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WORKING PAPER

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Sixteenth Scrutiny Working Group Meeting (GTE/16)
Mexico City, Mexico, 5- 9 September 2016

Agenda Item 1: **Review of Previous CARSAMMA and Scrutiny Group Meeting Conclusions and Recommendations**

VERTICAL COLLISION RISK (CRM) IN 2015 FOR THE CAR/SAM REGIONS

(Presented by CARSAMMA)

EXECUTIVE SUMMARY	
This Working Paper presents a summary of the calculation of the vertical collision risk in CAR/SAM Flight Information Regions (FIRs) in 2015 using the CRM methodology	
Action:	Suggested actions in section 13
Strategic Objectives:	• Safety • Air Navigation Capacity and Efficiency
References:	• ICAO Doc 9574 — *Manual on a 300 m (1 000 ft) Vertical Separation Minimum Between FL 290 and FL 410 Inclusive* AN/934, Third Edition - 2012 • ICAO Doc 9937 — *Operating Procedures and Practices for Regional Monitoring Agencies in Relation to the Use of a 300 m (1 000 ft) Vertical Separation Minimum Between FL 290 and FL 410 Inclusive* AN/477, First Edition – 2012 • Aircraft movements in RVSM airspace in 2015 • Report of Large Height Deviations (LHD) in 2015

1. Introduction

1.1 The purpose of this paper is to show that safety criteria defined in the ICAO Doc 9574 continue to be met in the RVSM airspace of the CAR/SAM Regions.

1.2 This document reports on the analysis of the vertical collision risk in Reduced Vertical Separation Minimum (RVSM) airspace in 2015 in the Caribbean and South America FIRs. For this work, the vertical Collision Risk Model (CRM) calculation methodology was used, as recommended by ICAO in RVSM airspace.

2. Discussion

2.1 This report presents the results of safety assessment in 2015 in RVSM airspace of the CAR/SAM Regions. This step corresponds to the continuation of the RVSM implementation strategy.

2.2 In accordance with Doc 9574 and Doc 9937, the assessment must be made to ensure that operations in RVSM airspace not induce an increase in the risk of collision such that the total vertical risk does not exceed Target level of safety (TLS) defined.

2.3 For the quantitative assessment, the REICH vertical collision risk model is used, as recommended by ICAO. This is a model of intensive mathematical foundations that, after analysing aircraft movements (spreadsheets containing data on flights conducted in RVSM airspace), calculates the Target Level of Safety (TLS) of the flight region under study. Several calculation tools and databases are used for the various calculations during the process, as well as several hours of analysis by experts.

2.4 This paper contains a summary of the assessment results of continuing safety of the 300m (1000 ft) reduced vertical separation minimum in Caribbean and South American airspace in 2015.

2.5 The RVSM safety assessment covers a period of twelve consecutive months.

2.6 Special attention should be paid to ensure that:

- All aircraft operating in reduced vertical separation minimum airspace are RVSM-certified
- The aircraft certification is current
- The TLS of 5 x 10^{-9} mortal accidents per flight hour (for tracking height-keeping in a representative sample of aircraft) continues to be met
- The use of RVSM does not increase the level of risk due to operational errors and contingency procedures
- There is evidence of aircraft Altimetry System Error (ASE) stability
- The introduction of RVSM does not increase the level of risk due to operational errors and flight contingencies, in accordance with a predefined level of statistical confidence
- Additional effective safety measures are adopted to reduce the collision risk and to meet the safety targets due to operational errors and contingency procedures
- Air traffic control procedures continue to be effective

3. CAR/SAM airspace

3.1 The airspace of the CAR/SAM Regions is composed by 34 Flight Information Regions (FIRs) consisting of the following States: Antigua and Barbuda, Argentina, Barbados, Belize, Bolivia, Brazil, Chile, Colombia, Costa Rica, Cuba, El Salvador, Ecuador, Granada, Guadeloupe, Guatemala, Guyana, French Guyana, Haiti, Honduras, Jamaica, Martinique, Netherlands Antilles, Nevis, Nicaragua, Panama, Paraguay, Peru, Dominican Republic, Saint Barthelemy, Saint Kitts and Nevis , Saint Lucia, Saint Vincent and Grenadines, Suriname, Trinidad and Tobago, Uruguay and Venezuela.

