International Civil Aviation Organization
North American, Central American and Caribbean Office

WORKING PAPER

GTE/18 — WP/05
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CAR/SAM Planning and Implementation Regional Group (GREPECAS) Eighteenth Scrutiny Working Group Meeting (GTE/18)

Mexico City, Mexico, 22 – 26 October 2018

Agenda Item 1: **Review of the previous CARSAMMA and Scrutiny Group meetings Conclusions and Recommendations**

RISK OF VERTICAL COLLISION (CRM) OF THE YEAR 2016 IN THE CAR/SAM REGIONS (including ALL validated LHDs)

(Presented by CARSAMMA)

EXECUTIVE SUMMARY	
This working paper presents a summary of the vertical collision risk calculation in the CAR/SAM Regions in 2016 using the CRM methodology.	
Action:	Take note and review the contents of this Working Paper.
Strategic Objectives:	• Safety
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. • Movement of aircraft in the RVSM space in 2016. • Reports of Large Height Deviations (LHD) in 2016.

1. Introduction

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

1.2 This document reports on the analysis of vertical collision risk in the RVSM airspace in 2016 in the Flight Information Regions (FIR) of the Caribbean and South America. For this work, the calculation methodology of the vertical collision risk model (CRM) was used, as recommended by ICAO in the RVSM airspace.

2. Analysis

2.1 This report presents the results of the safety assessment in 2016 in the RVSM airspace of the Caribbean and South America (CAR/SAM). This step corresponds to the continuation of the RVSM implementation strategy.

2.2 According to Doc 9574 and Doc 9937, the assessment must be made to ensure that operations in the RVSM airspace do not induce an increase in collision risk so that the total vertical risk does not exceed the defined safety objectives.

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 fundamentals that, after analysing the movements of aircraft (spreadsheets containing data on flights made in RVSM airspace), calculates the safety level (TLS) of the Flight Information Region under study. Several calculation tools and databases are used for various calculations during the process, as well as several hours of analysis by experts.

2.4 This working document contains a summary of the results of the continuous safety assessment of the reduced vertical separation minimum of 300 m (1000 ft) in the Caribbean and South American airspace in 2016.

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

2.6 Special attention should be paid to:

- All aircraft operating in airspace of reduced vertical separation minimum are RVSM certified;
- The certification of the aircraft is current;
- The target safety level (TLS) of 5 x 10^{-9} fatal accidents per flight hour continues to be met (for height tracking in 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, according to a predefined level of statistical confidence;
- Effective additional safety measures are adopted to reduce the risk of collision and meet safety goals 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 of 34 Flight Information Regions (FIR) composed of the following States: Antigua and Barbuda, Netherlands Antilles, Barbados, Belize, Bolivia, Brazil, Chile, Colombia, Costa Rica, Cuba, Guatemala, Guyana, French Guiana, Haiti, Honduras, Jamaica, Martinique, Nevis, Nicaragua, Panama, Paraguay, Dominican Republic, Saint Barthelemy Saint Kitts and Nevis and Saint Lucia, Saint Vincent and the 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 Collection of Data Traffic - The sample used to evaluate the frequency of passage and physical and dynamic parameters of typical aircraft to assess the collision risk was collected in the period between 01 and 31 December 2016 from the 32 CAR/SAM FIR. In these movement data, in terms of flight hours of the collected samples, 1,160,614.66 flight hours were received from all the FIRs mentioned, with 329,143.16 hours from the CAR Region (28.36%) and 831,471.50 hours of the SAM Region (71.64%). As in previous years, a large part of the data received from some States could not be exploited in the CRM for various reasons, including errors in the entry and exit times of the RVSM space (less or equal data entry time), lack of complete information to identify and locate fixed routes and notifications, or even send data beyond the deadline. However, all the data sent was exploited in another CARSAMMA product, which is the RVSM airspace Audit.

