International Civil Aviation Organization

The 17th Meeting of the Regional Airspace Safety Monitoring Advisory Group (RASMAG/17)

Bangkok, Thailand, 28 – 31 August 2012

Agenda Item 3: Reports from Asia/Pacific RMAs and EMAs

KABUL FIR RVSM POST-IMPLEMENTATION STUDY

(Presented by the United States Air Forces Central (AFCENT) on behalf of the Ministry of Transport and Civil Aviation (MoTCA) of the Government of the Islamic Republic of Afghanistan (GIRoA)

SUMMARY

This paper presents the results of a post-implementation assessment of the upper levels of the Kabul Flight Information Region (FIR) based on International Civil Aviation Organization (ICAO) requirements for implementation of Reduced Vertical Separation Minimum (RVSM).

This paper relates to –

Strategic Objectives:
*A: **Safety** – Enhance global civil aviation safety*

Global Plan Initiatives:
GPI-2 Reduced vertical separation minima

1. INTRODUCTION

1.1 The United States (U.S.) Air Forces Central (AFCENT), Combined Forces Air Component Commander (CFACC) currently manages the Afghan airspace on behalf of the Government of the Islamic Republic of Afghanistan (GIRoA). A number of initiatives are underway to improve the civil aviation sector in Afghanistan, including the November 2011 implementation of RVSM within the Kabul FIR.

1.2 The ICAO guidance for RVSM implementation, as prescribed in ICAO Doc 9574 AN/934, *Manual on Implementation of a 300m Vertical Separation Minimum Between FL 290 and FL 410 Inclusive* [ICAO, 2002] calls for 90-day and 1-year post-implementation assessments to ensure the validity of pre-implementation assumptions and analyses. This report fulfills ICAO's safety assessment requirement for the 90-day post-implementation monitoring of RVSM in the Afghanistan airspace.

2. DISCUSSION

2.1 A safety assessment was conducted to determine whether the collision risk posed by the introduction of RVSM meets Target Levels of Safety (TLS) prescribed by ICAO. The assessment consisted of a quantitative assessment of the probability of a collision resulting from the loss of vertical separation during RVSM operations in the Kabul FIR based on guidance contained in the ICAO Doc 9574 [ICAO, 2002], and a qualitative assessment of the unique hazards associated with the introduction of RVSM operations in Afghanistan, and their respective mitigations. This paper presents the results of the quantitative safety assessment (**Attachment 1**).

2.2 The assessment for Afghanistan, using December 2011 Traffic Sample Data (TSD) from the region, produced an estimate for the technical risk due to loss of vertical separation, of 1.94×10^{-9} fatal accidents per flying hour. Additionally, a conservative estimate for technical vertical risk was calculated using the nominal TLS value for the probability of vertical overlap, yielding a conservative estimate for technical vertical risk of 2.09×10^{-9} fatal accidents per flying hour. Both estimates are within the stipulated TLS of 2.5×10^{-9} fatal accidents per flying hour.

3. ACTION BY THE MEETING

3.1 The meeting is invited to note the results of the post-implementation safety assessment presented in this working paper:

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Attachment 1: Post-implementation Study of Reduced Vertical Separation Minimum for the Kabul Flight Information Region

Presented by The United States Air Forces Central (AFCENT) on behalf of the Ministry of Transport and Civil Aviation (MoTCA) of the Government of the Islamic Republic of Afghanistan (GIRoA)

1 INTRODUCTION

1.1 A 90-day post-implementation safety assessment was conducted to determine whether the collision risk posed by the introduction of RVSM meets Target Levels of Safety (TLS) prescribed by ICAO. Additionally, an assessment of the hazards to aircraft operations that are unique to the use of RVSM in Afghanistan airspace and potential mitigations to these hazards was performed to fully consider the safety implications associated with the introduction of RVSM. The assessment for Afghanistan estimated the technical risk for fatal accidents per flying hour due to loss of vertical separation to be 1.94 x 10^{-9}. The estimate is within the stipulated TLS of 2.5 x 10^{-9} fatal accidents per aircraft flying hour.

