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WORKING PAPER

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Twenty-third Meeting of the Working Group on Scrutiny (GTE/23) of the CAR/SAM Regional Planning and Implementation Group (GREPECAS)

Lima, Peru, from September 11 to 15, 2023

Agenda Item 2: Review of the results of the Large High Deviations (LHD) analysis

VERTICAL COLLISION RISK CALCULATION (CRM)

(Presented by CARSAMMA)

EXECUTIVE SUMMARY

This working paper uses the CRM methodology to summarize the calculation of the vertical collision risk in the CAR/SAM Regions for 2022.

Action:	Monitoring and Documentation
Strategic Objectives:	• Safety
References:	• ICAO Doc. 9574 - Manual on a minimum vertical separation of 300 m (1 000 ft) between FL 290 and FL 410 inclusive. • ICAO Doc. 9937 - Operational procedures and methods for regional monitoring organizations in relation to the use of a vertical separation minimum of 300 m (1 000 ft) between FL 290 and FL 410 inclusive. • Aircraft movement in RVSM space in 2022. • Reports of Larger Altitude Deviations (LHD) in 2022

1. Introduction

1.1 This working paper aims 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 2020 in the flight information regions (FIRs) of the Caribbean and South America.

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 analyzing 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. Several calculation tools and databases are used for the various calculations during the process and several hours of analysis by CARSAMMA experts.

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

2.4 Safety Assessment Tools:

- ICAO Collision Risk Methodology;
- ICAO Doc 9574 is used to develop the Global System Performance Specification, with the specification and requirements for aircraft height-keeping performance;
- All aircraft operating in reduced vertical separation minima airspace are RVSM-certified;
- Aircraft certification is current;
- The target level of safety (TLS) of 5 x 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.

2.5 The risk model was adapted to take into account:

- Technical risk of the aircraft in the same airway and the intersecting airways and
- The effect of large height deviations (LHD) on system risk.

3. CAR/SAM airspace

3.1 The RVSM airspace monitored by CARSAMMA is made up of 34 Flight Information Regions (FIRs) in the Caribbean and South America. Each part of that airspace was treated as an isolated system with its own statistical parameters.

3.2 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 December 1 to December 31 - 2022, in the 34 CAR/SAM FIRs. In the sample collected, 287.439 lines of flight records were received, with 491,925.68 hours of duration of the mentioned FIRs, 104,780.17 hours from the CAR Region (21.30%), and 387,145.51 hours from the SAM Region (78.70%).

3.3 Regarding vertical deviations (LHDs) in the CAR/SAM Regions, CARSAMMA received 1280 LHD reports in 2022. After the analysis and validation conducted through teleconferences with representatives of the ICAO Lima and Mexico Offices, IATA, and CARSAMMA, 711 of these LHDs were considered valid in the CAR/SAM.

3.4 Therefore, the total number of LHDs analyzed by the CRM parameters were:

Code	A	B	C	D	E1	E2	F	G	H	I	J	K	L	M	Total
#LHD	**1**	**8**	**0**	**2**	**401**	**284**	**0**	**0**	**3**	**5**	**3**	**0**	**1**	**3**	**711**

Table 1 Total LHD

3.5 The following table describes the distribution of LHD per month

Month	# LHD	Duration (min)	Crossed Levels
January	43	30.50	42
February	39	28.50	35
March	51	79.50	74
April	80	55.00	87
May	50	86.50	47
June	57	34.00	82
July	66	81.00	113
August	52	57.83	70
September	73	173.50	82
October	60	62.22	51
November	73	76.98	82
December	67	85.50	65
Total	**711**	**851.03**	**830**

Tabla 2 – Monthly LHD

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 December 1 to December 31, 2022.

4.2 Upon receiving the aircraft movement data, CARSAMMA began 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 airplane, used as a dimension of the vertical risk calculation model.

