INTERNATIONAL CIVIL AVIATION ORGANIZATION

Second Meeting of the Africa - Indian Ocean Aviation System Planning and Implementation Group (AASPG/2)

Livingstone, Zambia, 2 - 6 November 2026

Agenda Item 4: Implementation of air navigation goals, targets and indicators, including the priorities set in the regional air navigation plan

AFI Collision Risk Assessment

(Presented by ARMA)

SUMMARY
This working paper assesses collision risk associated with the continued use of the Reduced Vertical Separation Minimum (RVSM) in the Africa - Indian Ocean (AFI) Region. It addresses two AFI RVSM Safety Policy objectives: assessing technical vertical collision risk against a Target Level of Safety (TLS) of 2.5 × 10^{-9} fatal accidents per flight hour and assessing total vertical collision risk against a TLS of 5 × 10^{-9} fatal accidents per flight hour. The paper outlines the parameters of the ICAO-recommended Collison Risk Model (CRM) by Reigh. The average aircraft population of the AFI region and encourages States to continue providing ARMA with traffic sample data of their respective FIRs, also to report Large Height Deviations (LHDs) as they also form part of the required parameters to calculate Collision Risk Assessment (CRA) of the AFI RVSM airspace. Action by the Meeting is in paragraph 6

Strategic Goals	*Every flight safe and secure*

1. INTRODUCTION

1.1. This working paper presents a Collision Risk Assessment (CRA) for the continued use of the Reduced Vertical Separation Minimum (RVSM) in ICAO's Africa - Indian Ocean (AFI) Region. The assessment covers 27 flight information regions/upper information regions (FIR/UIRs).

1.2. The paper addresses two objectives of the AFI RVSM Safety Policy (Ref. 1):

- Assess technical vertical collision risk against a Target Level of Safety (TLS) of 2.5 × 10^{-9} fatal accidents per flight hour.
- Assess total vertical collision risk against a TLS of 5 × 10^{-9} fatal accidents per flight hour.

Consistent with the RVSM guidance material in reference 2 and previous assessments, both assessments use collision risk models appropriate for the AFI Region.

2. ASSESSMENT OF METHODOLOGY AND MONITORING REQUIREMENTS

2.1. Technical vertical collision risk is the risk of collision between aircraft at adjacent flight levels arising from normal, or typical, height deviations of RVSM-approved aircraft. This section describes how that risk is assessed in the AFI Region.

2.2. The quantitative assessment uses the ICAO-recommended Reich vertical collision risk model. The model applies mathematical analysis to aircraft movement data from RVSM flights to estimate the level of safety in the FIR under assessment.

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

2.4. Monitoring should confirm that the following requirements continue to be met:

- 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.

3. AFI AIRSPACE AND ASSESSMENT DATA

3.1. AFI RVSM airspace comprises the following 27 FIR/UIRs: Accra, Addis Ababa, Antananarivo, Asmara, Beira, Brazzaville, Cape Town, Dakar, Dar Es Salaam, Entebbe, Gaborone, Harare, Johannesburg, Johannesburg Oceanic, Kano, Kinshasa, Lilongwe, Luanda, Lusaka, Mauritius, Mogadishu, Nairobi, N'Djamena, Niamey, Roberts, Seychelles and Windhoek.
Algiers, Canaries, Dakar Oceanic, Sal Oceanic, Cairo, Khartoum, Tunisia, Tripoli and Casablanca are not part of AFI RVSM airspace.

3.2. Because Large Height Deviation (LHD) data were limited, an average LHD occurrence rate was estimated and applied to each FIR according to its traffic category. These assumptions produced an estimated 458 LHD events, with a cumulative duration of 1,750 minutes.

3.3. Aircraft movement data received from the 27 AFI FIRs were processed to assess RVSM airspace safety, as recommended by ICAO. The table below groups aircraft that operated in these FIRs by typical dimensions and provides representative aircraft types.