1.2 The safety study consisted of both quantitative and qualitative assessments. The quantitative assessment addressed the acceptability of collision risk posed by RVSM implementation using the methodology prescribed by ICAO Doc 9574 [ICAO, 2002] given the prevalent operational environment at the time of RVSM the study was undertaken. The qualitative assessment was based on a thorough review of previously identified hazards with attention to the unique characteristics of the introduction of RVSM in Afghanistan.

1.3 The airspace considered as part of this study (referred to as "study airspace") included Class A airspace in the Kabul FIR, which, as shown in **Figure 1-1**, is the airspace between FL290 and FL410 inclusive encompassing a 10 Nautical Mile (NM) width on either side of the centerline of published upper level Air Traffic Service (ATS) routes [CFACC, 2011].

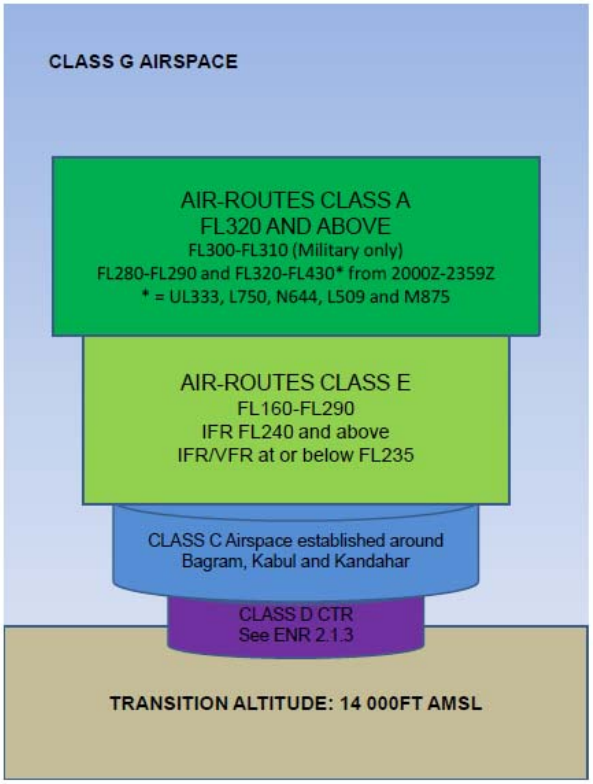

Figure 1-1. Airspace Classes within the Kabul FIR (Source: Afghanistan AIP)

1.4 Description of the Afghanistan Airspace

1.4.1 The implementation of RVSM introduced six additional flight levels to the civil air traffic routes in the Kabul FIR. The current ATS route structure in the study airspace includes six routes depicted in figure 1-2, namely UL333, N636/P628, L750, N644, M875/L509 and M881. The most used routes are N644, L750, and M875.