3.4 Regarding the occurrence of vertical deviations (LHDs) reported in the CAR/SAM Regions, CARSAMMA received a total of 1,280 LHDs in 2016. After the analysis and validation carried out through teleconferences with representatives of the ICAO Lima Offices and Mexico, IATA and CARSAMMA, 1,065 of these LHDs were considered valid in the CAR/SAM Regions.

3.5 Therefore, the total of LHD analysed by the CRM parameters were as follows:

Code	A	B	C	D	E	F	G	H	I	J	L	Total
#LHD	6	8	2	6	1007	16	2	3	11	1	3	1065

Table 1 – Total LHD

3.6 The following table describes the distribution of LHD per month:

MONTH	LHD	Duration (min)	Average Duration (min)
January	**115**	**105.58**	**0.92**
February	**70**	**144.97**	**2.07**
March	**92**	**141.02**	**1.53**
April	**77**	**107.67**	**1.40**
May	**97**	**489.83**	**5.05**
June	**70**	**197.67**	**2.82**
July	**108**	**308.53**	**2.86**
August	**104**	**106.67**	**1.03**
September	**102**	**215.25**	**2.11**
October	**74**	**73.35**	**0.99**

MONTH	LHD	Duration (min)	Average Duration (min)
November	89	105.03	1.18
December	67	154.92	2.31
Total	1065	2150.48	2.02

Table 2

4. Collection of aircraft movement data

4.1 The sample data to estimate the frequency of passage and the 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, 2016.

4.2 Aircraft movement data received from the 32 CAR/SAM FIRs were processed and used to assess the safety of RVSM airspace, as recommended by ICAO. The number of flight hours used is shown in Table 3.

Region	Flight Hours	%
CAR	329,143.16	28.36 %
SAM	831,471.50	71.64 %
CAR/SAM	1,160,614.66	100.00 %

Table 3

4.3 Upon receiving the movement data of the aircraft, CARSAMMA proceeded to filter and process the data. Table 4 shows the results and lists the aircraft that flew through the CAR/SAM FIRs, with their dimensions and percentage of flight hours, including a typical aircraft, used as a dimension of the Vertical Risk Calculation Model.

ACFT Type	Length λx	Wingspan λy	Height λz	Flights	% of Flight
A320	0.020286	0.018413	0.00640	55,445	26.03%
B738	0.021328	0.018521	0.00675	47,648	22.37%
E190	0.019568	0.015507	0.00571	22,769	10.69%
A319	0.018272	0.018413	0.00640	14,039	6.59%
B737	0.018898	0.011852	0.00675	12,489	5.86%
B763	0.029644	0.025702	0.00756	10,481	4.92%
A321	0.024033	0.018413	0.00640	9,819	4.61%
A332	0.031749	0.032559	0.00940	7,886	3.70%
B772	0.034395	0.032883	0.00999	5,975	2.81%
B77W	0.034395	0.034989	0.01004	4,330	2.03%
B752	0.025551	0.020788	0.00732	3,433	1.61%
B788	0.030778	0.032397	0.00918	3,140	1.47%
B789	0.034017	0.034017	0.00918	2,037	0.96%
A343	0.034341	0.032559	0.00910	1,913	0.90%
B733	0.017279	0.016199	0.00648	1,824	0.86%
B739	0.021328	0.018521	0.00675	1,778	0.83%
A346	0.040659	0.03426	0.00934	1,677	0.79%
B744	0.038175	0.034773	0.01048	1,327	0.62%

ACFT Type	Length λx	Wingspan λy	Height λz	Flights	% of Flight
MD83	0.024352	0.01771	0.04887	1,277	0.60%
B767	0.033153	0.028024	0.00907	1,267	0.59%
B77L	0.034395	0.034989	0.010043	1,216	0.57%
B734	0.019708	0.015605	0.00599	823	0.39%
B764	0.033153	0.028024	0.00756	392	0.18%
Typical Acft	**0.022923**	**0.020251**	**0.007219**	**212,985**	**100.00%**

Table 4 - Aircraft that flew RVSM in the CAR/SAM FIRs
(Measurements of dimensions are expressed in nautical miles)

5. Collision risk safety assessment (CRM)

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

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 Collision Risk Model of REICH

5.3.1 The material and quantity of the source used to estimate the values of each parameter of the internationally accepted collision risk model (CRM) used to assess the safety of RVSM airspace are summarized in Table 5.

