International Civil Aviation Organization

The 19th Meeting of the Regional Airspace Safety Monitoring Advisory Group (RASMAG/19)

Pattaya, Thailand, 26 – 30 May 2014

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

SEASMA SAFETY REPORT

(Presented by Singapore)

SUMMARY

This paper presents the horizontal safety assessment report from the South East Asia Safety Monitoring Agency (SEASMA) for operations on the six major air traffic service routes within the South China Sea for the period 1 Jan 2013 through 31 Dec 2013. The assessment concludes that the Asia and Pacific Region Target Level of Safety (TLS) values established for lateral and longitudinal separation standards were satisfied for the six-route system with high statistical confidence during the 12-month period examined.

This paper relates to –

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

1. INTRODUCTION

1.1 This working paper is a periodic assessment to ascertain if flight operations on the six major South China Sea routes meet with the APANPIRG-agreed Target Level of Safety (TLS) values for lateral and longitudinal separation standards. The examination period covered is from 1 Jan 2013 till 31 Dec 2013.

2. DISCUSSION

<u>Executive Summary</u>

2.1 **Table 1** provides the South China Sea airspace horizontal risk estimates.

Risk	**Risk Estimation**	**TLS**	**Remarks**
RASMAG 18 Lateral Risk	*1.89×10^{-9}*	*5.0×10^{-9}*	*Below TLS*
RASMAG 18 Longitudinal Risk	*0.79×10^{-9}*	*5.0×10^{-9}*	*Below TLS*
Lateral Risk	**0.055×10^{-9}**	5.0×10^{-9}	**Below TLS**
Longitudinal Risk	**1.18×10^{-9}**	5.0×10^{-9}	**Below TLS**

Table 1: South China Sea Airspace Horizontal Risk Estimates

2.2 **Table 2** contains a summary of Large Lateral Deviations (LLD) and Large Longitudinal Errors (LLE) received by SEASMA for the South China Sea airspace.

Code	Deviation Description	No.
E	ATC Coordination errors	4
Total		4

Table 2: Summary of South China Sea Airspace LLD and LLE Reports

2.3 **Figure 1** presents the lateral and longitudinal collision risk estimate trends for South China Sea airspace during the period January 2013 to December 2013.

