the oceanic airspace of Fukuoka FIR. The assessed separation was a time-based one. Now we are planning to make a risk calculation for the distance-based separation under ADS-C environment. Following section explains *general outline of the calculation process.

*Risk calculations used in this safety assessment are developed by the Electronic Navigation Research Institute (ENRI). For the detailed explanation of the methodology, please refer to the papers like “Safety Assessment prior to 30 NM Longitudinal Separation Minimum under ADS-C environment SASP-WG/WHL/13-IP/08”.

2.3.4 Loss /Gain time and ATC position comprehension error

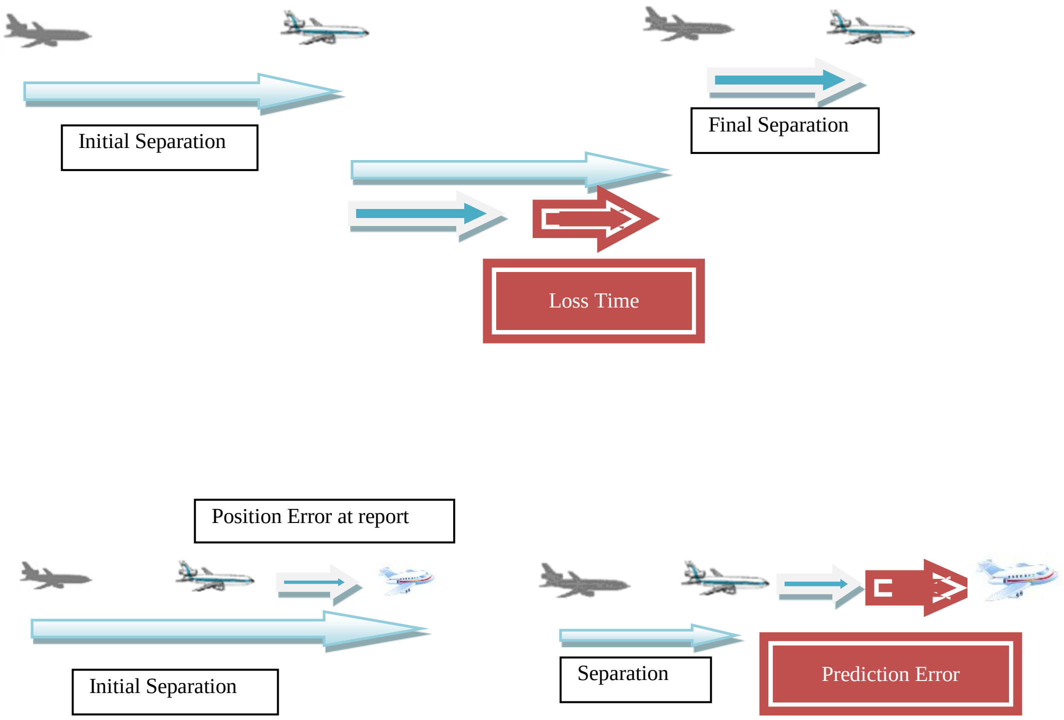

Figure 2: Loss time and ATC position comprehension error

Although the general ideas of CRM are basically similar but the required data sources are different. It is the same as assumptions of CRM. We used the idea of loss/gain time for the calculation of time-based longitudinal separation risk analysis. For the distanced-based calculation the difference in actual aircraft positions and displayed positions on the Oceanic Data Processing System (ODP) to which ATC applies distance separation must be taken into consideration.

2.3.5 ADS-C equipped aircraft periodically send their current GPS and future FMS calculated positions via SATCOM/INMARSAT/MTSAT data link communication. The ODP displays aircraft position as a current position by interpolating/extrapolating the reported and future positions. Strictly speaking the aircraft positions displayed on the ODP console do not represent exact position of the actual aircraft positions. The reported positions include navigational errors. The positions predicted by FMS and ODP have prediction errors. Consequently, the position error on the ODP display tends to grow till ATC receives the next position report.

2.3.6 T is the ADS-C position reporting time interval. The value ΔT is the gap between the reporting timing of two aircraft and t is the elapsed time from the reception of the last message transmitted by the first aircraft. The x_1 and x_2 denote the position error of the two aircraft pair and v_1 and v_2 are the estimated longitudinal speeds of two aircraft.

