International Civil Aviation Organization

The 18th Meeting of the Regional Airspace Safety Monitoring Advisory Group (RASMAG/18)

Bangkok, Thailand, 1-4 April 2013

Agenda Item 3: Reports from Asia/Pacific RMAs

CHINA RMA SAFTY REPORT

(Presented by the China RMA)

SUMMARY

This paper presents the results of the airspace safety oversight for the RVSM operation in the airspace of Chinese Flight Information Regions and the airspace of Pyongyang Flight Information Region for the time period of 1 January 2012 to 31 December 2012. This report contains a summary of using Sequential Sampling Procedure to determine whether the expected rate of accidents due to large height deviation occurred in Pyongyang Flight Information Region is less than the target level of safety (TLS).

This paper relates to –

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

Global Plan Initiatives:
GPI-2 Reduced vertical separation minima

1. INTRODUCTION

1.1 China Regional Monitoring Agency (China RMA) produces a periodic report which is distributed twice annually to Civil Aviation Administration of China (CAAC) and ICAO.

2. DISCUSSION

2.1. This paper provides the results of the airspace safety oversight for the RVSM operation in the airspace of Chinese FIRs for the time period of 1 January 2012 to 31 December 2012, as given in Attachment A. The analysis conducted for the airspace of China FIRs is based on one-month traffic sample data (TSD) collected in December 2012 and the latest 12-month Large Height Deviation (LHD) reports. The estimates of technical and total risks for the airspace of Chinese FIRs satisfy the agreed TLS value of no more than 2.5×10^{-9} and 5.0×10^{-9} fatal accidents per flight hour.

2.2. Based on the data from DPR Korea, there was no Large Height Deviation occurred for the time period of 1 January 2012 to 31 December 2012 in Pyongyang FIR. Considering the long-term nil LHD reports, to make a conservative estimate for the operational risk, China RMA used the operational risk value of Chinese FIRs, and the technical risk was calculated from the TSD data collected in December 2012 from the Pyongyang FIR. China RMA is studying the method of sequential sampling, hopes to discuss with other RMAs to develop this method and use it in the future safety assessment for Pyongyang FIR using this method. The detail of this study is discussed in the Section 5 of Attachment B.

Executive Summary

2.3. **Table 1** summarizes Chinese FIRs RVSM technical, operational, and total risks. **Figure 1** presents collision risk estimate trends during the period from Jan 2012 to Dec 2012.

The RVSM Airspace of Chinese FIRs – estimated annual flying hours = 2 388 992.6 hours *(note: estimated hours based on Dec 2012 traffic sample data)*			
Source of Risk	**Risk Estimation**	**TLS**	**Remarks**
RASMAG 17 Total Risk	*3.58 x 10^{-9}*	*5.0 x 10^{-9}*	*Below TLS*
Technical Risk	0.16 x 10^{-9}	2.5 x 10^{-9}	Below Technical TLS
Operational Risk	3.22 x 10^{-9}	-	-
Total Risk	**3.38 x 10^{-9}**	5.0 x 10^{-9}	**Below TLS**

Table 1: Airspace of Chinese FIRs RVSM Risk Estimates

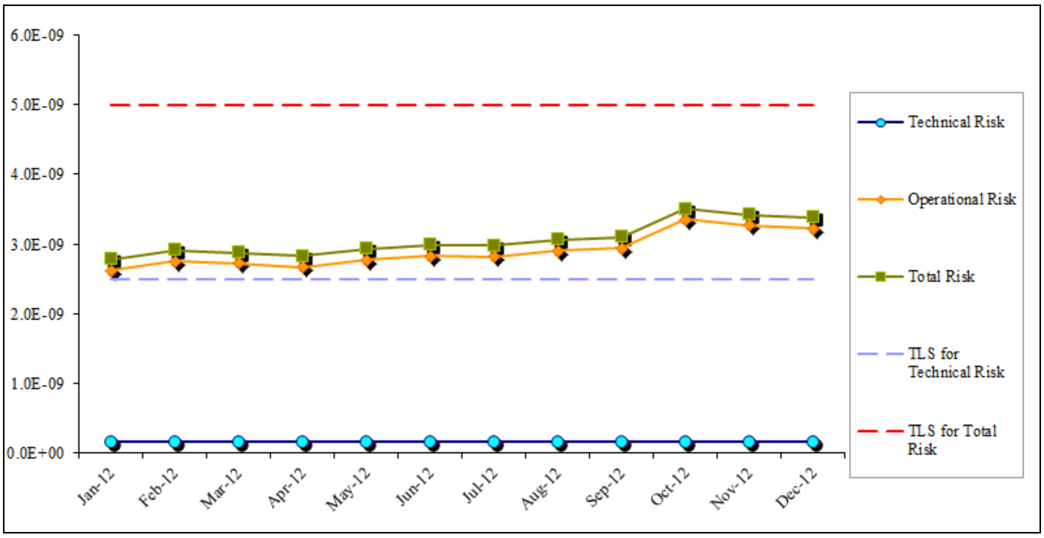

Figure 1: Airspace of Chinese FIRs RVSM Risk Estimate Trends

2.4. **Table 2** presents a summary of the LHD causes within Airspace of Chinese FIRs from Jan 2012 until Dec 2012.

Code	**LHD Category Description**	**No.**
A	Flight crew fails to climb or descend the aircraft as cleared	7
C	Incorrect operation or interpretation of airborne equipment	5
D	ATC system loop error	4
E	ATC transfer of control coordination errors due to human factors	22
G	Aircraft contingency leading to sudden inability to maintain level	4
H	Airborne equipment failure and unintentional or undetected level change	1
I	Turbulence or other weather related cause	11
L	An aircraft being provided with RVSM separation is not RVSM approved	1
Total		55

Table 2: Summary of LHD Causes within Airspace of Chinese FIRs

2.5. **Figure 2** provides the geographic location of risk bearing LHD reports within Airspace of Chinese FIRs during the assessment period.

Figure 2: Airspace of Chinese FIRs – Risk Bearing LHD

2.6. **Table 1** summarizes Pyongyang FIR RVSM technical, operational, and total risks. Figure 1 presents collision risk estimate trends during the period from Jan 2012 to Dec 2012.