ACFT Type	Length λx	Wingspan λy	Height λz	Flights	% of Flights
B738	0.021328	0.018521	0.006749	53628	20.4%
A320	0.020286	0.018413	0.006350	47499	18,1%
A20N	0.020286	0.018413	0.006350	27376	10.4%
B38M	0.021312	0.019395	0.006641	20945	8.0%
A321	0.024033	0.018413	0.006350	17583	6.7%
E190	0.019568	0.015507	0.005707	12114	4.6%
A319	0.018272	0.018413	0.000635	11344	4.3%
B763	0.029644	0.025702	0.007559	10821	4.1%
B737	0.018898	0.018521	0.006749	9342	3.6%
B789	0.034017	0.034017	0.009179	6421	2.4%
A332	0.031749	0.032559	0.009395	5894	2.2%
B788	0.030778	0.032397	0.009179	5887	2.2%
A21N	0.024033	0.018413	0.006350	5505	2.1%
B772	0.034395	0.032883	0.009989	4376	1.7%
B77W	0.034395	0.034989	0.010043	3936	1.5%
A359	0.036123	0.034557	0.009125	3299	1.3%
B739	0.021328	0.018521	0.006749	3055	1.2%
B752	0.025551	0.020788	0.007322	2411	0.9%
E295	0.025476	0.021823	0.006773	1821	0.7%
B734	0.019708	0.015605	0.005994	1808	0.7%
A333	0.034341	0.032559	0.009098	1776	0.7%
B744	0.038175	0.034773	0.010475	1762	0.7%
A339	0.034341	0.032559	0.009098	1592	0.6%
B77L	0.034395	0.034989	0.010043	1290	0.5%
B733	0.017279	0.016199	0.006479	1067	0.4%
Typical acft	**0.023050**	**0.020780**	**0.006690**	**262552**	**91.3 %**

Table 3 – The Top aircraft that flew RVSM in the CAR/SAM FIRs in terms of flights
(The measurements of the dimensions are expressed in nautical miles)

5. Collision risk safety assessment (CRM)

5.1 This section analyses the results of assessing 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:

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

Figure 1 – General formula of the REICH collision risk model

5.4 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 summarized in Table 4.

λx	Average length of the aircraft sample **0.023050 Nm**
λy	Average wingspan of the aircraft sample **0.020780 Nm**
λz	Average height of the aircraft sample **0.006690 Nm**
$\overline{\lvert V \rvert}$	Average speed of the aircraft sample (module) **432.355 kts**
$\overline{\lvert \Delta V \rvert}$	Relative speed of the same direction of the sample of the aircraft (module) **30.8340 kts**
$\overline{\lvert \dot{y} \rvert}$	Average speed relative to the transverse approximation of the sample of the aircraft (module) **13 kts**
$\overline{\lvert \dot{z} \rvert}$	Average relative vertical velocity 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 sample of the aircraft **0.344891**

Table 4 - CRM Parameter Estimates

5.5 Demonstration of the technical feasibility of RVSM in the CAR/SAM Regions:

- Step frequency **Nx**;
- Probability of vertical overlap **Pz (1000);** and
- Probability of lateral overlap **Py (0).**

To demonstrate this, the following objectives were established:

- Build confidence in technical TLS compliance; and
- Certify the stability of the ASE.

5.5.1 Pass frequency, Nx – 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.

Pass Frequency CAR/SAM	Same Direction	Opposite Direction	Equivalent	Flight Hours
	0.008463	**0.098498**	**0.066599**	**491,925.68**

Table 5 – Passage Frequency

5.5.2 The values are related to the CAR/SAM airspace system. It should be noted that the equivalent pass frequency shown in **Table 5 (0.066599)** has been calculated based on the flight hours of the 32 CAR/SAM FIRs.

The estimated value of **Pz(1000)** used in our calculations was **2.46 x 10-8.**

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

CAR/SAM	E (same)	ΔV (same)	Ez (opp)	ΔV (opp)	Ez	V
	0.09539	**17.2347 kt**	**0.02462**	**878.358 kt**	**0.05254**	**432.355 kt**

Table 6 – Physical and dynamic parameters

6. Conclusions of the evaluation of the Risk of Vertical Collision (CRM)

6.1 Collision Risk - Figure 2 shows the vertical collision risks calculated for each FIR of the CAR/SAM Regions during the year 2022. The FIRs **Bogotá, Piarco, Asunción, Guayaquil and Port-au-Prince were the ones that SUFFERED risk due to above the Desired Security Level (TLS).**

