



Agenda Item 5: Collision risk assessment and LHD

d) Collision risk assessment: CARSAMMA, ARMA; SATMA

2021 VERTICAL COLLISION RISK (CRM) IN THE SBAO

(Prepared by CARSAMMA)

SUMMARY

This working paper presents a summary of the calculation of the vertical collision risk in the SBAO FIR for 2021, using the CRM methodology.

REFERENCES

ICAO Doc 9574 - AN/934. third edition - 2012
ICAO Doc 9937 - AN/477. first edition - 2012
Aircraft movements in RVSM airspace in 2021
Reports of large height deviations (LHD) in 2021

1. Background

1.1 This work aims to assess the vertical collision risk in the RVSM airspace of the Atlántico Flight Information Region (FIR) and demonstrate that the safety criteria established by ICAO Doc 9574 and Doc 9937 continue to be met in SBAO FIR.

1.2 This document reports on the analysis of vertical collision risk in RVSM airspace in 2021 in the Flight Information Region - FIR of Atlántico (SBAO). The vertical collision risk model (CRM) calculation methodology was used for this analysis, as recommended by ICAO for RVSM airspace.

1.3 The CRM calculation process involves two inputs: RVSM Air Movement files of the studied FIRs and LHD occurrences in these FIRs.

1.4 The validation of the LHD is carried out by CARSAMMA and the FIR involved throughout the year, bringing with it a better distribution of the analysis work. With the RVSM Air Movement files, there is a concentration of debugging work since all are delivered at the beginning of the current year. For this reason, all CARSAMMA members are allocated to debugging these files since most of the collected files are delivered outside the examples requested by this Agency, requiring time and effort to use at least 85% of the information sent.

1.5 However, the COVID-19 pandemic led to a significant drop in air transport activities and several restrictions taken throughout all regions, such as travel bans, travel restrictions, mandatory quarantines, etc., the air movements were significantly impaired, which led to an absence of statistically significant data for the year of 2021.

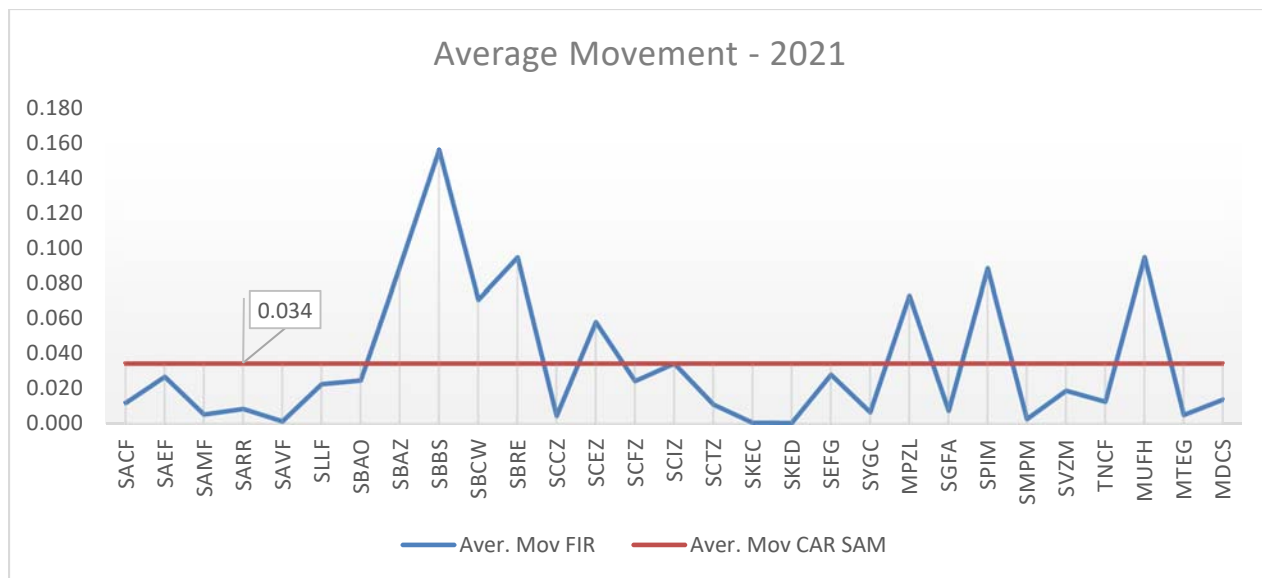


Table 1

Note 1: Five FIR RVSM movement could not be considered, due to non-receipt of data by CARSAMMA.

2. Analysis

2.1 According to ICAO Doc 9574 and Doc 9937, it is necessary to conduct an assessment to ensure that operations in RVSM airspace do not increase collision risk beyond the defined safety targets. This assessment aims to maintain the total vertical risk at an acceptable level.

2.2 ICAO recommends the Reich vertical collision risk model for the quantitative assessment. This model uses advanced mathematical calculations to analyze aircraft movements in RVSM airspace and determine the level of safety (TLS) for the studied FIR.