3.2 Each part of the airspace was treated as an isolated system, with its own statistical parameters.

3.3 Collect of Data Traffic Movement - The sample used to evaluate the frequency of passage and physical and dynamic parameters of typical aircraft for assessing the risk of collision, it was collected in the period between 1 and 31 December 2015, of the 31 FIRs of the CAR/SAM Regions. In these shipments data, in terms of flight hours of the collected samples they were received 12532,541 flight hours of all FIR mentioned, with 3021,665 hours of the CAR Region (~ 24%) and 9510,876 hours of the SAM Region (~ 76%). As in previous years, much of the data received from some States could not be exploited in CRM for various reasons, including errors in the times of entry and exit (less than or equal time input output), lack of complete information to identify and locate fixed routes and notification, or even send data beyond the deadline; however, all data sent were exploited in another product of CARSAMMA, which is the audit of RVSM airspace.

3.4 As to the occurrence of vertical Large height deviations (LHDs) reported in the CAR/SAM Regions, CARSAMMA received a total of 1,406 LHDs in 2015. Following the analysis and validation carried out through teleconferences with representatives of the ICAO Lima and Mexico Regional Offices, the FIRs involved, IATA and CARSAMMA, 1,225 of these LHD were considered valid for calculating the vertical Collision Risk Model (CRM).

4. Aircraft movement data collection

4.1 The sample data for estimating the pass frequency and the physical parameters, as well as the dynamics of a typical aircraft for the assessment of the vertical collision risk were collected from 1 to 31 December 2015.

4.2 Aircraft movement data received from the 31 CAR/SAM FIRs was processed and used to assess RVSM airspace safety, as recommended by ICAO. The number of flight hours used is shown in Table 1.

Region	Flight Hours	%
CAR	3021,665	24.00 %
SAM	9510,876	76.00 %
CAR/SAM	12532,541	100.00 %

Table 1

5. Aircraft fleet

5.1 Upon receiving the aircraft movement data, CARSAMMA proceeded to filter and process the data. Table 2 below shows the results, and lists the aircraft that flew across the CAR/SAM FIRs, with their dimensions and percentage of flight hours, including a typical aeroplane, used as a dimension of the Vertical CRM.

ACFT type	Length λx	Wingspan λy	Height λz	Number of flights	% of flights
B738	0.021328	0.018521	0.00675	43,162	22.2%
A320	0.020286	0.018413	0.0064	39,783	20.5%
E190	0.019568	0.015507	0.00571	21,097	10.8%
B737	0.018898	0.011852	0.00675	16,234	8.3%
A319	0.018272	0.018413	0.0064	15,508	8.0%
B763	0.029644	0.025702	0.007559	12,131	6.2%
A332	0.031749	0.032559	0.0094	7,360	3.8%
A321	0.024033	0.018413	0.0064	6,399	3.3%
B772	0.034395	0.032883	0.00999	5,484	2.8%
B77W	0.034395	0.034989	0.01004	4,504	2.3%
B752	0.025551	0.020788	0.00732	4,401	2.3%
B788	0.030778	0.032397	0.00918	3,501	1.8%
A343	0.034341	0.032559	0.0091	2,041	1.0%
B739	0.021328	0.018521	0.006749	1,644	0.8%
A346	0.040659	0.03426	0.00934	1,633	0.8%
B767	0.033153	0.028024	0.009071	1,410	0.7%
B744	0.038175	0.034773	0.01048	1,404	0.7%
B733	0.017279	0.016199	0.00648	1,356	0.7%
B789	0.034017	0.034017	0.009179	1,278	0.7%
MD83	0.024352	0.01771	0.048866	1,077	0.6%
B734	0.019708	0.015605	0.005994	1,056	0.5%
B764	0.033153	0.028024	0.007559	1,019	0.5%
B77L	0.034395	0.034989	0.010043	1,000	0.5%
Typical Acft	**0.0278024**	**0.025005**	**0.009772**		
Total				**194,482**	**100,00%**

Table 2 – Aircraft that flew RVSM in the CAR/SAM FIR
(Dimension measurements are expressed in nautical miles)

6. Data processing

6.1 Some products can already be obtained from the first data processing step of the risk calculation programme, such as the ratio between the number of LHDs and the characteristic of the aircraft population that used the airways in RVSM levels. Some of these products are listed in this chapter.