Aircraft Group	Typical Criteria (Dimensions)	Representative Aircraft
General	Length < **25 m**; Wingspan < **25 m**; Height < **10 m**	C500, C525, C560, CL60, FA20, FA50, GLEX, GLF series, LJ series, H25 series, TBM7
Regional Aircraft	Length **25-37 m**; Wingspan **19-31 m**; Height **6-11 m**	AT72, AN72, CRJ1/2/7/9, CRJX, E135, E145, E170,

		J328, RJ85, F70, F100, B190
Narrow-Body Aircraft	Length **30-46 m**; Wingspan **27-37 m**; Height **7-14 m**	A318, A319, A320, A321, B721, B722, B732-B739, DC92, DC93, E190, MD81-MD87
Medium Wide-Body Aircraft	Length **45-65 m**; Wingspan **36-61 m**; Height **12-19 m**	A300, A310, A330, A340-200/-300/-500, B752, B753, B762, B763, B764, B772, B77L, B788, B789, DC10, MD11, L1011
Heavy Wide-Body Aircraft	Length **> 64 m** or Wingspan **> 60 m**	A340-600, A350-900, A380, B747 family, B773, B77W
Heavy Cargo / Military Aircraft	Large cargo aircraft requiring dedicated handling facilities; typically wingspan **> 48 m** and/or specialised apron requirements	A124, C17, C130, IL76

Table 1. Aircraft groups, typical dimensions and representative aircraft

4. COLLISION RISK MODEL AND DATA LIMITATIONS

4.1. This section describes the model, parameters and data requirements used to assess collision risk in AFI RVSM airspace.

4.2. The internationally accepted collision risk methodology (CRM) has been used for the safety assessment of RVSM airspace in the AFI region.

4.3. **REICH COLLISION RISK MODEL**

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

Figure 1. Reich vertical collision risk model

4.3.1. The table below summarises the parameters, descriptions and values used in the collision risk model (CRM) to assess RVSM airspace safety.

Parameter	Description	Values
Sz	The vertical separation minimum, i.e. the vertical spacing between adjacent flight levels	1 000
Pz(Sz)	The probability of vertical overlap for aircraft nominally flying at adjacent flight levels	1.93×10^{-9}
Py(0)	The probability of lateral overlap for aircraft nominally flying on the same route	0.12
nx(same)	The frequency with which same-direction aircraft at adjacent flight levels of the same route enter into longitudinal overlap	0.0700
nx(opp)	The frequency with which opposite-direction aircraft at adjacent flight levels of the same route enter into longitudinal overlap	0.0019
$\|\Delta V\|$	The average of the absolute value of the relative along-track speed between two same-direction aircraft flying at adjacent	13

	flight levels of the same route	
V	The average ground speed of a typical aircraft	480
$\|y\|$	The average of the absolute value of the relative cross-track speed between two typical aircraft flying at adjacent flight levels of the same route	5.0
$\|z\|$	The average of the absolute value of the relative vertical speed between two typical aircraft which have lost Sz feet of vertical separation	1.5
λx	The average length of a typical aircraft	0.00785
λy	The average width of a typical aircraft	0.01880
λz	The average height of a typical aircraft	0.00640

Table 2. Collision risk model parameters and values

4.4. TECHNICAL FEASIBILITY OF RVSM IN THE AFI REGION

4.4.1. Assessing technical feasibility involves evaluating the following Reich model parameters:

- Pass frequency **Nx;**
- Probability of vertical overlap, **Pz (1000)**.

To demonstrate this, the following objectives were established:

- Build confidence that the technical TLS is achieved; and
- Certify ASE stability.