Parameter	Description	Values
λx	Average length of the aircraft sample	**0.022923nm**
λy	Average wingspan of the aircraft sample	**0.020251nm**
λz	Average height of the aircraft sample	**0.007219nm**

Parameter	Description	Values
$\overline{V}$	Average speed of the aircraft sample (module)	**435.9665 kts**
$\overline{\Delta V}$	Relative speed of the same direction of the sample of the aircraft (module)	**32.03411 kts**
$\overline{\dot{y}}$	Average speed relative to the transverse approximation of the sample of the aircraft (module)	**13 kts**
$\overline{\dot{z}}$	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	**0.408635**

Table 5 - Estimates of CRM parameters

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

5.4.1 This involves evaluating the results of the values of the parameters of the REICH Collision Risk Model:

- Frequency of passage **Nx**;
- Probability of vertical superposition **Pz (1000)**; and
- Probability of lateral overlap **Py (0).**

To demonstrate this, the following objectives were established:

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

5.5 System performance specifications

5.5.1 Pass Frequency, **Nx** - This is the parameter of the airspace in which the aircraft is exposed to the risk of vertical collision. The equivalent step frequency was estimated considering airplanes flying in the same direction and in opposite directions, as shown in Table 6.

Pass Frequency CAR/SAM	Same Direction	Opposite Direction	Equivalent	Flight Hours
	0.00496611	**0.02762529**	**0.03591072**	**1,160,614.66**

Table 6 – Pass Frequency

5.5.2 The values are related to the CAR/SAM airspace system. It should be noted that it has been calculated that the equivalent Pass frequency shown in Table 6 **(0.03591072**) was 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.

5.6 Estimation of collision risk

5.6.1 Table 7 contains the sets of the physical and dynamic parameters that are estimated in the risk profile, as well as the monitoring of the main parameters for the CAR/SAM FIRs. All parameters were determined based on the airspace of each region that is considered an isolated system.

CAR/SAM	E (same)	ΔV (same)	Ez (opposite)	ΔV (opposite)	Ez	V
	0.03898688	32.03411	0.00690632	418.36722	0.047480129	435.9665

Table 7 – Physical and dynamic parameters

6. Conclusions of the Collision Risk Assessment (CRM)

6.1 Collision Risk - The estimated values of the monthly Technical, Operational and Risk Errors are presented in Table 8 and Figure 2, which result from the processing of all the LHDs received and validated in 2016, plus the files that contain movements of aircraft in the RVSM airspace, processed in the specific CRM software.

Month	Technical Error	Operational Error	Risk
January	0.0257 E-09	1.79E-09	1.82E-09
February	0.0261 E-09	1.51E-09	1.54E-09
March	0.0261 E-09	1.48E-09	1.50E-09
April	0.0261 E-09	1.36E+09	1.38E-09
May	0.0261 E-09	2.83E-09	2.85E-09
June	0.0297 E-09	1.00E-09	1.03E-09
July	0.0258 E-09	2.23E-09	2.30E-09
August	0.0260 E-09	1.02E-09	1.05E-09
September	0.0260 E-09	0.65E-09	0.67E-09
October	0.0260 E-09	0.88E-09	0.91E-09
November	0.0260 E-09	1.06E-09	1.09E-09
December	0.0260 E-09	0.96E-09	0.99E-09

