



**Middle East Regional Monitoring Agency**

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**THE MID RVSM  
SAFETY MONITORING  
REPORT 2006**

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<b>Abstract</b>			
<p>This document constitutes the RVSM Safety Monitoring Report for the MID RVSM Programme in 2006.</p> <p>The aim of this document is to show by means of argument and supporting evidence that the implementation of RVSM in the Middle East is acceptably safe.</p>			
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Assigned Altitude Deviation (AAD)	Probability of vertical overlap	Collision Risk Model	Altitude Deviation Report (ADR)
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## EXECUTIVE SUMMARY

This document constitutes the first annual MID RVSM Safety Monitoring Report and tries to demonstrate, according to the data used, that the key safety objectives set out in section 2 of this document in accordance with ICAO Doc 9574 (2<sup>nd</sup> Edition) [1] are met in operational service.

The Report is constructed using an approach that claims that the Middle East RVSM operations will be acceptably safe. This aim is achieved by means of satisfying the following principal safety objectives:

- Objective #1** That the vertical-collision risk in MID RVSM airspace due solely to technical height-keeping performance meets the ICAO target level of safety (TLS) of  $2.5 \times 10^{-9}$  fatal accidents per flight hour.
- Objective #2** That the overall vertical-collision risk – i.e. the overall risk of mid-air collision in the vertical dimension - in MID RVSM airspace meets the ICAO overall TLS of  $5 \times 10^{-9}$  fatal accidents per flight hour.
- Objective #3** Address any safety-related issues raised in this report by recommending improved procedures and practices.
- Objective #4** Propose safety level improvements to ensure that any identified serious or risk-bearing situations do not increase and, where possible, that they decrease. This should set the basis for a continuous assurance that the operation of RVSM will not adversely affect the risk of en-route mid-air collision over the years.

Each of the above objectives is developed in the relevant sections of this Report. The evidence provided tries to demonstrate whether the objectives have been achieved and draw detailed conclusions, according to the data used and based on the initial assumptions. These conclusions can be summarised as follows:

- Objective #1** The computed vertical-collision risk due to technical height-keeping performance -  $2.17 \times 10^{-14}$  - meets the ICAO technical TLS of  $2.5 \times 10^{-9}$  fatal accidents per flight hour.
- Objective #2** This Report does not provide an estimate for the overall vertical-collision risk because of the absence of suitable information on atypical errors; therefore it is not possible to assess compliance with the ICAO overall TLS of  $5 \times 10^{-9}$  fatal accidents per flight hour.  
  
Nevertheless, this Report provides recommendations to the MID RMA for collecting that information for future assessments.
- Objective #3** All safety related issues regarding the Middle East RVSM operations have been identified and improved procedures and practices have been recommended for future MID RMA practices.
- Objective #4** Current risk bearing situations have been identified in the Report and actions have been proposed to the MID RMA to ensure relevant information is collected in order to identify operational issues and potential mitigations.

## Conclusions

In summary, subject to the limitations of data available and the collision risk model used, this Report demonstrates that the Middle East RVSM operations met three (safety objectives #1, #3 and #4) out of the four principal safety objectives.

For Safety Objective #2 (i.e. that the overall risk of mid-air collision in the vertical dimension in MID RVSM airspace meets the ICAO overall TLS of  $5 \times 10^{-9}$  fatal accidents per flight hour), it was not possible to assess its compliance as no suitable information was available to provide an estimate for the overall vertical-collision risk.

However, recommendations were made in this Report to improve the situation for future assessments.

Finally, taking into account that evidence has not been provided for all the Safety Objectives, it cannot be concluded on whether the initial claim that the Middle East RVSM operations are acceptably safe is satisfied. It is therefore very important that the MID RMA implement the proposed recommendations of this Report to provide means for assessing satisfaction of this claim in future safety assessments.

## Recommendations

This is a summary of the main recommendations laid out in this document with a view to their implementation in the next reporting year:

**Recommendation #1** MID RMA continue the collection of radar data from the region, review the list of monitoring groups for the region and initiate actions on monitoring groups specific to the region.

**Recommendation #2** MID RMA, in coordination with concerned States, assure that incidents and altitude deviations occurring over the Red Sea Area are reported in a continuous basis and copy of those reports are sent to the MID RMA in due time for their operational assessment in future safety analysis.

**Recommendation #3** MID RMA to continue monitoring RVSM operations in the whole Middle East RVSM airspace over the months by the collection of altitude deviation reports from the participating States. Those reports should describe the nature, duration and length of the altitude deviation itself.

## 1. INTRODUCTION

### 1.1 Background

Reduced Vertical Separation Minima (RVSM) was introduced into Middle Eastern airspace in 27<sup>th</sup> November 2003, reducing the vertical separation between RVSM-approved aircraft from 600m (2000ft) to 300m (1000ft) for aircraft operating at/between Flight Levels 290 and 410 inclusive.

The 11 States participating in the MID RVSM Programme are listed in Table 1.

Bahrain	Egypt	Iran	Jordan	Kuwait	Lebanon
Oman	Saudi Arabia	Syria	UAE	Yemen	

**Table 1: States participating in RVSM**

The FIRs/UIRs where RVSM was implemented in MID RVSM airspace are the following:

Bahrain FIR	Cairo FIR	Tehran FIR	Amman FIR	Kuwait FIR	Beirut FIR
Muscat FIR	Jeddah FIR	Damascus FIR	UAE FIR	Sana'a FIR	

**Table 2: FIRs/UIRs representing MID RVSM airspace**

The FIRs/UIRs where RVSM need to be implemented in the near future are listed in table in table 3;

Kabul FIR	Baghdad FIR
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**Table 3: Future RVSM implementation FIRs**

Table 1. Mentioned above is also stating all the states that are participating in the MID RMA project and submitted their traffic data for this safety monitoring report, except UAE.

### 1.2 Aim

This Report responds to the official ICAO request to MID RMA to show by means of argument and supporting evidence that the implementation of RVSM in the Middle East region satisfies the safety criteria defined in section 2 of this report.

The Report has been issued for endorsement by the ICAO Middle East Air Navigation Planning and Implementation Regional Group (MIDANPIRG).

### 1.3 Scope

This 2006 MID RVSM Safety Monitoring Report (SMR) tries to demonstrate that the key safety objectives set out in section 2 of this report are met in operational service. The scope of the document is therefore limited to arguments and evidence regarding the safety of RVSM measured against the safety objectives as well as identifying any safety-related issues that need to be addressed in future assessments.

### 1.4 Structure of the document

The Report is constructed using an approach that claims that the Middle East RVSM operations are acceptably safe. This claim is broken down into four main safety objectives, which represent necessary and sufficient conditions to be met for the above claim to be true. These principal safety objectives are listed in **Section 2** and are discussed and assessed in **Sections 3, 4, 5 and 6** of this Report.

**Section 2** of this document lists the four RVSM safety objectives that relate directly to the ongoing safety of MID RVSM.

**Sections 3, 4, 5 and 6** collect the results from **Appendixes A, B and C** and build direct and supporting evidence of compliance with the four principal safety objectives.

**Section 7** summarises all the conclusions and recommendations raised in the aforementioned sections to assess whether the overall risk of collision can be considered as acceptably safe.

**Appendix A** provides an update on, and the current results and actions of, the height-monitoring activities carried out by Eurocontrol on operators that also operate in the Middle East airspace throughout the reporting period.

**Appendix B** provides the results for the assessment of operator-type monitoring compliance.

**Appendix C** provides the current results of the collision risk assessment of the estimated levels of vertical-collision risk that would pertain in MID RVSM airspace. The results are compared against the first two quantifiable safety objectives, the ICAO TLS of  $5 \times 10^{-9}$  fatal accidents per flight hour for overall vertical risk and  $2.5 \times 10^{-9}$  fatal accidents per flight hour for risk due to technical height-keeping performance, set out in Section 2.

### 1.5 Future activities

For the development of the MID RVSM SMR 2007-2008, Operational data will continue to be collected and aircraft height-keeping performance monitored to populate the statistical models for assessing the overall risk in MID RVSM airspace.

## 2. RVSM SAFETY OBJECTIVES

A key issue for the assessment of RVSM safety is the satisfaction of a number of safety objectives. The following four objectives are directly relevant to the ongoing safety of RVSM:

- Objective #1** In accordance with ICAO Guidance Material **[1]**, the risk of mid-air collision in the vertical dimension within RVSM airspace, due to technical height-keeping performance, shall meet a TLS of  $2.5 \times 10^{-9}$  fatal accidents per flight hour.
- Objective #2** In accordance with ICAO Guidance Material **[1]**, the management of overall vertical-collision risk within RVSM airspace shall meet a TLS of  $5 \times 10^{-9}$  fatal accidents per flight hour.
- Objective #3** Address any safety-related issues raised in this report by recommending improved procedures and practices.
- Objective #4** Propose safety level improvements to ensure that any identified serious or risk-bearing situations do not increase and, where possible, that they decrease. This should set the basis for a continuous assurance that the operation of RVSM will not adversely affect the risk of en-route mid-air collision over the years.