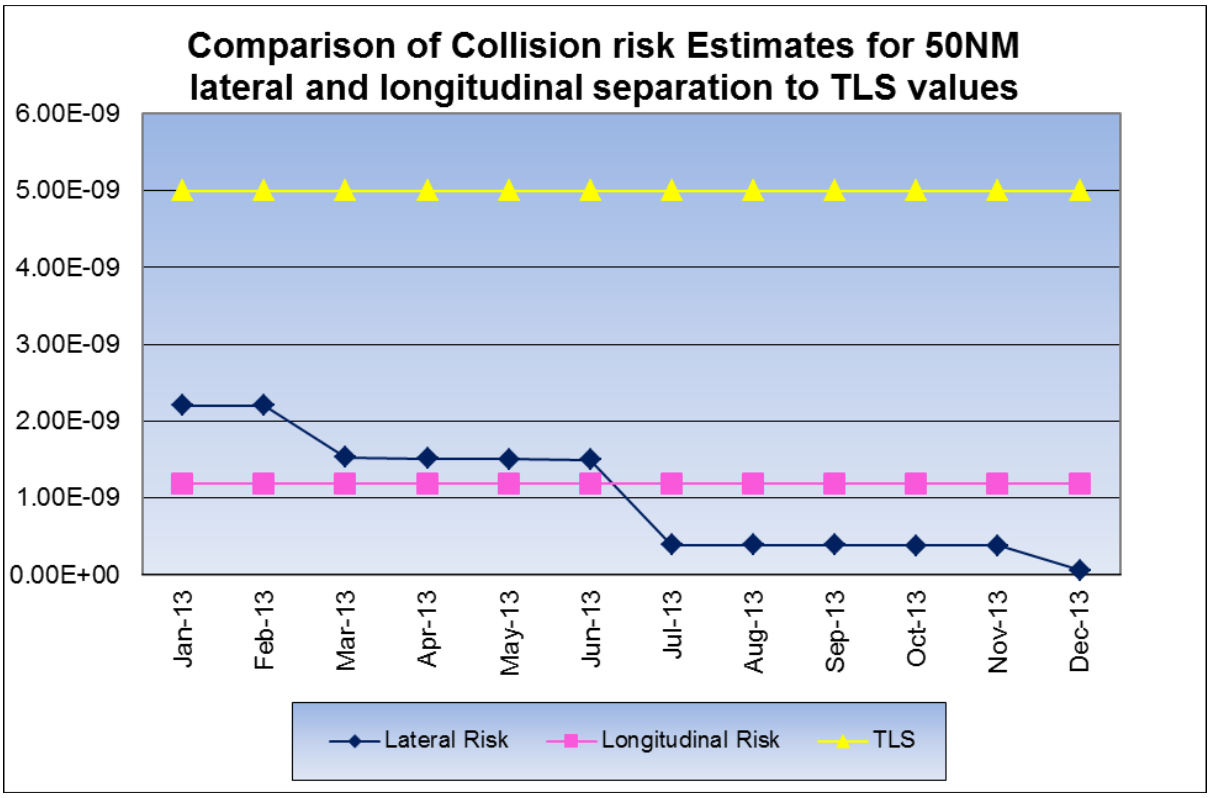

Figure 1: South China Sea Airspace Horizontal Risk Estimates

2.4 **Figure 2** provides the geographical location of GNEs within the South China Sea Airspace.

GNE Hotspot 2013

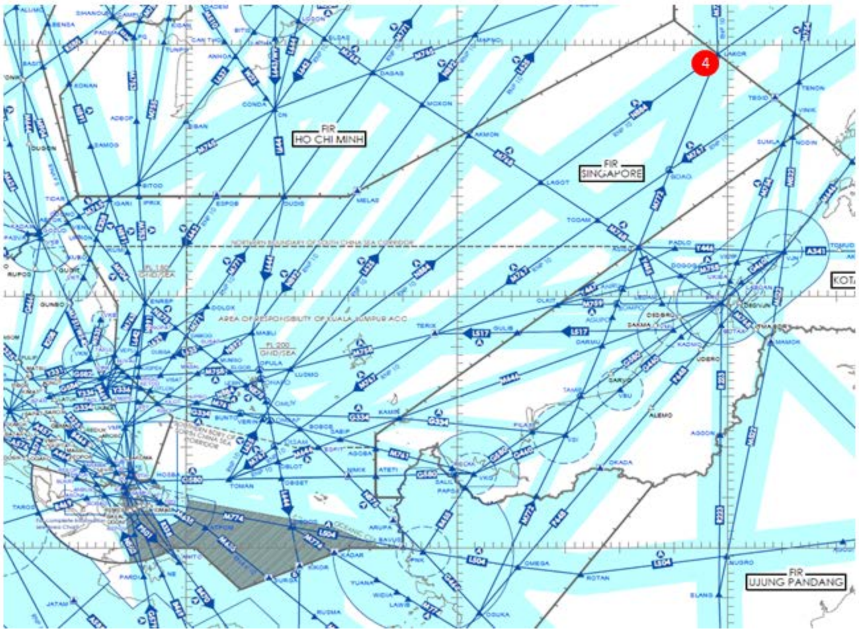

Figure 2: South China Sea Airspace- Location of GNEs

2.5 The main concerns for the South China Sea Airspace are:

a) Human Error - The 4 LLEs are attributed to human error as a result of an ATCO forgetting to execute an action. The follow up action was to brief ATCOs on the importance of proper handover and to be more vigilant of all time revisions.

b) Inconsistent reporting - There were 8 instances of reports that were reported by one FIR but not by the other. In 6 of these reports, the checkbox “notified by the adjacent supervisor” was ticked. The follow up action was to remind ATCOs and Watch Managers to fill in the report when notified by adjacent FIR of LHDs/LLEs /LLDs.

c) Lack of understanding of definition of LLE. Some of the LHDs reported are due to lack of revision of the estimate over FIR boundary. These are also considered as LLEs. But the FIRs only reported the errors as LHDs. The follow up action is to ensure all concerned are clear of the definition of LLE.

