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

Assessment of the Safety of 50-NM Lateral and 50-NM Longitudinal Separation Standards on RNAV Routes M635 and M774

(Presented by South East Asia Safety Monitoring Agency)

SUMMARY

This paper presents the results of an assessment of the risk associated with the implementation of 50NM lateral and 50NM longitudinal separation standards on RNAV routes M635 and M774. The safety assessment was conducted using internationally applied ICAO collision risk methodology, making use of relevant results developed in other portions of the Asia and Pacific Region where appropriate. The main sources of data used in the safety assessment are information extracted from the December 2010 Traffic Sample Data (TSD) collection, radar-based measurements of position obtained from the Singapore Air Traffic Control Centre and the result of monitoring navigational performance on the routes – a process which has been underway on a continuous basis since January 2009. The risk associated with the 50NM lateral separation standard is estimated to be in compliance with the Regional Target Level of Safety (TLS). Examination of the risk associated with the 50NM longitudinal separation standard also indicates that the TLS is satisfied with high confidence. In light of favorable risk estimates and the ongoing program for monitoring navigational performance, the safety assessment supports the introduction of 50NM lateral and 50NM longitudinal separation standards on M635 and M774.

1 Introduction

1.1 In March 2010, the Second Meeting of the ICAO South East Asia Route Review Task Force, SEA-RR/TF-2, Indonesia and Singapore agreed to implement the realignment of ATS routes to meet RNP 10 requirement on a step by step basis in the respective FIRs. In this regard, one of the steps is to focus on two of the major routes that operate to/from South-East Asia and Australasia. These two routes are ATS routes A464 and A576. The current minimum longitudinal separation on these 2 routes is 10 minutes based on the Mach number technique on these 2 routes already have RNAV10 capabilities.

1.2 The following tasks were planned:

a) Realignment of RNAV10 route M774 and lowering the upper limit of ATS route A464.

b) Implementation of new RNAV 10 route M635 and lowering the upper limit of ATS route A576 and implementation of 50 NM lateral separation in Jakarta and Singapore FIR

c) Implementation of 50NM longitudinal separation on both M635 and M774.

2 Background

2.1 Description of Routes A464 and A576 Airspace

2.1.1 Prior to the implementation of the EMARSSH Route Structure which involved Indonesia on routes to/from Australia, Indonesia implemented RNP10 routes within Indonesia airspace. One such route was L511 which served flights to/from Australia to South East Asia. However L511 has some route segments which are less than 50 NM laterally separated with ATS route A576. In order to have both routes laterally separated for RNAV RNP 10 operations, Indonesia intends to modify A576 to an RNP 10 route M635 as well as continue the usage of L511. In addition it is proposed to realign M635 (presently A576) to the North. This action will give a small mileage increase in this change however the overall benefit with the implementation of both RNAV will more than compensate this small mileage increase.