Table 8 – Monthly Collision Risk

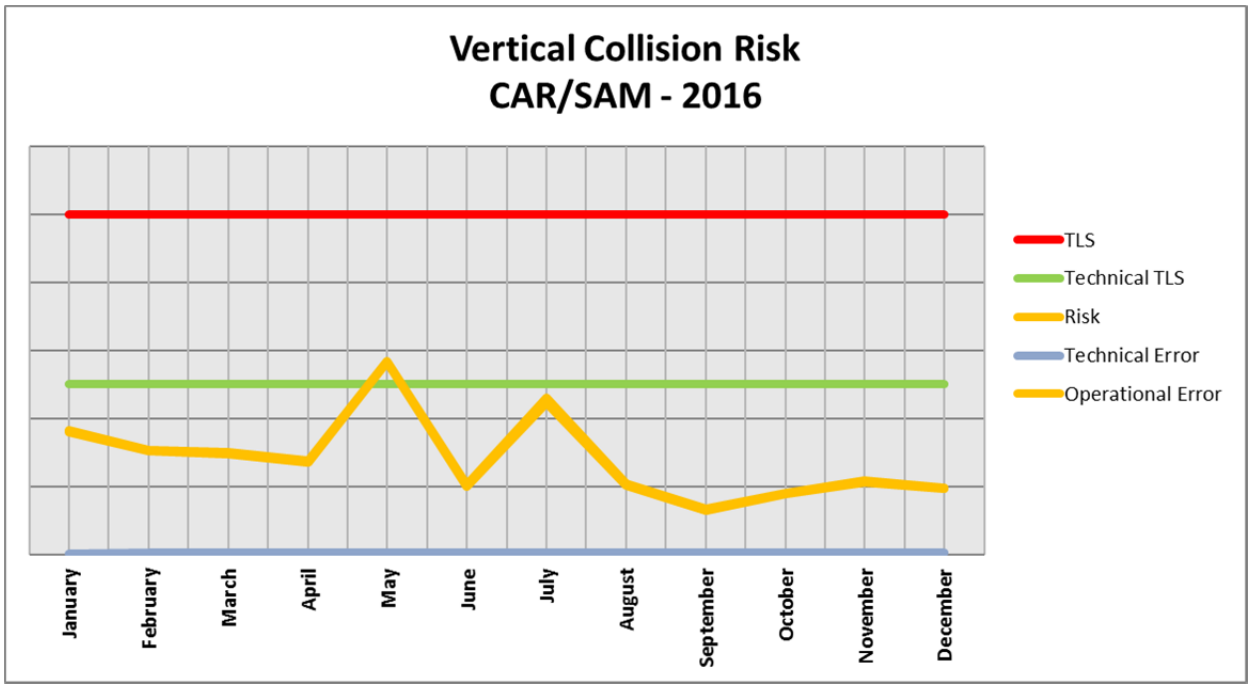

Figure 2 - Monthly Collision Risk

6.2 In Figure 3 shown below, the collision risk calculated for each FIR of the CAR/SAM Regions are presented during 2016. The Amazonas, Bogota, Guayaquil, Montevideo and Curacao FIR were the ones that suffered the risk above of the Target Level of Security (TLS).