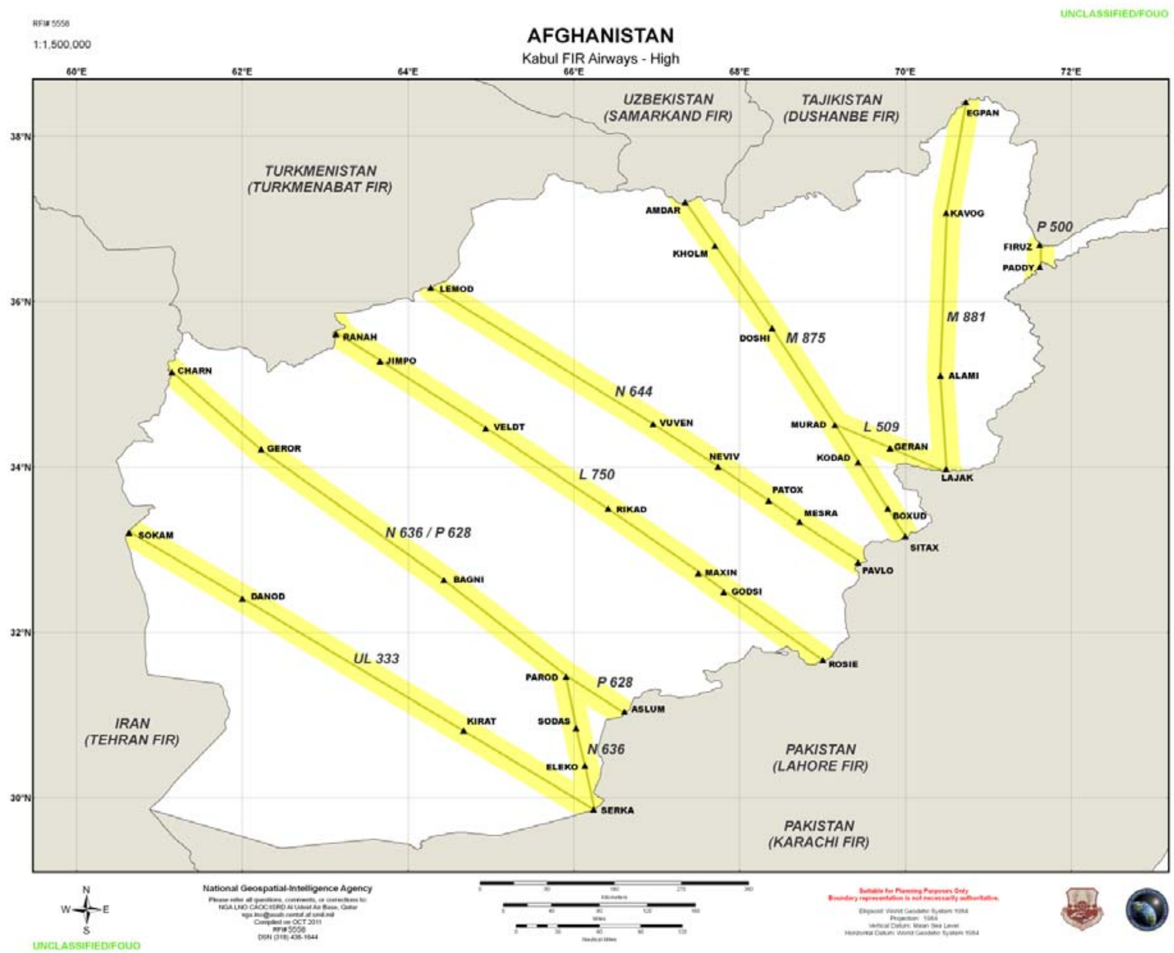

Figure 1-2. Upper ATS Routes within Kabul FIR

1.5 Reduced Horizontal Separation

1.5.1 The Bay of Bengal Reduced Horizontal Separation (RHS) Task Force (BOB-RHS/TF) held a meeting in February 2011, where an agreement was reached to undertake specific initiatives to reduce longitudinal separations over the Bay of Bengal. As part of these initiatives, the dependency between ATS routes M875 and N644 was relaxed.

1.6 Multilateration

1.6.1 Afghanistan enroute controllers currently employ procedural methods to separate traffic. Knowledge of aircraft position comes from controller-pilot communications at entry/exit points and mandatory reporting points, and, in some limited cases, from adjacent FIRs with radar overlap into the Kabul FIR. In an effort to improve surveillance within the Kabul FIR, a MLAT system is currently scheduled to be deployed at Kabul Area Control Center (KACC). MLAT is a technology developed to accurately locate the position of aircraft. MLAT ground stations receive replies from all transponder-equipped aircraft, including legacy radar and Automatic Dependent Surveillance Broadcast ADS-B avionics, and determine aircraft position based on the Time Difference of Arrival (TDOA) of the replies. Once established, MLAT will enhance the provision of Air Traffic Management (ATM) at KACC in a variety of applications, from "radar-like" air traffic control purposes to enhanced situational awareness of surface movements. MLAT applications will have a direct effect upon aerodrome operations, traffic synchronization, airspace user operations, and conflict management. These effects will then influence the nature of airspace organization and management, demand and capacity balancing, and ATM service delivery management.

