GTE/22 — WP/06
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CAR/SAM Planning and Implementation Regional Group (GREPECAS) Twenty Second Scrutiny Working Group Meeting (GTE/22)
Mexico City, Mexico, 26 to 30 September 2022

Agenda Item 4: **Activities and tasks to be reported to GREPECAS**
4.2 Review of tasks to be reported to GREPECAS

2021 AIRCRAFT ASE AND RVSM COLLISION RISK ANALYSES (CRM) IN THE CAR/SAM REGIONS

(Presented by CARSAMMA)

EXECUTIVE SUMMARY	
This working paper presents a summary of the calculation of the vertical collision risk in the CAR/SAM for 2021, using the CRM methodology.	
Action:	Suggested actions are included in Section 11.
Strategic Objectives:	• Safety
References:	• Doc 9574, Manual on a 300 m (1 000 ft) Vertical Separation Minimum Between FL 290 and FL 410 Inclusive. • 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. • 2021 Large Altitude Deviations (LHD) Reports. • Aircraft movements in RVSM airspace in 2021.

1. Introduction

1.1 In all regions where RVSM has been implemented, regional monitoring agencies (RMAs) have been established by the appropriate planning and implementation regional groups (PIRG) to satisfy the objectives of the RVSM monitoring program (ICAO Doc9574, paragraph 6.4.4 and 6.4.5 – Responsibilities of an RMA). One of the duties and responsibilities includes providing annual reports to the Planning and Implementation Regional Group.

1.2 The purpose of this working paper is to show that the safety criteria defined in ICAO Doc. 9574 and Doc. 9937 continue to be met in the CAR/SAM Regions.

2. Context

2.1 The vertical collision risk model (CRM) calculation methodology was used for this analysis, as recommended by ICAO for RVSM airspace.

2.2 The ICAO Collision Risk Methodology used to develop ICAO Doc 9574 global system performance specification, height keeping performance specification and aircraft height keeping performance requirements, consists of:

- Target Level of Safety (TLS) (=safety goal)
- Collision risk model (=risk estimation tool) and
- Agreed means to evaluate the risk.

2.3 The CRM calculation process involves two inputs:

a) Collect reports of large height deviations (LHD) and traffic sample data (TSD) from Air Navigation Service Providers (ANSPs) of the studied FIRs.
b) Results from aircraft height-keeping performance monitoring systems from regional monitoring systems and data-sharing with other RMAs.

2.4 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 the work of debugging these files, since most of the collected files are not delivered in accordance with the examples requested by this Agency, requiring time and effort to use at least 85% of information sent.

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

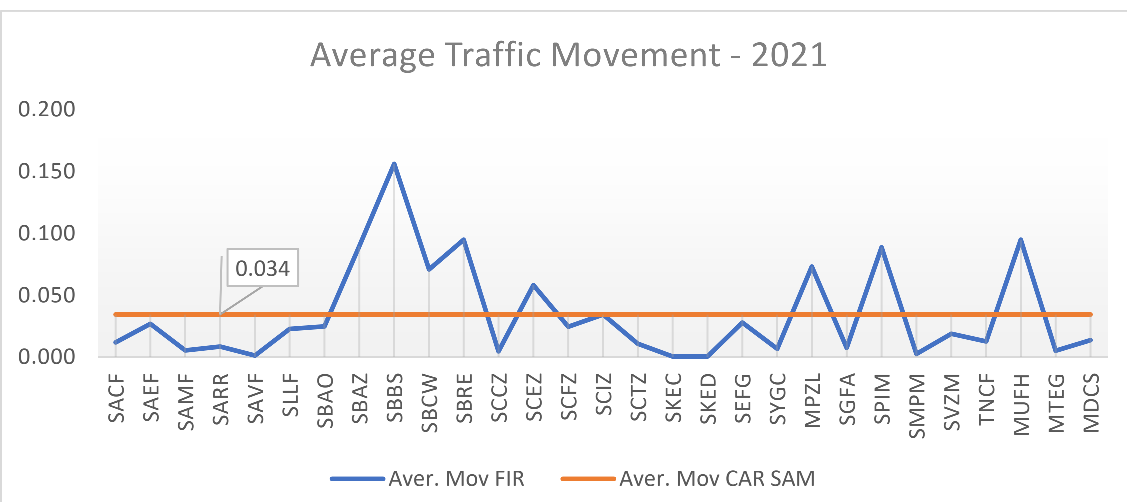

Table 1

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

3. Analysis.

3.1 According to Doc. 9574 and Doc. 9937, the assessment is required 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.