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### 3. ASSESSMENT OF THE TECHNICAL-VERTICAL RISK AGAINST THE TLS OF $2.5 \times 10^{-9}$ FATAL ACCIDENTS PER FLIGHT HOUR

#### **Objective # 1**

The objective of this section is to set out the arguments and evidence that the vertical-collision risk due solely to aircraft technical height-keeping performance is within the ICAO TLS of  $2.5 \times 10^{-9}$  fatal accidents per flight hour.

#### 3.1 Direct evidence of compliance with TLS for technical height-keeping error

The results show that the vertical-collision risk due to technical height-keeping performance is estimated to be  $2.17 \times 10^{-14}$  fatal accidents per flight hour, compared with the ICAO TLS of  $2.5 \times 10^{-9}$ .

#### 3.2 Supporting evidence of compliance with TLS for technical height-keeping performance

The above evidence concerning vertical-collision risk due to technical height-keeping performance is considered reliable if it can be shown that:

- (i) the estimated value of the frequency of horizontal overlap, used in the computations of vertical-collision risk, is valid;
- (ii) the probability of vertical overlap between RVSM-approved aircraft due to technical height-keeping performance – is valid and is less than the ICAO requirement of  $1.7 \times 10^{-8}$ ;
- (iii) all RVSM-approved aircraft using MID RVSM airspace meet the individual ICAO performance specification for the components of total vertical error (TVE) – also known as the technical height-keeping group requirements;
- (iv) problems in individual aircraft technical height-keeping performance are identified;
- (v) an adequate process is in place to investigate and correct problems in aircraft technical height-keeping performance.

##### *(i) Frequency of horizontal overlap*

The process of determining the frequency of horizontal overlap is rigorous and is based on actual measurements taken at the three European HMUs between 1 December 2005 and 31 May 2006. Therefore the estimated value can be considered valid.

Based on the current data set, the frequency of horizontal overlap in European RVSM airspace is estimated in Section C.2.1 and is  $6.99 \times 10^{-3}$  per flight hour for pairs of aircraft at adjacent flight levels.

*(ii) Probability of vertical overlap compliance*

Evidence concerning the probability of vertical overlap in Section C.2.2 shows that the estimated value for the probability is valid and is of  $3.1 \times 10^{-12}$ .

This value satisfies the ICAO requirement of  $1.7 \times 10^{-8}$ .

*(iii) Compliance with ICAO TVE component requirements (group requirements)*

Evidence concerning achievement of the ICAO TVE component requirements is presented in **Appendix A**, paragraph A.4.1.

Three requirements have to be met:

- (i) The mean ASE for any aircraft group shall not exceed  $\pm 25\text{m}$  ( $\pm 80\text{ft}$ ).
- (ii) The sum of the absolute value of the group mean ASE and three standard deviations of group ASE shall not exceed  $75\text{m}$  ( $245\text{ft}$ ). In addition no individual measurement shall exceed  $245\text{ft}$  excluding monitoring system measurement error.
- (iii) Errors in altitude keeping shall be symmetric about a mean of  $0\text{m}$  ( $0\text{ft}$ ), shall have a standard deviation not greater than  $13\text{m}$  ( $43\text{ft}$ ) and be such that the error frequency decreases with increasing error magnitude at a rate which is at least exponential.
- (iv) No individual measurement of ASE for each aircraft approved on a non-group basis for RVSM operations may exceed  $49\text{m}$  ( $160\text{ft}$ ) in magnitude, excluding monitoring system measurement error

The pertinent paragraph presents the ASE results against (i) and (ii), which show that the majority of aircraft monitoring groups satisfy requirements (i) and (ii). However, the following aircraft monitoring groups currently fail to meet (i) and/or (ii):

- (ii) B74S, DC86-7-1, E135-145, H25B-700, FA50, IL76, A310, A320, A321, B737, B747, B777, L-1011 TRISTAR, T154 and VC10.

The paragraph also presents the results for altitude keeping against requirement (iii), which show that, on the basis of the data currently available, this requirement is satisfied for the standard deviation and the mean (see also paragraph A.4.4).

**Appendix A** of this report provides the list of individual aircraft that have shown ASE measurements exceeding  $160\text{ft}$  (iv).

The list of those individual aircraft is as follows:

- (iv) VC10

*(v) Corrective action*

The means by which instances of poor technical height-keeping performance by RVSM-approved aircraft are followed up are described in Appendix A, paragraphs A.4.3 and A.4.4

The airspace monitoring and evaluation activities carried out in coordination with Eurocontrol in the last months ensure that the number of monitoring groups and individual aircraft showing poor technical height-keeping performance do not increase over the years, problems are identified and follow-up actions are taken in solving potential safety issues for future assessments.

Eurocontrol will keep informed the MID RMA in due time of the results from any actions undertaken.

It is recommended that MID RMA continue following-up Eurocontrol activities and include the outcome of those activities in future assessments.

In addition to that, it is recommended for future assessments that MID RMA continue the collection of radar data from the region, review the list of monitoring groups for the region and initiate actions on monitoring groups and individual aircraft specific to the region.

### **3.3 Conclusions on technical height-keeping**

It has been shown in this section that:

- (i) the current computed vertical-collision risk due to technical height-keeping performance meets the ICAO TLS;
- (ii) the probability of vertical-overlap estimation satisfies the ICAO global system performance specification;
- (iii) most monitoring groups are complying with ICAO TVE component requirements (also known as technical height-keeping group requirements). There are, however, a few groups that do not comply with those requirements;
- (iv) a few number of individual aircraft have shown excessive ASE measurements;
- (v) corrective actions are in place for monitoring groups and aircraft showing poor height-keeping performance.

### **3.4 Recommendations applicable to this Objective**

- (i) MID RMA continue the collection of radar data from the region, review the list of monitoring groups for the region and initiate actions on monitoring groups specific to the region.
- (ii) For those groups that do not perform according to the requirements, when applicable, the MID RMA will continuously support Eurocontrol in the investigations and follow-up actions to prevent this becoming a potential safety issue. The result of those actions will be included in the next safety Report.

- (iii) Regarding individual aircraft performance, the MID RMA will continuously support Eurocontrol, when applicable, in the investigation of the causes and follow-up actions. The result of those actions will be included in the next safety Report.

#### 4. ASSESSMENT OF THE OVERALL-VERTICAL RISK AGAINST THE TLS OF $5 \times 10^{-9}$ FATAL ACCIDENTS PER FLIGHT HOUR

##### **Objective # 2**

The objective of this section is to set out the arguments and evidence that the overall vertical-collision risk – i.e. the risk of mid-air collision in the vertical dimension in RVSM airspace due to all causes - meets the ICAO overall TLS of  $5 \times 10^{-9}$  fatal accidents per flight hour.

##### 4.1 Direct and supporting evidence of compliance with overall TLS

In the absence of suitable altitude deviation reports, it was not possible to provide an estimate for the probability of vertical overlap due to atypical errors. Hence, it is neither possible to provide in this Report direct nor supporting evidence of compliance with the ICAO overall TLS of  $5 \times 10^{-9}$  fatal accidents per flight hour.

Nevertheless, this Report provides recommendations in **Appendix C** for the MID RMA to initiate actions to ensure that operational errors are collected in a continuous basis by the participating States and sent in due time to the MID RMA. Such information will allow the MID RMA to provide in future assessments estimates of the vertical-risk due to atypical errors and eventually the overall vertical-risk within the Middle East RVSM airspace.

It is important to note that the vertical-risk estimation due to atypical errors has been demonstrated to be the major contributor in the overall vertical-risk estimation for the EUR RVSM airspace. In addition to that, the EUR RVSM safety monitoring reports have highlighted the sensitivity of this estimation to future traffic growth - reference [10] provides further information -.

Although currently the operational situation may not be critical the estimated forecast increase of **8%** traffic growth per year in the Middle East RVSM airspace may contribute to a scenario when the overall ICAO vertical TLS may be exceeded.

##### 4.2 Conclusions on the overall vertical risk

- (i) It is not possible to provide an estimate of the overall vertical-risk for current Middle East RVSM operations in this Report.
- (ii) Therefore, no comparison with the ICAO overall TLS of  $5 \times 10^{-9}$  fatal accidents per flight hour can be made at the current time.
- (iii) Concerns have been raised in **Appendix C** of this Report regarding the absence of suitable data to provide those estimates and recommendations have been made to the MID RMA to ensure future estimations.