2.1.2 Figure 1 shows the map of the New RNAV route M635 and the realigned M774.

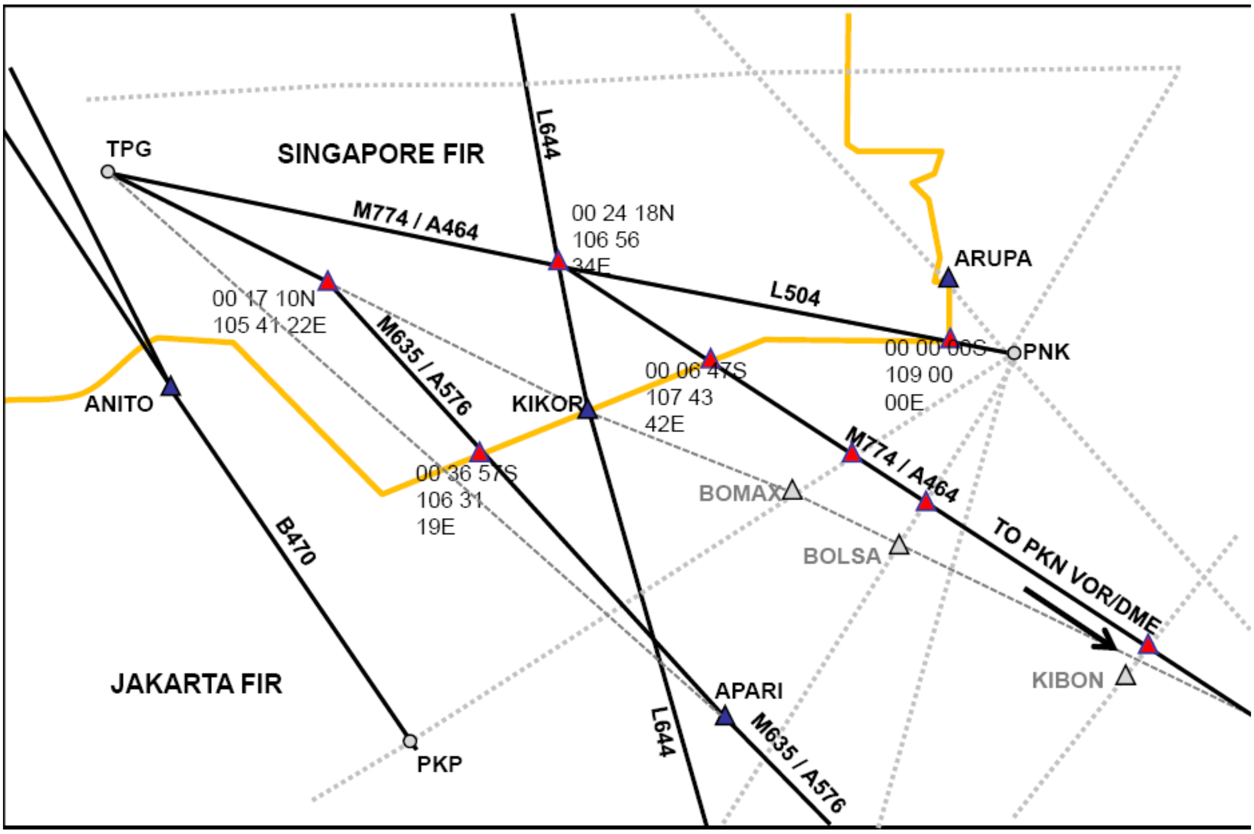

Figure 1: Implementation of M635 and Realignment of M774

3 Results of Data Collection

3.1 The December 2010 Traffic Sample Data (TSDs) were obtained from Indonesia and Singapore.

3.2 There were no Navigational Error reports reported for the period July 2010 through June 2011.

3.3 Table 1 presents the total traffic counts reported by month for ATS routes A576 and M774 monitoring fixes for the period July 2010 through June 2011.

Monitoring Month	Total Monthly Traffic Count Reported over Monitored Fixes	Cumulative 6-Month Count of Traffic reported Over Monitored Fixes Through Monitoring Month
July 2010	4046	41647
August 2010	4048	42017
September 2010	3839	42404
October 2010	4108	42699
November 2010	4254	43264
December 2010	4112	43508
January 2011	4113	43789

February 2011	3709	43910
March 2011	3963	44018
April 2011	3872	43966
May 2011	4023	44021
June 2011	3955	44151

Table 1: Monthly Count of Monitored Flights Operating on A576 and M774 for the period July 2010 through June 2011

3.5 Table 2 presents the cumulative totals of Large Lateral Deviations (LLDs) and Large Longitudinal Errors (LLEs) for the Monitoring Period July 2010 through June 2011.

Monitoring Month	Cumulative 6-Month Count of LLDs Reported Over Monitored Fixes Through Monitoring Month	Cumulative 6-Month Count of LLEs Reported Over Monitored Fixes Through Monitoring Month
July 2010	0	0
August 2010	0	0
September 2010	0	0
October 2010	0	0
November 2010	0	0
December 2010	0	0
January 2011	0	0
February 2011	0	0
March 2011	0	0
April 2011	0	0
May 2011	0	0
June 2011	0	0

Table 2: Monthly Count of LLDs and LLEs Reported on A576 and M774 for the period July 2010 through June 2011

3.6 It is of the utmost importance that relevant information be provided so that the safety assessment will be correct and effective. States are strongly urged to provide accurate data to facilitate the conduct of the safety assessment and to identify trends.

4 Risk Assessment and Safety Oversight

4.1 The safety assessment has been conducted using the internationally applied collision risk methodology which has supported airspace separation changes in several ICAO regions. As applied to a proposed separation change, the methodology consists of using a mathematical model to estimate the risk of midair collision for the proposed standard and comparing the estimated risk to a safety goal, the Target Level of Safety (TLS), which is a value of risk agreed as tolerable by decision makers. If the estimated risk is less than the TLS, the outcome of applying the methodology is to support the proposed change.