Then the longitudinal position error is given by

$$d = \begin{cases} x_1 - x_2 + v_1 t - v_2 (T - \Delta T + t) & t < \Delta T \\ x_1 - x_2 + v_1 t - v_2 (T - \Delta T) & t < \Delta T \end{cases} \qquad (1)$$

2.3.7 Let $f_x(d;v_1,v_2,t,\Delta T,T)$ be the probability density function of d assuming that variables v_1, v_2, t, ΔT and T are constant. Then the longitudinal overlap probability of a typical aircraft pair is given by the following formula:

$$P_x(x;\tau)=\frac{1}{T(T+\tau)}\int_0^T\int_0^{T+\tau}\int_{-\infty}^{\infty}\int_{-\infty}^{\infty}\int_{x-\lambda}^{x+\lambda} f_d(u;v_1,v_2,t,\Delta T)\,f_v(v_1)\,f_v(v_2)\,du\,dv_1\,dv_2\,dt\,d(\Delta T) \tag{2}$$

2.3.8 The collision risk is estimated by the following formula:

$$N_{ax}(x;\tau)=2\cdot P_y(0)\cdot P_z(0)\cdot P_x(x;\tau)\cdot\left(\frac{\overline{|\Delta V|}}{2\lambda_x}+\frac{\overline{|\dot{y}|}}{2\lambda_y}+\frac{\overline{|z|}}{2\lambda_z}\right) \tag{3}$$

2.3.9 In the previous equation, the distribution of nominal separation is fixed. We evaluate the mean collision risk with respect to the nominal separation (separation of aircraft on ODP consoles.);

$$N_{ax}(\tau)=\sum_{x=0}^{\infty}N_{ax}(x;\tau)E_x(x) \tag{4}$$

2.3.10 We consider the time required for the resolution of potential collision. It is also considered to be a random variable. The average collision risk with respect to this parameter is given by

$$N_{ax}=\sum_{\tau=0}^{\infty}N_{ax}(\tau)E_\tau(\tau) \tag{5}$$

2.3.11 Equation (5) assumes that all aircraft have the same navigation performance. Proportion of GPS equipped aircraft (? ?) taken into consideration we get;

$$N_{ax}=\alpha^2N_{ax}(GPS,GPS)+2\alpha(1-\alpha)N_{ax}(GPS,nonGPS)+(1-\alpha)^2N_{ax}(nonGPS,nonGPS) \tag{6}$$

Table 4: Parameters in Equation (2)

Parameter	Description
$P_x(x;\tau)$	Longitudinal overlap probability. Mean probability that a typical aircraft pair which is nominally x NM separated on the same route at the same flight level overlaps in the longitudinal dimension.
$f_v(V)$	Probability density function of longitudinal speed prediction errors. (Prediction is done by ODP using the ADS-C message downlinked from the aircraft) It is determined by the accuracy of position prediction by the aircraft, the performance of the ground ATC system interpolation/extrapolation function and so on.
$f_x(d;v_1,v_2,t,\Delta T,T)$	Probability density function of longitudinal position errors d at the given v_1 v_2, t and ΔT. It is calculated by means of equation (1).
T	Reporting interval of ADS position report.
T	Time required for the resolution of a potential collision.

λ_x	Average aircraft length

Table 5: Parameters in Equation (3)

Parameter	Description
$N_{ax}(x;\tau)$	Collision risk of a typical aircraft pair on the same route at the same flight level whose nominal separation is x (NM). Remember that τ is time required for the resolution of a potential collision.
$P_y(0)$	Lateral overlap probability. Probability that an aircraft pair on the same route overlaps in the lateral dimension.
$P_z(0)$	Vertical overlap probability. Probability that an aircraft pair at the same flight level overlaps in the vertical dimension.
$V_{rx}(x)$	Mean longitudinal relative velocity of aircraft pairs which are about losing their longitudinal separation in spite of the nominally being x NM apart.
V_{ry}	Mean lateral relative velocity of aircraft pairs on the same route.
V_{rz}	Mean vertical relative velocity of aircraft pairs at the same flight level.
λ_y	Mean aircraft length
λ_z	Mean aircraft wingspan

Table 6: Parameters in Equation (4)

Parameter	Description
N_{ax}	The average collision risk in the airspace in consideration
$E_\tau(\tau)$	The relative frequency of time required to resolve a potential collision

Table 7: Parameters in Equation (5)

parameter	Description
N_{ax}	Collision risk of the airspace under ADS-C environment
N_{ax}(GPS, GPS)	Collision risk calculated by means of Equation (6) under the assumption that both aircraft 1/2 have the navigation accuracy of GPS-equipped aircraft
N_{ax}(GPS, nonGPS)	Collision risk calculated by means of Equation (6) under the assumption that aircraft 1 has the navigation accuracy of GPS-equipped aircraft and aircraft 2 has the navigation accuracy of non-GPS-equipped aircraft
N_{ax}(nonGPS, nonGPS)	Collision risk calculated by means of Equation (6) under the assumption that both aircraft 1/2 have the navigation accuracy of non-GPS-equipped aircraft
A	Proportion of GPS-equipped ADS aircraft

3. ACTION BY THE MEETING

3.1 The meeting is invited to:

a) note the information contained in this paper; and

b) discuss any relevant matters as appropriate.

………………………….