VERTICAL OVERLAP AND TOTAL VERTICAL ERROR

4.5. The probability of vertical overlap $Pz(Sz)$ for aircraft flying at adjacent flight levels (separated by Sz) of the same route or intersecting routes is calculated from the probability distribution of normal, or typical height deviations of RVSM approved aircraft. These aircraft height deviations are usually defined in terms of Total Vertical Error (TVE)

4.5.1. The figure below illustrates the components of Total Vertical Error (TVE).

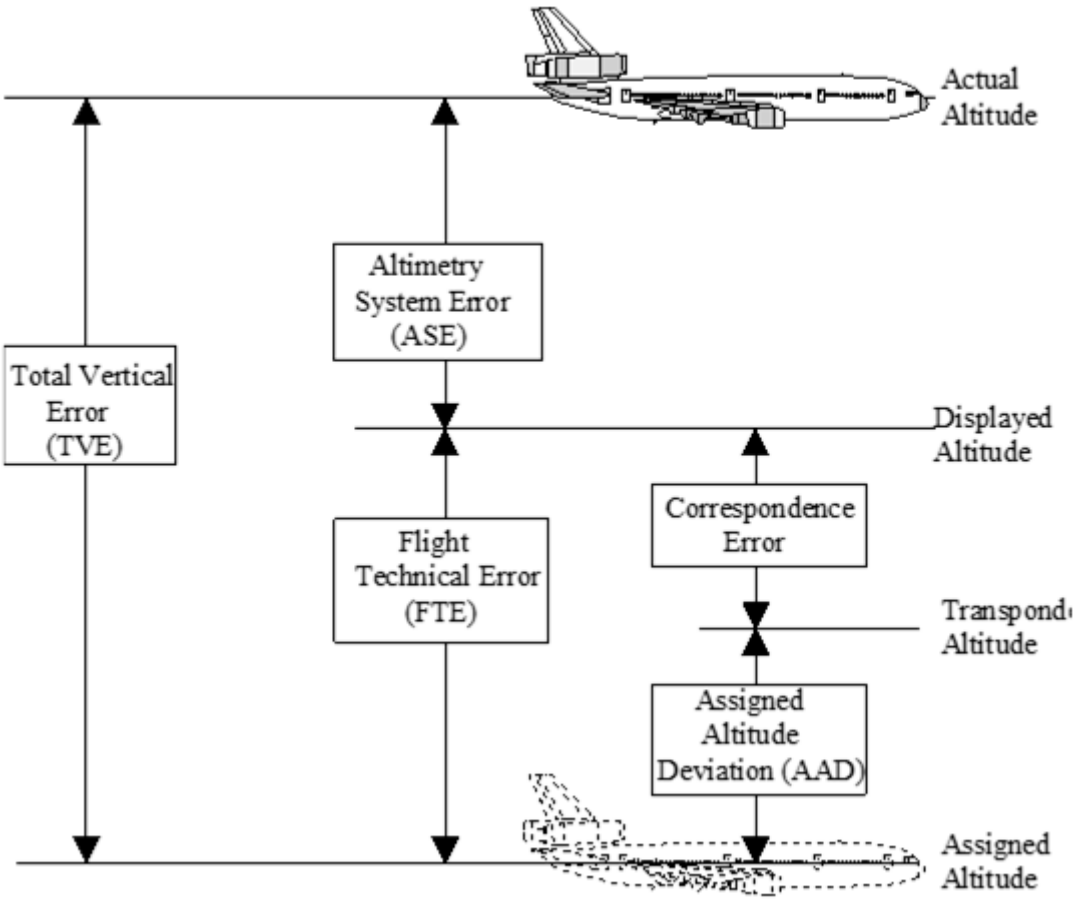


Figure 2. Components of Total Vertical Error (TVE)

4.6. **DATA LIMITATIONS AND REPORTING REQUIREMENTS**

4.6.1 A representative estimate of technical vertical collision risk in AFI RVSM airspace requires comprehensive traffic flow data covering all flights on all routes from FL290 to FL410 inclusive. Collected through ARMA Form 4, these data support estimates of total flight hours within this band and the number of horizontal passing events by type.

4.6.2. Assessing longitudinal passing events using ARMA Form 4 requires complete flight progress data: waypoint identifiers, crossing times and associated flight levels. Because passing events may occur within any route segment, crossing times are needed at consecutive waypoints. Flight progress data should therefore cover every waypoint along each aircraft's trajectory within the FIR/UIR so that all potential conflict scenarios are captured.