3. ACTION BY THE MEETING

3.1 The meeting is invited to:

a) note the information contained in this paper;

b) remind States to brief their staff on the concerns and mitigation contained in para 2.5.

c) note the performance on the South China Sea RNAV routes is compliant with the APANPIRG-agreed lateral and longitudinal TLS; and

d) discuss any relevant matters as appropriate.

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Appendix: SEASMA Safety Report for the South China Sea

Background

1.1 The lateral separation standard applied in the six South China Sea routes – L642, M771, N892, L625, N884 and M767 – is 50NM. The longitudinal separation minimum applied is 50NM for pairs of co-altitude aircraft on L642 and M771 and 10 minutes, with Mach number technique applied, or 80NM RNAV for the rest of the four routes.

Results of Data Collection

1.2 The fidelity of large-error and traffic-count reporting by each responsible air navigation service provider (ANSP) for the period Jan 2013 through Dec 2013 is shown in **Table 1**.

Month	**Report Received from:**		
	Hong Kong, China	**Philippines**	**Singapore**
Jan 2013	Yes	Yes	Yes
February 2013	Yes	Yes	Yes
March 2013	Yes	Yes	Yes
April 2013	Yes	Yes	Yes
May 2013	Yes	Yes	Yes
June 2013	Yes	Yes	Yes
July 2013	Yes	Yes	Yes
August 2013	Yes	Yes	Yes
September 2013	Yes	Yes	Yes
October 2013	Yes	Yes	Yes
November 2013	Yes	Yes	Yes
December 2013	Yes	Yes	Yes

Table 1: Record of ANSP Reporting by Month for Period Jan 2013 through Dec 2013

Reported Traffic Counts for Jan 2013 through Dec 2013 Monitoring Period

1.3 **Table 2** presents the total traffic counts reported by month transiting all South China Sea monitoring fixes for the period Jan 2013 through Dec 2013.

Monitoring Month	**Total Monthly Traffic Count Reported Over Monitored Fixes**	**Cumulative 12-Month Count of Traffic Reported Over Monitored Fixes Through Monitoring Month**
January 2013	9983	119637
February 2013	9666	119916
March 2013	10733	120590
April 2013	10711	121297
May 2013	11147	122159
June 2013	10744	122891
July 2013	10767	123458
August 2013	10824	124060
September 2013	10272	124350
October 2013	11139	125190
November 2013	10689	125633
December 2013	11484	126358

Table 2: Monthly Count of Monitored Flights Operating on South China Sea RNAV Routes for the period Jan 2013 through Dec 2013

Monitoring Reports

1.4 **Table 3** presents the cumulative totals of Large Lateral Deviations (LLDs) and Large Longitudinal Errors (LLEs) LLDs and LLEs for the period January 2013 until December 2013.

Monitoring Month	Monthly Count of LLDs Reported	Cumulative 12- Month Count of LLDs	Monthly Count of LLEs Reported	Cumulative 12- Month Count of LLEs
January 2013	0	4	0	0
February 2013	0	4	0	0
March 2013	0	3	0	0
April 2013	0	3	0	0
May 2013	0	3	0	0
June 2013	0	3	0	0
July 2013	0	1	1	1
August 2013	0	1	0	1
September 2013	0	1	2	3
October 2013	0	1	1	4
November 2013	0	1	0	4
December 2013	0	0	0	4

Table 3: Monthly Count of LLDs and LLEs Reported on South China Sea RNAV Routes for the period Jan 2013 through Dec 2013

1.5 **Table 4** presents the cause of deviation in the LLD and LLE reports received for the period Jan 2013 through Dec 2013.

Deviation Code	Cause of Deviation	No of Occurrences
E	ATC coordination errors.	4
Total		4

Table 4: Cause of LLE deviation

Risk **Assessment and Safety Oversight**

1.6 This section presents the results of safety oversight to the lateral and longitudinal separations standards applied in the South China Sea RNAV route structure. Analysis techniques used are in conformance with the internationally applied collision risk methodology.

Estimate of the CRM Parameters

1.7 The lateral separation standard between the six RNAV routes is 50NM. The form of the lateral collision risk model used in assessing the safety of operations on the South China Sea RNAV routes is:

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

1.8 The longitudinal separation standard for co-altitude aircraft on RNAV routes L642 and M771 is 50NM. And in Dec 2013 with the implementation of ADS-B surveillance in the Singapore FIR the longitudinal separation has reduced to 40NM. These two routes are fully covered under surveillance. For the other four RNAV routes, the longitudinal separation standard is either 10 minutes with Mach Number Technique (MNT) or 80NM RNAV.