6.2 Segments most frequently flown in CAR/SAM FIRs:

Table 3 below shows the number of LHD occurred in a more flown airway segment.

FIR	Movements	Fix A	Airway	Fix B	Movements in the AWY segment	LHD in segment	Total LHD 2015
SACU	6058	PORKA	UL550	OPTIR	32	2	39
SAEU	11862	ROMUR	UA558	ISOPO	36	0	5
SAMV	3574	TOSOR	UA306	RYD	39	9	18
SARU	3858	TODES	UL793	KILIP	26	10	72
SAVU	2063	IREMO	UA570	VIE	22	4	61
SLLF	3117	SALBI	UA304	TERAX	50	1	35
SBAO	2699	ORARO	UN873	TASIL	27	0	61
SBAZ	3672	POPTI	UM417	OPVEX	14	0	89
SBBR	34097	USAMO	UZ14	MULAP	54	0	11
SBCW	17694	EDNAN	UM409	BBC	39	1	70
SBRE	8164	VUTNO	UZ14	LIBRA	24	5	33
SCCZ	600	EGOSA	UG550	NAS	16	0	0
SCEZ	7709	NUXUP	UL302	DALUS	21	1	1
SCFZ	127	LOA	UL550	XONOG	13	0	29
SCIZ	190	SAURI	UL348	SAKOB	8	0	0
SCTZ	1542	TOSET	UQ805	IRUNI	14	0	0
SKEC	18	OTAMO	UA301	SIPOK	3	0	28
SKED	5954	BUXOS	UL780	UGUPI	40	22	91
SEFG	7096	ENSOL	UM674	NEGAL	26	10	144
SYGC	2466	KORTO	UG449	LEPOD	25	1	3
SOOO	-	-	-	-	-	3	3
MPZL	18053	TORIL	UL780	ASIBO	35	4	26
SGFA	1925	REPAM	UA556	SAMGU	25	0	12
SPIM	15391	ISREM	UL780	TRU	27	12	92
SMPM	1784	KOXAM	UA312	ACARI	25	3	5
SUEO	-	-	-	-	-	12	12
SVZM	3675	ENPUT	UA567	STB	28	4	20
TNCF	7122	VESKA	UA315	PENKO	63	23	69
MHTG	13480	TALAG	UZ512	ILESU	27	4	52
MUFH	20562	UVA	UG448	TADPO	69	1	8
MTEG	3586	JOSES	UA315	MEDON	68	27	49
MKJK	-	-	-	-	-	23	23

MDCS	**8301**	**KATIN**	**UA315**	**VESKA**	**59**	**9**	**24**
TTZP	**4484**	**ANADA**	**UG449**	**PELMA**	**40**	**0**	**5**

Table 3 – LHD occurred in an airway segment.

6.3 The following **Graph 1** shows the LHD occurred in the most frequently flown airway segments in the CAR/SAM Regions. The airway most frequently flown segments with the highest rate of LHD are:

JOSES/MEDOM – UA315 – PORT-AU-PRINCE FIR (MTEG);

VESKA/PENKO – UA315 – CURAZAO FIR (TNCF);