2 DATA SUBMISSION

2.1 Traffic Sample Data (TSD)

2.1.1 The safety assessment was based on traffic sample data for the month of December 2011 provided by KACC. The data consisted of approximately 8000 physical flight strips which were manually transcribed into a digital log containing individual records for each flight with the following fields: flight number, registration number, origin airport, destination airport, planned departure time, aircraft type, ATS route in the Kabul FIR, entry time into the Kabul FIR, entry flight level, exit time from the Kabul FIR and exit flight level. This transcription exercise was undertaken by KACC. Since the flight strips contain manual entries which were then manually transcribed into the digital data log, a data review exercise was undertaken to delete irrelevant information and to correct obvious errors.

2.2 Large Height Deviation (LHD) Data

2.2.1 KACC has been submitting formal reports of LHDs since June 2010. In the Afghanistan case, only two LHDs were reported within the past 24 months. One of these was filed in November 2010 and was caused by a TCAS RA. In response, flight-crew descended 300 feet in compliance with the RA and returned to the cleared flight level (FL310) after 2 minutes. Based on ICAO classification of LHD events, this is a Category J LHD event and is not considered to be a risk-bearing deviation. The second of these occurred in January 2011 at FL280 and was due to coordination errors in the ATC-to-ATC transfer of control responsibility as a result of human factors issues (Category E). While Category E LHDs are considered risk-bearing based on ICAO guidance, this single event is insufficient for calculation of an operational risk estimate. Instead, analysts derived the allowable portion of total vertical risk that could be allocated to operational risk without exceeding overall safety targets; this approach is described in paragraph 3.4.

3 ESTIMATE OF VERTICAL COLLISION RISK FOR THE AFGHANISTAN AIRSPACE

3.1 Objective

3.1.1 The objective of the quantitative portion of the safety assessment is to determine the acceptability of collision risk posed by RVSM implementation using the methodology in ICAO Doc 9574 [ICAO, 2002] given the prevalent operational environment expected at the time of RVSM implementation (discussed in Section 1.5). The results of the quantitative assessment present best estimates based on the available data and are considered to be adequate for use in the post-implementation safety assessment.

3.2 Methodology

3.2.1 Figure 3-1 describes the specific components of total vertical risk that were calculated. In generic terms, the total vertical risk comprised the technical vertical risk calculated as the risk due to loss of the planned vertical separation of 1000 feet in an RVSM environment. This was calculated using the ICAO CRM model, the details of which are provided in Appendix A. The calculated technical vertical risk was compared against the total vertical risk to yield an estimate of the allowable portion of the total vertical risk that may be allocated to operational risk.

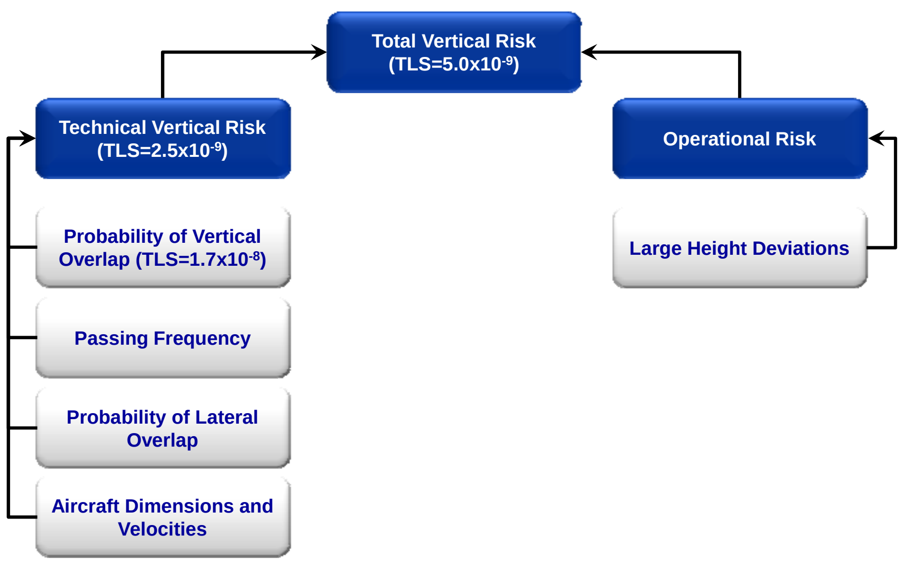

Figure 3-1. Safety Assessment Methodology

The following sections provide more details on the assessment of vertical collision risk.