1.9 The form of the longitudinal collision risk model used in assessing the safety of operations on the South China Sea RNAV routes is:

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

1.10 **Table 5** summarizes the value and source material for estimating the values for each of the inherent parameters of the internationally accepted Collision Risk Model (CRM).

Model Parameter	**Definition**	**Value Used in TLS Compliance Assessment**	**Source for Value**
For Lateral Collision Risk Model			
N_{ay}	Risk of collision between two aircraft with planned 50NM lateral separation	5.0 x 10^{-9} fatal accidents per flight hour	TLS adopted by APANPIRG for changes in separation minima
S_y	Lateral separation minimum	50NM	Current lateral separation minimum in the South China Sea
$P_y(50)$	Probability that two aircraft assigned to parallel routes with 50NM lateral separation will lose all planned lateral separation	2.02 x 10^{-9}	Value required to meet exactly the APANPIRG-agreed TLS value using equation (1), given other parameter values shown in this table.
λ_x	Aircraft length	0.0399NM	Based on December 2013 TSD operations on L642/M771
λ_y	Aircraft wingspan	0.0350NM	
λ_z	Aircraft height	0.0099NM	
$P_z(0)$	Probability of vertical overlap for airplanes assigned to the same flight level	0.538	Commonly used in safety assessments
S_x	Length of half the interval, in NM, used to count proximate aircraft at adjacent fix for occupancy estimates	120NM, equivalent to the +/- 15-minute pairing criterion	Arbitrary criterion which does not affect the estimated value of lateral collision risk
$E_y(same)$	Same-direction lateral occupancy	0.0	Result of direction of traffic flows on each pair of RNAV routes
$E_y(opp)$	Opposite-direction lateral occupancy	0.255	Based on December 2013 TSD
$\overline{V}$	Individual-aircraft along-track speed	507 knots	Based on December 2013 TSD
$\left\lvert\overline{\dot{y}(S_y)}\right\rvert$	Average relative lateral speed of aircraft pair at loss of planned lateral separation of S_y	75 knots	Conservative value based on assumption of waypoint insertion error
$\left\lvert\overline{\dot{z}}\right\rvert$	Average relative vertical speed of a co altitude aircraft pair assigned to the same route	1.5 knots	Conservative value commonly used in safety assessments

Model Parameter	Definition	Value Used in TLS Compliance Assessment	Source for Value
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 x 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	December 2013 TSD
$\overline{\lvert\dot{x}(m)\rvert}$	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 2013 TSD
$\overline{\lvert\dot{y}(0)\rvert}$	Relative across-track speed of same-route aircraft pair	1 knot	December 2013 TSD
m	Longitudinal separation minimum in NM	50NM	Longitudinal separation minimum on L642 and M771
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 2013 TSD
$Q(k)$	Proportion of aircraft pairs with initial longitudinal separation k	Initial distribution of longitudinal separation for RNAV routes L642 and M771 used in RASMAG/9 safety assessment	December 2013 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 2013 TSD

Table 5: Summary of Risk Model Parameters Used in the CRM

Safety Oversight

1.11 **Table 6** summarizes the results of the airspace oversight, as of Dec 2013.

Type of Risk	Risk Estimation	TLS	Remarks
Lateral Risk	0.055×10^{-9}	5×10^{-9}	Below TLS
Longitudinal Risk	1.18×10^{-9}	5×10^{-9}	Below TLS

Table 6: Lateral and Longitudinal Risk Estimation

1.12 **Figure 1** presents the results of the collision risk estimates for each month using the cumulative 12-month LLD and LLE reports since Jan 2013.