4.2 The APANPIRG has adopted the value 5×10^{-9} fatal accidents per flight hour as the TLS for each separation dimension – lateral, longitudinal and vertical – in the Asia and Pacific Region.

4.3 Factors Affecting the Risk of Collision in the Airspace

4.3.1 One of the assumptions made in developing the collision risk model is that there is no independent surveillance of aircraft position. As a result, there is no allowance made for the value of air traffic control intervention to reduce the risk that a pair of aircraft loses planned separation. Consequently, the risk estimates presented in this working paper should be considered conservative, that is, higher than is likely the case in the airspace.

4.3.2 As shown in Table 2, no 15NM or greater magnitude lateral errors and no large longitudinal-error events have been reported on A576 and M774 during the monitoring period.

4.3.3 Operators and aircraft flying at or above FL280 on these routes require State RNP 10 approval. Compliance with this requirement is equivalent to stating that 95 percent of lateral deviations from route centerline are 10NM or less. In turn, under the assumptions made in the development of the RNP 10 standard, this containment percentage is equivalent to requiring that the standard deviation of lateral errors is roughly 5NM. Radar-based measurements of the positions of aircraft indicate that the standard deviation of lateral errors is on the order of 0.5 NM. As a result, decision makers should have high confidence that RNP 10 requirements for lateral navigational performance are being met. This estimate of standard deviation would seem to support the reported results of monitoring lateral errors: there has been no report of a 15NM or greater magnitude lateral error since 2009. Based on the radar-based evidence, it would seem that, if a 15NM or greater magnitude error were to occur in the future, it would not be the result of typical navigational performance in the airspace.

4.4 Estimate of the Collision Risk Model Parameters

4.4.1 The targeted lateral separation standard between M635 and M774 is 50NM. The form of the lateral collision risk model used in assessing the safety of operations on these routes is:

$$N_{ay} = P_y(S_y)P_z(0)\frac{\lambda_x}{S_x}\left\{E_y(same)\left[\frac{\overline{|\dot{x}|}}{2\lambda_x}+\frac{\overline{|\dot{y}(S_y)|}}{2\lambda_y}+\frac{\overline{|\dot{z}|}}{2\lambda_z}\right]+E_y(opp)\left[\frac{\overline{V}}{\lambda_x}+\frac{\overline{|\dot{y}(S_y)|}}{2\lambda_y}+\frac{\overline{|\dot{z}|}}{2\lambda_z}\right]\right\}$$

4.4.2 The longitudinal separation standard for co-altitude aircraft on M635 and M774 to be implemented is 50NM; the current longitudinal separation standard is either 10 minutes with Mach Number Technique (MNT) or 80NM otherwise for the routes.

4.4.3 The form of the longitudinal collision risk model used in assessing the safety of operations on these two routes is:

$$N_{ax} = P_y(0)P_z(0)\frac{2\lambda_x}{\overline{|\dot{x}|}}\left[\frac{\overline{|\dot{x}|}}{2\lambda_x}+\frac{\overline{|\dot{y}(0)|}}{2\lambda_y}+\frac{\overline{|\dot{z}|}}{2\lambda_z}\right]\times\sum_{k=m}^{N}\sum_{K=k}^{M}Q(k)\times P(K>k)$$

4.4.4 Table 3 summarizes the value and source material for estimating the values for each of the inherent parameters of the internationally accepted Collision Risk Model (CRM). Appendix A provides the details in deriving the parameters used in the lateral and longitudinal collision risk model.