Pyongyang FIR – estimated annual flying hours = 3 234.2 hours *(note: estimated hours based on Dec 2012 traffic sample data)*			
Source of Risk	**Risk Estimation**	**TLS**	**Remarks**
RASMAG 17 Total Risk	*3.39×10^{-9}*	*5.0×10^{-9}*	*Below TLS*
Technical Risk	2.06×10^{-9}	2.5×10^{-9}	Below Technical TLS
Operational Risk	3.22×10^{-9}	-	-
Total Risk	**3.43×10^{-9}**	5.0×10^{-9}	**Below TLS**

Table 1: Airspace of Pyongyang FIR RVSM Risk Estimates

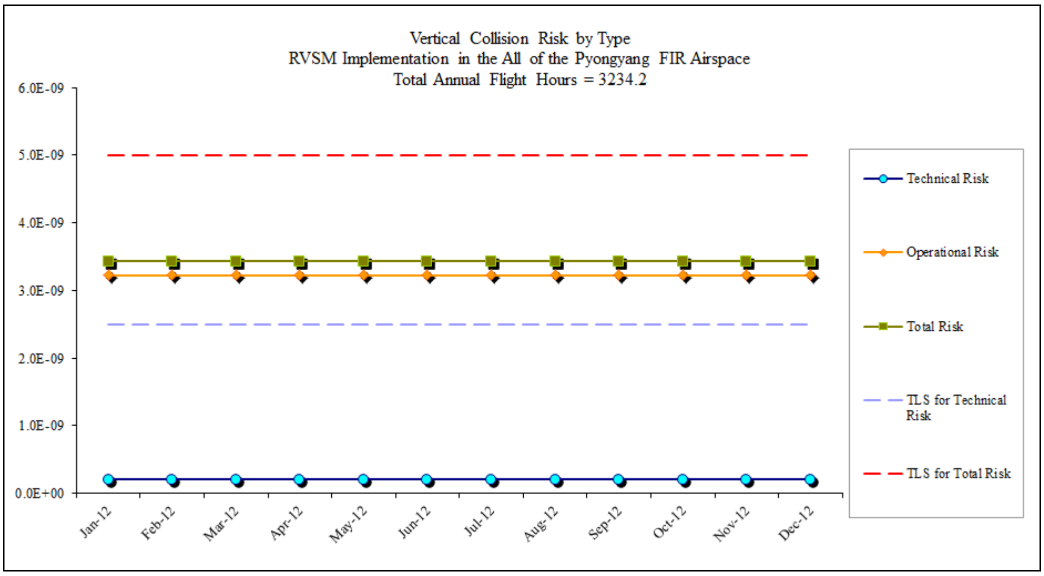

Figure 1: Airspace of Pyongyang FIR RVSM Risk Estimate Trends

3. ACTION BY THE MEETING

3.1 The meeting is invited to:

a) note the results of the airspace safety oversight presented in the attachment to this working paper; and

b) discuss the solutions to the problems encountered in sequential sampling test of vertical performance.

……………………………………

ATTACHMENT A

AIRSPACE SAFETY REVIEW FOR THE RVSM OPERATION IN THE AIRSPACE OF CHINESE FLIGHT INFORMATION REGIONS JANUARY 2012 - DECEMBER 2012

Presented by

中国地区监控组织
CHINA REGIONAL MONITORING AGENCY

March 2013

SUMMARY

This report presents the airspace safety oversight from China Regional Monitoring Agency for the time period 1 January 2012 - 31 December 2012. The purpose of this report is to compare actual performance to safety goals related to continued use of reduced vertical separation minimum (RVSM) in the airspace of Chinese FIRs. This report contains a summary of large height deviation reports received by China RMA for the most recent reporting period of 1 January 2012 - 31 December 2012. This report also contains an update of the vertical collision risk. The vertical collision risk estimate for Chinese RVSM airspace is below the target level of safety (TLS) value of 5.0×10^{-9} fatal accidents per flight hour, a value well within that range agreed internationally as “safe”.

1. Introduction

1.1 China Regional Monitoring Agency (China RMA) serves as the regional monitoring agency (RMA) for the airspace of Chinese FIRs.

1.2 This report covers the current reporting period 1 January 2012 - 31 December 2012 in the China RMA's ongoing process of providing periodic updates of information relevant to the continued safe use of the RVSM in in the airspace of Chinese FIRs. China RMA produces two reports each calendar year following the standardize reporting period and format guidelines set forth by the International Civil Aviation Organization's (ICAO's) Asia and Pacific Region Regional Airspace Safety Monitoring Advisory Group (RASMAG).

1.3 Within this report, the reader will find the summary of airspace safety oversight for the airspace of Chinese FIRs, including the Large Height Deviation (LHD) reports analysis and an update of the vertical collision risk estimate for Chinese RVSM airspace.

2. Data Submissions

2.1. China RMA requests an annual one-month traffic movement sample and monthly large height deviation reports from the ATS providers in Chinese RVSM airspace. The second and third column of **Table 1** lists the Flight Information Regions (FIRs) and relevant Area Control Centers in China.

2.2. Traffic Sample Data (TSD)

2.2.1. Traffic sample data for December 2012 for the airspace of Chinese FIRs were used in the assessment of risk for the RVSM airspace. **Table 1** contains a summary of the traffic sample data received by China RMA for each FIR. Traffic sample data were received from all of the FIR's.

FIR Name	FIR Code	Data Collected in ACCs	Collecting Method	Status	Remarks
Beijing	ZBPE	Beijing	Automatic system	Received	Data completed
		Taiyuan	-	-	Included in Beijing ACC
		Hohhot	-	-	Included in Beijing ACC
Shanghai	ZSHA	Shanghai	Automatic system	Received	Data completed
		Qingdao	Automatic system	Received	Data completed
		Jinan	Automatic system	Received	Data completed
		Xiamen	-	-	Included in Shanghai ACC
		Nanchang	-	-	Included in Shanghai ACC
		Hefei	-	-	Included in Shanghai ACC
Guangzhou	ZGZU	Guangzhou	Automatic system	Received	Data completed
		Guilin	Automatic system	Received	Data completed
		Zhanjiang	Automatic system	Received	Data completed
		Nanning	Automatic system	Received	Data completed
		Changsha	-	-	Included in Guangzhou ACC
Wuhan	ZHWH	Wuhan	-	-	Included in Guangzhou ACC
		Zhengzhou	Automatic system	Received	Data completed
Shenyang	ZYSH	Shenyang	Automatic system	Received	Data completed
		Dalian	Automatic system	Received	Data completed
		Harbin	Automatic system	Received	Data completed
		Hailar	Manual	Received	Data completed
Lanzhou	ZLHW	Lanzhou	Automatic system	Received	Data completed
		Xian	Automatic system	Received	Data completed
Urumqi	ZWUQ	Urumqi	Automatic system	Received	Data completed
Kunming	ZPKM	Kunming	-	-	Included in Chengdu ACC
		Chengdu	Automatic system	Received	Data completed
		Lhasa	Manual	Received	Data completed
		Guiyang	-	-	Included in Chengdu ACC
Sanya	ZJSA	Sanya	Automatic system	Received	Data completed

Table 1: Summary of Traffic Sample Data of December 2012 in the Airspace of Chinese FIRs

2.3. **Large Height Deviation (LHD)**

2.3.1. Series of cumulative 12-month of LHD reports were used in this safety assessment starting from January 2012 - December 2012. **Table 2** provides the summary of LHD reports submitted by each FIR.