2.3 The RVSM safety assessment covers 12 consecutive months to provide a comprehensive and accurate picture of the risk level.

2.4 To ensure the continued safety of RVSM operations, it is crucial to focus on several key factors, including:

- a) Ensuring that all aircraft operating in reduced vertical separation minima airspace are RVSM-certified;
- b) Ensuring that aircraft certification is up-to-date;
- c) Maintaining the target level of safety (TLS) of 5×10^{-9} fatal accidents per flight hour for a representative sample of aircraft;
- d) Preventing an increase in risk due to operational errors and contingency procedures;
- e) Ensuring the stability of the aircraft altimetry system (ASE);
- f) Avoiding an increase in risk due to operational errors and flight contingencies, based on a predefined level of statistical confidence;
- g) Implementing additional safety measures to reduce the risk of collision due to operational errors and contingency procedures and meet safety goals; and
- h) Maintaining the effectiveness of air traffic control procedures.

3. CAR/SAM airspace

3.1 The CAR/SAM airspace covers a wide area from the Gulf of Mexico to Patagonia, encompassing 34 Flight Information Regions (FIRs) of the countries listed on the table below. Each part of the airspace was treated as an isolated system with its own statistical parameters.



Table 2 – CAR / SAM Airspace

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 - 2021, in the SBAO FIR. In the sample collected, 3.204 lines of flight records were received from the FIR. All records were purged, leaving 2.816 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 SBAO 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.

3.3 Regarding the occurrence of vertical deviations (LHDs) in the SBAO, CARSAMMA received a total of 5 LHD reports in 2021. After analysis and validation based in the Risk CRM parameters, 4 of these LHDs were considered valid in the CAR/SAM Regions. **These 4 LHDs are outside the EUROSAM Corridor, occurring at the Falkland/Malvinas Islands to the Ascension Island.**

3.4 Being that only 2 flight levels on these LHD were crossed, however, with a high time of wrong persistence in these levels (502 minutes) without bilateral contact with ATC.

3.5 In terms of comparison, we show below a table with the occurrences of LHD divided by the number of air movements per FIR, with the average CAR/SAM being **0.00046**.

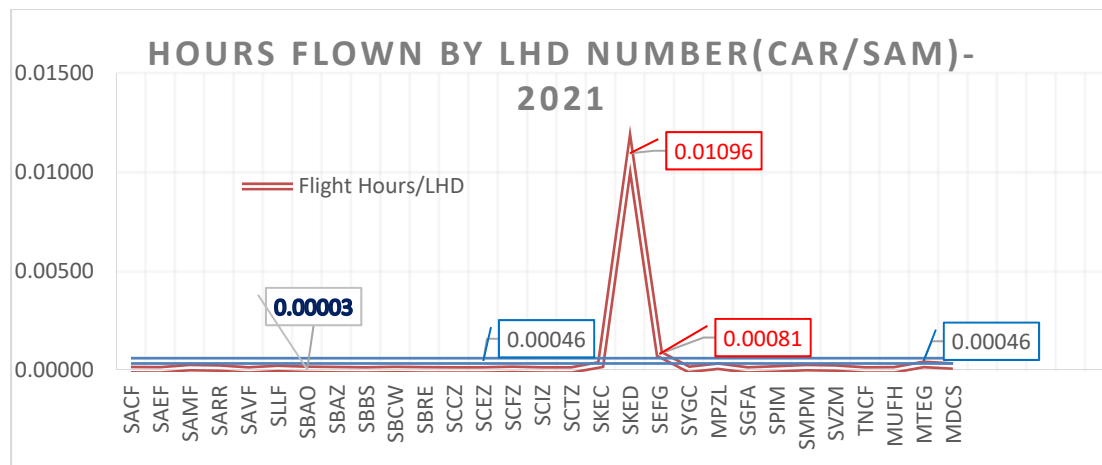


Table 3 – LHD by Movement

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 assessing vertical collision risk, were collected from December 1 to December 31, 2021.

4.2 Aircraft movement data received from the 29 CAR/SAM FIRs were processed and used to assess RVSM airspace safety, as recommended by ICAO.

4.3 CARSAMMA proceeded to its filtering and processing upon receiving the aircraft movement data. Table 4 shows the results and lists the aircraft that flew through the SBAO FIR, with the percentage by aircraft type used in the calculation model.

ACFT Type	# Flights	% ACFT
A339	411	14,6%
B789	392	13,9%
B77W	388	13,8%
A359	238	8,5%
A332	222	7,9%
B788	165	5,9%
B763	154	5,5%
B748	129	4,6%
B77L	119	4,2%
A35K	117	4,2%
A333	101	3,6%
A21N	90	3,2%
Others	290	10,3%
Total	2816	100,0%

Table 4 – Aircraft type that flew RVSM in SBAO FIR

5. Collision risk safety assessment (CRM)

5.1 This section analyses the results of the assessment of the collision risk in RVSM airspace of SBAO FIR

5.2 The internationally accepted collision risk methodology (CRM) has been used for the safety assessment of RVSM airspace in the SBAO FIR.