### **4.3 Recommendations applicable to this Objective**

- (i) MID RMA, in coordination with concerned States, assure that incidents and altitude deviations occurring over the Red Sea Area are reported in a continuous basis and copy of those reports are sent to the MID RMA in due time for their operational assessment in future safety analysis.
- (ii) MID RMA to continue monitoring RVSM operations in the whole Middle East RVSM airspace over the months by the collection of altitude deviation reports from the participating States. Those reports should describe the nature, duration and length of the altitude deviation itself.
- (iii) MID RMA to use a form based on the Eurocontrol altitude deviation report form to ensure that the appropriate operational information is collected.

## 5. ASSESSMENT OF SAFETY-RELATED ISSUES RAISED IN THIS REPORT

### **Objective # 3**

The objective of this section is to address any safety-related issues raised in this Report by recommending improved procedures and practices.

#### *Methodology*

The approach is to show that any safety-related issues associated with the Middle East RVSM operations have been identified and recommendations to mitigate any impact in the safety Report, as far as practical, have been made.

The identified safety-related issues are:

- (i) Identification of operators requiring monitoring before the next safety Report.
- (ii) Confirmation of the approval status of aircraft filling RVSM flight plan (W in field 10).

Regarding (i), currently there is a deficit of monitoring results for all operators and types in the Middle East RVSM airspace. The recommended practice in this case is targeting operators for monitoring that will identify any technical performance issues.

Concerning (ii), the recommended procedure is to confirm the approval status of aircraft to ensure that technically non-compliant aircraft will not operate in the region and constitute a safety issue.

### 5.1 Conclusions

All safety-related issues regarding the Middle East RVSM operations have been identified and improved procedures and practices have been recommended in this section for future MID RMA practices.

Therefore, it can be concluded that this safety Objective has been met.

### 5.2 Recommendations applicable to this Objective

- (i) Target operators for monitoring to identify any technical performance issues.
- (ii) Confirm the approval status of aircraft to ensure that technically non-compliant aircraft will not operate in the region and constitute a safety issue.

## 6. SAFETY LEVEL IMPROVEMENTS TO MITIGATE RISK-BEARING SITUATIONS

### **Objective # 4**

Propose safety level improvements to ensure that any identified serious or risk-bearing situations do not increase and, where possible, that they decrease. This should set the basis for a continuous assurance that the operation of RVSM will not adversely affect the risk of en-route mid-air collision over the years

#### *Methodology*

The proposed methodology consists in collecting all the identified risk-bearing situations raised along this Report together with any other situations that have been qualitatively assessed.

For the assessment that RVSM operations will not adversely affect the risk of en-route mid-air collision over the years, the direct evidence can be obtained by comparing the frequency of operational error reports classified by the different types of error over different periods of time.

#### *Identified risk-bearing situations in the Report*

The major concern regarding risk-bearing situation raised in this Report is the non adherence to the Red Sea procedure. **Appendix C**, section C.3 provides the recommendations by the scrutiny group created to assess the suitability of the altitude deviation reports provided by the States.

The scrutiny group considered that the no adherence to current Red Sea procedure was of special concern as it might have a negative safety influence in the Middle East RVSM operations within coordinated airspace. More precisely, the occurrence of an aircraft leaving the Red Sea un-coordinated airspace and entering into Middle East RVSM coordinated airspace at unexpected flight levels would be considered in the future as risk bearing and constitute an altitude deviation itself.

The scrutiny group recommended to the MID RMA, in coordination with concerned States, assure that incidents and altitude deviations occurring over the Red Sea Area are reported in a continuous basis and copy of those reports are sent to the MID RMA in due time for their operational assessment in future safety analysis.

In addition to that, the scrutiny group strengthened the need for the MID RMA to continue monitoring RVSM operations in the whole Middle East RVSM airspace over the months by the collection of altitude deviation reports from the participating States. Those reports should describe the nature, duration and length of the altitude deviation itself.

In that sense, it is also recommended that the MID RMA should use a form based on the Eurocontrol altitude deviation report form to ensure that the appropriate operational information is collected.

## 6.1 Conclusions

Current risk-bearing situations have been identified in the Report and actions have been proposed to the MID RMA to ensure relevant information is collected in order to identify operational issues and potential mitigations.

Therefore, it is concluded that this Safety Objective is currently met.

## 6.2 Recommendations applicable to this Objective.

- (i) MID RMA, in coordination with concerned States, assure that incidents and altitude deviations occurring over the Red Sea Area are reported in a continuous basis and copy of those reports are sent to MID RMA in due time for their operational assessment in future safety analysis.
- (ii) MID RMA to continue monitoring RVSM operations in the whole Middle East RVSM airspace over the months by the collection of altitude deviation reports from the participating States. Those reports should describe the nature, duration and length of the altitude deviation itself.
- (iii) MID RMA to use a form based on the Eurocontrol altitude deviation report form to ensure that the appropriate operational information is collected.

## 7. SUMMARY OF CONCLUSIONS AND RECOMMENDATIONS

### 7.1 Conclusions

This section is intended to summarise all the conclusions drawn throughout the document, more precisely in Sections 3 to 6:

- (iii) Most monitoring groups are compliant with ICAO TVE component requirements. There are, however, a few groups that give reason for concern. Nevertheless, corrective actions are taking place to ensure that the number of monitoring groups does not increase over the years, problems are identified and follow-up actions are taken in solving potential safety issues for future assessments.
- (iv) The current computed vertical-collision risk due to technical height-keeping performance meets the ICAO technical TLS of  $2.5 \times 10^{-9}$  fatal accidents per flight hour (Objective #1).
- (v) The effect of future traffic growth in the vertical-collision risk due to technical height-keeping performance has been assessed, estimating that the ICAO technical TLS will continue to be met until 2010.
- (vi) It is not possible to provide an estimate for the vertical risk due to atypical errors.
- (vii) Hence, this Report can not provide an estimate of the overall vertical-collision risk to be compared with the ICAO overall TLS of  $5 \times 10^{-9}$  fatal accidents per flight hour (Objective #2).
- (viii) All safety related issues regarding the Middle East RVSM operations have been identified and improved procedures and practices have been recommended for future MID RMA practices (Objective #3).
- (ix) Current risk bearing situations have been identified in the Report and actions have been proposed to the MID RMA to ensure relevant information is collected in order to identify operational issues and potential mitigations (Objective #4).

In summary, subject to the limitations of data available and the European collision risk model used, this Report demonstrates that the Middle East RVSM operations met three (Objectives #1, #3 and #4) out of the four principal safety objectives.

In the case of the Safety Objective#2, it was not possible to provide evidence of the achievement as no suitable information was available by the time of this assessment. However, recommendations were made in this Report improve the situation for future assessments.

Finally, taking into account that evidence has not been provided for all the Safety Objectives, it cannot be concluded on whether the initial claim that the Middle East RVSM operations are acceptably safe is satisfied. It is therefore very important that the MID RMA implement the proposed recommendations

of this Report to provide means for assessing satisfaction of this claim in future safety assessments.

## 7.2 Recommendations

The following recommendations relate to actions proposed in various sections in this Report.

- (i) MID RMA continue the collection of radar data from the region, review the list of monitoring groups for the region and initiate actions on monitoring groups specific to the region, and therefore.
- (ii) For those groups that do not perform according to the requirements, when applicable, the MID RMA shall continuously support Eurocontrol in the investigations and follow-up actions to prevent this becoming a potential safety issue. The result of those actions will be included in the next safety Report.
- (iii) Regarding individual aircraft performance, the MID RMA shall continuously support Eurocontrol, when applicable, in the investigation of the causes and follow-up actions. The result of those actions will be included in the next safety Report.
- (iv) MID RMA, in coordination with concerned States, assure that incidents and altitude deviations occurring over the Red Sea Area are reported in a continuous basis and copy of those reports are sent to MID RMA in due time for their operational assessment in future safety analysis.
- (v) MID RMA to continue monitoring RVSM operations in the whole Middle East RVSM airspace over the months by the collection of altitude deviation reports from the participating States. Those reports should describe the nature, duration and length of the altitude deviation itself.
- (vi) MID RMA to use a form based on the Eurocontrol altitude deviation report form to ensure that the appropriate operational information is collected.
- (vii) Target operators for monitoring to identify any technical performance issues.
- (viii) Confirm the approval status of aircraft to ensure that technically non-compliant aircraft will not operate in the region and constitute a safety issue

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## APPENDIX A - TECHNICAL HEIGHT-KEEPING PERFORMANCE

### A.1. Introduction

ICAO Document 9574 [1] requires a height-monitoring programme to be conducted in order to demonstrate that the prescribed level of safety is being achieved. In particular, it requires the height-monitoring programme to provide:

- i. confidence that the ICAO technical TLS of  $2.5 \times 10^{-9}$  fatal accidents per aircraft flight hour will be met when RVSM is implemented and will continue to be met thereafter;
- ii. guidance on the efficacy of MASPS and the effectiveness of altimetry system modifications; and
- iii. Evidence of altimetry system error (ASE) stability.

