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**CAR/SAM Planning and Implementation Regional Group (GREPECAS)
Nineteenth Scrutiny Working Group Meeting
Barranquilla, Colombia, 18 to 22 November 2019**

Agenda Item 3: Review of the results of the analysis of large height deviations (LHDs)

c) 2018 results of the safety assessment (CRM) in reduced vertical separation minima (RVSM) airspace

2018 VERTICAL COLLISION RISK (CRM) IN THE CAR/SAM REGIONS

(Presented by CARSAMMA)

SUMMARY	
This working paper presents a summary of the calculation of the vertical collision risk in the CAR/SAM Regions for 2018, using the CRM methodology.	
REFERENCES:	
<ul style="list-style-type: none">• ICAO Doc 9574 - AN/934, third edition - 2012• ICAO Doc 9937 - AN/477, first edition - 2012• Aircraft movements in RVSM airspace in 2018• Reports of large height deviations (LHD) in 2018	
ICAO strategic objectives	<i>A - Safety</i>

1 Background

1.1 The purpose of this work is to show that the safety criteria defined in ICAO Doc 9574 and Doc 9937 continue to be met in CAR/SAM RVSM airspace.

1.2 This document reports on the analysis of vertical collision risk in RVSM airspace in 2018 in the flight information regions (FIRs) of the Caribbean and South America. The vertical collision risk model (CRM) calculation methodology was used for this analysis, as recommended by ICAO for RVSM airspace.

2 Analysis

2.1 According to Doc 9574 and Doc 9937, the assessment is required in order to ensure that operations in RVSM airspace do not generate an increase in collision risk, so that total vertical risk does not exceed the defined safety targets.

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 fundamentals that, after analysing aircraft movements (spreadsheets containing data on flights conducted in RVSM airspace), it calculates the level of safety (TLS) of the flight information region under study.

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

2.4 Special attention should be paid to make sure that:

- All aircraft operating in reduced vertical separation minima airspace are RVSM-certified;
- Aircraft certification is current;
- The target level of safety (TLS) of 5×10^{-9} fatal accidents per flight hour continues to be met (for follow-up of a representative sample of aircraft);
- The use of RVSM does not increase the level of risk due to operational errors and contingency procedures;
- There is evidence of the stability of the aircraft altimetry system (ASE);
- 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;
- Effective additional safety measures are adopted to reduce the risk of collision due to operational errors and contingency procedures and meet safety goals;
- Air traffic control procedures continue to be effective.

3 CAR/SAM airspace

3.1 CAR/SAM airspace covers a broad area extending from the Gulf of Mexico to Patagonia, encompassing 35 flight information regions (FIRs) of the following countries: Antigua, Netherlands Antilles, Argentina, Barbados, Barbuda, Belize, Bolivia, Brazil, Chile, Colombia, Costa Rica, Cuba, Dominica, El Salvador, Ecuador, Grenada, Guadeloupe, Guatemala, Guyana, French Guiana, Haiti, Honduras, Jamaica, Martinique, Nevis, Nicaragua, Panama, Paraguay, Peru, Dominican Republic, Saint Barthelemy, St. Kitts, 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 Collection of traffic data – The sample used for assessing the pass frequency and physical and dynamic parameters of typical aircraft to determine the collision risk was collected from 1 December to 31 December 2018 in the 34 CAR/SAM FIRs. In the sample collected, **342,239** lines of flight records were received from the aforementioned FIRs. All records were purged, leaving **330,200** lines of flight records validated in the process. However, all the data sent was used in another CARSAMMA product, namely the RVSM airspace audit. As in previous years, a large portion of the data received from some States could not be used in the CRM for various reasons, including errors in the entry and exit times of RVSM airspace (less or equal flight entry time), lack of complete information to identify and locate fixed routes and reports, or even send data beyond the deadline.