3.2 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.

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

3.4 Special attention should be paid to make sure that:

a) Technical risk, or the risk of collision associated with aircraft height-keeping performance, does not exceed a Target Level of Safety (TLS) of 2.5 x 10 -9 fatal accidents per flight hour (fapfh);
b) Overall risk, or the risk of collision due to all causes, which includes the technical risk and all risk due to operational errors, such as pilot/controller errors, does not exceed a TLS of 5 x 10 -9 fapfh;
c) All aircraft operating in reduced vertical separation minima airspace are RVSM-certified;
d) The use of RVSM does not increase the level of risk due to operational errors and contingency procedures.
e) There is evidence of the stability of the aircraft altimetry system (ASE);
f) 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;
g) Effective additional safety measures are adopted to reduce the risk of collision due to operational errors and contingency procedures and meet safety goals;
h) Air traffic control procedures continue to be effective.

4. CAR/SAM RVSM Airspace

4.1 The CAR/SAM airspace covers a wide area extending 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.

4.2 Among the various parameters used in the CRM calculation, we can highlight some, but not all, as for example in the FIR traffic samples:

- Traffic density on the airways each FIR (passage frequency);
- Single or dual-way airways;
- Crossing of airways, and the angle of this crossing;
- Typical size of aircraft;
- Average ASE of the aircraft in the sample of each FIR, according to the ASE Calculation database made by the CARSAMMA Altimetry Laboratory;
- “rogue” aircraft that flew in the FIR.

4.3 In addition to the use of 2021 LHD collection, and analyzed for obtaining Quantity, duration, severity and existence of other traffic during the event, in the FIR.