FIR Name	Beijing	Shanghai	Guangzhou	Wuhan	Shenyang	Lanzhou	Urumqi	Kunming	Sanya
01-12	X	X	X	X	X	X	X	X	X
02-12	X	X	X	X	X	X	X	X	X
03-12	X	X	X	X	X	X	X	X	X
04-12	X	X	X	X	X	X	X	X	X
05-12	X	X	X	X	X	X	X	X	X
06-12	X	X	X	X	X	X	X	X	X
07-12	X	X	X	X	X	X	X	X	X
08-12	X	X	X	X	X	X	X	X	X
09-12	X	X	X	X	X	X	X	X	X
10-12	X	X	X	X	X	X	X	X	X
11-12	X	X	X	X	X	X	X	X	X
12-12	X	X	X	X	X	X	X	X	X

Table 2: Summary of LHD Reports collected from Chinese FIRs

X = Large Height Deviation Report was received for the specified month (including reports indicating "NIL" events)

3. Summary of LHD Occurrences

3.1. Based on the received LHD reports shown in **Table 2**, the LHD occurrences between January 2012 and December 2012 in the airspace of Chinese FIRs are summarized as follows:

3.2. **Table 3**, **Figure 1** and **Figure 2** summarize the number of LHD occurrences, associated LHD durations (in minutes) and the number of flight levels transitioned without clearance by month in the airspace of Chinese FIRs:

Month-Year	No.of LHD Occurrences	LHD Duration(Minutes)	No.of flight levels transitioned without clearance
Jan-12	3	22.25	2
Feb-12	8	0.75	4
Mar-12	4	0	4
Apr-12	2	0.5	0
May-12	7	1.25	2
Jun-12	8	0.75	6
Jul-12	4	0.25	3
Aug-12	6	0.25	5
Sep-12	4	0.5	3
Oct-12	2	5	6
Nov-12	5	6.916	3
Dec-12	2	0.3	1
Total	55	38.716	39