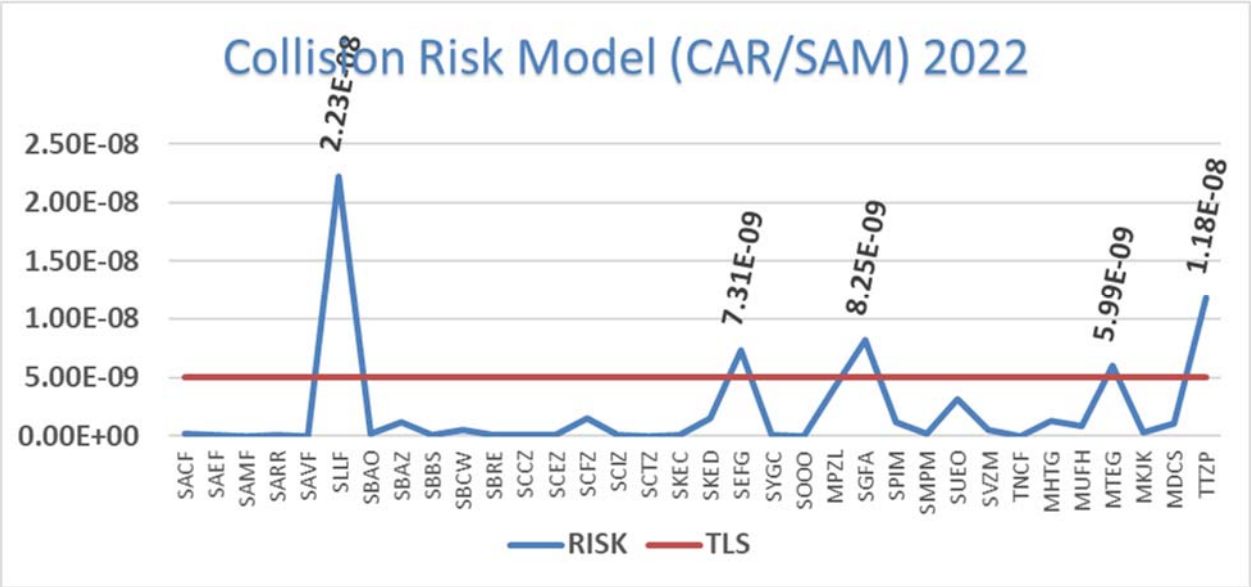

Figure 2 - Risk of Collision

6.2 The CARSAMMA Altimetry laboratory attached to this working paper the main quantitative parameters that influenced the CRM calculations of the 05 FIRs that exceeded the TLS in 2022 and includes a list of LHDs that occurred.

6.3 At the end of this work, we would like to recall some data that make up our calculations:

- 287,439 aircraft movements were received, and after processing, 247,198 flight records were validated. In relation to previous years, this use is satisfactory.
- In the CRM calculation, an aircraft without certification that uses RVSM airspace significantly increases the risk of vertical collision. A more significant effort is necessary on the CAAs and the ANSP of the CAR/SAM regions for the correct use of the RVSM space.
- Among the 247,198 validated movements, at the end of an audit process carried out by CARSAMMA, with the support of the RMAs and CAAs of the CAR\SAM regions, some aircraft whose registration does not appear in the RVSM approval database of CARSAMMA.

This may have been caused by:

a) Error in the writing of the F2 (RVSM approval) by the CAA;
b) failure to send F2 to CARSAMMA by the AAC;
c) Error in the writing of the F2 by CARSAMMA in the RVSM data bank; either
d) that the aircraft is NOT RVSM certified.

- Considering the occurrences in the RVSM space, 711 LHDs were validated during the teleconferences held during the year by the LHD sector in CARSAMMA.
- The LHD event duration (time) and level crossing parameters also negatively influence the CRM calculation. The FIRs with areas with an oceanic region or large distances between mandatory reporting positions are the most affected in this calculation.

6.4 The technical error of the CAR/SAM FIRs satisfies the objective that establishes that it should not exceed 2.5 x 10-9 fatal accidents per flight hour due to the loss of the standard vertical separation of 1000 feet and all other causes.

Operational risk does not have a predetermined limit, according to ICAO Doc.9574.

6.5 **In the case of the CAR/SAM Regions, the estimated average risk is 1.255 x 10-9 below the TLS, which is 5.0 x 10-9.**

CAR/SAM RVSM airspace – Estimated Flight Hours = 491,925.68 hours			
Source of Risk	**Estimated Risk**	**TLS**	**Observation**
Technical Error	**0.033 x 10-9**	**2.5 x 10-9**	**Below**
Operational Error	**1.073 x 10-9**	**-**	-
Risk	**1.255 x 10-9**	**5.0 x 10-9**	**Below**

Table 7

7 Suggested action

7.1 The Meeting is invited to:

a) Note and review the contents of this working paper;

b) take actions to reduce risk in those FIRs above the maximum risk expected value; and

c) use this information to reduce LHDs and improve the level of safety in the airspace of CAR/SAM FIRs.

— END —