*****/***** – ***** – KINGSTON FIR (MKJK);

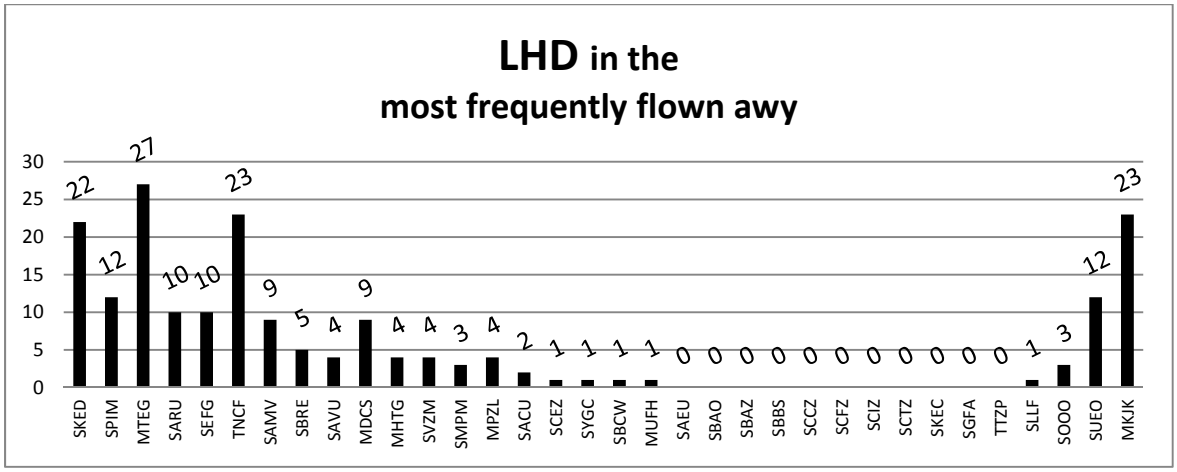
BUXOS/UGUPI – UL780 – BOGOTA FIR (SKED);

ISREM/TRU – UL780 – LIMA FIR (SPIM);

*****/***** – ***** – MONTEVIDEO FIR (SUEO);

TODES/KILIP – UL793 –RESISTENCIA FIR (MTEG) HAITI; and

ENSOL/NEGAL – UM674 – GUAYAQUIL FIR (SEFG);



Graph 1 – LHD in the most frequently flown airway.

6.4 The graph shows that there is a higher incidence of LHD in these segments, although the FIR in which the events occurred is not necessarily responsible.

6.5 The following three LHD illustrate the situations that occur in RVSM airspace, which probably have led to an extremely unsafe level of the collision risk index.

LHD 139 – FIR exposed to the risk: CENTRAL AMERICA –Day: 30 January 2015

Report #:	139	POSITION: LIXAS		*AMERICAN*		LIXAS		MODE C: NO		HT LHD: 0	
DATE: 30/01/2015		HOUR: 12:21		FLIGHT ID: AAL988		REGISTRATION: N388AA		CLRD FL: 0		DURATION: 1.860	
ROUTE: UZ512 - SPJC / KDFW						ACFT TYPE: B763		EVENT FL: 380		CODE: F	
REPORTING UNIT: CENTRAL AMERICA		FIR ERROR : GUAYAQUIL				IMC / VMC: I		XFL SAME: 0		XFL OPS 0	
OTHER ACFT (2ª):				#N/D		DISTANCE:		POSITION 2ª ACFT:		FL 2ª ACFT:	
CAUSE: AUSENCIA DE COORDINACION ATC						STATUS RVSM: APPROVED		GTE TIME:	1.860	GTE CODE:	F
ACC GUAYAQUIL NO PASÓ ESTIMADO SOBRE LIXAS. LA AERONAVE LLAMÓ A LAS 12:21 UTC NOTIFICANDO HABER PASADO LIXAS A LAS 11:50 UTC. *** CARSAMMA: EN 18/05 GUAYAQUIL INFORMA QUE DESDE 29/01 HASTA EL 05/03 HUBO FALLA EN LOS EQUIPOS PARA PASAR TRANSFERENCIA. ***											
PROBABILIDAD:	4	DURACIÓN:	3	GRAVEDAD:	4	RADAR / ADS:	10	WEATHER:	5	OTRO TRAFICO:	0
VALOR DEL RIESGO:	63			ACCIÓN MITIGADORA:		REQUIERE MONITOREO Y GESTIÓN					