Model Parameter	**Description**	**Value Used in Preliminary Safety Assessment**	**Source for Value**
For Lateral Collision Risk Model			
N_{ay}	Risk of collision between two aircraft with planned 50-NM lateral separation	5.0 x 10^{-9} fatal accidents per flight hour	TLS adopted by APANPIRG as safety goal for changes in separation minima
S_y	Lateral separation minimum	50 NM	Targeted lateral separation minimum on RNAV routes M635 and M774.
$P_y(50)$	Probability that two aircraft assigned to parallel routes with 50-NM lateral separation will lose all planned lateral separation	5.98 x 10^{-7}	Value required to meet exactly the TLS value of 5 x 10^{-9} fatal accidents per flight hour, given other parameters used in the safety assessment.
$P_z(0)$	Probability of vertical overlap for airplanes assigned to the same flight level	0.538	Commonly used in safety assessments
λ_x	Aircraft length	0.0399 NM	Merged December 2010 TSDs
λ_y	Aircraft wingspan	0.0350 NM	
λ_z	Aircraft height	0.0099 NM	
S_x	Length of the interval, in NM, used to count proximate aircraft at adjacent fix for occupancy estimates	+120 NM to -120 NM, equivalent to the +15-minute to -15-minute pairing criterion used in the preliminary safety assessment, for aircraft operating at 480 kts.	Arbitrary criterion which does not affect the value of risk
$E_y(same)$	Same-direction lateral occupancy	0.018	December 2010 TSD
$E_y(opp)$	Opposite-direction lateral occupancy	0.0	NA

Model Parameter	**Description**	**Value Used in Preliminary Safety Assessment**	**Source for Value**
$\lvert\bar{\dot{x}}\rvert$	Average relative along-track speed of 2 aircraft travelling in the same direction	46.5 kts.	December 2010 TSD
$\lvert\bar{\dot{y}}\rvert$	Average relative speed of a pair of aircraft as they lose all planned 50-NM lateral separation	75 kts.	Reference 1
$\lvert\bar{\dot{z}}\rvert$	Average relative vertical speed of a co altitude aircraft pair assigned to the same route	1.5 kts.	Conservative value commonly used in safety assessments
For Longitudinal Collision Risk Model			
N_{ax}	Risk of collision between two co-altitude aircraft with planned longitudinal separation equal to at least the applicable minimum longitudinal separation standard	5.0×10^{-9} fatal accidents per flight hour	TLS adopted by APANPIRG for changes in separation minima
$P_y(0)$	Probability of lateral overlap for airplanes assigned to the same route	0.2	Reference 2
$\overline{\lvert\dot{x}(m)\rvert}$	Minimum relative along-track speed necessary for following aircraft in a pair separated by m at a reporting point to overtake lead aircraft at next reporting point	100 knots	December 2010 TSDs
$\overline{\lvert\dot{y}(0)\rvert}$	Relative across-track speed of same-route aircraft pair	1 knot	Reference 2
m	Longitudinal separation minimum in NM	50NM	Targeted longitudinal separation minimum on RNAV routes M635 and M774.

Model Parameter	Description	Value Used in Preliminary Safety Assessment	Source for Value
N	Maximum initial longitudinal separation in NM between aircraft pair which will be monitored by air traffic control in order to prevent loss of longitudinal separation standard	150NM	Arbitrary value of actual initial separation beyond which there is negligible chance that actual longitudinal separation will erode completely before next air traffic control check of longitudinal separation based on position reports
M	Maximum longitudinal separation loss in NM observed over all pairs of co-altitude aircraft	Dependent on initial longitudinal separation distance	December 2010 TSD
$Q(k)$	Proportion of aircraft pairs with initial longitudinal separation k	Initial distribution of longitudinal separation for ATS routes A576 and M774.	December 2010 TSD
$P(K > k)$	Probability that a pair of same-route, co-altitude aircraft with initial longitudinal separation of k NM will lose at least as much as k NM longitudinal separation before correction by air traffic control	Values derived to satisfy TLS of 50NM longitudinal separation minimum	December 2010 TSD

Table 3: Summary of Risk Model Parameters Used in the CRM

4.5 Safety Oversight - Lateral

4.5.1 For the lateral safety assessment, the 2 realigned routes were considered and the parameters used for the lateral collision risk model were calculated.

4.5.2 As the monitoring program ATS routes A576 and M774 started in January 2009, there were two years and 6 months of traffic being monitored. The following risk assessment employs 2 method of analysis, a) Sequential Sampling, b) Direct Estimation.

4.5.3 Sequential Sampling: As can be seen in figure 2, the number of large lateral deviations is plotted against the number of operations monitored. There was no 15NM deviation reported since Jan 2009 and for a monitored traffic count of 115,075, the plot falls within the green zone. The location of this plot falls within the “green zone’ which indicates that it meets the TLS.

4.5.4 As a result, it can be concluded with 95 percent statistical confidence that the continued use of 50NM lateral separation standard for the two routes meets the TLS.

