International Civil Aviation Organization
Fifteenth Meeting of the GREPECAS
Scrutiny Working Group (GTE/15)
Lima, Peru, 16 to 20 November 2015

GTE/15-WP/02
Rev.
16/11/15

Agenda Item 1: **Review of conclusions and recommendations of previous CARSAMMA and Scrutiny Group meetings**

b) Presentation of the quantitative calculation of the vertical collision risk (CRM) for year 2014

CALCULATION OF THE VERTICAL COLLISION RISK IN RVSM AIRSPACE OF THE CAR/SAM FIRs

(Presented by CARSAMMA)

SUMMARY

This paper presents a summary of the calculation of the vertical collision risk in CAR/SAM FIRs in 2014 and the analysis using the ICAO CRM methodology.

References:

- Manual on implementation of a 300 m (1000 ft) vertical separation minimum between FL 290 and FL 410 inclusive – ICAO Doc 9574-AN/934, Third Edition – 2012.
- Aircraft movements in RVSM airspace in 2014.
- Report of Large Height Deviations (LHDs) in 2014.

ICAO strategic objectives:	*A - Safety*

1. Background

1.1. The purpose of this work is to show that the safety criteria defined in 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 RVSM airspace in 2014 in the flight information regions (FIRs) of the Caribbean and South America. For this work, the vertical collision risk model (CRM) calculation methodology was used, as recommended by ICAO in RVSM airspace.

2. **Discussion**

2.1. The activities of an RMA (such as CARSAMMA) include an on-going assessment of the safe use of RVSM airspace, using quantitative methods (CRM) for assessing the collision risk.

2.2. 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.

2.3. This working paper contains a summary of the results of the assessment of continuing safety of the 300m (1000 ft) reduced vertical separation minimum in Caribbean and South American airspace in 2014.

2.4. This stage is the follow-up to the implementation strategy contained in ICAO Doc 9574 – *"Manual on implementation of a 300 m (1000 ft) vertical separation minimum between FL 290 and FL 410 inclusive"*, Third Edition – 2012.

2.5. According to this document, an assessment should be made to ensure that operations in RVSM airspace have not increased the collision risk, and that the total vertical risk does not exceed the safety targets defined in the aforementioned manual.

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

2.7. 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 target level of safety (TLS) of 5×10^{-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 (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;
- There is evidence of stability of the altimetry system error (ASE);
- Air traffic control procedures continue to be effective.

2.8. The methodological procedures used are based on ICAO standards, internationally accepted as the most appropriate for assessing RVSM airspace. The data assessment, and the conclusions and recommendations will be presented at the end.

3. CAR/SAM RVSM airspace

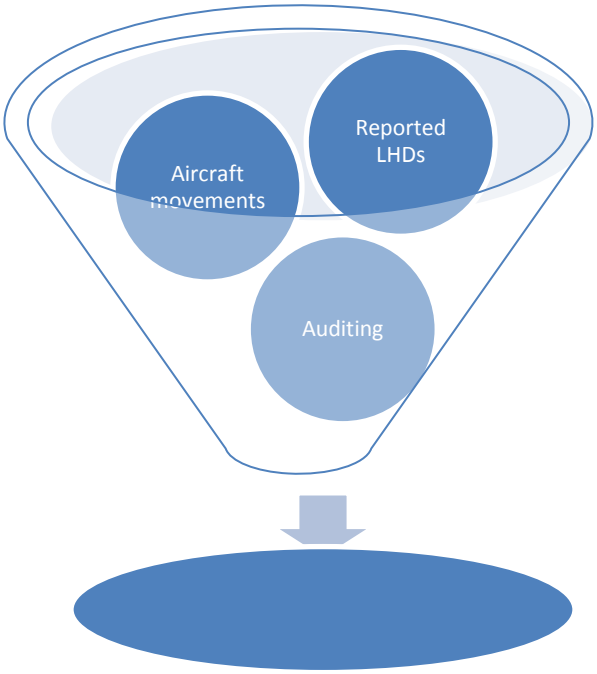
3.1. CAR/SAM RVSM airspace consists of 34 flight information regions (FIRs), which include the following States: Antigua, Argentina, Barbados, Belize, Bolivia, Brazil, Chile, Colombia, Costa Rica, Cuba, Dominican Republic, Ecuador, El Salvador, Grenada, Guadeloupe, Guatemala, Guyana, French Guiana, Haiti, Honduras, Jamaica, Martinique, Netherlands Antilles, Nicaragua, Panama, Paraguay, Peru, St. Barts, St. Kitts and Nevis, St. Lucia, St. Vincent, 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. The data used corresponded to 967.135:07 flight hours of aircraft in transit that used segments of 486 airways in the 34 (thirty-four) CAR/SAM FIRs, between flight levels 290 and 410.