3.3 Technical Vertical Risk

3.3.1 Technical vertical risk was calculated as aircrafts' ability to maintain assigned altitudes and accounts for deviations of less than 300 feet due to any cause. The following are the contributors to technical vertical risk:

1. Probability of vertical overlap, calculated as the probability that two aircraft will lose procedural vertical separation of 1000 feet

2. Passing frequency, calculated as the frequency of events in which two aircraft are in longitudinal overlap when travelling in the opposite or same direction on the same track at adjacent flight levels. While exact time and position of flight level changes were unknown, conservative estimates were used to address their impact on passing frequency.

3. Probability of lateral overlap, calculated as the likelihood that two aircraft on the same track have lateral positions that differ by less than one aircraft width.

4. Aircraft dimensions and velocities, which are represented by mean values from the traffic population.

3.3.2 Contrary to many of the contributors to technical vertical risk, such as those dependent on aircraft performance or fleet mix, the passing frequency was substantially influenced by the implementation of RVSM. The introduction of new flight levels allowed a greater spread of traffic with fewer interactions between adjacent flight levels. The passing frequency was reduced by more than 25% from pre-implementation levels.

The most noticeable change was evident during BOBCAT hours (2000-2359 UTC) when there is a significant westbound swell of traffic through the Kabul FIR. Figure 3-2 depicts passing frequency versus the time of day for the pre-implementation (October 2010) and post-implementation (December 2011) TSD. The pre-implementation TSD reflects the spike in traffic congestion during BOBCAT hours, while the congestion is mitigated by the addition of flight levels during post-implementation.

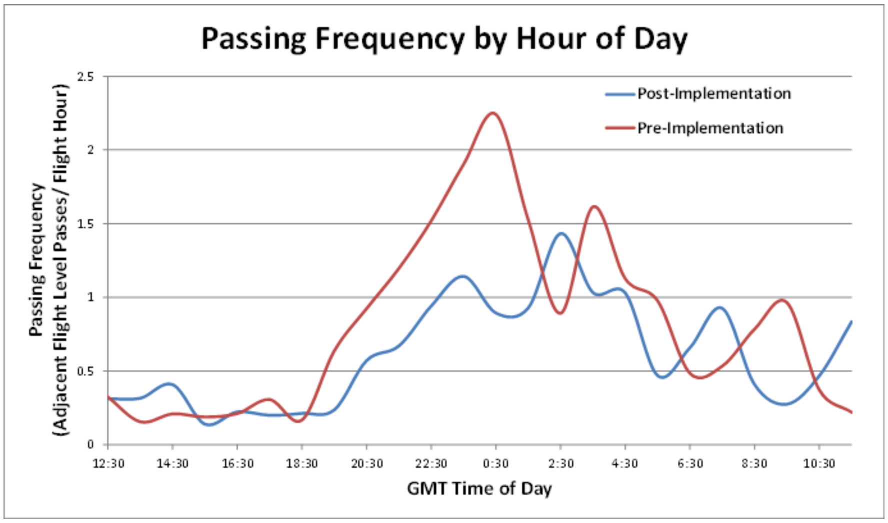

Figure 3-2. Passing Frequency by Hour of Day (Centered on BOBCAT hours 2000-2359 UTC)

3.3.3 The quantitative assessment used the December 2011 TSD from the Afghanistan airspace, yielding an estimate for technical vertical risk of 1.94 x 10^{-9} fatal accidents per aircraft flying hour. To test the sensitivity of the overall risk estimate to the sampled data, analysts produced a conservative estimate of the technical vertical risk, using the prescribed value for vertical overlap probability (1.7 x 10^{-8} ,which is the TLS specified in the ICAO Doc 9574) and a conservative estimate of lateral overlap probability (based on guidance provided in section 8.5 of the RASMAG\4 meeting report); this approach yielded a more conservative technical vertical risk estimate of 2.09 x 10^{-9} fatal accidents per aircraft flying hour. Both the initial and conservative estimates are within the stipulated TLS of 2.5 x 10^{-9} fatal accidents per aircraft flying hour.