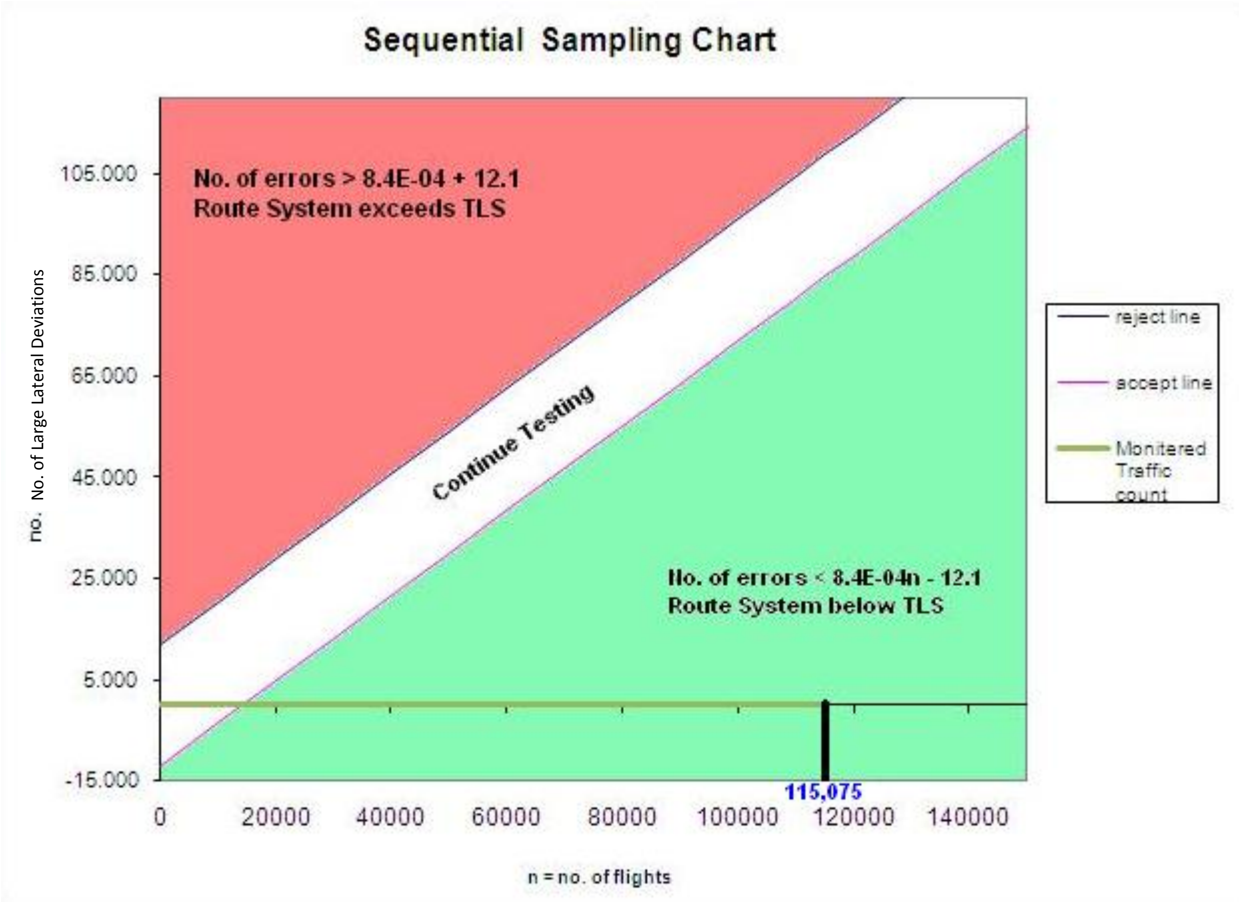

Figure 2: Sequential Sampling Approach to Demonstrate That Lateral Collision Risk for 50-NM Lateral Separation Standard Applied to the two routes

4.5.5 Direct Estimation: This approach was used as a confirmation that the lateral risk can meet the TLS. The lateral risk was estimated based on the number of navigation error reports received. Using this method, the lateral collision risk is estimated to be 1.22 x 10^{-12} which meets the TLS.

4.6 Safety Oversight – Longitudinal

4.6.1 Given the values of $P_y(0)$, $P_z(0)$ and other risk model parameters, the value of the summation of $[Q(s) \cdot P(S \geq s)]$ in paragraph 4.4.4 for all values of s needed to meet the TLS is 4.34 x10^{-8} for a value of T equal to 30 minutes, the interval between position updates allowing air traffic control to intervene, if necessary, to increase separation.