3.4. As to the occurrence of vertical deviations (LHDs) reported in the CAR/SAM Regions, CARSAMMA received a total of 1,717 LHDs in 2014. Following the analysis and validation carried out through teleconferences with representatives of the ICAO Lima and Mexico Offices, the FIRs involved, IATA and CARSAMMA, 1,451 of these LHDs (scenario 1) were considered valid for calculating the vertical collision model (CRM), and 58 LHDs (scenario 2) were considered valid in the event “E” LHDs were not taken into account.

DATA FLOW FOR CALCULATING THE VERTICAL COLLISION RISK



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 2014.

4.2. Aircraft movement data received from the 34 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**.

	Flight hours	%
CAR Region	32 133:02	3.3225 %
SAM Region	935 002:05	96.6775 %
CAR/SAM Regions	967 135:07	100.00 %

Table 1 – Total flight hours in the CAR/SAM Regions

5. Aircraft fleet

5.1. It is essential that 100% of the RVSM-approved aircraft meet RVSM requirements. However, during the safety assessment, CARSAMMA identified some aircraft that were not contained in its RVSM database and that had used this airspace in 2014.

5.2. This led to a global search supported by monitoring agencies from other ICAO Regions, through the exchange of information contained in their databases. In the end, it was noted that, in fact, some of these aircraft were not RVSM certified by a State, as described in **Table 2**.

STATE	FIR	DATE	DELIVERED	NO RVSM	% NO RVSM
Argentina	Córdoba – SACU	13/02/15	5823	67	1,15
	Ezeiza – SAEU	13/02/15	3702	38	1,03
	Mendoza – SAMV	13/02/15	4170	156	3,74
	Resistência – SARU	15/02/15	3414	34	1,00
	Comodoro - SAVU	13/02/15	2322	72	3,10
Bolivia	La Paz – SLLF	12/01/15	5544	53	0,96
Brazil	Atlântico – SBAO	09/03/15	5462	10	0,18
	Amazônica – SBAZ	13/02/15	39328	213	0,54
	Brasília – SBBS	12/02/15	38450	111	0,29
	Curitiba – SBCW	13/02/15	65532	337	0,51
	Recife – SBRE	13/02/15	25130	66	0,26
Chile	Punta Arena – SCCZ	03/02/15	473	11	2,33
	Santiago – SCEZ	03/02/15	12969	56	0,43
	Antofagasta – SCFZ	03/02/15			
	Isla de Pascua – SCIZ	03/02/15	180	1	0,56
	Puerto Montt – SCTZ	03/02/15	1564	0	0,00
Colombia	Bogotá – SKED	26/03/15	13109	15	0,11
	Barranquilla – SKEC	26/03/15			
Ecuador	Guayaquil – SEGU	06/03/15	7740	146	1,89
Guyana	Georgetown – SYGC	06/03/15	2073	49	2,36
French Guiana	Cayenne – SOOO	14/04/15	1166	44	3,77
Panama	Panamá – MPZL	07/04/15	16999	148	0,87
Paraguay	Asunción – SGFA	21/01/15	1991	18	0,90
Peru	Lima – SPIM	15/02/15	12594	15	0,12
Suriname	Paramaribo – SMPM	30/03/15	2119	5	0,24
Uruguay	Montevideo – SUEO	11/02/15	4373	172	3,93
Venezuela	Maiquetia – SVZM	13/02/15	3720	636	17,10
SUBTOTAL SAM	27	27	279947	2473	0,88
STATE	**FIR**	**DATE**	**DELIVERED**	**NO RVSM**	**% NO VSM**
Netherlands Antilles	Curacao – TNCF	26/01/15	6815	100	1,47
COCESNA	Central America – MHTG	02/02/15	14052	120	0,85
Cuba	Havana – MUFH	15/02/15	20258	21	0,10
Haiti	Port Au Prince – MTEG	12/01/15	3246	77	2,37
Jamaica	Kingston – MKJK				
Dominican Republic	Santo Domingo – MDCS	15/02/15	7735	105	1,36
Trinidad & Tobago	Piarco – TTZP	20/04/15	6388	71	1,11
SUBTOTAL CAR	7	6	58494	494	0,84
					R
TOTAL CAR/SAM	34	33	338441	2967	0,88

Table 2 –NON-RVSM flights in the CAR/SAM R degions

**absence of data in the tables is the result of failure to deliver aircraft movement data*

5.3. Reports containing the nominal list of non-RVSM aircraft identified in this analysis will be individually delivered to the civil aviation authorities attending this GTE/15 Meeting, so that they can make the necessary arrangements. The number of non-certified aircraft was presented to the Meeting of Monitoring Agencies

held by ICAO in May of this year in Bangkok, Thailand – where RMAs received a list of non-RVSM aircraft that had used this airspace.