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 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 5.

Parameter	Description	Values
Λ_x	Average aircraft sample length	0.029081 nm
Λ_y	Aircraft Sample Mean Spread	0.027894 nm
Λ_z	Average height of the aircraft sample	0.008577 nm
$ \bar{V} $	Aircraft sample mean speed (modulus)	447.656 kt
$ \Delta V $	Relative speed of the same direction of the aircraft sample (module)	31.57 kt
$ \dot{y} $	Average speed relative to the transverse approach of the aircraft sample (modulus)	13 kts
$ \dot{z} $	Mean relative vertical speed during loss of vertical separation of aircraft sample (modulus)	1.5 kts
$P_z(0)$	Probability that two aircraft with the same nominal level overlap laterally in the aircraft sample	0.298265

Table 5 – RVSM parameters in the SBAO FIR

6. System performance specifications

6.1 Cc 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 considering aircraft flying in the same direction and in opposite directions, as shown in Table 6

SBAO	Same direction	Opposite direction	Equivalent
Pass frequency	0.009937	0.083167	0.058727

Table 6 – Pass frequency

6.2 Values are related to the CAR/SAM airspace system. It should be noted that the equivalent pass frequency shown in Table 6 (0.058727) was calculated based on flight hours in the 28 CAR/SAM FIRs

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

7. Estimating the collision risk

7.1 Table 7 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 SBAO FIR. All parameters were determined based on the airspace of SBAO FIR that is considered as an isolated system.

SBAO	Ez (same)	Ez (opposite)	Ez	ΔV (same)	ΔV (opposite)	V
	0.08277	0.02079	0.04113	31.5762	886.344	447.656 kt

Table 7 - Parameters

7.2 Table 8 shows the consolidated collision risk in the CAR/SAM FIRs in for 2021, showing the estimated vertical collision risk 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.

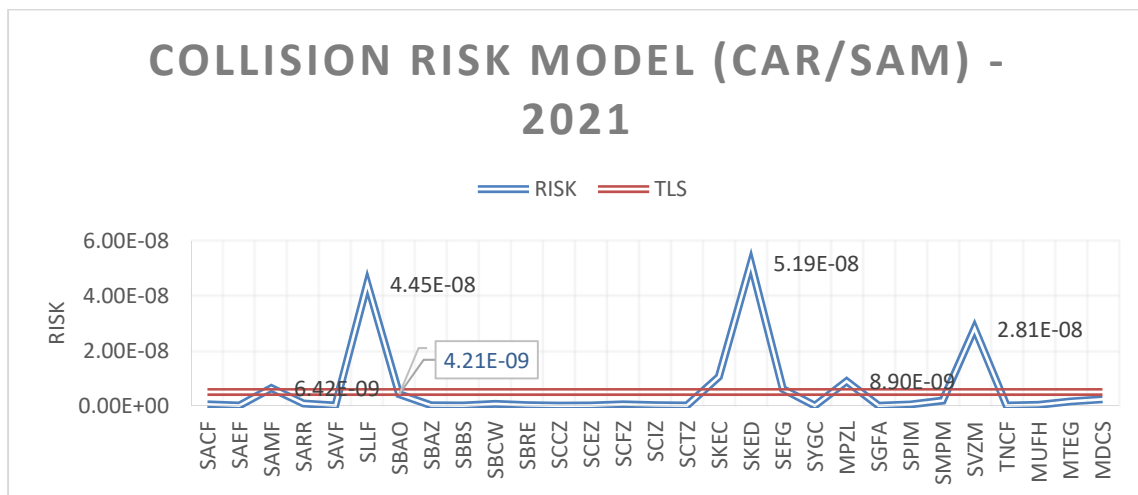


Table 8 – Vertical Collision Risk

8. Conclusions of the safety assessment (CRM)

8.1 The risk was estimated based on the FIR values presented in Table 9, which were obtained after processing all data received, compiled, and processed in the specific CRM software.

FIR	Vertical Risk
BRASIL – ATLANTICO - SBAO	4.21E-09
CAR	0.52E-09
SAM	3.09E-09
VERTICAL RISK CAR/SAM	2.76E-09

Table 9

8.2 The technical risk of the SBAO FIR 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.

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

8.4 The estimated total risk for the SBAO FIR is **4.21×10^{-9} below the TLS (5.0×10^{-9})**.

8.5 The presented study is founded on 2021 data. To perform an analogous study for 2022, CARSAMMA is appealing to the CAR/SAM Region States to furnish this monitoring agency with air traffic movement data for December 2022. CARSAMMA recognizes that everyone's cooperation is indispensable in advancing airspace safety.

9. Action by the meeting

9.1 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 SBAO FIR.