4.6.2 The resulting value for summation of [Q(s) • P(S ≥ s)] for all values of s, 1.84×10^{-10}, is less than the required value of 4.24×10^{-8} required to meet the TLS. The longitudinal collision risk is then estimated to be 2.13×10^{-11}.

4.7 Table 4 summarizes the result of the airspace risk assessment.

Type of risk	Risk estimation	TLS	Remarks
Lateral Risk	0.00122×10^{-9}	5×10^{-9}	Below TLS
Longitudinal Risk	0.0213×10^{-9}	5×10^{-9}	Below TLS

Table 4: Comparison of Risk Estimates with TLS for the 2 Routes

4.8 Figure 3 presents the results of the collision risk estimate for each month using the cumulative twelve month LLDs and LLEs report since July 2010.

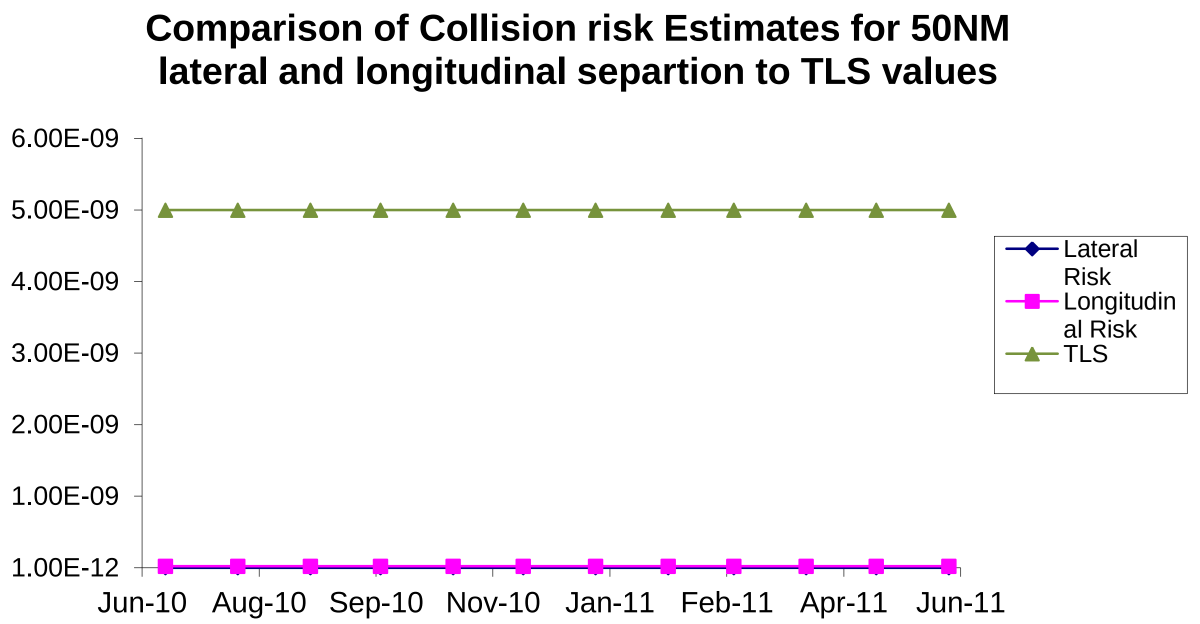

Figure 3: Assessment of Compliance with Lateral and Longitudinal TLS

4.9 Conclusions and Recommendations from the Safety Assessment concerning the implementation of the 50-NM Lateral and the implementation of 50NM Longitudinal Separation Standard on the two RNAV routes M635 and M774

4.9.1 As can be seen, both the estimates of lateral and longitudinal risk shows compliance with the corresponding TLS values during the months of the monitoring period.

5. Action by the Meeting

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

Appendix A

References

1. Information Paper on the Examination of Operations Conducted On ATS Routes in the Bay of Bengal Region (BOB/RHS/TF/5)

2. "A Summary of Airspace Characteristics Related to the Operational Trial of 30/30NM lateral and longitudinal separation standards in the Oakland Oceanic Flight Information Region (FIR)," Twenty-fifth meeting of the informal pacific ATC coordinating group (IPACG/25), Tokyo, Japan, 24-27 October 2006, IP-4 Rev.1.