6. Filtering of the data received

6.1. Upon receiving the aircraft movement data, CARSAMMA proceeded to filter and process the data. **Table 3** 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 Risk Calculation Model.

ACFT type	Length λx	Wingspan λy	Height λz	Flight hours	% flight hours	Number of flights	% of flights
A320	0,020286	0,018413	0,00640	24334:22	2,5	44371	16,3
E190	0,019568	0,015507	0,00571	11942:57	1,2	29216	10,8
B763	0,029644	0,025702	0,00756	17013:38	1,8	21857	8,0
B737	0,018898	0,011852	0,00675	9560:43	1,0	20681	7,6
A319	0,018272	0,018413	0,00640	40218:23	4,2	17407	6,4
A332	0,031749	0,032559	0,00940	7969:46	0,8	9589	3,5
B772	0,034395	0,032883	0,00999	7202:07	0,7	9521	3,5
B738	0,021328	0,018521	0,00675	27039:03	2,8	54243	2,8
B752	0,025551	0,020788	0,00732	45073:43	4,7	6690	2,5
B77W	0,034395	0,034989	0,01004	4630:17	0,5	6076	2,2
A321	0,024033	0,018413	0,00640	3415:18	0,4	5357	2,0
A343	0,034341	0,032559	0,00910	3225:25	0,3	3395	1,2
B733	0,017279	0,016199	0,00648	437070:51	45,3	2992	1,1
A318	0,016982	0,018413	0,00678	816:32	0,1	2410	0,9
A346	0,040659	0,034260	0,00934	1977:26	0,2	2304	0,8
B788	0,030778	0,032397	0,00918	2058:22	0,2	2268	0,8
B744	0,038175	0,034773	0,01048	1763:45	0,2	2075	0,8
B762	0,026188	0,025702	0,00756	1317:20	0,1	2004	0,7
B77L	0,034395	0,034989	0,01004	1562:05	0,2	1915	0,7
B764	0,033153	0,028024	0,00756	1129:10	0,1	1720	0,6
MD11	0,033261	0,028077	0,00947	1249:39	0,1	1463	0,5
Other				315665:45	32,6	24105	8,87
Typical Acft	**0,01686493**	**0,0154023**	**0,0052932**				
				967135:07	**100,00**	**271659**	**100,00**

Table 3 – Aircraft that flew RVSM in the CAR/SAM FIRs
(Dimension measurements are expressed in nautical miles)

7. Data processing

7.1. 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.

7.2. Segments most frequently flown in CAR/SAM FIRs

7.2.1 **Table 4** below shows an index where the number of LHDs that occurred in an airway segment was divided by the total number of aircraft movements in that same segment.

State	FIR	Total movements	Fix A	Airway	Fix B	Movements in the segment (7)	Percentage of movements	Number of LHDs	LHF/ (7)
Antilles	Curacao	21188	DUSAN	UA315	PENKO	1023	5%	20	1,96%
Argentina	Córdoba	18981	PORKA	UL550	OPTIR	1001	5%	-	-
	Ezeiza	6161	ROKER	UL550	ROS	502	8%	-	-
	Mendoza	9390	TOSOR	UA306	RYD	930	10%	4	0,43%
	Resistência	10316	MCS	UW64	KORTA	876	8%	4	0,46%
	Comodoro	7488	MIGUS	UA570	VIE	819	11%	2	0,24%
	La Paz	25401	MEVOT	UA304	MOSGO	933	4%	-	-
Brazil	Atlântico	15558	BUGAT	UL206	REGIS	752	5%	-	-
	Amazônica	39328	ACARI	UZ52	NEBAN	405	1%	2	0,49%
	Brasilia	14731	ETIGU	UM409	REINA	831	6%	-	-
	Curitiba	25146	OGNAV	UZ10	TBE	1226	5%	-	-
	Recife	15059	POSMU	UZ36	MARSU	703	5%	-	-
Chile	Punta Arena	431	SATIN	UT100	PNT	416	97%	-	-
	Santiago Antofagasta	9502	VISEK	UL531	NEBEG	980	10%	-	-
	Isla Pascua	177	MORSA	UL348	VINAP	64	36%	-	-
	P. Montt	1447	NIA	UT112	ICO	741	51%	-	-
Cocesna	Central América	43960	PENSO	UB753	PIKRO	1165	3%	6	0,52%
Colombia	Bogotá Barranquilla	13109	AGUJA	UA319	NESMO	405	3%	13	3,21%
Cuba	Havana	44824	URSUS	UA301	UCA	4783	11%	3	0,06%
Ecuador	Guyaquil	4505	VAKUD	UL780	UGUPI	1489	33%	55	3,69%
Guyana	Georgetown	7256	TIM	UA312	KOXAM	983	14%	2	0,20%
French Guiana	Cayenne	1628	MAVKO	DCT	GOGSO	305	19%	4	1,31%