Table 3: Summary of LHD Occurrences in the Airspace of Chinese FIRs

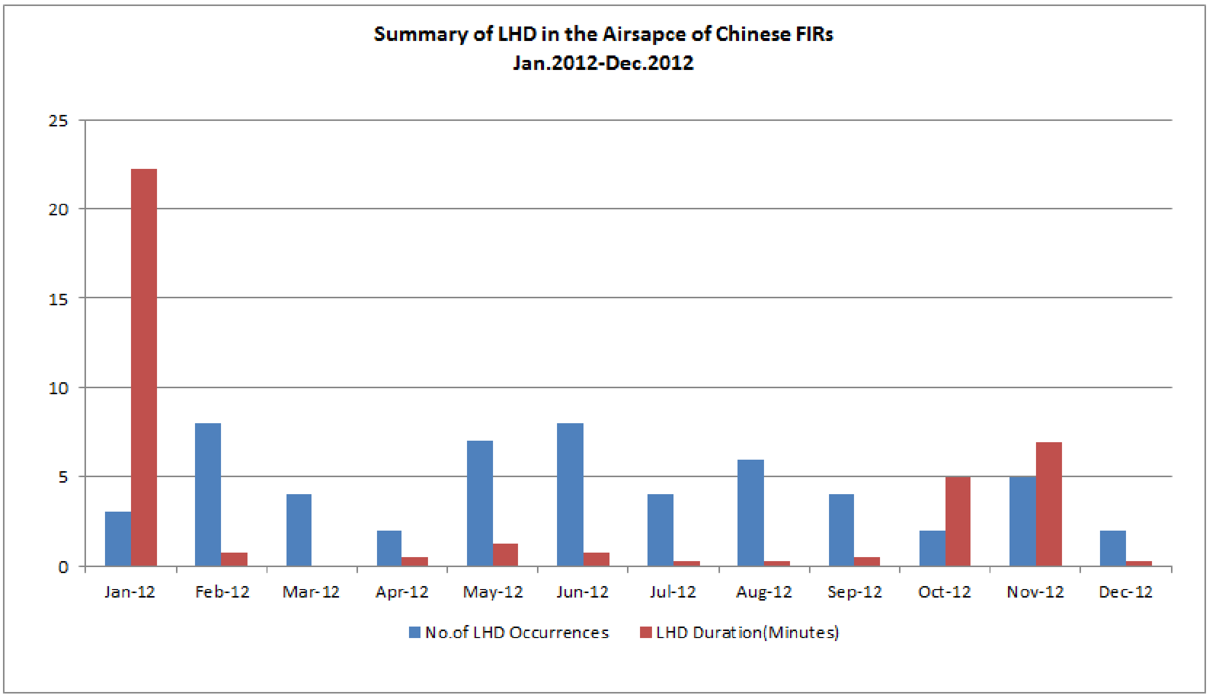

Figure 1: Summary of LHD in the Airspace of Chinese FIRs

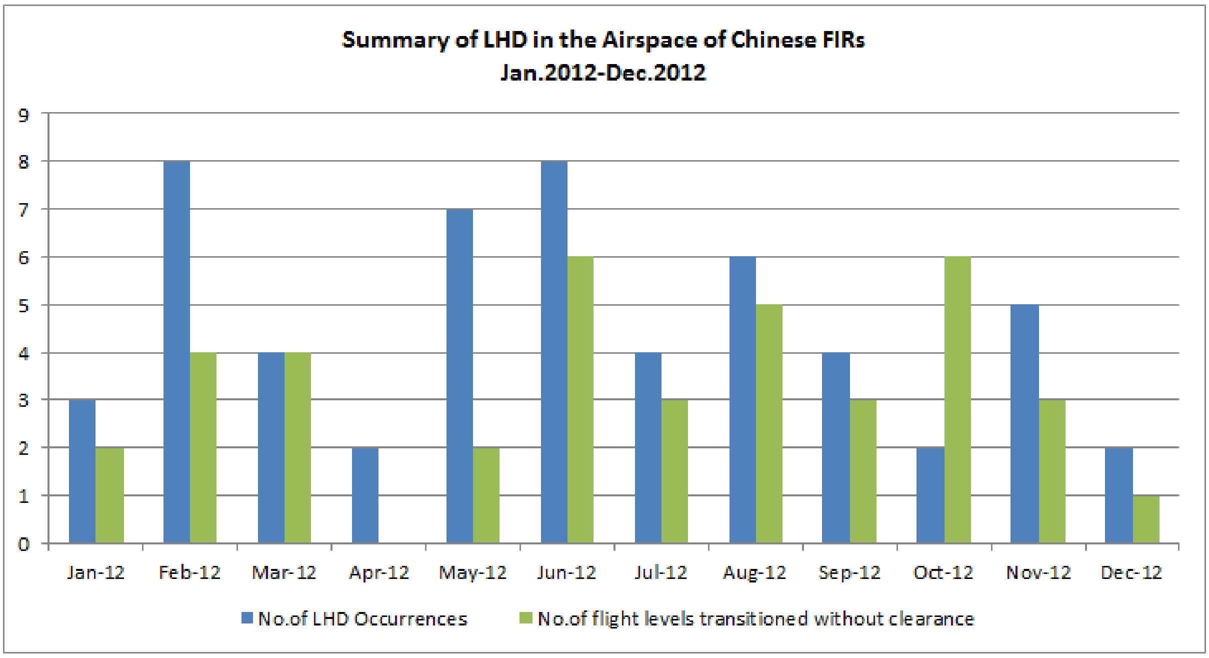

Figure 2: Summary of LHD (No. of flight levels transitioned without clearance) in the Airspace of Chinese FIRs

3.3. The large height deviation reports are separated by categories based on the details provided for each deviation. **Table 4**, **Figure 3** and **Figure 4** summarize the number of LHD occurrences by cause of the deviation.

LHD Category Code	LHD Category Description	No. of LHD Occurrences	LHD Duration (Min)	No. of flight levels transitioned without clearance
A	Flight crew failing to climb/descend the aircraft as cleared;	7	0.083	9
C	Incorrect operation or interpretation of airborne equipment (e.g. incorrect operation of fully functional FMS, incorrect transcription of ATC clearance or re-clearance, flight plan followed rather than ATC clearance, original clearance followed instead of re-clearances etc.);	5	0	5
D	ATC system loop error; (e.g. ATC issues incorrect clearance or flight crew misunderstands clearance message);	4	5	8
E	Coordination errors in the ATC-to-ATC transfer of control responsibility as a result of human factors issues (e.g. late or non-existent coordination, incorrect time estimate/actual, flight level, ATS route etc not in accordance with agreed parameters);	22	27	0
G	Aircraft contingency event leading to sudden inability to maintain assigned flight level (e.g. pressurization failure, engine failure);	4	0	4
H	Airborne equipment failure and unintentional or undetected level change	1	0.5	1
I	Turbulence or other weather related causes;	11	0.133	12
L	An aircraft being provided with RVSM separation is	1	6	0

LHD Category Code	LHD Category Description	No. of LHD Occurrences	LHD Duration (Min)	No. of flight levels transitioned without clearance
	not RVSM approved			
Total		55	38.716	39