LHD 470 – FIR exposed to the risk: ATLANTICO –Day: 19 April 2015

Report #:	470	POSITION: 0624S 01441W		*TOWLINE*		SBAODIII2		MODE C: NO		HT LHD: 0	
DATE: 19/04/2015		HOUR: 07:26		FLIGHT ID: TOW2230		REGISTRATION: GVYGJ		CLRD FL:		DURATION: 900	
ROUTE: 0624S01441W - ASI - FHAW						ACFT TYPE: A332		EVENT FL: 300		CODE: E2	
REPORTING UNIT: ATLANTICO		FIR ERROR : ABIDJAN				IMC / VMC:		XFL SAME: 0		XFL OPS 0	
OTHER ACFT (2ª):				#N/D		DISTANCE:		POSITION 2ª ACFT: 0		FL 2ª ACFT: 0	
CAUSE: ATC LOOP ERROR						STATUS RVSM: APPROVED		GTE TIME:	900	GTE CODE:	E2
DAKAR AND ABDJAN DID NOT COORDINATE THE TRAFFIC. THE ATLANTIC ATCO WAS ONLY AWARE OF TRAFFIC WHEN ASCENCION CALLED TO INFORM THE LANDING OF THE AIRCRAFT.											
PROBABILIDAD:	3	DURACIÓN:	3	GRAVEDAD:	3	RADAR / ADS:	10	WEATHER:	5	OTRO TRAFICO:	0
VALOR DEL RIESGO:	51			ACCIÓN MITIGADORA:		REQUIERE MONITOREO Y GESTIÓN					

LHD 1155 – FIR exposed to the risk: LIMA –Day: 20 October 2015

Report #:	1155	POSITION: ELAKO		*PERUVIAN*		ELAKO		MODE C: NO		HT LHD: 0	
DATE: 20/10/2015		HOUR: 14:40		FLIGHT ID: PVN330		REGISTRATION: OB2037		CLRD FL:		DURATION: 480	
ROUTE: UA304 - SLLP (LA PAZ) / SPZO (CUSCO)						ACFT TYPE: B733		EVENT FL: 360		CODE: E2	
REPORTING UNIT: LIMA		FIR ERROR : LA PAZ				IMC / VMC: I		XFL SAME: 0		XFL OPS 0	
OTHER ACFT (2ª):				#N/D		DISTANCE: 0		POSITION 2ª ACFT: 0		FL 2ª ACFT: 0	
CAUSE: ATC LOOP ERROR						STATUS RVSM: APPROVED		GTE TIME:	480	GTE CODE:	E2
SLLP OMITE TRANSFERENCIA, SIENDO LAS 14:47 SE OBSERVA EN COBERTURA RADAR AL PVN330 FL360 10 MILLAS DE JUL VOR. SPIM NO TENIA LA TRANSFERENCIA.											
PROBABILIDAD:	3	DURACIÓN:	3	GRAVEDAD:	3	RADAR / ADS:	10	WEATHER:	5	OTRO TRAFICO:	0
VALOR DEL RIESGO:	51			ACCIÓN MITIGADORA:		REQUIERE MONITOREO Y GESTIÓN					

7. Collision risk safety assessment

7.1 This section analyses the results of the safety assessment of RVSM airspace in the CAR/SAM FIR.

7.2 The internationally accepted Collision Risk Methodology (CRM) has been used for the safety assessment of RVSM airspace in the Caribbean and South American.

7.3 At this stage of the data analysis, massive use is made of IT to know the end results of the collision risk model. We briefly describe how the data derived from the aircraft movement sample is used and combined, together with the validated LHD data.

7.4 The filtered aircraft movement data was combined with the LHD data issued in 2015 for the FIR under study. This data was compiled and analysed during the monthly teleconferences held with

the experts of the FIR involved, the officers of the ICAO Lima and Mexico Regional Offices and CARSAMMA. IATA also participates in these teleconferences as guest consultant.

7.5 During the teleconferences, the LHD is validated and parameter values are merged and inserted in the General Formula of the REICH Collision Risk Model shown in the next chapter.