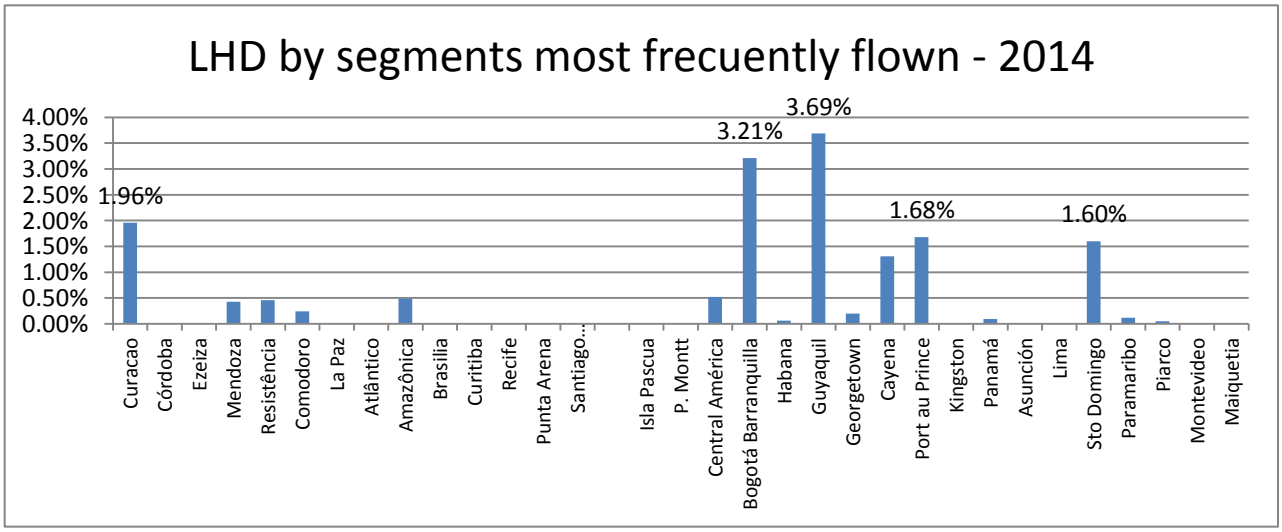
State	FIR	Total movements	Fix A	Airway	Fix B	Movements in the segment (7)	Percentage of movements	Number of LHDs	LHF/ (7)
Haiti	Port au Prince	11485	MEDON	UA315	JOSES	1492	13%	25	1,68%
Jamaica	Kingston	-	-	-	-	-	-	15	-
Panama	Panama	19457	BUFEO	UA317	BITOR	1132	6%	1	0,09%
Paraguay	Asunción	1732	REPAM	UA556	SAMGU	283	16%	-	-
Peru	Lima	35194	ATOGO	UG436	BTE	1705	5%	-	-
Dominican Republic	Sto Domingo	17670	VESKA	UA315	KATIN	1378	8%	22	1,60%
Suriname	Paramaribo	1493	KOXAM	UA312	ACARI	834	56%	1	0,12%
Trinidad & Tobago	Piarco	10718	PELMA	UG449	PERRY	2102	20%	1	0,05%
Uruguay	Montevideo	11607	ISALA	UN741	OGLAP	1102	9%	-	-
Venezuela	Maiquetia	24159	ENPUT	UA567	STB	608	3%	-	-

Table 4 – LHD index by airway segment

7.2.2 In Table 4, out of a total of 180 LHDs and 31,968 movements, the median index is 0.56%.

7.2.3 The following graph shows the estimated rate in the most frequently flown airway segments in the CAR/SAM Regions. The airway segments with the highest rate are:

- VAKUD/UGUPI – UL780 –GUAYAQUIL FIR (SEFG) ECUADOR;
- AGUJA/NESMO – UA319 –BARRANQUILLA FIR (SKEC) COLÔMBIA;
- DUSAN/PENKO – UA315 –CURAZAO FIR (TNCF) NETHERLANDS ANTILLES;
- MEDON/JOSES – UA315 –PORT-AU-PRINCE FIR (MTEG) HAITI; and
- VESKA/KATIN – UA315 –STO. DOMINGO FIR (MDCS) DOMINICAN REPUBLIC.