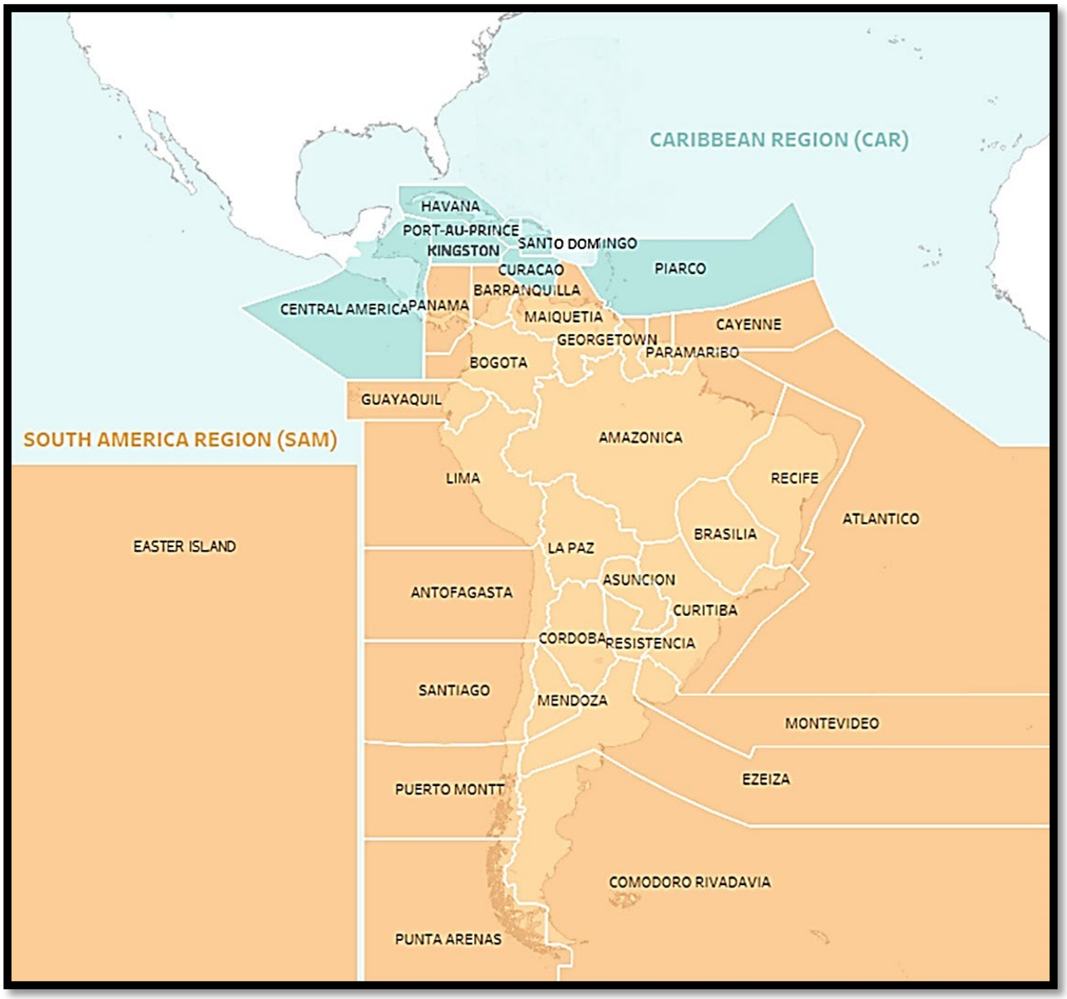

Figure 1 – CAR / SAM Airspace

5. Data collection, ASE Average, and Standard Deviation

5.1 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, 2021.

5.2 Upon receiving the aircraft movement data, CARSAMMA proceeded to filter and process the data received from the 29 FIR CAR/SAM, which were processed and used to assess the safety of the RVSM airspace, as recommended by the ICAO.

5.3 In the sample collected, 316,354 lines of flight records were received. All records were purged, leaving 243,349 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 could not be used in the CRM for several reasons, including errors in the entry/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.

5.4 Table 2 shows the results obtained and lists the aircraft that flew in CAR/SAM space, with the percentage, mean of the ASE, and the standard deviation, by type of aircraft to be used in the calculation model, as well as a typical aircraft.

ACFT Type	Lenght	Wingspan	Height	# Flight	% ACFT	ASE Average	ASE Standard Deviation	3 times (Standard Deviation)
B737NX	0.021166	0.018521	0.006803	44257	18.19%	12.3	43.52	130.56
A320	0.020286	0.018413	0.00635	23455	9.64%	39.9	53.69	161.06
A20N	0.020286	0.01933	0.00635	22035	9.06%	41.5	52.75	158.26
E190	0.019568	0.015507	0.005707	12430	5.11%	33.1	61.06	183.18
B787	0.030778	0.028078	0.009179	12338	5.07%	36	12.73	38.18
B767	0.033153	0.028024	0.009071	9134	3.75%	-29.1	56.91	170.73
B38M	0.021339	0.019384	0.006636	7623	3.13%	12.3	43.52	130.56
B737C	0.018898	0.018521	0.006749	6263	2.57%	7.1	65.43	196.28
A330	0.034341	0.032559	0.009087	5814	2.39%	81.9	38.07	114.21
B39M	0.022765	0.019384	0.006636	3459	1.42%	-14.7	19.48	58.43
A21N	0.024033	0.018413	0.00635	3420	1.41%	33.34	24.09	72.27
B77W	0.034395	0.034989	0.010043	3060	1.26%	11.00	25.92	77.76
B739	0.021328	0.018521	0.006749	2371	0.97%	23.39	52.38	157.14
B734	0.019708	0.015605	0.005994	2129	0.87%	-69.89	54.97	164.91
B772	0.034395	0.032883	0.009989	2104	0.86%	13.35	37.42	112.26
B733	0.017279	0.016199	0.006479	2068	0.85%	-14.95	56.47	169.41
B744	0.038175	0.034773	0.010475	1676	0.69%	-74.99	40.36	121.08
A359	0.036123	0.034557	0.009125	1462	0.60%	-30.56	23.26	69.78
A333	0.034341	0.032559	0.009098	1455	0.60%	9.53	30.05	90.15
A339	0.034374	0.034557	0.009066	1440	0.59%	6.68	18.52	55.56
Typical Aircraft	**0.026837**	**0.024539**	**0.007797**			**6.36**	**40.53**	**121.59**

Table 2 – Aircraft that flew in the RVSM CAR/SAM airspace, with average ASE

5.5 It should be noted that in addition to separating the various types of aircraft that used it in the aircraft movement sent by each FIR, a cross-check is made between this movement with the CARSAMMA ASE monitoring results database, to find the average ASE and the standard deviation of the ASE in the sample, because these parameters will be considered when calculating the vertical risk.