To meet these requirements, the MID RVSM Programme has established a height-monitoring programme, based on ICAO requirements and with the support of Eurocontrol [1].

The RVSM height-monitoring programme is currently based on data provided by the European height monitoring infrastructure reinforced with individual aircraft performance results produced by onboard GPS Monitoring Units.

The quality and reliability of the monitoring infrastructure and its output data have been ensured through the specification of the systems and through verification of performance during flight testing.

### A.2. Scope

Confidence in meeting requirement (i) related to the ICAO technical TLS is provided in APPENDIX C - where the Eurocontrol Collision Risk Model is applied to the monitoring data to estimate the vertical risk due to technical height-keeping performance in the Middle East RVSM airspace.

Requirement (iii) is currently subject to investigations by various national and international bodies and involves evaluation of many years of height monitoring data to determine the accuracy and stability of ASE over time. These investigations are not within the scope of individual RMA safety reporting. Eurocontrol is involved in evaluation of ASE stability and will report any findings to the MID RMA.

This **Appendix** focuses in the technical height-keeping performance of operators that use Middle East RVSM airspace, in relation to ICAO requirement (ii). in particular it:

- i. summarises the results of the MID RVSM operators results to date concerning compliance with the MASPS for the overall aircraft population; and
- ii. summarises the results to date concerning compliance with expected performance for individual airframes;

- iii. concludes with a summary of recommendations to address non-compliances in the future.

The results contained herein are based solely on data as described in the following section. It should be noted that the calculations of the collision risk included in APPENDIX C - of this Report are also based on this information.

### **A.3. *Data used in the technical-height keeping performance assessment***

All results presented in this **Appendix** are based on height-measurement data that was;

- recorded between 1 January 2005 and 31 December 2006; and
- recorded by the Linz, Nattenheim, Geneva and Strumble HMUs as well as the different GMUs from all regions; and
- fully correlated to an identified airframe.

**Table A- 1:** Total number of measurements by region

	Other Regions (NAT, NAM)	EUR
Number of measurements	<b>45,353</b>	<b>1,041,704</b>

### **A.4. *Verification of the aircraft height-keeping performance requirements***

#### **A.4.1. Performance requirements for TVE components**

Aircraft of similar performance are categorised into aircraft monitoring groups for which performance requirements are specified by ICAO. Aircraft that cannot be categorised into a group are considered non-Group that have different performance requirements<sup>1</sup>.

The performance requirements for group aircraft, non-group aircraft and individual airframes are described further in [11]. These requirements are summarised in **Table A-2** and describe the normal operational performance that aircraft monitoring groups, non-groups and individual airframes need to be capable of achieving in service, exclusive of human factor errors and extreme environmental influences, if the airspace-system TVE requirements are to be satisfied. These requirements were the basis for development of the MASPS against which aircraft are to be approved.

<sup>1</sup> See JAA TGL No. 6 [5] Para. 9.3.1 for a definition of group and non-group aircraft.

**Table A- 2: Aircraft Height Keeping Performance Requirements**

Category of Requirement	Description
Group Aircraft (i)	The mean altimetry system error (ASE) of the monitoring group shall not exceed $\pm 25\text{m}$ ( $\pm 80\text{ft}$ ).
Group Aircraft (ii)	The sum of the absolute value of the mean ASE for the monitoring group and three standard deviations of ASE within the group shall not exceed 75m (245ft). In addition No individual measurement should exceed 245 ft in magnitude excluding monitoring system measurement error
Group Aircraft (iii)	Errors in altitude-keeping shall be symmetric about a mean of 0m (0ft), shall have a standard deviation not greater than 13m (43ft) and be such that the error frequency decreases with increasing error magnitude at a rate which is at least exponential
Non-group Aircraft (iv)	No individual measurement of ASE for each aircraft approved on a non-group basis for RVSM operations may exceed 49m (160ft) in magnitude, excluding monitoring system measurement error.

It is important to note that in the collision risk assessment (APPENDIX C - ) no distinction is made between group aircraft and non-group aircraft.

#### **A.4.2. Assessment of ICAO performance requirements : ASE by monitoring group and non-group,**

The ASE mean and standard deviation of each aircraft monitoring group was calculated and a comparison made against requirements (i) and (ii) listed in the previous section.

**Table A-3** and **Table A-4** show the resulting ASE means and standard deviations for the groups and non-groups respectively. The following paragraphs summarise the observed performance compared with the requirements. It should be noted that for a number of aircraft the available data was limited to only a few measurements.

*Aircraft monitoring groups meeting the group requirements*

The following aircraft monitoring groups have enough data to assess their ASE performance. It has been shown that they are successful in meeting the specified capability requirements or the current amount of data suggests the monitoring group is meeting the ICAO Group performance requirements (i) and (ii):

A124, A300, A306, A310-GE, A310-PW, A320, A330, A340, A345, A346, AN72, AVRO, B727, B732, B737CL, B737NX, B744-10, B744-5, B747CL, B752, B753, B767, B772, B773, BD100, BE40, C17, C525, C550-B, C550-II, C560, C56X, C650, C680, C750, CARJ, CL600, CL604, DC10, DC86-7, DC95, E170, F100, F2TH, F900, FA10, FA20, GALX, GLEX, GLF2-G, GLF3, GLF4, GLF5, H25B-800, H25C, IL86, IL96, L101, LJ31, LJ35/6, LJ55, LJ60, MD11, MD80, MD90, T134, T154, T204, and YK42.

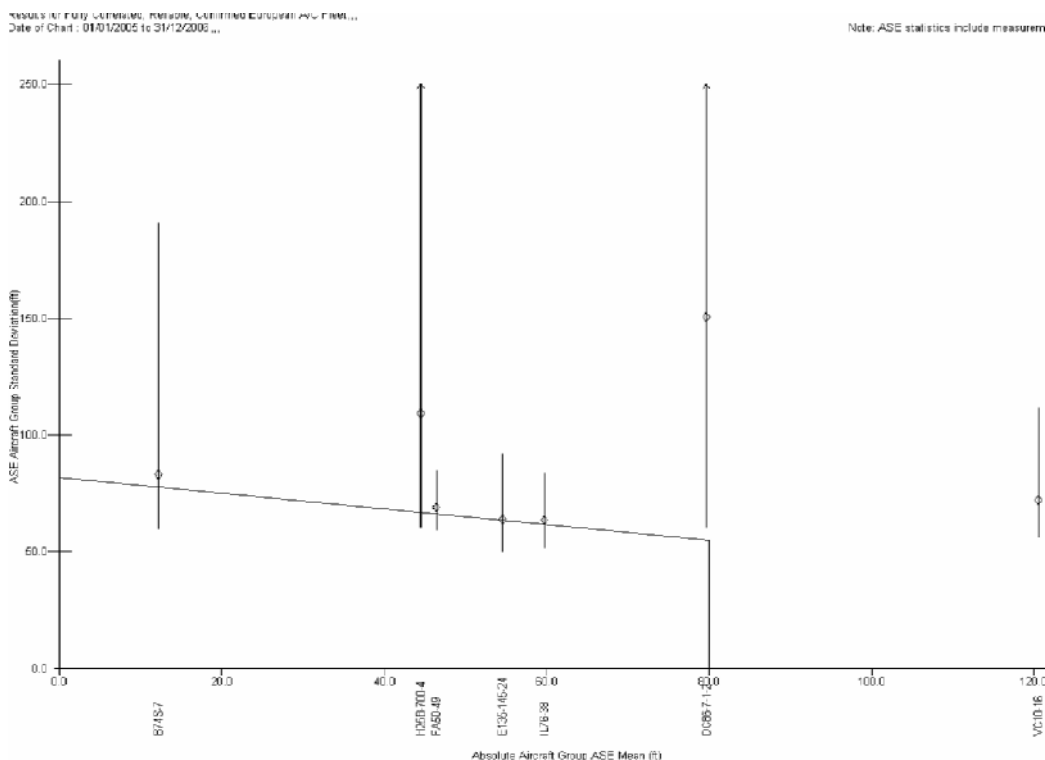
*Aircraft not meeting ICAO performance requirements*

The following aircraft do not meet the ICAO performance requirements according to current data;

Requirement (ii): B74S, DC86-7-1, E135-145, H25B-700, FA50, IL76.

Figure A-1 shows a graphical representation of these aircraft against the two ICAO group requirements. The diamonds represent the point estimates of the standard deviation of the overall ASE measurements of the aircraft plotted against the overall [mean]. The vertical line segments represent the **95%** confidence intervals for the standard deviation.