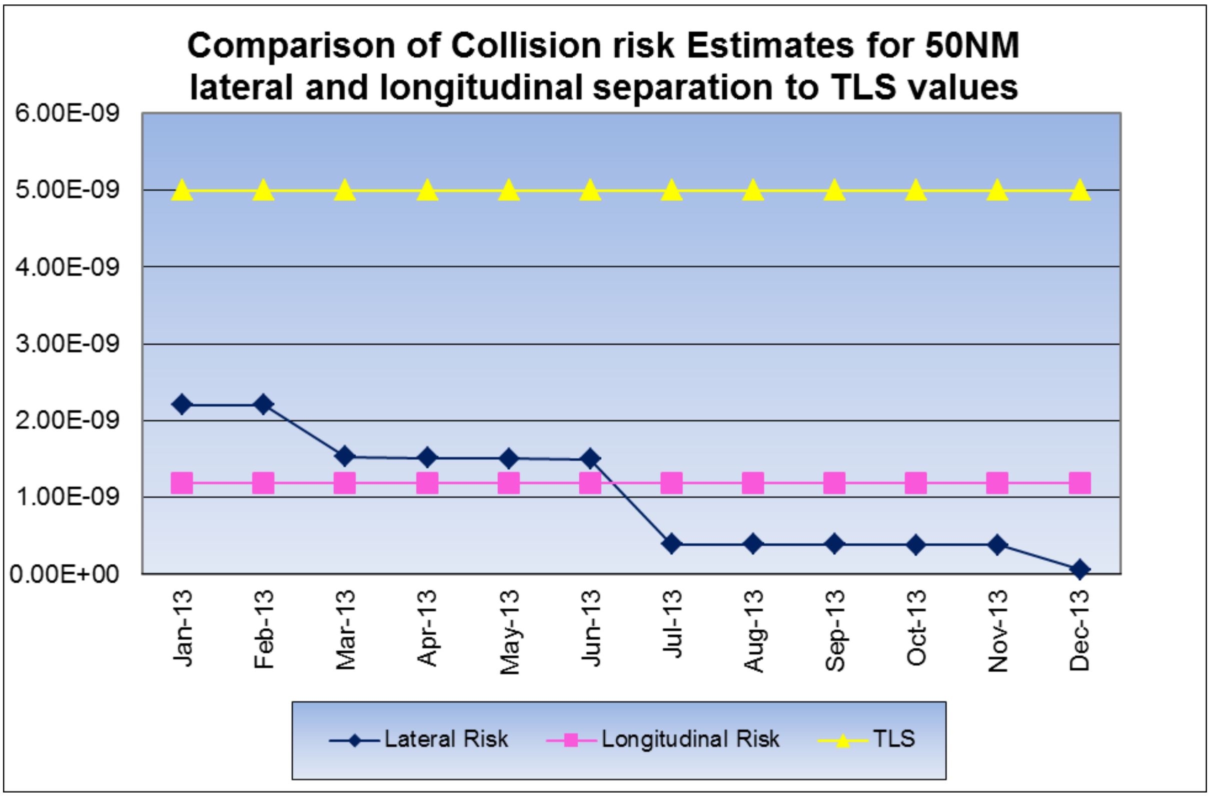

Figure 1 - Assessment of Compliance with Lateral and Longitudinal TLS Values Based on Navigational Performance Observed During South China Monitoring Program

1.13 The estimates of lateral and longitudinal risk show compliance with the corresponding respective TLS values during all months of the monitoring period.

Alternate Longitudinal risk assessment using Hsu Model

1.14 The Hsu model is used as on trial basis as an ongoing improvement to longitudinal risk assessment. The generalized model states the collision risk [Reference 1] as

$$CR(t_0,t_1) = 2NP \int_{-\infty}^{\infty} \int_{-\infty}^{\infty} \int_{t_0}^{t_1} HOP(t|V_1,V_2) P_z(h_z) \left(\frac{2V_{rel}}{\pi \lambda_{xy}} + \frac{\overline{|\dot{z}|}}{2\lambda_z} \right) f_1(V_1) f_2(V_2) dt dV_1 dV_2$$

1.15 The component HOP(t) represents the probability of the pair of aircraft having a horizontal overlap during a given time interval given the speeds of the pair of aircraft. It is based on reliability theory and is evaluated in terms of multiple integrals of the probability density functions for the along and cross track position errors of each aircraft and is stated in [Reference 1] as

$$HOP(t|V_1V_2) = \frac{\pi\lambda_{xy}^2}{16\lambda^2}e^{-|D_x(t)|/\lambda}\left(\frac{|D_x(t)|}{\lambda}+1\right)$$

1.16 The South China Sea route system comprises of 6 unidirectional non intersecting parallel routes. Thus this risk assessment will only consider the case of same identical track.