3.4 Regarding the occurrence of vertical deviations (LHDs) in the CAR/SAM Regions, **CARSAMMA received a total of 976 LHD reports in 2018. After analysis and validation, 834 of these LHDs were considered valid in the CAR/SAM Regions.**

3.5 Therefore, total LHDs analysed according to CRM parameters were as follows:

Code	A	B	C	D	E	F	G	H	I	J	K	L	M
Total LHDs	5	2	0	7	743	67	0	1	1	5	1	1	1

Table 1

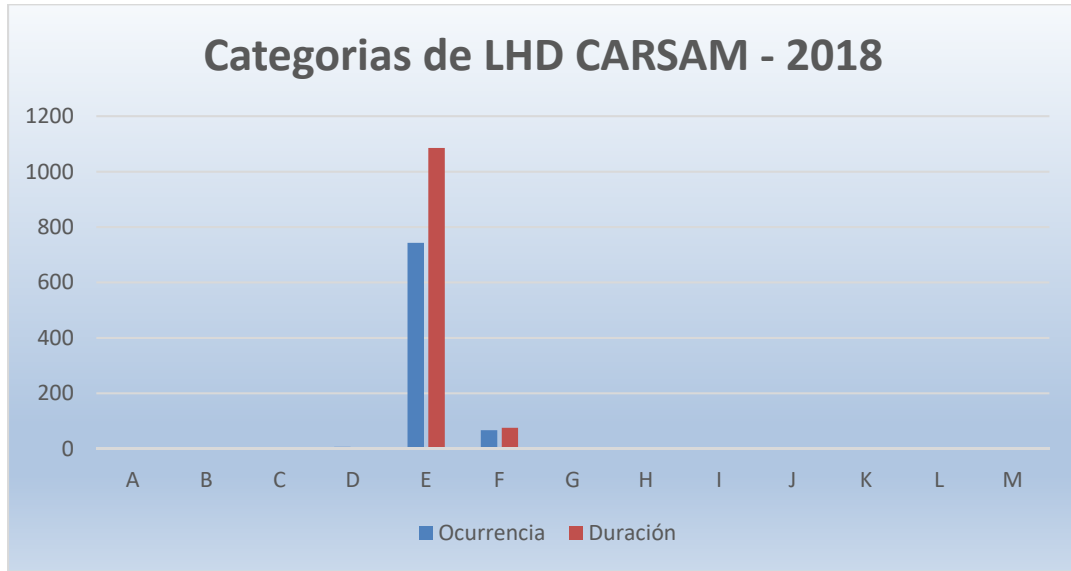


Figure 1

3.6 The following table describes the monthly distribution of LHDs:

MONTH	LHD	Total duration (min)	Average duration (min)
January	57	59.25	1.04
February	59	65.08	1.10
March	74	90.67	1.23
April	57	80.17	1.41
May	53	48.92	0.92
June	73	79.50	1.09
July	63	90.92	1.44
August	72	71.67	1.00
September	64	69.92	1.09
October	75	89.25	1.19
November	107	236.00	2.21
December	80	196.23	2.45
Total	834	1,177.57	1.41

Table 2

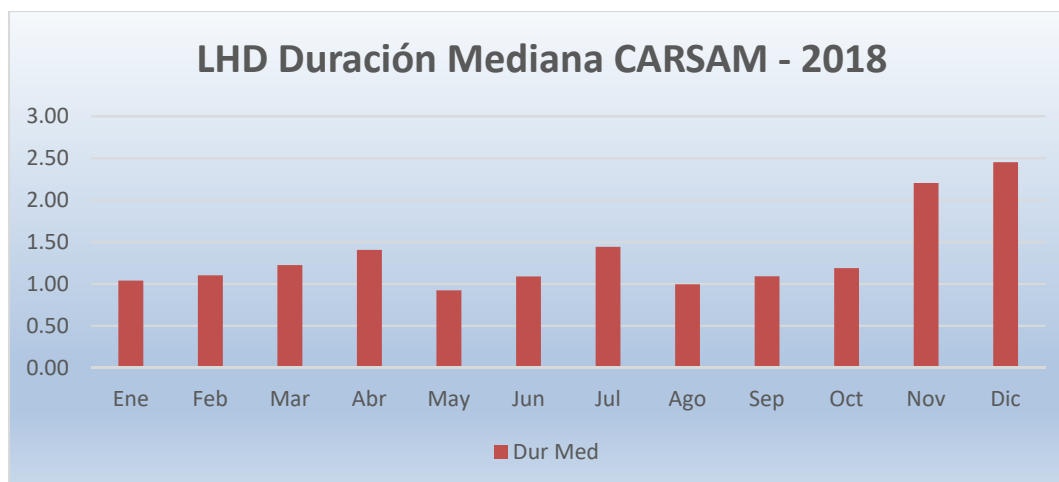


Figure 2

4 Collection of aircraft movement data

4.1 The sample data to estimate the pass frequency and physical parameters, as well as the dynamics of a typical aircraft for the assessment of vertical collision risk were collected from 1 December to 31 December 2018.