6. Occurrences of Vertical Deviations

6.1 Regarding the occurrence of vertical deviations (LHDs) in the CAR/SAM regions, CARSAMMA received a total of 520 LHD reports in 2021. After analysis and validation based in the Risk CRM parameters, 418 of these LHDs were considered valid in the CAR/SAM Regions.

6.2 Since 407 flight levels of these LHDs were crossed, with a high time of erroneous persistence in these levels (1,099 minutes) without bilateral contact with ATC. And even more importantly, 92 aircraft that are not in our RVSM database.

6.3 Just 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.

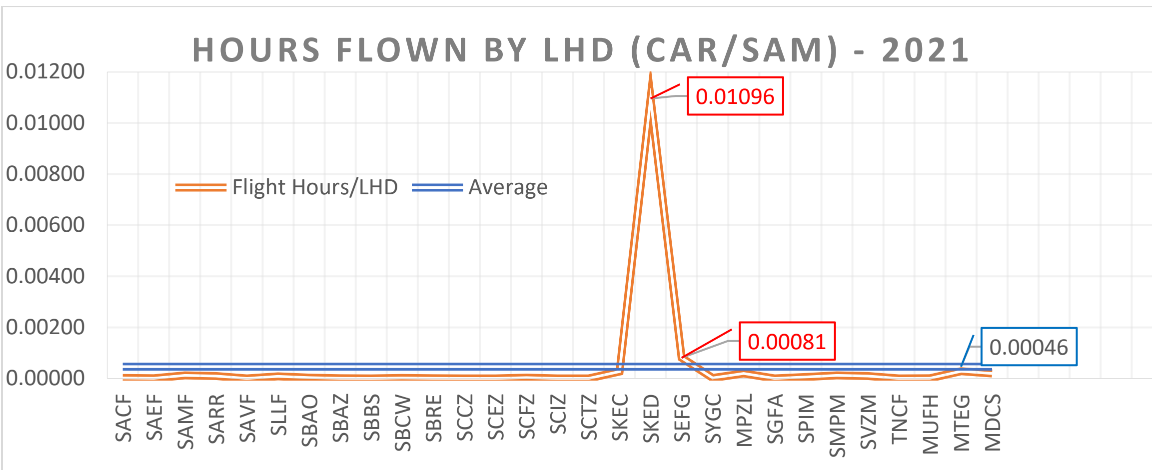

Table 3 – LHD by Movement

7. Collision risk safety assessment (CRM)

7.1 This section analyses the results of the assessment of the collision risk in RVSM airspace

7.2 The internationally accepted collision risk methodology (CRM) has been used for the safety assessment of RVSM airspace in the CAR/SAM.

7.3 Estimates of the CRM parameter: The estimate of vertical collision risk associated with RVSM is compared to the agreed RVSM safety goals.

- ***Safety Goal 1: Technical risk,*** *or the risk of collision associated with aircraft height-keeping performance, does not exceed a* ***Target Level of Safety (TLS) of 2.5 x 10-9 fatal accidents per flight hour (fapfh).***

"Technical risk" is the term used to describe the risk of collision associated with aircraft height-keeping performance. Some of the factors which contribute to technical risk are:

- *errors in aircraft altimetry and automatic altitude control systems;*
- *aircraft equipment failures resulting in unmitigated deviation from the cleared flight level, including those where not following the required procedures further increases the risk; and*
- *responses to false collision avoidance resolution advisories.*

One of vertical overlap probability parameter that take into account the ASE performance of the aircraft population **Pz(1000)**, is the probability that two aircraft nominally separated by 1 000 ft are in vertical overlap.