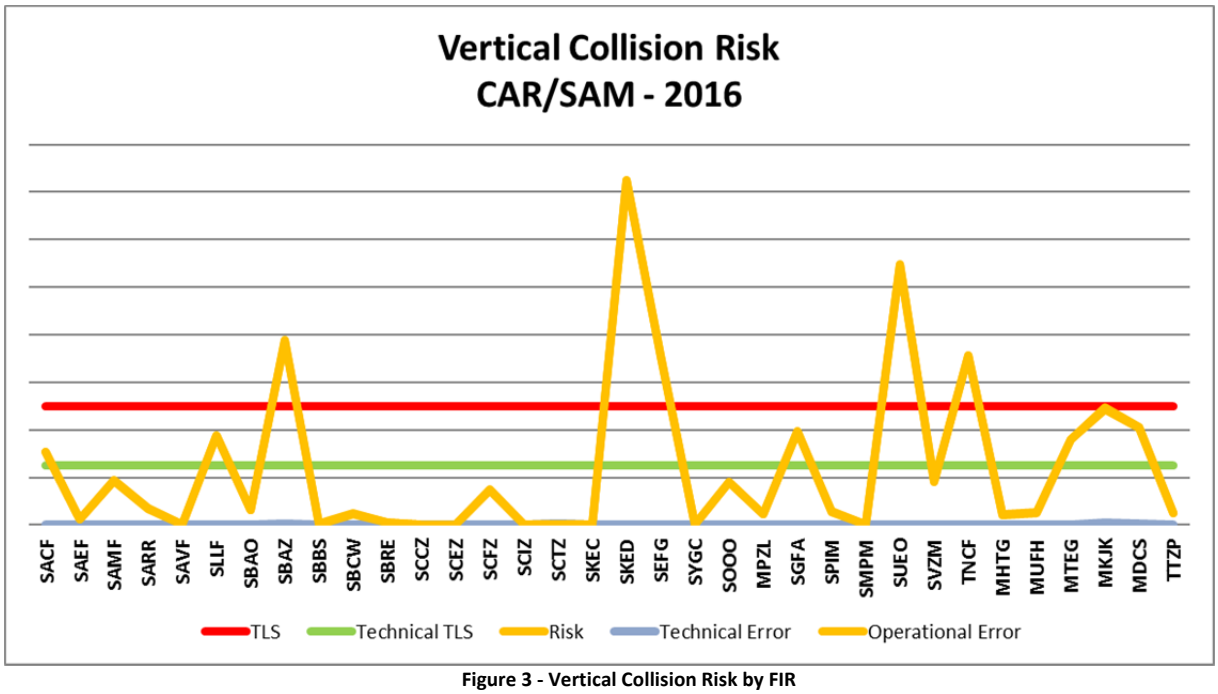

Figure 3 - Vertical Collision Risk by FIR

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

- Received 256,867 movements of aircraft that after processing validated 212,985 flight records. In relation to previous years, this use is satisfactory.
- Among the 212,985 validated movements, were identified at the end of an audit process done by CARSAMMA, with the support of the RMA and CAA of the CAR \ SAM regions, some aircraft whose registration does not appear in the RVSM approval database of CARSAMMA This could have been caused by:

  a) error in the F2 writing by the AAC;
  b) lack of sending to CARSAMMA of the F2 by the AAC;
  c) error in the writing of the F2 by CARSAMMA in the RVSM data bank; and
  d) or that the aircraft is NOT RVSM certified.

- In the CRM calculation, an uncertified aircraft using the RVSM airspace induces a significant increase in the risk of collision. A greater effort is needed by the CAAs and the ANSPs of the CAR \ SAM Regions for the correct use of the RVSM space.
- 1,065 LHD were considered valid during teleconferences of this year.
- The event duration parameter LHD (time) also has a negative influence on the calculation of CRM. FIR that have 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 FIR meets the objective that it must 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.
- In the case of the CAR/SAM Regions, the estimated average risk is 1.71 x 10-9 below the TLS, which is 5.0 x 10-9.

RVSM airspace CAR/SAM Flight Hours estimated = 1,160,614.66 hours			
Source of Risk	**Estimated Risk**	**TLS**	**Observation**
Technical Error	**0.0258 x 10-9**	**2.5 x 10-9**	**Below**
Operational Error	**1.686 x 10-9**	**-**	-
Risk	**1.71 x 10-9**	**5.0 x 10-9**	**Below**

Table 9

7. Suggested Actions

7.1 The Meeting is invited to:

a) take note and review the contents of this working document; and

b) share experiences and express opinions on the actions of CARSAMMA in this matter.

— END —