1.17 Assumptions

a. This assessment takes a conservative approach and does not account for controllers' intervention or system alerts to mitigate collision.

1.18 **Table 7** shows the parameters used.

Parameters	Description	Value	Source
V_1	Assumed average ground speed of a/c 1	480knots	Reference 1
V_2	Assumed average ground speed of a/c 2	480knots	Reference 1
λ_{xy}	Average aircraft wingspan or length (whichever is greater)	0.0363NM	December 2013 TSD
λ_z	Aircraft height	0.0101NM	December 2013 TSD
λ_v	scale factor for speed error distribution	5.82	Reference 1
T	ADS periodic report	27mins	ICAO Doc 4444
NP	No. of a/c per hour	1	Reference 1
$P_z(0)$	Probability of vertical overlap for airplanes assigned to the same flight level	0.538	Commonly used in safety assessments
$\overline{\lvert\dot{z}\rvert}$	Average relative vertical speed of a co altitude aircraft pair assigned to the same route	1.5knots	Commonly used in safety assessments
τ	controller intervention buffer	3 cases	Reference 1

Table 7: Parameters used in the Hsu's model

1.19 **Table 8** shows the summary of the 3 cases of Controllers intervention buffer (τ) [reference 1 and 2] used in the computation of the horizontal risk. **Tables 9 - 11** present the detailed component of each of the cases as used in Reference 1 & 2. The final collision risk is also stated as

$$0.95\times (0.95\times CR\ (\tau=4) + 0.05\times CR\ (\tau=10.5)) + 0.05\times CR\ (\tau=13.5)$$

τ	Minutes
Case 1: normal ADS ops	4
Case 2: ADS report received & response to CPDLC uplink NOT received in 3 mins	10.5
Case 3: ADS periodic reports takes more than 3 mins	13.5

Table 8: 3 cases of τ

Case 1: normal ADS ops	Seconds
Screen update time/controller conflict recognition	30
Controller message composition	15
CPDLC uplink	90
Pilot reaction	30
Aircraft inertia plus climb	75
Total	240

Table 9: Case 1

Case 2: ADS report received & response to CPDLC uplink NOT received in 3 mins	Seconds
Screen update time/controller conflict recognition	30
Controller message composition	15
CPDLC uplink and wait for response	180
HF communication	300
Pilot reaction	30
Aircraft inertia plus climb	75
Total	630

Table 10: Case 2

Case 3: ADS periodic reports takes more than 3 mins	Seconds
Controller wait for ADS report	180
Controller message composition	15
CPDLC uplink & wait for response	180
HF communication	300
Pilot reaction	30
Aircraft inertia plus climb	75
Extra allowance	30
Total	810

Table 11: Parameters used in the Hsu's model

1.20 In the model, the value for CPDLC uplink is stated as 90 sec [Reference1]. To better model the actual Communication Navigation and Surveillance (CNS) component, an operational value of CPDLC uplink delivery time could be derived from the actual uplink delivery time database. Further collaboration is needed to collect useful data for analysis. The current ADS CPDLC data collection is shown in **Table 12**.

Uplink Message Delivery Time	30 s	40 s	60 s	120 s	180 s	360 s	>360 s	Total No. of CPDLC Uplink Messages
Jan-13	87.88%	89.72%	92.91%	98.45%	99.39%	99.91%	100.00%	19,878
Feb-13	87.21%	89.53%	93.18%	98.30%	99.23%	99.90%	100.00%	20,594
Mar-13	84.81%	87.50%	91.71%	97.62%	98.92%	99.81%	100.00%	21,409
Apr-13	85.21%	87.74%	92.06%	97.54%	98.77%	99.71%	100.00%	23,435
May-13	86.12%	88.45%	92.54%	97.89%	99.09%	99.83%	100.00%	24,398
Jun-13	86.00%	88.37%	92.59%	97.78%	99.01%	99.85%	100.00%	23,750
Jul-13	86.08%	88.37%	92.56%	97.94%	99.00%	99.76%	100.00%	25,632
Aug-13	86.50%	89.06%	93.12%	98.00%	98.99%	99.83%	100.00%	26,108
Sep-13	86.30%	88.83%	92.87%	98.01%	99.20%	99.84%	100.00%	25,485
Oct-13	88.01%	89.91%	93.40%	98.10%	99.23%	99.84%	100.00%	20,552
Average %	86.41%	88.75%	92.69%	97.96%	99.08%	99.83%	100.00%	23,124