- *Safety Goal 2: Overall risk, or the risk of collision due to all causes, which includes the technical risk and all risk due to operational errors, such as pilot/controller errors - does not exceed a TLS of 5 x 10-9 fapfh.*
- *The term "operational error" is used to describe any vertical deviation of an aircraft from the correct flight level due to incorrect action by ATC or the flight crew.*

The other vertical overlap probability parameter that takes into account **Pz(0)**, is the probability that two aircraft flying at the same flight level are in vertical overlap.

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

Figure 2 – General formula of the REICH collision risk model

7.4 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	Mean length of the aircraft sample	0.026837 nm
λv	Mean wingspan of the aircraft sample	0.024539nm
λz	Mean height of the aircraft sample	0.007797 nm
$\lvert V \rvert$	Mean speed of the aircraft sample (module)	446.786 kt
$\lvert \Delta V \rvert$	Relative same-direction speed of the aircraft sample (module)	30.37 kt
$\lvert \dot{y} \rvert$	Mean speed relative to the transverse approach of the aircraft sample (module)	13 kt
$\lvert \dot{z} \rvert$	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 – RVSM parameters

8. System performance specifications

8.1 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 considering aircraft flying in the same direction and in opposite directions, as shown in Table 5.

Pass frequency	Same direction	Opposite direction	Equivalent
	0.009937	0.083167	0.058727

Table 5 – Pass frequency

8.2 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 29 CAR/SAM FIRs.

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

9. Estimating the collision risk

9.1 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 FIR. All parameters were determined based on the airspace of CAR/SAM FIR that is considered as an isolated system.

CAR/SAM	Ez (same)	Ez (opposite)	Ez	ΔV (same)	ΔV (opposite)	V
	0.08277	0.02079	0.04113	31.5762	886.344	446.786 kts

Table 6 – Parameters

9.2 The process to assess aircraft total vertical error (TVE) and estimate Pz(1000) and Pz(0) is the same. Data required:

- Assigned altitude deviation (AAD - radar data)
- Large Height Deviations (LHDs), including events due to turbulence and aircraft equipment failures
- Aircraft type population
- ASE performance for the aircraft observed in airspace.