3.3.4 Table 3-1 presents a summary of the parameters used in estimating the technical vertical risk. Based on the values in table 3-1, the risk for fatal accidents per flying hour due to loss of vertical separation is estimated to be 1.94 x 10^{-9} fatal accidents per aircraft flying hour.

Parameter	Symbol	Estimated Value	Source
Technical Vertical Risk	Naz	1.94 x 10^{-9}	Output of the CRM
Probability of Vertical Overlap with a planned vertical separation of 1000 feet (Reference: Appendix B)	Pz	1.19 x 10^{-8}	Calculated based on December 2011 TSD
Probability of Lateral Overlap	Py	0.078 feet	Guidance provided in the RASMAG\4 meeting report
Passing Frequency	nz(opp)	0.7462 adjacent flight level passes per flight hour	Calculated based on traffic sample data
Average aircraft length	λx	228.74 feet	Calculated based on TSD
Average aircraft width	λy	205.56 feet	Calculated based on TSD
Average aircraft height	λz	60.22 feet	Calculated based on TSD
Average absolute relative cross track speed for an aircraft pair nominally on the same track	$\lvert\dot{y}\rvert$	4 knots	Global Height Keeping Performance Specification
Average absolute relative vertical speed of an aircraft pair that has lost the vertical separation minimum of 1000 ft	$\lvert\dot{z}\rvert$	10 knots	Global Height Keeping Performance Specification
Average aircraft ground speed	$\bar{V}$	401 knots	Calculated based on duration in Kabul FIR and track length (assuming constant speed)

Table 3-1. CRM Parameters used in the Vertical Collision Risk Estimate for the Kabul FIR

3.4 Operational Risk

As noted in section 2.5.1, one LHD event was reported in the Kabul FIR within the past 24 months. This single event is insufficient for calculation of an operational risk estimate. Although there is no TLS associated with LHDs alone, the difference between the overall TLS and that of the technical vertical risk could be considered an allowable level of risk. If the calculated vertical risk due to technical errors is below the 2.5×10^{-9} TLS, then the resulting buffer will allow for an equivalent increase in the proportion of total risk attributable to operational errors. Using the calculated risk of technical error, the actual rate of large height deviations could be 2.9×10^{-9} and still meet the overall TLS. The uncertainty associated with this estimate is larger than the uncertainty associated with other parameters, and would benefit from increased data collection.

The lack of LHD reports may be explained by the fact that the KACC is a procedural (non-radar) operation. In contrast to surrounding facilities with position and altitude surveillance, the Kabul controller will be made aware of the altitude deviation only through a pilot report or from the notification of an adjacent sector's controller In the latter case, the altitude error is resolved prior to the aircraft entering the Kabul FIR.

3.5 Total Vertical Risk Results

3.5.1 ICAO policy requires that a minimum of 90% of aircraft operating in the airspace under consideration be RVSM approved prior to the implementation of RVSM. Based on the aircraft registration numbers derived from the traffic sample data provided by KACC, and aircraft approval information provided by EUROCONTROL, Pacific Approvals Registry and Monitoring Organization (PARMO) and Monitoring Agency for Asia Region (MAAR), it was determined that 88% of aircraft operating in the study airspace are RVSM approved.

3.5.2 The estimate of technical risk based on fundamental principles was calculated by the MAAR, using the TSD provided by KACC. Section 5.10 of the 9574 notes that large height deviations not involving whole numbers of flight levels are to be combined with the distribution of the assigned altitude deviation (AAD) and thus "this type of large height deviation is included in the distribution of technical height-keeping errors and in the estimate of the technical risk." As noted in section 2.5, sufficient large height deviation data "not involving whole numbers of flight levels" were unavailable at the time the study was undertaken. The absence of these data results in a low estimate of technical risk.