Table 4: Summary of LHD Causes in the Airspace of Chinese FIRs

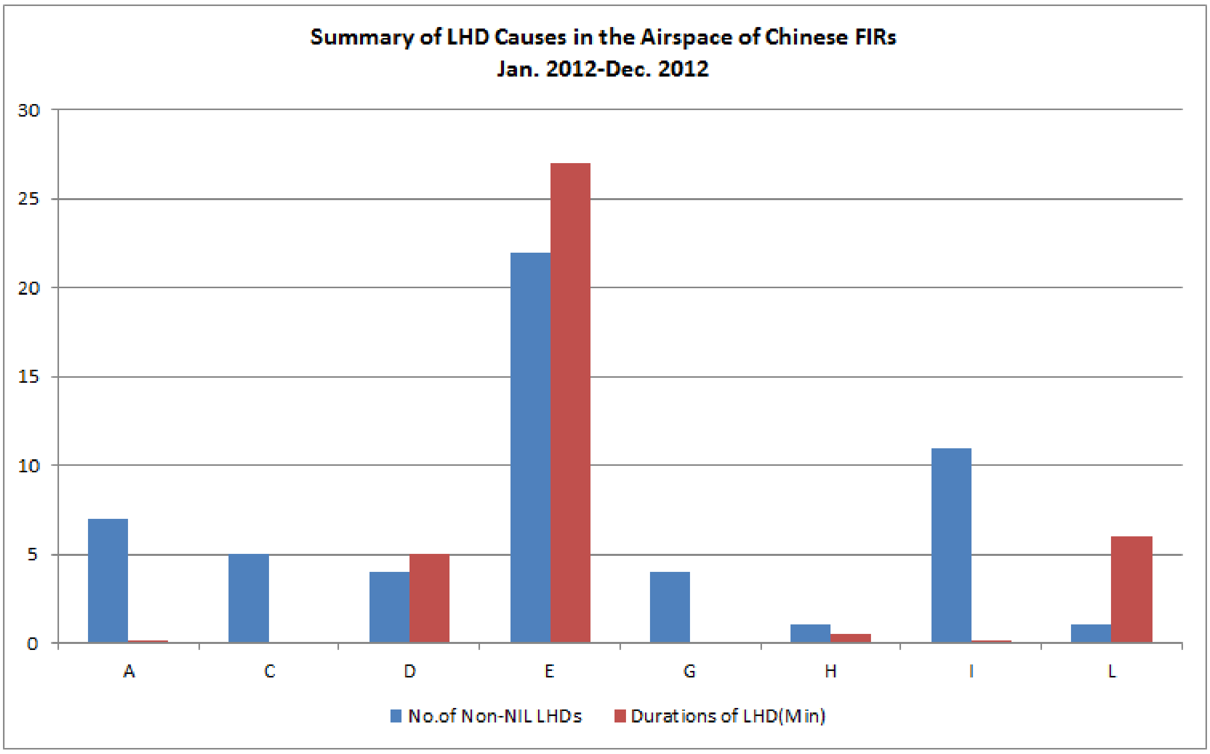

Figure 3: Summary of LHD Causes in the Airspace of Chinese FIRs

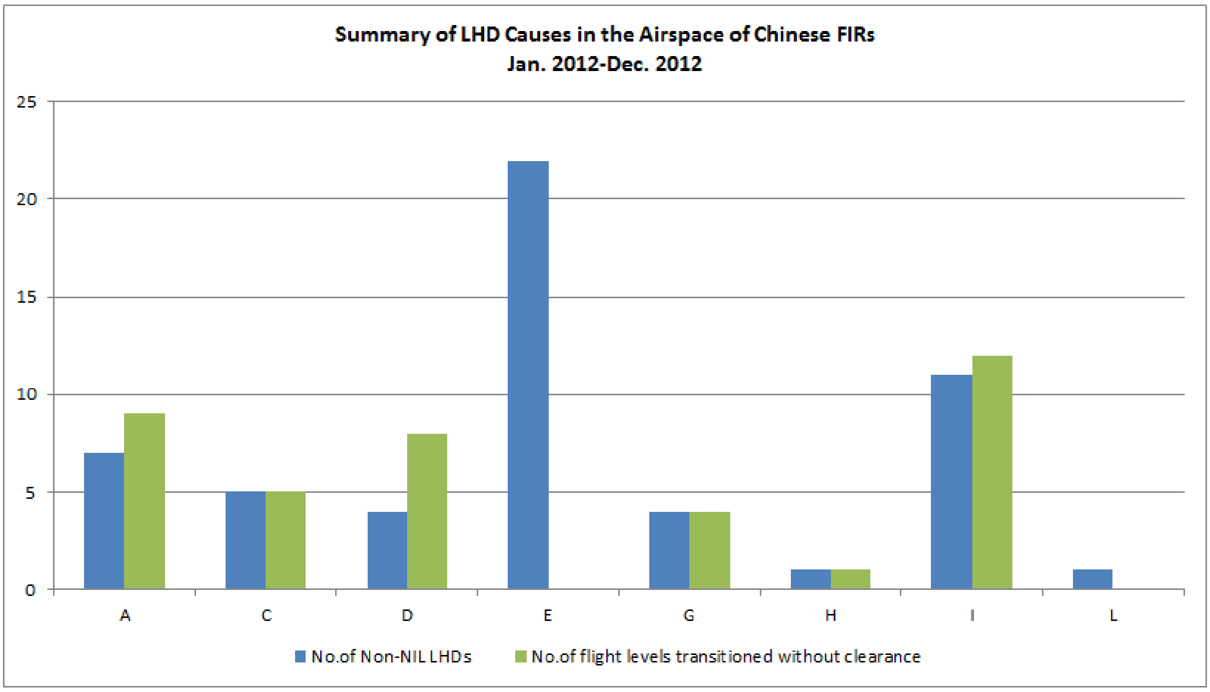

Figure 4: Summary of LHD Causes (No. of flight levels transitioned without clearance) in the Airspace of Chinese FIRs

LHD Analysis and Safety Treatment of Identified LHDs

In light of the above, the LHD occurrences in the China RVSM airspace are summarized as follows:

- Compared to the previous Meeting (August 2012 assessment period), the number of 12-month cumulative LHD occurrences increased from 40 to 55 occurrences and the 12-month cumulative duration increased from 20.7 to 38.7 minutes;
- There were fifty-five (55/38.7 min) reported large height deviations during the reporting period. All of these deviations were reported to the China RMA from domestic ATC departments or airlines. Seventeen events (17/6.63 min) contribute to technical risk and thirty-eight (38/32.08 min) events contributed to the operational risk.
- Significant portion of large height occurrences is contributable to Category E, which accounted for 20 occurrences; Locations of an long-time large height occurrence is in Urumqi FIR, due to transfer error.
- Significant portion of large height duration is contributable to Category E, which accounted for 22 minutes; a long-time Category E LHDs occurred in Sanya FIR;
- China RMA has reported all the events to ATMB and tried to coordinate the matter through ATMB with Urumqi ACC concerned. China RMA confirmed that due to the lack of communication ability between Urumqi ACC and the Lahore ACC, direct communications during events from both sides is difficult to establish. Urumqi ACC has made contact several times with Lahore ACC to discuss the possibility to establish direct communication through satellite. Both sides have not made an agreement on the investment, and the plan was suspended. China RMA has tried her best to help to resolve this, and China RMA suggests ICAO APAC office can also help to coordinate with Pakistan to resolve this.

4. Estimate of Vertical Collision Risk for Chinese RVSM Airspace

4.1. The vertical collision risk was estimated in order to determine whether the target level of safety (TLS) continued to be met in Chinese RVSM airspace, thus supporting the ongoing safe application of RVSM.

4.2. This section updates the results of safety oversight for the RVSM implementation in the airspace of Chinese FIRs, which was fully implemented on 22 November 2007. Accordingly, the internationally accepted collision risk methodology is applied in assessing the safety of implementing the RVSM in this airspace.

4.3. The TSD of December 2012, the continuous LHD reports in the airspace of Chinese FIRs between January 2012 and December 2012 are used to produce the risk estimates presented in this report.

4.4. Estimate of the CRM parameters

4.4.1. **Table 5** summarizes the value and source material for estimating values for each of the empirical parameters of the internationally accepted Collision Risk Model (CRM), which is used to conduct the risk assessment and the safety oversight for the RVSM implementation in the airspace of Chinese FIRs.

Parameter Symbol	Parameter Definition	Parameter Value	Source for Value
S_x	Longitudinal separation standard for a region, or Length of longitudinal window used to calculate occupancy	80Nm	Standard value used in overall airspace
S_h	Planned Horizontal Separation	80Nm	Standard value used in overall airspace
$P_z(0)$	Probability of vertical overlap (with planned vertical separation equal to zero)	0.4026	Estimated based on the radar data form from Upper Control Area of Beijing, Guangzhou, Shanghai, August 2008
$P_z(S_z)$	Prob. that 2 aircraft nominally separated by the vertical separation minimum S_z are in vertical overlap.	5.604 x 10^{-9}	
$P_y(0)$	Probability of Lateral Overlap	0.025	Estimated by FAA Technical Center based on the proportion of GPS operations observed in the TSD data collected in China
$P_h(\theta)$	Probability of Horizontal Overlap	6.88 x 10^{-7}	Value used in the Western Pacific/South China Sea safety assessment
$\left\lvert\overline{\dot{h}(\theta)}\right\rvert$	Average relative horizontal speed during overlap for aircraft pairs on routes with crossing angle θ (let θ=45°)	367.4 knots	Value used in Western Pacific/South China Sea safety assessment (corresponds to an average aircraft speed of 480 knots)
$\lvert\overline{\dot{y}}\rvert$	Average absolute relative cross track speed for an aircraft pair nominally on the same track	2.8 knots	Estimated by FAA Technical Center based on the proportion of GPS operations observed in the TSD data collected in China
$\lvert\overline{\dot{z}}\rvert$	Average absolute relative vertical speed of an aircraft pair that has lost all vertical separation	1.5 knots	Value used in NAT RVSM safety assessment
λ_x	Average aircraft length	0.02345Nm	Estimated based on the collected TSD
λ_y	Average aircraft wingspan	0.02073Nm	
λ_z	Average aircraft height	0.0070 Nm	
λ_h	Diameter of the disk representing the shape of an aircraft in the horizontal plane	0.02345Nm	

Table 5: Estimate of the empirical Parameters in the CRM

4.4.2. **Table 6** summarizes the value and source material for estimating values for each of the empirical parameters of the internationally accepted Collision Risk Model (CRM), which is used to conduct the risk assessment and the safety oversight for the RVSM implementation in the airspace of Chinese FIRs.