CONSOLIDATED COLLISION RISK RESULTS

4.7. The figure below presents consolidated collision risk results for AFI FIRs for 2025, including estimated vertical collision risk by year and FIR. FIRs submitting LHD reports show higher risk estimates; however, the paper notes that these events frequently arise from failures in adjacent FIRs.

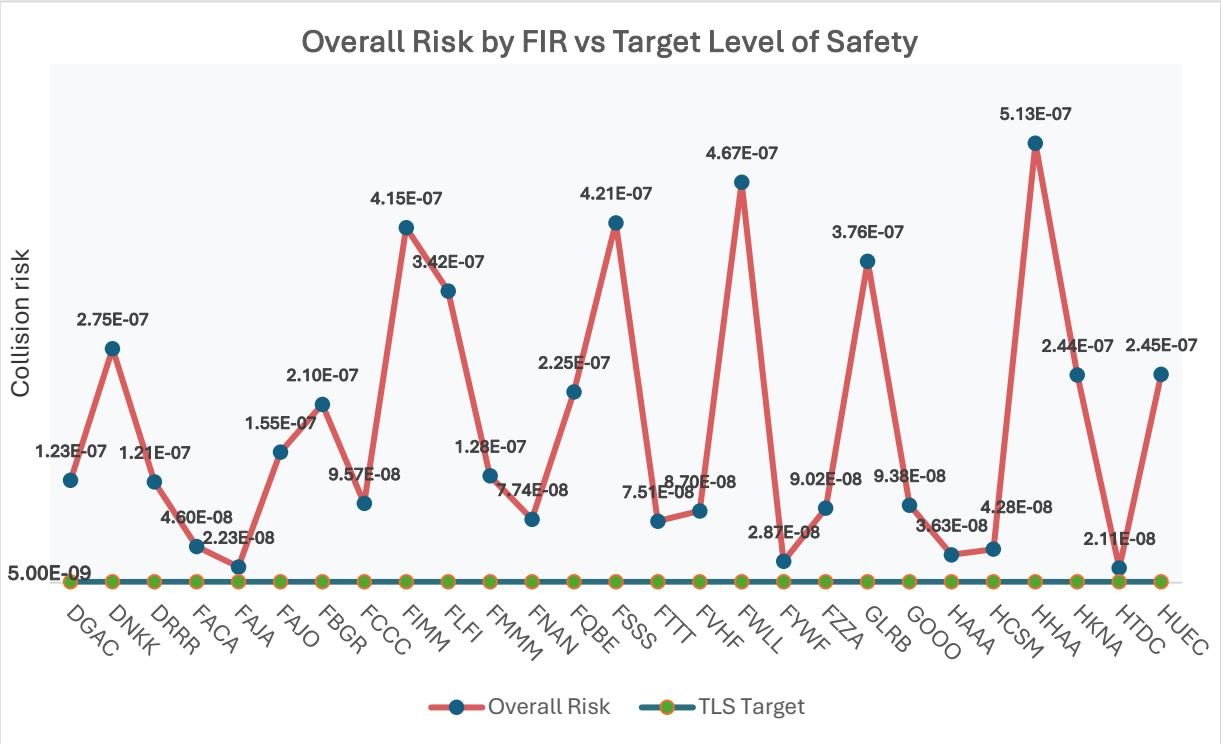


Figure 3. Consolidated collision risk results for AFI FIRs, 2025

5. SAFETY ASSESSMENT RESULTS AND CONCLUSIONS

5.1 The FIR risk values in the table below were derived by compiling, processing and analysing all available traffic data. Where data were incomplete or unavailable, estimates were based on established traffic patterns and FIRs with comparable operational characteristics.

December traffic data were selected because December is generally among the busiest months of the year. This sample provides a conservative representation of the maximum risk that may occur in the assessed airspace.