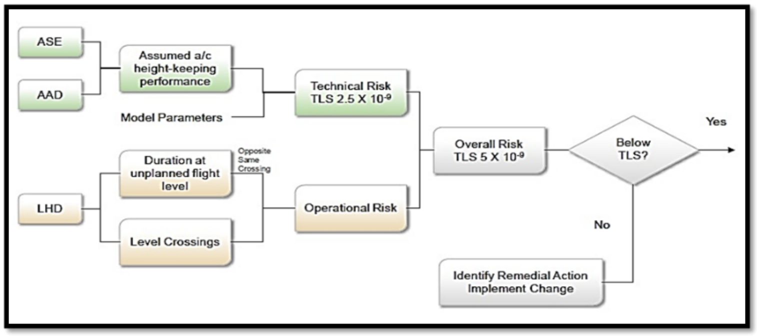

Figure 3 – Collision Risk Model (CRM) Monitoring Flow

9.3 Table 7 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 a higher LHD report have a higher risk.

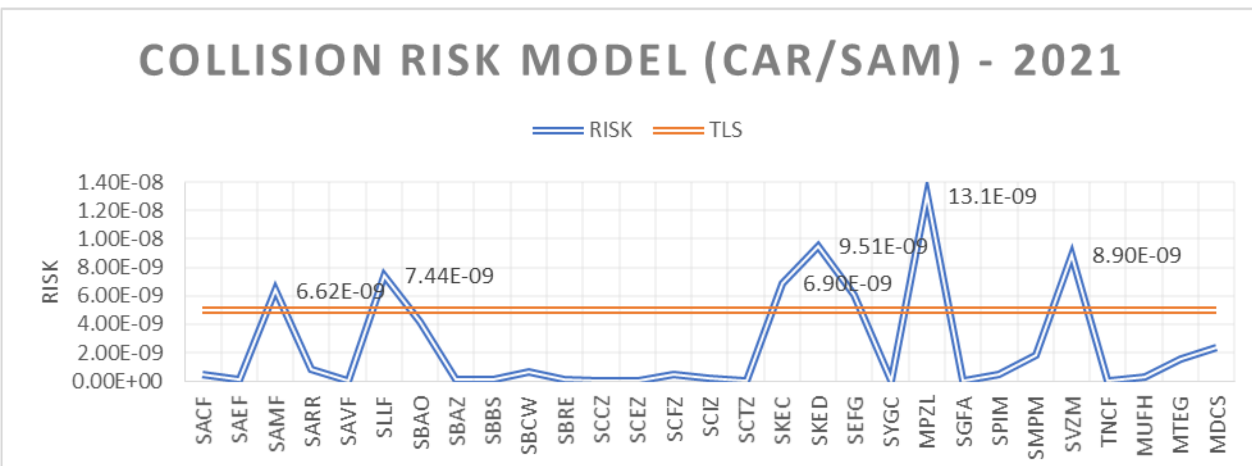

Table 7 – Vertical Collision Risk

10. Conclusions of the safety assessment (CRM)

10.1 The risk was estimated based on the FIR values presented in Table 8, which were obtained after processing all data received, compiled, and processed in the specific CRM software.

FIR	Vertical Risk
CAR	**0.52E-09**
SAM	**3.09E-09**
VERTICAL RISK CAR/SAM	**2.76E-09**

Table 8

10.2 The estimate of vertical collision risk associated with RVSM is compared to the agreed RVSM safety goals.

10.3 The technical risk of the CAR/SAM meets the TLS value, not exceeding 2.5 x 10-9 fatal accidents per flight our due to loss of the standard vertical separation of 1,000 ft and all other causes.

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

10.5 The estimated total risk for the CAR/SAM FIR is 2.76 x 10-9 below the TLS (5.0 x 10-9)

10.6 We show below the results of the last six years of vertical collision risk in our regions, in which we have noticed an increase trend.

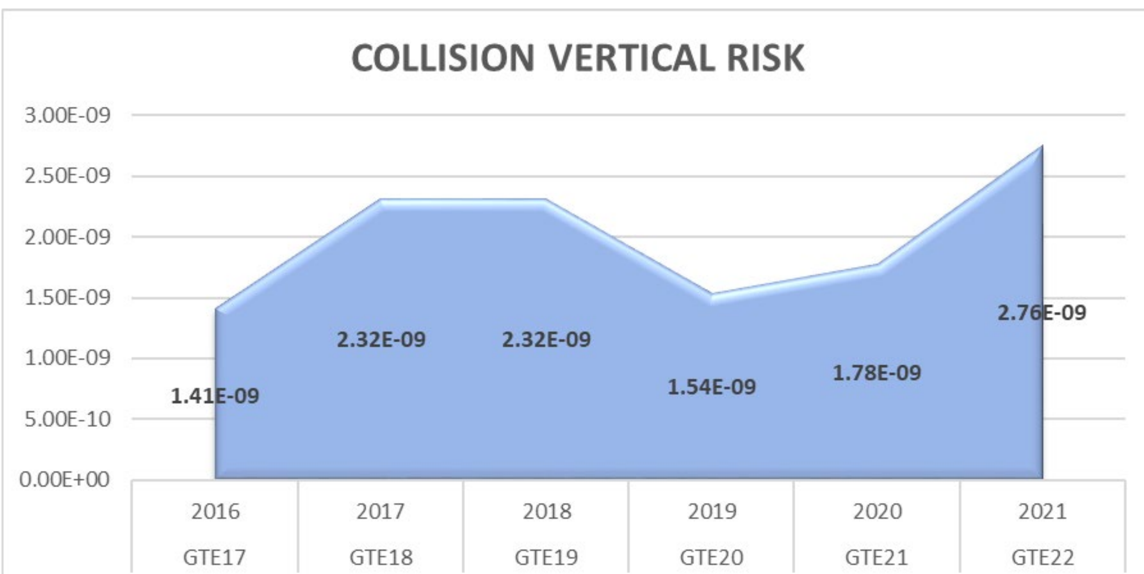

Table 9

11. Suggested actions

11.1 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) States/FIR are urged to give priority attention to addressing coordination failures between ACCs in order to enhance RVSM safety, including the implementation of awareness programs to mitigate human errors induced coordination failures, and conduct remedial actions to mitigate the risk.

— END —