**Figure A- 1: Aircraft not meeting the ICAO group requirements**



*Aircraft monitoring groups with insufficient data*

The following monitoring groups have insufficient data to be able to conclude as to whether or not they are successful in meeting the specified ICAO group performance requirements. Results in bold indicate non-group aircraft;

**B703NG**, B712, B747LCF, **CL600NG**, GLF2, GLF2B, GLF2B-G, **LJ31-NG**, **SBR1-65**.

**Table A- 3: ASE Parameters by monitoring groups**

Monitoring Group	Group ASE mean (<80ft)	Overall ASE standard deviation	mean +3*Stdev (<245ft)	AAD_stdev	#AC	#Mes
A124	40.20	59.10	217.50	42.71	24	610
A300	-2.60	49.20	150.20	24.37	41	8452
A306	18.80	56.40	188.00	21.99	80	15610
A310-GE	-68.10	49.70	217.20	13.94	62	8542
A310-PW	14.80	45.00	149.80	9.19	33	3593
A320	30.10	48.10	174.40	14.14	953	322883
A330	38.90	36.00	146.90	10.68	226	39397
A340	-5.00	45.30	140.90	14.29	162	34853
A345	-3.70	31.90	99.40	7.59	21	739
A346	22.30	30.70	114.40	18.32	34	2578
AN72	7.30	69.30	215.20	84.52	4	6
AVRO	13.50	68.10	217.80	2.72	15	6945
B727	41.20	55.00	206.20	25.15	14	338
B732	-2.50	52.50	160.00	16.51	18	1014
B737CL	-45.40	50.50	196.90	14.63	392	123001

Monitoring Group	Group ASE mean (<80ft)	Overall ASE standard deviation	mean +3*Stdev (<245ft)	AAD stdev	#AC	#Mes
B737NX	-1.80	47.80	145.20	9.91	434	158911
B744-10	-68.00	41.00	191.00	14.90	335	34107
B744-5	-67.10	51.40	221.30	24.52	95	10539
B747CL	-40.00	56.10	208.30	29.30	152	14086
B74S	-12.20	83.10	261.50	29.54	7	1008
B752	-18.30	40.50	139.80	14.24	211	47574
B753	-4.10	45.00	139.10	10.23	30	15975
B767	-74.90	47.90	218.60	20.38	328	47963
B772	25.70	37.70	138.80	11.82	207	39053
B773	52.70	37.50	165.20	1.59	49	9291
BD100	-21.50	42.90	150.20	1.93	8	189
BE40	-8.20	36.30	117.10	7.51	18	1204
C17	7.40	45.40	143.60	2.70	4	593
C525	10.70	42.70	138.80	3.25	19	552
C550-B	31.40	40.20	152.00	10.76	34	3639
C550-II	21.50	65.70	218.60	9.85	5	176
C560	17.70	55.20	183.30	26.90	11	634
C56X	-31.50	39.20	149.10	7.16	56	5198
C650	0.20	47.50	142.70	3.52	7	430
C680	-35.60	40.90	158.30	0.88	2	35
C750	-25.20	43.00	154.20	11.47	15	511
CARJ	-19.30	36.40	128.50	3.40	12	1894
CL600	-8.30	48.40	153.50	13.82	40	834
CL604	14.60	41.40	138.80	9.35	67	2452
DC10	-9.80	58.50	185.30	23.98	38	2987
DC86-7	-70.30	55.60	237.10	28.04	16	188
DC86-7-1	-79.60	150.90	532.30	10.91	2	134
DC95	-24.60	43.30	154.50	0.98	3	6
E135-145	54.50	63.70	245.60	4.37	24	1201
E170	36.40	61.80	221.80	3.23	25	2634
F100	-38.90	37.60	151.70	13.43	5	1173
F2TH	-25.20	61.60	210.00	7.23	64	3581
F900	28.00	56.50	197.50	19.04	106	3596
FA10	21.80	40.40	143.00	14.73	5	468
FA20	-13.30	58.30	188.20	12.79	11	397
FA50	46.40	69.10	253.70	20.62	49	1829
GALX	-9.80	51.40	164.00	1.45	11	257
GLEX	44.60	66.50	244.10	14.14	55	631
GLF2-G	34.60	33.80	136.00	0.30	3	16
GLF3	-63.20	46.90	203.90	27.09	13	130
GLF4	-31.60	50.90	184.30	19.56	122	1790
GLF5	20.20	71.50	234.70	20.64	79	947
H25B-700	-44.50	109.30	372.40	30.34	4	45
H25B-800	17.40	61.10	200.70	12.05	70	3973
H25C	64.20	47.00	205.20	6.36	3	129
IL62	51.90	50.90	204.60	8.65	10	68
IL76	59.60	63.60	250.40	30.14	38	517
IL86	13.00	74.10	235.30	58.44	17	56
IL96	44.90	63.70	236.00	17.03	12	84
L101	11.80	66.70	211.90	24.57	17	2456
LJ31	-13.00	36.40	122.20	14.96	9	231
LJ35/6	67.20	47.20	208.80	15.02	11	907

Monitoring Group	Group ASE mean (<80ft)	Overall ASE standard deviation	mean +3*Stdev (<245ft)	AAD_stdev	#AC	#Mes
LJ55	32.40	36.30	141.30	7.28	4	98
LJ60	54.90	41.10	178.20	8.40	29	1210
MD11	-10.20	53.30	170.10	15.12	141	11174
MD80	-10.20	39.50	128.70	15.01	147	27768
MD90	42.50	43.50	173.00	10.18	19	2673
T134	-18.60	46.80	159.00	15.27	4	9
T154	2.20	68.10	206.50	30.77	64	1293
T204	-17.40	64.60	211.20	12.32	10	254
YK42	54.90	42.30	181.80	35.69	10	126

**Table A- 4: ASE Parameters by non-group aircraft**

Aircraft Type	ASE mean (<80ft)	Overall ASE standard deviation	mean +3*Stdev (<245ft)	AAD_stdev	#AC	#Mes
B701	30.90	57.70	204.00	81.76	10	79
BE40-BEECH	25.60	38.10	139.90	1.38	2	48
H25B-800NG	25.00	38.30	139.90	18.57	2	60
DC86-7NG	-46.90	55.10	212.20	32.45	6	246
VC10	120.50	72.20	337.10	49.89	16	679

#### **A.4.3. Conclusions on ICAO group requirements (i) and (ii)**

As a result of the data collected for this Report, a number of monitoring groups have been identified as not complying with the group-performance requirements as defined in ICAO Doc 9574. In addition one type does not meet the non-group performance requirements.

Those aircraft monitoring groups are currently under investigation by Eurocontrol. Eurocontrol will keep the MID RMA informed in due time of the results from any actions undertaken.

It is recommended that MID RMA continue following-up Eurocontrol activities and include in this **Appendix** the outcome of those activities for future assessments.

In addition to that, it is recommended for future assessments that MID RMA continues the collection of radar data from the region, review the list of monitoring groups for the region and initiate actions on monitoring groups specific to the region.

#### **A.4.4. Assessment of ICAO group requirements (iii): Errors in altitude-height keeping**

Requirement (iii) sets performance limits on the errors in altitude-height keeping exclusive of human factors. This is interpreted to mean "allowable" altitude deviations (AAD) as represented by the height-monitoring data when the absolute value is less than 350ft and contributes to the technical-vertical risk. Larger deviations are assumed to be due to human factors and are included as such in the assessment of the total vertical risk in APPENDIX C - of this Report.

Figure C-2 at the end of APPENDIX C - , shows a distribution based on empirical assigned altitude deviation (AAD) data rounded to the nearest 100ft with a standard deviation of 37.82ft and a mean of -0.35ft.

So the current data shows that requirement (iii) is being met for the combination of the distribution type the standard deviation and mean.

#### **A.5. Individual aircraft performance (Requirement ii and iv)**

From the data set used in this assessment, several aircraft have been identified as having individual Altimetry System Error (ASE) measurements whose absolute value exceeds 275ft (245ft plus 30ft allowance for measurement system error) for EUR measurements or exceeds 300ft (245ft plus 55ft allowance for measurement system error) for NAT measurements. The information is summarised in the following tables.

**Table A- 5: Aircraft with large ASE values.**

Monitoring group	Aircraft type	#AC	ASE values
A310-GE	A310	1	-302.1
A320	A320	3	296, 299, 297, 285, 284.6
B737CL	B737	1	-275.8
B744-10	B747	1	-296.5
B772	B777	2	297, 289
L101	L-1011 TRISTAR	1	285
T154	T154	1	348.5
<b>VC10<sup>2</sup></b>	VC10	2	293.4, 320.5

The data in Table A-5 is derived from the European monitoring programme and the aircraft are currently subject to investigation by Eurocontrol.