Parameter Symbol	Parameter	Parameter Definition
T	2 388 992.6	Annual flight hours
E_z(same)	0.0412	Same-direction vertical occupancies
E_z(opposite)	0.0193	Opposite-direction vertical occupancies
Crossing pairs	2 973 384	Annual estimate of crossing pairs in crossing route
$\overline{\lvert\Delta V\rvert}$	51.44	Average relative along-track speed between aircraft on same direction routes
$\overline{\lvert V\rvert}$	448.31	Average absolute aircraft ground speed

Table 6: Estimate of the Parameters based on the collected TSD

4.5. **Estimate of Vertical Collision Risk for Chinese RVSM Airspace**

4.5.1. This section summarizes the results of the safety assessment for the airspace of Chinese FIRs. **Figure 1** presents the Technical Risk computed by the TSD collected in December 2012.

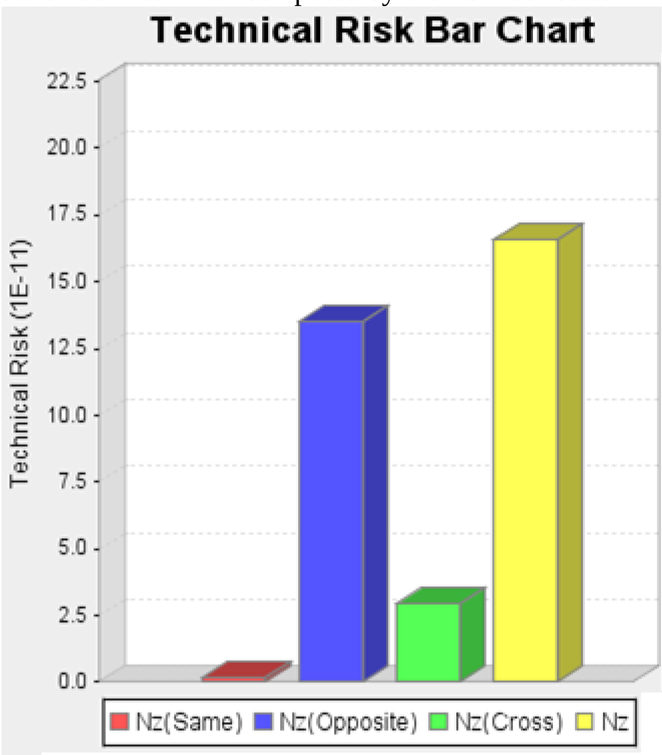

Figure 5: Technical Risk Bar Chart computed by the TSD collected in December, 2012

4.5.2. **Table 7** presents the estimates of vertical collision risk for the airspace of Chinese FIRs, in terms of the technical, operational, and total risks. The technical risk is estimated to be 0.155 x 10^{-9} fatal accidents per flight hour. The operational risk estimate is 3.22 x 10^{-9} fatal accidents per flight hour. The estimate of the overall vertical collision risk is 3.38 x 10^{-9} fatal accidents per flight hour, which satisfies the globally agreed TLS value of 5 x 10^{-9} fatal accidents per flight hour.

The RVSM Airspace of Chinese FIRs– estimated annual flying hours = 2 388 992.6 hours *(note: estimated hours based on the Dec 2012 traffic sample data)*			
Source of Risk	**Lower Bound Risk Estimation**	**TLS**	**Remarks**
Technical Risk	0.155 x 10^{-9}	2.5 x 10^{-9}	Below Technical TLS
Operational Risk	3.22 x 10^{-9}	-	-
Total Risk	**3.38 x 10^{-9}**	**5.0 x 10^{-9}**	**Below Overall TLS**

Table 7: Risk Estimates for the RVSM Implementation in the airspace of Chinese FIRs

4.5.3. **Figure 2** presents the trends of collision risk estimates for each month using the appropriate cumulative 12-month of LHD reports since January 2012

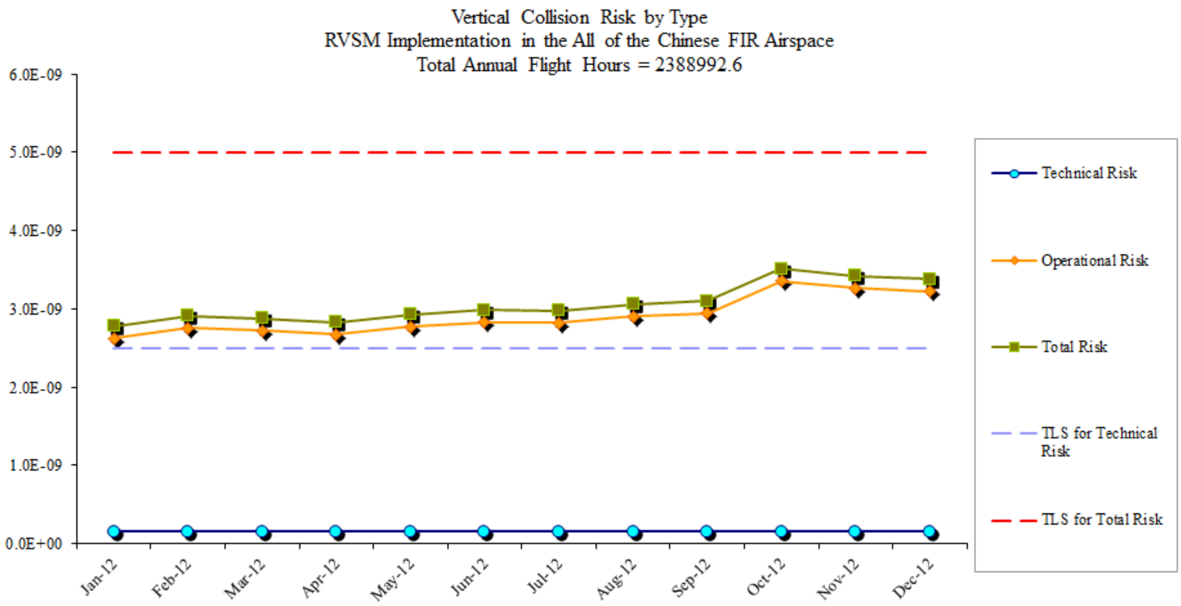

Figure 6: Trends of Risk Estimates for the RVSM Implementation in the Airspace of Chinese FIRs

4.5.4. Based on these collision risk estimates, both the estimates of technical and total risks from the available TSD and LHD reports satisfy the agreed TLS value of no more than 2.5 x 10^{-9} and 5.0 x 10^{-9} fatal accidents per flight hour.