Graph 1 – LHDs by airway segment

7.2.3 The indices show that there is a higher incidence of LHDs in these segments, although the FIRs in which the events occurred are not necessarily responsible.

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

LHD 192 – FIR exposed to the risk: CENTRAL AMERICA – Day: 9 February 2014

Report #:	192	POSITION:	LIXAS	*AMERICAN*	LIXAS	MODE C:	NO	HT LHD:	2.000
DATE:	09/02/2014	HOUR:	07:12	FLIGHT ID: AAL940	REGISTRATION: N765AN	CLRD FL:	340	DURATION:	1.800
ROUTE:	UZ512 - SCEL (SANTIAGO) / KDFW (DALLAS FORT WORTH)				ACFT TYPE: B772	EVENT FL:	360	CODE:	E1
REPORTING UNIT:	CENTRAL AMERICA	FIR ERROR :	GUAYAQUIL		IMC / VMC: V	XFL SAME:	1	XFL OPS	1
OTHER ACFT (2ª):				#N/D	DISTANCE: 0	POSITION 2ª ACFT:	0	FL 2ª ACFT:	0
CAUSE:	ERROR OPERACIONAL EN EL CICLO DE COORDINACIÓN ATC				STATUS RVSM: APPROVED	GTE TIME:	1.800	GTE CODE:	B
ACC GUAYAQUIL PASO ESTIMADO LIXAS 07:12 FL340 PERO NO PASO CAMBIO DE NIVEL A FL360. AAL940 NOTIFICO RADIM 07:43 FL360, SE RECLAMO A GUAYAQUIL ACC Y DIJERON QUE ELLOS LO TENIAN A FL340 Y NO PUDO EXPLICAR QUE PASO O QUIEN LO ASCENDIO A FL360.									
PROBABILIDAD:	4	DURACIÓN:	3	GRAVEDAD: 4	RADAR / ADS: 10	WEATHER:	0	OTRO TRAFICO:	0
VALOR DEL RIESGO:	58				ACCIÓN MITIGADORA:	REQUIERE MONITOREO Y GESTIÓN			

LHD 576 – FIR exposed to the risk: MONTEVIDEO – Day: 22 April 2014

Report #:	576	POSITION:	3400S 03200W	*IBERIA*	SUEOSAEU6	MODE C:	NO	HT LHD:	0
DATE:	22/04/2014	HOUR:	17:40	FLIGHT ID: IBE6842	REGISTRATION: ECJCY	CLRD FL:	0	DURATION:	N/A
ROUTE:	AORRA - FHAW (ILLAS ASCENCION)				ACFT TYPE: A346	EVENT FL:	350	CODE:	E2
REPORTING UNIT:	MONTEVIDEO	FIR ERROR :	EZEIZA		IMC / VMC:	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:	3.000	GTE CODE:	E2
NO SE RECIBIO TRANSFERENCIA DE LA FIR EZEIZA NI COMODORO RIVADAVIA. LA INFORMACION FUE RECIBIDA POR LA FIR SBAO. *** CARSAMMA: DEL PUNTO DE ENTRADA HASTA EL PUNTO EN QUE LA AERONAVE LLAMA ATLANTICO SON 3.000 SEGUNDOS VOLADOS EN ESPACIO AEREO DE MONTEVIDEO. ***									
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 588 – FIR exposed to the risk: ANTOFAGASTA – Day: 25 April 2014