8. Estimates of CRM parameter

$$N_{ax} = 2P_y(0)P_z(0)\left(\frac{\overline{|\dot{x}(m)|}}{2\lambda_x} + \frac{\overline{|\dot{y}_0|}}{2\lambda_y} + \frac{\overline{|\dot{z}_0|}}{2\lambda_z}\right)\frac{2\lambda_x}{\overline{|\dot{x}(m)|}}\frac{1}{T}\sum_s E(s)Q(s)$$

Figure 1 – General Formula of the REICH Collision Risk Model

8.1 The material and quantity of the source used for estimating the values of each parameter of the internationally accepted CRM used for assessing the safety of the RVSM airspace are summarised in Table 4.

Parameter	Description	Value
λx	Mean length of the aircraft sample	0.0278024 nm
λy	Mean extent of the aircraft sample	0.025005 nm
λz	Mean height of the aircraft sample	0.009772 nm
$\overline{\lvert V \rvert}$	Mean speed of the aircraft sample (module)	430.7261 kt/h
$\overline{\lvert \Delta V \rvert}$	Relative same-direction speed of the aircraft sample (module)	40.16171 kt/h
$\overline{\lvert \dot{y} \rvert}$	Mean speed relative to the transverse approach of the aircraft sample (module)	13 kts
$\overline{\lvert \dot{z} \rvert}$	Mean relative vertical speed during loss of vertical separation of the aircraft sample (module)	1.5 kts
Pz(0)	Probability that two aircraft with the same nominal level overlap laterally in the aircraft sample	0.397646

Table 4 – CRM parameter estimates

9. Demonstration of the technical feasibility of RVSM in the CAR/SAM Regions

9.1 This involves assessing the results of the values of the parameters of the REICH Collision Risk Model:

- Pass frequency **Nx**
- Probability of vertical overlap **Pz (1000)**
- Probability of lateral overlap **Py (0)**

To demonstrate this, the following objectives were established:

- o Generate confidence in the compliance with the technical TLS; and
- o Certify ASE stability

10. System performance specifications

10.1 **Pass frequency, Nx** – This is the parameter of the airspace where the aircraft is exposed to the vertical collision risk. The equivalent pass frequency was estimated taking into account aircraft flying in the same direction and in opposite directions, as shown in Table 5.

Pass frequency	Same direction	Opposite direction	Equivalent	Flight time (h)
CAR/SAM	0,00772065	0.01416411	0.02485241	12532,541

Table 5 – Pass frequency

10.2 Values are related to the CAR/SAM airspace system. It should be noted that the pass frequency shown in Table 5 **(0.02485241)** was calculated on the basis of total filtered flight hours in the 31 CAR/SAM FIR.

- o The estimated value of ***Pz (1000)*** used in our calculations was **2.46×10^{-8}**

11. Estimating the collision risk

11.1 Table 6 contains the sets of physical and dynamic parameters estimated in the REICH Collision Risk Model, as well as the follow-up to the main parameters for the CAR/SAM FIRs. All parameters were determined based on the airspace of each region being considered as an isolated system.

	Ez (same)	**ΔV (same)**	**Ez (0p)**	**ΔV (op)**	**Ez (cross)**	**V**
CAR/SAM	**0.03639376**	**40.16171**	**0.00354103**	**915,7849**	**0,051583**	**430.7261**