Table 12: ADS CPDLC uplink message delivery time

1.21 **Figure 2** presents the comparison of the longitudinal risk estimates using 2 methods

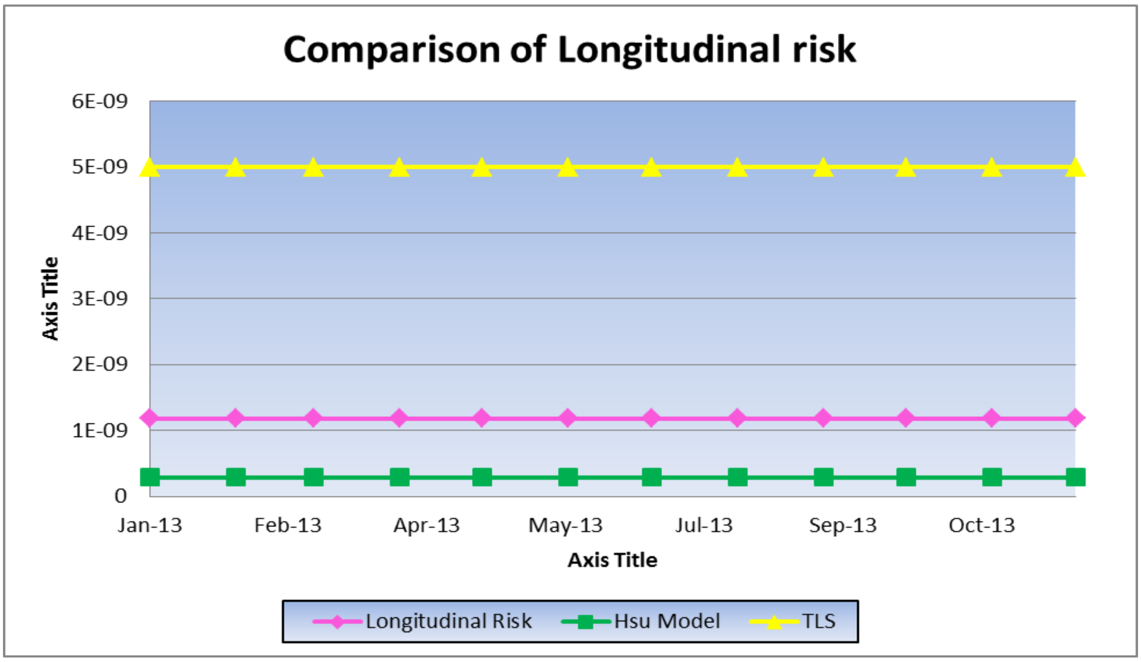

Figure 2 – Comparison of Longitudinal Risk values

1.22 **Table 13** compares the longitudinal risk as of Dec 2013 using 2 methods

Type of Risk	Risk Estimation	TLS	Remarks
Longitudinal Risk	1.18×10^{-9}	5×10^{-9}	Below TLS
Longitudinal Risk Hsu model	0.34×10^{-9}	5×10^{-9}	Below TLS

Table 13: Longitudinal Risk Estimation

1.23 The Hsu model takes into account the ADS reporting time interval, time needed for controller's intervention and the risk of flight level changes by aircraft. These parameters would better model the horizontal risk value. Therefore this model will be used for future longitudinal risk assessment in the South China Sea airspace.

1.24 References

1. Anderson, D., "A collision risk model based on reliability theory that allows for unequal RNP navigational accuracy" ICAO SASP-WG/WHL/7-WP/20, Montreal, Canada, May 2005.

2. PARMO, "Safety Assessment to support use of the 50-NM Longitudinal, 30-NM Lateral and 30-NM Longitudinal Separation Standards in New York Oceanic Airspace." Attachment to MAWG/1 WP/2, Honolulu, USA, Dec 2013.