Report #:	588	POSITION:	KONRI	*TRANS PERU*	KONRI	MODE C:	NO	HT LHD:	0
DATE:	25/04/2014	HOUR:	11:46	FLIGHT ID: TPU904	REGISTRATION: N492TA	CLRD FL:		DURATION:	240
ROUTE:	UL550 - SAEZ / SPIM				ACFT TYPE: A320	EVENT FL:	340	CODE:	E2
REPORTING UNIT:	ANTOFAGASTA	FIR ERROR :	CORDOBA		IMC / VMC:	XFL SAME:	0	XFL OPS	0
OTHER ACFT (2ª):				#N/D	DISTANCE: 0	POSITION 2ª ACFT:	0	FL 2ª ACFT:	0
CAUSE:	AUSENCIA DE COORDINACIÓN				STATUS RVSM: APPROVED	GTE TIME:	240	GTE CODE:	E2
A LAS11:46 TPU904 NOTIFICA EM POSICION KONRI A FL340 SIN TRANSFERENCIA POR PARTE DE CORDOBA ACC. EL TRANSITO ES VISUALIZADO POSTERIOR A LA NOTIFICACION, 20 NM AL NW DE KONRI.									
PROBABILIDAD:	3	DURACIÓN:	3	GRAVEDAD: 3	RADAR / ADS: 10	WEATHER:	5	OTRO TRAFICO:	0
VALOR DEL RIESGO:	51				ACCIÓN MITIGADORA:	REQUIERE MONITOREO Y GESTIÓN			

8. Collision risk safety assessment (CRM)

8.1. This section analyses the results of the safety assessment of RVSM airspace in CAR/SAM FIRs.

8.2. The internationally accepted collision risk methodology (CRM) has been used for the safety assessment of RVSM airspace in the Caribbean and South America.

8.3. 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.

8.4. The filtered aircraft movement data was combined with the LHD data issued in 2014 for the FIRs under study. This data was compiled and analysed during the monthly teleconferences held with the experts of the FIRs involved, the officials of the ICAO Lima and Mexico Regional Offices and of CARSAMMA. IATA also partcipates in these teleconferences as guest consultant.

8.5. 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.

9. CRM parameter estimates

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

Figure 1 – General Formula of the REICH Collision Risk Model

9.1. The material and quantity of the source used for estimating the values of each parameter of the internationally accepted collision risk model (CRM) used for assessing the safety of the RVSM airspace are summarised in **Table 5**.

Parameter	Description	Value
λ_x	Mean length of the aircraft sample	0.01686493 nm
λ_y	Mean extent of the aircraft sample	0.0154023 nm
λ_z	Mean height of the aircraft sample	0.0052932 nm
$\overline{\lvert V \rvert}$	Mean speed of the aircraft sample (module)	463.1245 kt/h
$\overline{\lvert \Delta V \rvert}$	Relative same-direction speed of the aircraft sample (module)	30.25444 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
$P_z(0)$	Probability that two aircraft with the same nominal level overlap laterally in the aircraft sample	0.353416

Table 5 – CRM parameter estimates

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

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

- Pass frequency N_x;
- Probability of vertical overlap ***Pz (1000)***; and
- Probability of lateral overlap P_y ***(0)***.

To demonstrate this, the following objectives were established:
- Generate confidence in the compliance with the technical TLS; and
- Certify ASE stability.

11. System performance specifications

11.1. Pass frequency, N_x – 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 6**.

Pass frequency	Same direction	Opposite direction	Equivalent	Filght time (h)
CAR Region	0,00278103	0,05379315	**0,053793156**	32 133:02
SAM Region	0,01215089	0,07857791	**0,078577917**	935 002:05
CAR/SAM Regions	0,00746596	0,06618553	**0,066185537**	967 135:07

Table 6 – CAR/SAM pass frequency

11.2. Values are related to the CAR/SAM airspace system. It should be noted that the pass frequency shown in Table 6 (**0.066185537**) was calculated on the basis of total filetered flight hours in the 34 CAR/SAM FIRs.

- The estimated value of ***Pz (1000)*** used in our calculations was **2.46 x 10^{-8}**.
- The estimated value of **Py (0)** calculated for 2014 is **0.045606**. Bearing in mind that the lateral overlap probability **Py (0)** shall not exceed **0.05800** according to ICAO Doc 9574 (Ref. 1), the lateral overlap probability obtained for 2014 is normal.

12. Estimating the total collision risk

12.1. **Table 7** 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	0,045382	22,91634	0,016077	934,4065	0,059224	457,5213
SAM	0,052684	37,59253	0,022186	897,1633	0,043942	468,7277
CAR/SAM	0,049033	30,25444	0,019132	915,7849	0,051583	463,1245

Table 7 – Physical and dynamic parameters

13. Conclusions of the safety assessment (CRM)

13.1. Total Collision Risk (scenario 1 – all LHDs) – The estimated values of the Operational Risk are presented in **Table 8**, which result from processing all LHDs received and validated in 2014, plus the files containing aircraft movements in RVSM airspace, as processed in the specific CRM software.