Figure 7. Chinese FIRs – Risk Bearing (Non-NIL) RVSM Large Height Deviations January 2012 – December 2012

ATTACHMENT B

AIRSPACE SAFETY REVIEW FOR THE RVSM OPERATION IN THE AIRSPACE OF PYONGYANG FLIGHT INFORMATION REGION JANUARY 2012 - DECEMBER 2012

Presented by

中国地区监控组织
CHINA REGIONAL MONITORING AGENCY

August 2012

SUMMARY

This report presents the airspace safety oversight from China Regional Monitoring Agency for the airspace of Democratic People's Republic of Korea (DPR Korea) for the time 1 January 2012 - 31 December 2012. The purpose of this report is to compare actual performance to safety goals related to continued use of reduced vertical separation minimum (RVSM) in the airspace of Pyongyang Flight Information Region (FIR). This report also contains an update of the vertical collision risk. The vertical collision risk estimate for the airspace of Pyongyang FIR is below the target level of safety (TLS) value of 5.0 x 10^{-9} fatal accidents per flight hour, a value well within that range agreed internationally as “safe”.

1. Introduction

1.1 China Regional Monitoring Agency (China RMA) serves as the regional monitoring agency (RMA) for the airspace of Pyongyang FIR.

1.2 This report covers the current reporting period from 1 January 2012 - 31 December 2012 in the China RMA's ongoing process of providing periodic updates of information relevant to the continued safe use of the RVSM in the airspace of Pyongyang FIR. China RMA produces two reports each calendar year following the standardized reporting period and format guidelines set forth by the International Civil Aviation Organization's (ICAO's) Asia and Pacific Region Regional Airspace Safety Monitoring Advisory Group (RASMAG).

2. Data Submission

2.1. China RMA requests an annual one-month traffic movement sample and monthly large height deviation reports from the General Administration of Civil Aviation, DPR Korea.

2.2. Traffic Sample Data (TSD)

2.2.1. Traffic sample data for December 2012 for the RVSM airspace of DPR Korea were used in the assessment of risk. Table 8 contains a summary of the traffic sample data received by China RMA for RVSM safety oversight of Pyongyang FIR.

FIR Name	FIR Code	Data Collected in ACC	Collecting Method	Status	Remarks
Pyongyang	ZKKP	Pyongyang	Manual	Received	Data completed

Table 8: Summary of Traffic Data of December 2012 in the DPR Korea's RVSM Airspace

2.3. **Large Height Deviation (LHD)**

2.3.1. Monitoring of large height deviations has been continuous in Pyongyang FIR since 2009, with the criterion to identify a large height deviation set at 300 ft in magnitude. DPR Korea has had knowledge about the concept of large height deviation and continued to collect records of traffic movements and large height deviations from Pyongyang FIR. To date, all LHD reports for the airspace of Pyongyang FIR are NIL reports.

2.3.2. To make a conservative estimate for the operational risk, China RMA applied the same operational risk of Chinese FIRs.

3. Estimate of Vertical Collision Risk for DPRK's RVSM Airspace

3.1. The vertical collision risk was estimated in order to determine whether the target level of safety (TLS) continued to be met in the RVSM airspace of DPR Korea, thus supporting the ongoing safe application of RVSM.

3.2. This section updates the results of safety oversight for the RVSM implementation in DPRK's airspace, which was fully implemented in November 2009. Accordingly, the internationally accepted collision risk methodology is applied in assessing the safety of implementing the RVSM in the airspace of Pyongyang FIR.

3.3. The TSD of December 2012 and the LHD data are used to produce the risk estimates presented in this report.

3.4. Estimate of the CRM parameters

3.4.1. **Table 10** summarizes the value and source material for estimating values for each of the empirical parameters of the internationally accepted Collision Risk Model (CRM), which is used to conduct the risk assessment and the safety oversight for the RVSM implementation in DPR of Korea's airspace.

Parameter Symbol	Parameter Definition	Parameter Value	Source for Value
S_x	Longitudinal separation standard for a region, or Length of longitudinal window used to calculate occupancy	80Nm	Standard value used in overall airspace
S_h	Planned Horizontal Separation	80Nm	Standard value used in overall airspace
$P_z(0)$	Probability of vertical overlap (with planned vertical separation equal to zero)	0.5380	Conservative value used in NAT, Pacific, Western Pacific/South China Sea RVSM safety assessments
$P_z(S_z)$	Prob. that 2 aircraft nominally separated by the vertical	2.46 x 10^{-8}	

Parameter Symbol	Parameter Definition	Parameter Value	Source for Value
	separation minimum S_z are in vertical overlap.		
$P_y(0)$	Probability of Lateral Overlap	0.0835	Value used in NAT and average aircraft wingspan
$P_h(\theta)$	Probability of Horizontal Overlap	6.88 x10^{-7}	Value used in the Western Pacific/South China Sea safety assessment
$\left\lvert \overline{\dot{h}(\theta)} \right\rvert$	Average relative horizontal speed during overlap for aircraft pairs on routes with crossing angle θ (let θ=45°)	367.4 knots	Value used in Western Pacific/South China Sea safety assessment (corresponds to an average aircraft speed of 480 knots)
$\lvert\overline{\dot{y}}\rvert$	Average absolute relative cross track speed for an aircraft pair nominally on the same track	4 knots	Value specified in ICAO Doc. 9574
$\lvert\overline{\dot{z}}\rvert$	Average absolute relative vertical speed of an aircraft pair that has lost all vertical separation	1.5 knots	Value used in NAT RVSM safety assessment
λ_x	Average aircraft length	0.03162	Values used in the preliminary safety assessment report of DPR of Korea
λ_y	Average aircraft wingspan	0.02794	
λ_z	Average aircraft height	0.00861	
λ_h	Diameter of the disk representing the shape of an aircraft in the horizontal plane	0.03162	

Table 10: Estimate of the empirical Parameters in the CRM

Table 11 summarizes the values for estimating parameters in the CRM, which we estimated on the basis of TSD collected. They are demonstrated separately by air traffic control status.