#### **A.6. Conclusions**

- (i) According to results, most monitoring groups show compliance with the ICAO group requirements. However, the results also show that some monitoring groups are exceeding the group requirements.
- (ii) The airspace monitoring and evaluation activities carried out by Eurocontrol in the last months ensure that the number of monitoring groups and individual aircraft showing poor technical height-keeping performance do not increase over the years, problems are identified and follow-up actions are taken in solving potential safety issues for future assessments.

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<sup>2</sup> The VC10 fails requirement ii and iv

**A.7. Recommendations**

- (i) It is recommended that MID RMA continue following-up Eurocontrol activities and include in this **Appendix** the outcome of those activities for future assessments.
- (ii) In addition to that, it is recommended for future assessments that MID RMA continue the collection of radar data of the region and initiate, whenever necessary, actions on individual aircraft specific to the region.

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## **APPENDIX B - OPERATOR MONITORING COMPLIANCE**

### **B.1. Introduction**

In accordance with ICAO Guidance Material operators are required to participate in a regional monitoring programme. Each monitoring group is assigned a monitoring target that specifies the minimum number, or percentage, of each type flown by an operator that should be monitored. The valid duration for a monitoring result is part of ongoing international discussions of long term monitoring requirements; only Europe to date has specified a validity period of two years for height monitoring results.

Although the long term aim of all RMAs is to ensure sufficient aircraft are monitored to meet individual operator monitoring targets a first step is to ensure that all operators have at least one example of each type monitored.

### **B.2. Operator Compliance Analysis**

States have submitted RVSM flight plan data for a one month period (April 2006). Registration data extracted from the flight plan data together with the list of approvals submitted by the states to the Mid RMA was used to identify a total of **926** individual airframes operating from the Middle Eastern states, or from other regions submitting flight plans for the sample period. Of these **926** individual airframes **651** have HMU monitoring results from the European monitoring programme.

The percentage of approved aircraft from the Mid region monitored is very high with **413** out of a total list of **497** aircraft having successful HMU monitoring results, although some of these are more than 3 years old.

Although it was not possible to identify specific airframes from the rest of the flight plan data, analysis of the callsign and aircraft type data was used to identify a total of **1319** valid operator type combinations operating in the region. Of these **624** have valid monitoring results in the European region leaving **695** without any known result. Many of the operator/type combinations have US or Caribbean registrations which may have monitoring results from the NAARMO or PARMO monitoring programmes. Other operators from India, Pakistan etc. may similarly have monitoring results from the MAAR region. However, adequate protocols for obtaining monitoring results from these regions have yet to be established.

Additional analysis identified that some of the flight plans submitted for the sample period were not applicable to RVSM operations and so should not count towards the number of operators requiring monitoring. Typically these included flights that were below FL290 in RVSM airspace only climbing above this level when entering non-RVSM airspace. Future sample data should be restricted to those plans where a 'W' has been submitted in field 10 of the flight plan.

### B.3. Long Term Monitoring

For the purposes of height monitoring, aircraft are assigned to a monitoring group<sup>3</sup>. A monitoring group can consist of one or more aircraft types, or may alternatively be a subset of a type that has had specific alterations affecting the height keeping performance.

As a result of harmonisation between the different Regional Monitoring Agencies (RMAs) around the world, an initial set of aircraft monitoring groups was established and documented in the ICAO RMA handbook [16]. Since the first production of this document it has been necessary to amend these groups as new aircraft types have come on line and other groups have been modified against Supplementary Type Certificates, (STC) that have altered the height keeping performance.

Table B-1: lists the current monitoring group structure as defined for the Middle East RVSM region. Each monitoring group is assigned a monitoring target that specifies the minimum number, or percentage, of aircraft for each group that each operator should have monitored. As stated previously the period during which each operator should meet these targets has only been defined for the European region.

It is not practical to expect all operators to meet the monitoring targets for all types operated within a short time scale; however the MID RMA continues to monitor the frequency of operations by individual operators and will identify on this basis, a priority list of operators that require monitoring before production of the next safety report.

Eurocontrol will supply all results for Middle East registered ACFT that are flying over the European HMUs. For other Middle East registered ACFT the state of registry is responsible to instruct each ACFT operator to conduct GMU monitoring in accordance with ICAO ACFT grouping categories.

**Table B-1: Current Middle East RVSM Monitoring Group Structure**

Monitoring group	Target	A/C ICAO	A/C type	A/C series
<b>A124</b>	60%	A124	AN-124 RUSLAN	ALL SERIES
<b>A300</b>	60%	A30B	A300	B2-100, B2-200, B4-100, B4-100F, B4-120, B4-200, B4-200F, B4-220, B4-220F, C4-200
<b>A306</b>	60%	A306	A300	600, 600F, 600R, 620, 620R, 620RF
<b>A310-GE</b>	60%	A310	A310	200, 200F, 300, 300F
<b>A310-PW</b>	30%/2	A310	A310	220, 220F, 320
<b>A320</b>	30%/2	A319 A320 A321	A319 A320 A321	CJ, 110, 130, 210, 230

<sup>3</sup> Aircraft monitoring groups are those of nominally identical design and build with respect to all details that could influence the accuracy of height-keeping performance. A detailed explanation is given in JAA TGL No. 6 Para. 9.3.1

Monitoring group	Target	A/C ICAO	A/C type	A/C series
<b>A330</b>	10%/2	A332, A333	A330	200, 220, 240, 300, 320, 340
<b>A340</b>	30%/2	A342, A343	A340	210, 310
<b>A345</b>	30%/2	A345	A340	540
<b>A346</b>	60%	A346	A340	640
<b>AN72</b>	60%	AN72	AN-74, AN-72	ALL SERIES
<b>AVRO</b>	30%/2	RJ1H, RJ70, RJ85	AVRO	RJ70, RJ85, RJ100
<b>B712</b>	60%	B712	B717	200
<b>B727</b>	60%	B721, B722	B727	100, 100C, 100F, 100QF, 200, 200F
<b>B732</b>	60%	B732	B737	200, 200C
<b>B737CL</b>	30%/2	B733, B734, B735	B737	300, 400, 500
<b>B737NX</b>	30%/2	B736, B737, B738, B739	B737	600, 700, 700BBJ, 800, 800BBJ, 900
<b>B744-10</b>	30%/2	B744	B747	400, 400D, 400F
<b>B744-5</b>	60%	B744	B747	400, 400D, 400F
<b>B747CL</b>	60%	B741, B742, B743	B747	100, 100B, 100F, 200B, 200C, 200F, 200SF, 300
<b>B747LCF</b>	60%	B744	B747	LCF
<b>B74S</b>	60%	B74S	B747	SP, SR
<b>B752</b>	30%/2	B752	B757	200, 200PF
<b>B753</b>	30%/2	B753	B757	300
<b>B767</b>	60%	B762, B763	B767	200, 200EM, 200ER, 200ERM
<b>B772</b>	10%/2	B772	B777	200, 200ER
<b>B773</b>	30%/2	B773	B777	300, 300ER
<b>BE40</b>	60%	BE40	BEECHJET 400A HAWKER 400XP	ALL SERIES
<b>C17</b>	60%	C17	C-17 GLOBEMASTER 3	ALL SERIES
<b>C525</b>	30%/2	C525	525 CITATIONJET, 525 CITATIONJET I	ALL SERIES
<b>C550-B*</b>	30%/2	C550	550 CITATION BRAVO	ALL SERIES
<b>C550-II</b>	60%	C550, C551	550 CITATION II, 551 CITATION II SINGLE PILOT	ALL SERIES
<b>C560</b>	60%	C560	560 CITATION V, 560 CITATION V - ULTRA, 560 CITATION V - ULTRA ENCORE	ALL SERIES
<b>C56X</b>	30%/2	C56X	560 CITATION EXCEL 560 CITATION XLS	ALL SERIES
<b>C650</b>	60%	C650	650 CITATION III,	ALL SERIES