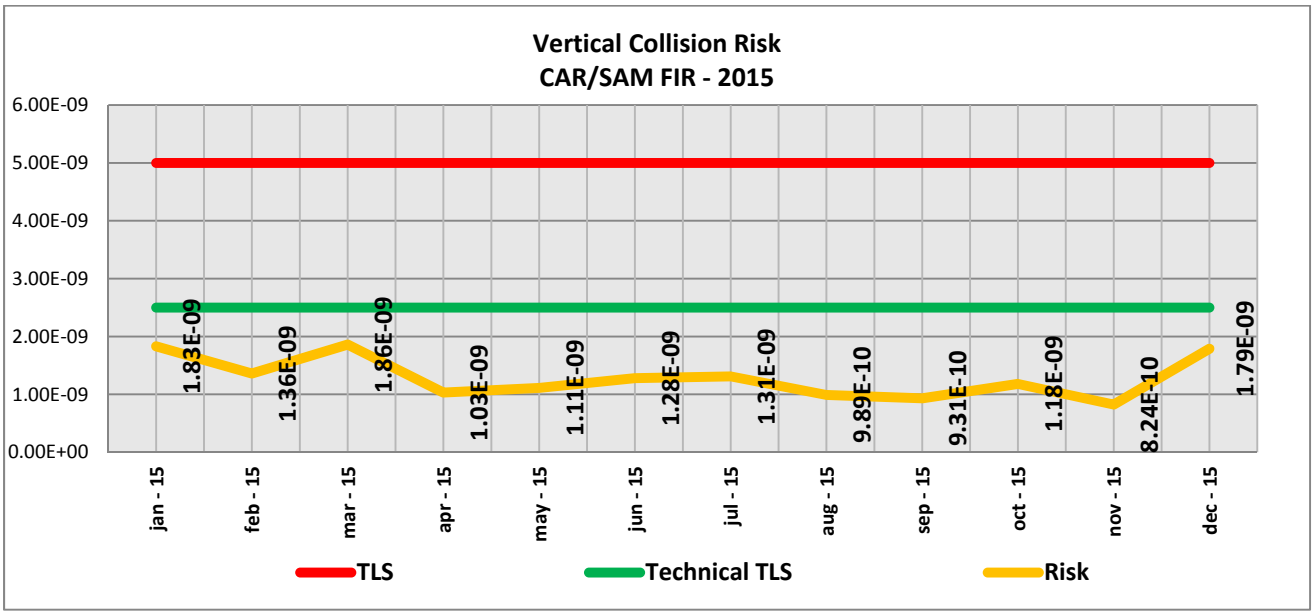
Table 6 – Physical and dynamic parameters

12 Conclusions of the safety assessment (CRM)

12.1 Collision Risk – The estimated values of the Operational Error are presented in Table 7, which result from processing all LHD received and validated in 2015, plus the files containing aircraft movements in RVSM airspace, as processed in the specific CRM software.

Month	Technical Error	Operational Error	Risk
January	2.46×10^{-11}	1.808×10^{-9}	1.83×10^{-9}
February	2.46×10^{-11}	1.333×10^{-9}	1.36×10^{-9}
March	2.46×10^{-11}	1.836×10^{-9}	1.86×10^{-9}
April	2.46×10^{-11}	1.000×10^{-9}	1.03×10^{-9}
May	2.46×10^{-11}	1.090×10^{-9}	1.11×10^{-9}
June	2.46×10^{-11}	1.256×10^{-9}	1.28×10^{-9}
July	2.46×10^{-11}	1.289×10^{-9}	1.31×10^{-9}
August	2.46×10^{-11}	9.642×10^{-10}	9.89×10^{-10}
September	2.46×10^{-11}	9.066×10^{-10}	9.31×10^{-10}
October	2.46×10^{-11}	1.156×10^{-9}	1.18×10^{-9}
November	2.46×10^{-11}	7.990×10^{-10}	8.24×10^{-10}
December	2.46×10^{-11}	1.765×10^{-9}	1.79×10^{-9}

Table 7 – Safety Assessment



Graph 2 – Vertical Collision Risk

12.2 The technical error of the CAR/SAM FIR **satisfies** the goal that states that it should not exceed **2.5×10^{-9}** fatal accidents per flight hour due to loss of standard vertical separation of 1 000 ft and all other causes.

- The operational risk does not have a predetermined limit in accordance with ICAO Doc 9574
- In the case of the FIR under study, the estimated medium risk is **1.29×10^{-9}** below the TLS, which is **5.0×10^{-9}.**

CAR/SAM RVSM airspace Estimated flight hours = 12532,541 hours			
Source of Risk	**Estimated Risk**	**TLS**	**Remarks**
Technical Error	**2.46×10^{-11}**	**2.5 x 10-9**	**Below**
Operational Error	**1.27×10^{-9}**	**-**	-
Risk	**1.29×10^{-9}**	**5.0 x 10-9**	**Below**

Table 8

13. Suggested actions:

13.1 The meeting is invited to:

a) note and review the contents of this Working paper; and

b) share experiences and express opinions concerning CARSAMMA's actions in this matter.

— END —