Region	Technical risk	Operational risk	Total risk
CAR	0,0150 E^{-09}	1,84 E^{-09}	1,86 E^{-09}
SAM	0,0585 E^{-09}	1,79 E^{-09}	1,85 E^{-09}
CAR/SAM mean	**0,0508 E^{-09}**	**1,80 E^{-09}**	**1,85 E^{-09}**

Table 8 – Total vertical collision risk (scenario 1)

13.1.1. The technical risk of the CAR/SAM FIRs **satisfies** the goal that states that it should not exceed **2.5 x 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 according to ICAO Doc 9574.

- In the case of the FIRs under study, the estimated total risk is **1.80 x 10^{-9}** below the TLS, which is **5.0 x 10^{-9}.**

CAR/SAM RVSM airspace Estimated flight hours = 967 135:07 hours			
Source of risk	**Estimated risk**	**TLS**	**Remark**
Technical risk	**0.0508 x 10^{-9}**	**2.5 x 10^{-9}**	**Below**
Operational risk	**1.80 x 10^{-9}**	-	-
Total risk	**1.85 x 10^{-9}**	**5.0 x 10^{-9}**	**Below**

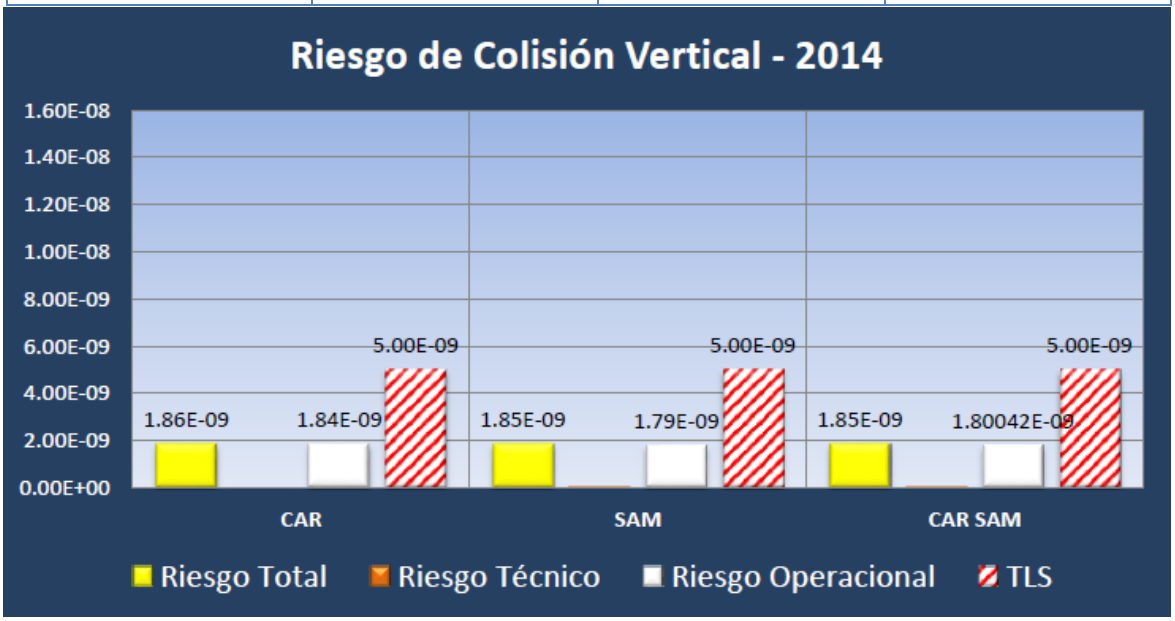


Table 9 and Graph 2 – Annual risk estimates for the CAR/SAM FIRs in RVSM airspace

13.2. Collision risk (scenario 2 – without E-coded LHDs) – The estimated values of the operational risk--excluding all E-coded LHDs--and processed in the specific CRM software, are shown in **Table 10.**

Region	Technical risk	Operational risk	Total risk
CAR	0,0150 E^{-9}	0,379 E^{-9}	0,394 E^{-9}
SAM	0,0585 E^{-9}	0,0581 E^{-9}	0,117 E^{-9}
CAR/SAM mean	**0,0508 E^{-9}**	**0,115E E^{-9}**	**0,166E E^{-9}**

Table 10 – Vertical collision risk (scenario 2)

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

- The opeational risk does not have a predetermined limit according to ICAO Doc 9574.
- In the case of the FIRs under study, the estimated total risk is 0.166 x 10^{-9} below the TLS, which is 5.0 x 10-9.