FIR	Total Technical Risk	Total Operational Risk	Overall Risk
Accra	2.37E-11	1.23E-07	**1.23E-07**
Addis Ababa	2.37E-11	3.63E-08	**3.63E-08**
Antananarivo	2.37E-11	1.28E-07	**1.28E-07**
Asmara	2.38E-11	5.13E-07	**5.13E-07**
Beira	2.37E-11	2.25E-07	**2.25E-07**
Brazzaville	2.37E-11	9.57E-08	**9.57E-08**
Cape Town	2.37E-11	4.60E-08	**4.60E-08**
Dar es Salaam	2.37E-11	2.11E-08	**2.11E-08**
Dakar	2.37E-11	9.37E-08	**9.38E-08**
Entebbe	2.37E-11	2.45E-07	**2.45E-07**
Gaborone	2.37E-11	2.10E-07	**2.10E-07**
Harare	2.37E-11	8.69E-08	**8.70E-08**
Johannesburg	2.37E-11	2.22E-08	**2.23E-08**
Johannesburg Oceanic	2.37E-11	1.55E-07	**1.55E-07**

Kano	2.38E-11	2.75E-07	**2.75E-07**
Kinshasa	2.37E-11	9.02E-08	**9.02E-08**
Lilongwe	2.38E-11	4.67E-07	**4.67E-07**
Luanda	2.37E-11	7.74E-08	**7.74E-08**
Lusaka	2.38E-11	3.42E-07	**3.42E-07**
Mauritius	2.38E-11	4.15E-07	**4.15E-07**
Mogadishu	2.37E-11	4.28E-08	**4.28E-08**
Nairobi	2.37E-11	2.44E-07	**2.44E-07**
N'Djamena	2.37E-11	7.51E-08	**7.51E-08**
Niamey	2.37E-11	1.21E-07	**1.21E-07**
Roberts	2.38E-11	3.76E-07	**3.76E-07**
Seychelles	2.38E-11	4.21E-07	**4.21E-07**
Windhoek	3.53E-12	2.87E-08	**2.87E-08**
AFI FIR	Technical Risk	Operational Risk	**Risk**
	3.49E-12	1.03E-08	**1.03E-08**

Table 3. Technical, operational and overall collision risk by FIR

TECHNICAL AND OPERATIONAL RISK

5.2 The technical risk of the AFI FIRs meets the TLS value, not exceeding 2.5 x 10^{-9} fatal accidents per flight hours due to loss of the standard vertical separation of 1,000 ft and all other causes. The operational risk does not have a predefined limit, in accordance with ICAO Doc 9574.

TOTAL RISK AND COMPARISON WITH THE PREVIOUS ASSESSMENT

5.3 The estimated total collision risk for the assessed FIRs is 1.03 × 10^{-8}. This is above the TLS of 5.0 × 10^{-9}, or approximately 2.1 times the TLS. Compared with the previous assessment period, the estimated risk has decreased by a factor of approximately 7, indicating a significant improvement in the assessed safety performance. The paper attributes this improvement primarily to the availability and sharing of more operational data, which made the estimates more representative and reduced reliance on conservative assumptions.

AFI RVSM airspace **Estimated annual flight hours** = 1 843 643 **(Note: Estimated time based on December 2025 sample)**			
Source of risk	**Estimated risk**	**TLS**	**Comments**
Technical risk	**3.49 × 10^{-12}**	**2.5 x 10^{-9}**	below
Operational risk	**3.49 × 10^{-9}**	-	
Total risk	**1.03 × 10^{-8}**	**5.0 x 10^{-9}**	Above

Table 4. AFI RVSM collision risk estimates and Target Levels of Safety

6. ACTION BY THE MEETING

6.1 The meeting is invited to:

- note and review the contents of this working paper;
- enhance data reporting and sharing across AFI FIRs to support more reliable safety assessments; and
- implement measures to reduce LHDs and enhance safety performance across AFI FIRs.