Monitoring group	Target	A/C ICAO	A/C type	A/C series
			650 CITATION VI, 650 CITATION VII	
<b>C680</b>	60%	C680	680 CITATION SOVEREIGN	ALL SERIES
<b>C750</b>	30%/2	C750	750 CITATION X	ALL SERIES
<b>CARJ</b>	60%	CRJ1, CRJ2	REGIONALJET	100, 100ER, 200, 200ER, 200LR
<b>CL600</b>	30%/2	CL60	CL-600, CL-601	CL-600-1A11, CL-600-2A12, CL-600-2B16
<b>CL604</b>	30%/2	CL60	CL-604	CL-600-2B16
<b>BD100</b>	60%	CL30	CHALLENGER 300	ALL SERIES
<b>DC10</b>	30%/2	DC10	DC-10	10, 10F, 5, 30, 30F, 40, 40F
<b>DC86-7</b>	60%	DC86, DC87	DC-8	61, 63, 71, 73
<b>DC86-7-1</b>	60%	DC86 DC87	DC-8	62, 72
<b>DC95</b>	60%	DC95	DC-9	51
<b>E135-145</b>	60%	E135, E145	ERJ-135, ERJ-145	ALL SERIES, LEGACY 600, LEGACY, LR, ER, BJ
<b>E170</b>	60%	E170 E190	ERJ-170, ERJ-175, ERJ -190, ERJ-195	ALL SERIES
<b>F100</b>	30%/2	F100	F-100	ALL SERIES
<b>F2TH</b>	60%	F2TH	FALCON 2000, FALCON 2000EX	ALL SERIES
<b>F900</b>	60%	F900	FALCON 900, FALCON 900EX, FALCON 900DX	ALL SERIES
<b>FA10</b>	60%	FA10	FALCON 10	ALL SERIES
<b>FA20</b>	60%	FA20	FALCON 20, FALCON 200	ALL SERIES E5, F5, F
<b>FA50</b>	60%	FA50	FALCON 50, FALCON 50EX	ALL SERIES
<b>GALX</b>	60%	GALX	1126 GALAXY, G200	ALL SERIES
<b>GLEX</b>	60%	GLEX	BD-700 GLOBAL EXPRESS	ALL SERIES
<b>GLF2</b>	60%	GLF2	GULFSTREAM II (G-1159)	ALL SERIES
<b>GLF2-G</b>	60%	GLF2	GULFSTREAM II (G-1159)	ALL SERIES
<b>GLF2B</b>	60%	GLF2	GULFSTREAM IIB (G-1159B)	ALL SERIES
<b>GLF2B-G</b>	60%	GLF2	GULFSTREAM IIB (G-1159B)	ALL SERIES
<b>GLF3</b>	60%	GLF3	GULFSTREAM III (G-1159A)	ALL SERIES
<b>GLF4</b>	30%/2	GLF4	GULFSTREAM IV (G-1159C), G300, G350, G400, G450	ALL SERIES
<b>GLF5</b>	30%/2	GLF5	GULFSTREAM V (G-1159D), G500,	ALL SERIES

Monitoring group	Target	A/C ICAO	A/C type	A/C series
			G550	
<b>H25B-700</b>	60%	H25B	BAE 125 / HS125	700
<b>H25B-800</b>	60%	H25B	BAE 125 / HAWKER 800XP, BAE 125 / HAWKER 800, HAWKER 800XPI	ALL SERIES
<b>H25C</b>	60%	H25C	BAE 125 / HAWKER 1000	ALL SERIES A, B
<b>IL76</b>	60%	IL76	IL-76	M, T
<b>IL86</b>	100%	IL86	IL-86	ALL SERIES
<b>IL96</b>	60%	IL96	IL-96	M, T, 300
<b>L101</b>	60%	L101	L-1011 TRISTAR	1(385-1), 40(385-1), 50(385-1), 100, 150(385-1-14), 200, 250(385-1-15), 500(385-3)
<b>LJ31</b>	30%/2	LJ31	LEARJET 31	ALL SERIES
<b>LJ35/6</b>	60%	LJ35, LJ36	LEARJET 35, LEARJET 36	ALL SERIES,
<b>LJ45</b>	30%/2	LJ45	LEARJET 45	ALL SERIES
<b>LJ55</b>	60%	LJ55	LEARJET 55	ALL SERIES
<b>LJ60</b>	10%/2	LJ60	LEARJET 60	ALL SERIES
<b>MD11</b>	30%/2	MD11	MD-11	COMBI, ER, FREIGHTER, PASSENGER
<b>MD80</b>	30%/2	MD81, MD82, MD83, MD87, MD88	MD-80	81, 82, 83, 87, 88
<b>MD90</b>	30%/2	MD90	MD-90	30, 30ER
<b>T134</b>	60%	T134	TU-134	A, B
<b>T154</b>	30%/2	T154	TU-154	A, B, M, S
<b>T204</b>	60%	T204, T224, T234	TU-204, TU-224, TU-234	100, 100C, 120RR, 200, C
<b>YK42</b>	60%	YK42	YAK-42	ALL SERIES

\* Minimum of two aircraft are required to be monitored for each group mention in the above table

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## APPENDIX C - VERTICAL-COLLISION RISK ASSESSMENT

### C.1. Introduction

This **Appendix** presents the results of the vertical-collision risk estimation process which aims to assess the vertical-collision risk within Middle East RVSM airspace against the two quantitative safety objectives (ICAO Target Levels of Safety) detailed in Section 2 of this Safety Monitoring Report. The results contained in this **Appendix** will be used in Section 2 of the main text, where all the necessary arguments and evidence to demonstrate that the safety objectives are met are set out.

The quantitative safety objectives to be satisfied by the vertical-collision risk estimated within Middle East RVSM airspace are:

**Objective #1** In accordance with ICAO Guidance Material [1], the risk of mid-air collision in the vertical dimension within RVSM airspace, due to technical height-keeping performance, shall meet a ICAO TLS of  $2.5 \times 10^{-9}$  fatal accidents per flight hour.

**Objective #2** In accordance with ICAO Guidance Material [1], the management of the overall vertical-collision risk within RVSM airspace shall meet a ICAO TLS of  $5.0 \times 10^{-9}$  fatal accidents per flight hour.

The information in this **Appendix** is primarily concerned with:

- the traffic distribution over the MID RVSM flight levels;
- technical height-keeping performance<sup>4</sup>; and
- frequency of operational vertical errors.

Applying the European mathematical collision risk model, this information leads to estimates of the parameters of the model and thus to an estimate of the vertical-collision risk.

#### C.1.1. Initial assumptions

The safety estimations that address the above objectives are based on the two following assumptions:

- That the European mathematical collision risk model (CRM), as detailed in the European RVSM Mathematical Supplement [8] and after suitable adjustments, can be applied to the Middle East RVSM airspace.
- That the Altimetry System Error (ASE) for Middle East RVSM-approved aircraft is stable over time.

#### C.1.2. Vertical-collision risk – general concept

The European mathematical model for vertical-collision risk has two key

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<sup>4</sup> More detailed information on technical height-keeping performance is included in Appendix A.

components:

- One component is the frequency with which aircraft flying at the vertical separation minimum pass directly overhead one another. This is termed the horizontal-overlap frequency.
- The other component is the probability that aircraft, which are nominally separated by the vertical-separation minimum, are actually, for reasons of error, flying at the same level. This is termed the probability of vertical overlap.

It is the product of these two components which results in the collision risk in the vertical dimension. The data used to estimate each component is dependent on the type of vertical risk being considered, i.e. technical or operational vertical-collision risk.

## **C.2.      *Technical vertical-risk estimation***

### **C.2.1.    Frequency of horizontal overlap**

#### *Methodology*

The estimate of the frequency of horizontal overlap is obtained from the combination of two parameters based on the number of proximate events. A proximate event is defined as the occurrence of two aircraft passing within a horizontal distance R whilst separated by the vertical separation minimum (1000ft).

Those two parameters are the probability of proximate events and the proximity frequency. Based on the range of different geometries (pairs of aircraft in crossing, parallel and opposite direction) and relative velocities seen across the set of proximate events, the first parameter takes into account the probability that the proximity is less than a distance equal to the size of the average aircraft, given that it is within the distance R. The second parameter, the proximity frequency, is then estimated from the number of estimated proximate events divided by the overall number of flight hours.

**Table C-1** lists all the relevant data used in the current calculations of the frequency of horizontal overlap. A summary of the methodology is given in the following paragraph and additional details on this methodology can be found in the European RVSM Mathematical Supplement **[3]**.

#### *Data*

The horizontal source data used for the estimation of the proximity frequency was the Bahrain SSR radar system (RVSM level traffic recorded between 1 September 2006 and 30 September 2006) providing coverage to 250 Nm and representative of some of the densest airspace in the region.

Regarding the probability of proximate events, this was estimated using the Bahrain SSR radar data and the European model for geometries and velocities. In the absence of a suitable model for the Middle East, the European model is considered to represent the most conservative scenario

due to the density of the European traffic, leading to a conservative estimation for the probability.

For future assessments, it is recommended to investigate the possibility to develop a customised Middle East model for the estimation of the probability of proximate events.

#### *Results for frequency of horizontal overlap*

Based on the current data set, the frequency of horizontal overlap in European RVSM airspace is estimated to be  $6.99 \times 10^{-3}$  per flight hour for pairs of aircraft at adjacent flight levels.