3.5.3 The post-implementation safety assessment of RVSM yielded risk estimates within prescribed limits and supports a qualified positive assessment for continued use of RVSM in the Kabul FIR. In the absence of surveillance systems, there is an abnormally high reliance on self-reporting of deviations in the Afghanistan airspace; continued pressure should be exerted to remedy this situation. In the near future, the expected implementation of MLAT should greatly facilitate the collection of periodic TSDs and aid in monitoring of aircraft that deviate from the cleared altitude or route. Although qualitative assessment of other issues associated with RVSM implementation (training, special procedure handling, controller error, etc.) were not specifically addressed in this report, KACC has expressed that they have not experienced any difficulties or abnormalities since implementation. Annual monitoring of RVSM operations will assure continued safety and to identify potential safety related issues that might arise in the future.

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APPENDIX A COLLISION RISK MODEL

The Collision Risk Model (CRM) was developed by ICAO Review of the General Concept of Separation Panel (RGCSP) as the means for assessing the potential number of accidents per flight hour due to collisions caused by the loss of procedural vertical separation in RVSM airspace. The general form of the CRM for same and opposite direction traffic is as follows:

$$N_{az} = 2P_z(S_z)P_y(0)\left[n_z\,(same)\left\{1 + \frac{2\lambda_x}{2\lambda_y}\frac{|\overline{\dot{y}}|}{|\overline{\Delta V}|} + \frac{2\lambda_x}{2\lambda_z}\frac{|\overline{\dot{z}}|}{|\overline{\Delta V}|}\right\} + n_z\,(opp)\left\{1 + \frac{2\lambda_x}{2\lambda_y}\frac{|\overline{\dot{y}}|}{2\overline{V}} + \frac{2\lambda_x}{2\lambda_z}\frac{|\overline{\dot{z}}|}{2\overline{V}}\right\}\right]$$

Where:

N_z	=	Expected number of fatal accidents per flight hour due to loss of vertical separation
S_z	=	The vertical separation minimum
$P_z(S_z)$	=	Probability of vertical overlap for aircraft on adjacent flight levels
Py (0)	=	Probability of lateral overlap for aircraft nominally on the same ATS route
n_z (same)	=	The frequency with which same direction aircraft on adjacent flight levels of the same ATS route pass each other (i.e. frequency of same direction longitudinal overlap)
n_z (opp)	=	The frequency with which opposite direction aircraft on adjacent flight levels of the same ATS route pass each other (i.e. frequency of opposite direction longitudinal overlap)
λx	=	average aircraft length
λy	=	average aircraft width
λz	=	average aircraft height
$\overline{\dot{y}}$	=	average absolute relative cross track speed for an aircraft pair nominally on the same track
$\overline{\dot{z}}$	=	average absolute relative vertical speed of an aircraft pair that has lost the vertical separation minimum of 1000 feet
$\overline{V}$	=	average aircraft ground speed
$|\overline{\Delta V}|$	=	average of the absolute value of the relative along-route speed between two same direction aircraft flying at adjacent flight levels of the same ATS route

The CRM takes slightly different forms for same direction, opposite direction, and crossing traffic analysis. The ATS route structure in the Kabul FIR does not include crossing routes, and the longitudinal spacing is designed to preclude co-altitude same-direction passing events. Thus, the CRM equation below has been adapted to reflect the prevalent operational environment at the time of RVSM implementation and it incorporates only an opposite direction passing frequency parameter:

$$N_{az} = 2P_z(S_z)P_y(0)\left[n_z\,(opp)\left\{1 + \frac{2\lambda_x}{2\lambda_y}\frac{|\overline{\dot{y}}|}{2\overline{V}} + \frac{2\lambda_x}{2\lambda_z}\frac{|\overline{\dot{z}}|}{2\overline{V}}\right\}\right]$$

Of the parameters tabulated above, a first group of parameters – the probability of vertical overlap, the probability of lateral overlap and the passing frequency – have the greatest impact on the collision risk. The aircraft dimensions and velocities are less critical to the safety assessment since the CRM is less sensitive to these parameters, which are expected to remain relatively stable over time. Nevertheless, these parameters should be reassessed intermittently to ensure they reflect the prevailing RVSM airspace.