4.2 Aircraft movement data received from the 34 CAR/SAM FIRs were processed and used to assess RVSM airspace safety, as recommended by ICAO.

4.3 Upon receiving the aircraft movement data, CARSAMMA proceeded to its filtering and processing. **Table 3** shows the results and lists the aircraft that flew through the CAR/SAM FIRs, with their dimensions, number and percentage of flights, including a typical aeroplane, used as one dimension of the vertical risk calculation model.

Type ACFT	Length	Wingspan	Height	# Flights	% ACFT
B738	0.021328	0.018521	0.006749	58,359	22.18%
A320	0.020286	0.018413	0.00635	57,756	21.96%
E190	0.019568	0.015507	0.005707	16,831	6.40%
A321	0.024033	0.018413	0.00635	15,836	6.02%
A319	0.018272	0.018413	0.00635	14,902	5.66%
B737	0.018898	0.018521	0.006749	12,834	4.88%
B763	0.029644	0.025702	0.007559	10,823	4.11%
A332	0.031749	0.032559	0.009395	9,255	3.52%
E195	0.019568	0.015507	0.005707	6,531	2.48%
B77W	0.034395	0.034989	0.010043	5,361	2.04%
B772	0.034395	0.032883	0.009989	5,335	2.03%
B789	0.034017	0.034017	0.009179	4,708	1.79%
B788	0.030778	0.032397	0.009179	2,782	1.06%
B752	0.025551	0.020788	0.007322	2,217	0.84%

CRJ2	0.014454	0.011452	0.003358	2,125	0.81%
B733	0.017279	0.016199	0.006479	2,087	0.79%
B38M	0.021328	0.021328	0.006749	1,783	0.68%
A346	0.040659	0.003426	0.009341	1,659	0.63%
A333	0.034341	0.032559	0.009098	1,611	0.61%
B739	0.021328	0.018521	0.006749	1,582	0.60%
B77L	0.034395	0.034989	0.010043	1,517	0.58%
B744	0.038175	0.034773	0.010475	1,513	0.58%
A20N	0.020286	0.018413	0.00635	1,293	0.49%
A343	0.034341	0.032559	0.009098	1,253	0.48%
B734	0.019708	0.015605	0.005994	1,200	0.46%
Others				20,087	8.33%
Typical	0.02678	0.02376	0.00834	261,240	100.00%

**Table 3 – Aircraft that flew RVSM in CAR/SAM FIRs
(Measurements of dimensions are expressed in nautical miles)**

5 Collision risk safety assessment (CRM)

5.1 This section analyses the results of the assessment of the collision risk in RVSM airspace of CAR/SAM FIRs.

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

5.3 Estimates of the CRM parameter:

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

Figure 3 – General formula of the REICH collision risk model

5.3.1 The material and quantity of the source used for estimating the values of each parameter of the internationally accepted collision risk model (CRM) applied for the assessment of RVSM airspace safety are summarised in **Table 4**.

Parameter	Description	Values
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λ_x	Mean length of the aircraft sample	0.02678 nm
λ_y	Mean wingspan of the aircraft sample	0.02376 nm
λ_z	Mean height of the aircraft sample	0.00834 nm
$ \bar{V} $	Mean speed of the aircraft sample (module)	431.697 kt
$ \Delta V $	Relative same-direction speed of the aircraft sample (module)	29.90851 kt
$ \dot{y} $	Mean speed relative to the transverse approach of the aircraft sample (module)	13 kt
$ \dot{z} $	Mean relative vertical speed during loss of vertical separation of the aircraft sample (module)	1.5 kt
Pz(0)	Probability that two aircraft with the same nominal level overlap laterally in the aircraft sample	0.298265

Table 4 - CRM parameter estimates

5.4 Demonstration of the technical feasibility of RVSM in the CAR/SAM Regions

5.4.1 This involves assessing the value of parameters in the REICH collision risk model:

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

To demonstrate this, the following objectives were established:

- Generate trust in the attainment of the technical TLS; and
- Certify ASE stability.

5.5 System performance specifications

5.5.1 Pass frequency, N_x – This is the airspace parameter in which 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**.

CAR/SAM Pass frequency	Same direction	Opposite direction	Equivalent	Hours of flight
	0.00496611	0.02762529	0.03591072	1,038,066

Table 5 – Pass frequency

5.5.2 Values are related to the CAR/SAM airspace system. It should be noted that the equivalent pass frequency shown in **Table 5 (0.03591072)** was calculated on the basis of flight hours in the 34 CAR/SAM FIRs.