CAR/SAM RVSM airspace Estimated flight hours = 967 135:07 hours			
Source of risk	**Estimated risk**	**TLS**	**Remark**
Technical risk	**0,0508 x 10^{-9}**	**2.5 x 10^{-9}**	**Below**
Operational risk	**0,115 x 10^{-9}**	**-**	**-**
Total risk	**0,166 x 10^{-9}**	**5.0 x 10^{-9}**	**Below**

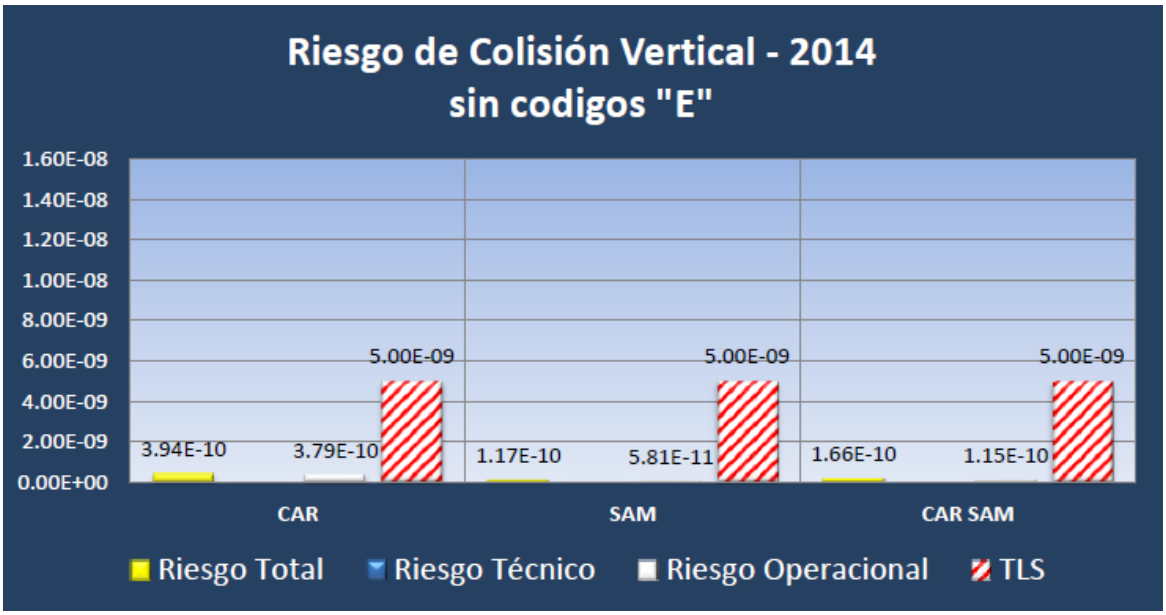


Table 11 and Graph 3 – Annual risk estimates for RVSM airspace in CAR/SAM FIRs

13.3. Analysis of vertical collision risk scenarios – The scenarios show that the greatest reduction in the vertical colllision risk estimates and in the annual volume of LHDs occurs in scenario 2 (excluding "E" codes), as shown in Tables 12a and 12b.

Month	#LHD	DURATION (min)
ENE	136	502
FEB	107	465
MAR	126	423
ABR	136	393
MAY	102	315
JUN	95	125
JUL	103	215
AGO	109	313
SEP	134	272
OCT	144	164
NOV	124	192
DIC	135	108
TOTAL	1451	3487
Total Risk: 1,85 x 10-9		

Table 12a – LHD comparative table (scenario 1)

MONTH	#LHD	DURATION (min)
JAN	4	2.67
FEB	8	36.08
MAR	3	2.40
APR	2	2.00
MAY	1	7.00
JUN	4	6.50
JUL	4	93.17
AUG	5	126.50
SEP	8	5.67
OCT	6	6.50
NOV	6	4.75
DEC	7	6.00
TOTAL	58	299.23
Risk excluding "E" codes: 0.166 x 10-9		

Table 12b – LHD comparative table (scenario 2)

13.3.1. The estimated vertical collision risk scenarios show without doubt that civil aviation authorities of the Regions should focus on improving coordination during the transfer of traffic to adjacent sectors, so as to reduce the CAR/SAM collision risk estimate to an insignificant level (scenario 2).

14. Suggested action

14.1. The Meeting is invited to:

a) take note of the information provided in this working paper, and States willing to do so may use this information as a reference for standardising their LHD mitigation processes and methodologies; and

b) submit that decision to the members of the GTE for their information.

-END-