Parameter Symbol	Parameter Value	Parameter Definition
T	3234.2	Annual flight hours
E_z(same)	0.0	Same-direction vertical occupancies
E_z(opposite)	0.0314	Opposite-direction vertical occupancies
Crossing pairs	84	Annual estimate of crossing pairs in crossing route
$\lvert\overline{\Delta V}\rvert$	NaN	Average relative along-track speed between aircraft on same direction routes
$\lvert\overline{V}\rvert$	502.39knots	Average absolute aircraft ground speed

Table 11: Estimate of the Parameters based on the collected TSD

4. Estimate of Vertical Collision Risk for DPR Korea's RVSM Airspace

4.1. **Table 12** presents the estimates of vertical collision risk for the airspace of Pyongyang in terms of the technical, operational, and total risks. The technical risk is estimated to be 0.206 x 10^{-10} fatal accidents per flight hour. The operational risk estimate is 3.22 x10^{-9} fatal accidents per flight hour. The estimate of the overall vertical collision risk is 3.43 x10^{-9} fatal accidents per flight hour, which satisfies the globally agreed TLS value of 5 x 10^{-9} fatal accidents per flight hour.

RVSM Airspace of DPR Korea – estimated annual flying hours = 3 234.2 hours *(note: estimated hours based on the December 2012 traffic sample data. Estimate represents the sum of total flying hours for Pyongyang FIR)*			
Source of Risk	**Lower Bound Risk Estimation**	**TLS**	**Remarks**
Technical Risk	2.06 x 10^{-10}	2.5 x 10^{-9}	Below Technical TLS
Operational Risk	3.22 x 10^{-9}	-	-
Total Risk	3.43 x 10^{-9}	**5.0 x 10^{-9}**	**Below Overall TLS**

Table 12: Risk Estimates for the RVSM Implementation in the Airspace of DPR Korea

4.2. **Figure 7** presents the trends of collision risk estimates for each month using the estimated LHD data since December 2012.

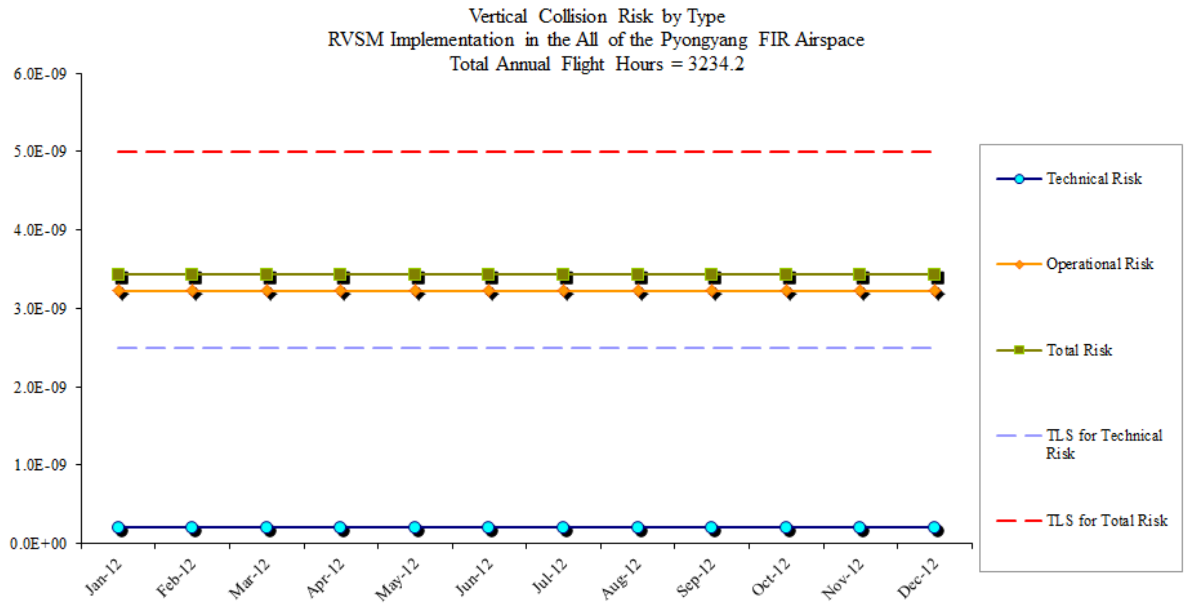

Figure 7: Trends of Risk Estimates for the RVSM Implementation in the Airspace of DPR Korea

4.3. Therefore, the estimates of both technical and total risks from the available TSD and LHD reports satisfy the agreed TLS value of no more than 2.5 x 10^{-9} and 5.0 x 10^{-9} fatal accidents per flight hour.

5. RVSM Safety Assessment for Pyongyang FIR by Sequential sampling

5.1. Considering the continuous nil LHD report and limited traffic sample from Pyongyang FIR, China RMA took the advice from other RMAs and is trying to utilize sequential sampling method to conduct the safety assessment.

5.2. Sequential sampling is a non-probability sampling technique wherein the researcher picks a single or a group of subjects in a given time interval, conducts his study, analyzes the results then picks another group of subjects if needed and so on. This method was used several times in the

Lateral Safety Assessment by EMAs. Based on the indicated TLS, it is easy to calculate an acceptable minimum Probability of Lateral Overlap Py(Sy). During the lateral assessment the Py(Sy) can be calculated by the historical number of Large Lateral Deviation (LLD) directly based on the empirical distribution of the aircraft lateral deviation, so based on the total flight number it is easy to indicate that if the airspace meets the TLS or not, or the continue test is need.

5.3. In the RVSM safety assessment, the China RMA plans to estimate the risk in a similar way using sequential sampling. Accordingly, a method should be developed to calculate the Probability of Vertial Overlap Pz(Sz) based on the number of Large Height Deviation (LHD) directly. However, in the RVSM safety assessment process, the Pz(Sz) is calculated by two times convolution from the distribution of Altimetry System Error (ASE) and Assigned Attitude Deviation (AAD). Indeed, the LHD situation is considered during the calculation, but the relationship is merged together with the fitting process of the vertical deviation.

5.4. China RMA hope to study this with other RMAs to develop this method for calculation of the Pz(Sz) based on the number of LHD events and estimate risk for Pyongyang FIR.