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

5.6 Estimating the collision risk

5.6.1 **Table 6** contains the sets of physical and dynamic parameters estimated in the risk profile, as well as the follow-up of the main parameters for the CAR/SAM FIRs. All parameters were determined based on the airspace of each Region that is considered as an isolated system.

CAR/SAM	E (same)	Ez (opposite)	Ez	ΔV (same)	ΔV (opposite)	V
	0.017081	0.030399	0.047480	29.90851	418.36722	431.697 kt

Table 6 – Physical and dynamic parameters

5.7 Figure 4 shows the consolidated collision risk in the CAR/SAM FIRs in for 2018, showing the estimated vertical collision risk by year and by FIR. It must be understood that the FIRs that present an LHD report have a higher risk, but frequently due to failures in the FIRs adjacent to their airspace.

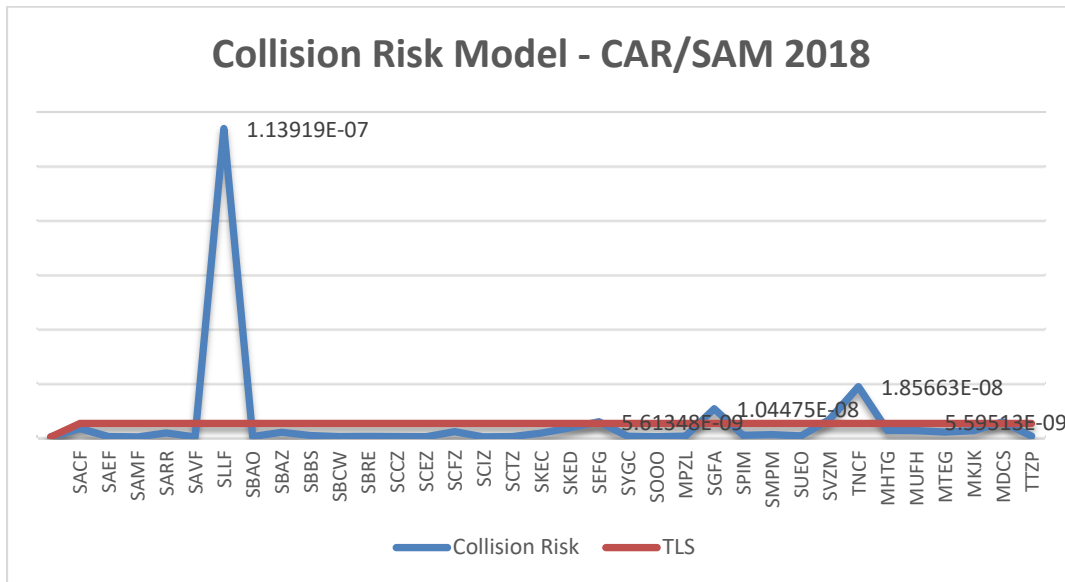


Figure 4 - Vertical collision risk by FIR

6 Conclusions of the safety assessment (CRM)

6.1 The risk was estimated based on the FIR values presented in Table 7, which were obtained after processing all data received, compiled and processed in the specific CRM software.

6.2 The technical risk of the CAR/SAM FIRs meets the TLS value, not exceeding 2.5×10^{-9} fatal accidents per flight hour due to loss of the standard vertical separation of 1,000 ft and all other causes.

6.3 The operational risk does not have a predefined limit, in accordance with ICAO Doc 9574.

6.4 **The estimated total risk for the assessed FIRs is 2.32×10^{-9} under the TLS (5.0×10^{-9}).**

CAR/SAM RVSM airspace – Estimated annual flight hours = 1,038,066 hours – (Note: Estimated time based on December 2018 sample)			
Source of risk	Estimated risk	TLS	Comments
Technical risk	0.0401×10^{-9}	2.5×10^{-9}	Below
Operational risk	2.28×10^{-9}	-	-
Total risk	2.32×10^{-9}	5.0×10^{-9}	Below

7 **Suggested action**

7.1 The Meeting is invited to:

- a) note and review the contents of this working paper;
- b) share experiences and comment on CARSAMMA actions on this matter; and
- c) use this information to reduce LHDs and improve the level of safety in the airspace of CAR/SAM FIRs.