### **C.2.2. Probability of vertical overlap due to technical height deviations**

#### *Methodology*

The applied methodology is based on two distributions: the overall ASE (Altimetry System Error) and the 'typical' AAD (Assigned Altitude Deviation) distributions (see **Figure C-1**). The combination of these two distributions provides the probability of vertical overlap due to technical height-keeping performance.

The overall ASE distribution is obtained from the combination of ASE distributions for each aircraft monitoring group, weighted by the proportion of flights made by that group.

A monitoring group's ASE distribution is made up of two different types of density distributions: a within-airframe ASE distribution and a between-airframe ASE distribution. The most suitable distribution curves to those types of distributions are to be found in order to fit the obtained HMU ASE measurements for each monitoring group.

'Typical' AAD performance has been taken to be that which is not greater than 350ft in magnitude. Any AAD greater than this value should be considered 'atypical' and then modelled as a contribution to the total vertical risk.

#### *Data*

The probability of vertical overlap has been derived from the European monitoring program results for operators in the Middle East for the period 1<sup>st</sup> January 05 to 31<sup>st</sup> December 2006.

#### *Results for probability of vertical overlap due to technical height deviations.*

The ASE density distributions derived for each aircraft monitoring group for the current collision risk analysis are shown in **Table C-2**.

**Table C-3** presents the currently observed proportions of typical AAD. The distribution chosen to model typical AAD is a DE, with a mean of -0.35ft and standard deviation value of 37.82ft. The closeness of the fit is shown in **Figure C-2**. It should be noted that this figure presents all measurement data rounded

to the nearest 100ft.

The value of  $P_z(1000)$  based on the currently observed ASE and typical AAD data is estimated to be of  $3.1 \times 10^{-12}$ .

This value satisfies the ICAO Global System Performance Specification, as laid down in ICAO Document 9574 (2<sup>nd</sup> Edition) [1], that the probability that two aircraft will lose procedural vertical separation of 1000ft should be no greater than  $1.7 \times 10^{-8}$ .

### **C.2.3. Results for technical vertical risk**

Combining the probability of vertical overlap with the horizontal overlap frequency gives an estimated vertical risk due to technical height-keeping performance for Middle East RVSM airspace of  $2.17 \times 10^{-14}$ .

The ICAO TLS of  $2.5 \times 10^{-9}$  fatal accidents per flight hour for the vertical-collision risk due to technical causes is therefore met.

## **C.3. Vertical risk estimation due to atypical errors**

### *Methodology*

In assessing the total vertical risk posed by all causes, the risk posed by technical height-keeping performance must be combined with the risk posed by all other sources of deviation from the assigned altitude. Such deviations are referred to as atypical.

The risk posed by all atypical errors is obtained by the combination of two parameters: the probability of vertical overlap due to atypical errors and the frequency of horizontal overlap.

The estimation for frequency of horizontal overlap was already obtained in section C.2.1.

For the estimation of the probability of vertical overlap due to atypical errors, information has to be gathered from the participating States in form of Altitude Deviation Reports<sup>5</sup> (ADRs) describing the nature, duration and length of the altitude deviation of any event within the RVSM airspace. A scrutiny group of experts has then to be created to ensure that only altitude deviations and not other type of deviations are used for the estimation. The duration of those deviations are then compared to the overall flight time for the airspace under assessment to derive the overall AAD operational error parameter.

### *Data used for the estimation of the probability of vertical overlap due to atypical errors.*

During 2006, the MID RMA participating States sent the Altitude deviation

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<sup>5</sup> An Altitude Deviation has occurred when the aircraft deviates, for any reason, by 300ft or more from the cleared flight level as specified in an ATC clearance.

reports related to un-coordinated flights not following the Read Sea procedure and ATC coordination errors.

*Results for probability of vertical overlap due to atypical errors*

A scrutiny group including Eurocontrol ATC and safety experts and Middle East RMA's experts was created to review the status of those reports and decide whether they eventually constituted RVSM altitude deviations.

The result of the scrutiny group was that the reported deviations did not constitute RVSM altitude deviations themselves as those took place in un-coordinated airspace – the Red Sea Procedure does not entail ATC clearance, which is not part of the altitude deviation definition- or outside Middle East RVSM airspace.

As all collected reports were not considered to be ADRs, it was not possible to quantifiably estimate the probability of vertical overlap due to atypical errors and eventually provide an estimation of the associated risk due to atypical errors.

Nevertheless, the scrutiny group qualitatively assessed the influence of deviations from those un-coordinated flights in the Red Sea airspace (non-standard non-procedural airspace). In this sense, the scrutiny group considered that the non-adherence to current Red Sea procedure was of special concern as it might have a negative safety influence in the Middle East RVSM operations within coordinated airspace. More precisely, the occurrence of an aircraft leaving the Red Sea un-coordinated airspace and entering into Middle East RVSM coordinated airspace at unexpected flight levels would be considered in the future as risk bearing and constitute an altitude deviation itself.

The scrutiny group recommended to the MID RMA, in coordination with concerned States, assure that incidents and altitude deviations occurring over the Red Sea Area are reported in a continuous basis and copy of those reports are sent to the MID RMA in due time for their operational assessment in future safety analysis.

In addition to that, the scrutiny group strengthened the need for the MID RMA to continue monitoring RVSM operations in the whole Middle East RVSM airspace over the months by the collection of altitude deviation reports from the participating States. Those reports should describe the nature, duration and length of the altitude deviation itself.

In that sense, it is also recommended that the MID RMA should use a form based on the Eurocontrol altitude deviation report form to ensure that the appropriate operational information is collected.

*Conclusions on the estimation of the vertical risk due to atypical errors*

Due to the lack of suitable information to feed the mathematical collision risk model, it has not been possible to compute the probability of vertical overlap due to atypical errors. In consequence this report cannot provide an estimate for the vertical risk due to atypical errors.

Nevertheless, recommendations to collect operational data from the

participating States are provided for future safety assessments.

### **C.3.1. Total vertical risk results**

In the absence of an estimate for the vertical risk due to atypical errors, it is not possible to provide an estimate for the total vertical risk for the Middle East RVSM airspace.

Hence, for the time being it is not possible to assess whether the ICAO TLS of  $5.0 \times 10^{-9}$  fatal accidents per flight hour for the overall vertical-collision risk due to all causes is met in the Middle East RVSM airspace.

### **C.3.2. Uncertainties**

The technical vertical risk has been estimated based on some initial assumptions and constraints, which leads to some uncertainties about the risk estimates, the main issues being believed to be:

- (i) the difficulty of ensuring that the type of probability distributions fitted to ASE measurements provide a realistic model for the large deviations that occur very rarely. Nevertheless, it is important to mention that the European curve fitting process has been improved along the years with additional density distributions that allow to capture the rare deviations more accurately;
- (ii) serious errors are rare so the risk estimate is constructed from small samples, which results in statistical uncertainty about model parameter estimates, even for a correctly specified model. Nevertheless, those errors have never prevented the EUR RVSM safety assessments from meeting the ICAO technical vertical TLS since EUR RVSM implementation. As this report has been obtained using suitable data from the EUR RVSM safety assessments, it is assumed that this conclusion is also applicable to the Middle East RVSM airspace.

## **C.4. *The effect of future traffic growth***

The effect of future traffic growth on the technical vertical-collision risk was estimated on the basis of a linear relationship between traffic growth and frequency of horizontal overlap from the year 2006 up to 2010.

Under that basis and considering an average traffic growth of 7.85% per year for the Middle East RVSM airspace, the technical vertical-collision risk estimation will continue to meet the technical TLS until 2010, as the estimation for that year is of  $1.23 \times 10^{-10}$  fatal accidents per flight hour.

It is important to note that the vertical-risk estimation due to atypical errors has been demonstrated to be the major contributor in the overall vertical-risk estimation for the EUR RVSM airspace. In addition to that, the EUR RVSM safety monitoring reports have highlighted the sensitivity of this estimation to future traffic growth - reference **[10]** provides further information -.

In that respect, although at the current time the operational situation may not be critical the estimated forecast increase of **8%** traffic growth per year in the Middle East RVSM airspace –this in practice represents that the frequency of horizontal overlap estimation will be doubled in 9 years - may contribute to a scenario when the overall ICAO vertical TLS may be exceeded.

### **C.5. Conclusions**

This **Appendix** has dealt with the estimation of the risk of collision due to the loss of vertical separation, based on the currently observed data and the European collision risk model.

The estimate for the vertical-risk due to height-keeping performance meets the ICAO TLS of  $2.5 \times 10^{-9}$  fatal accidents per flight hour.

The operational vertical-risk due to atypical errors has not been estimated due to the absence of suitable ADRs.

In this sense, it has not been possible to estimate the total vertical risk and compare it against the ICAO overall vertical TLS of  $5 \times 10^{-9}$  fatal accidents per flight hour.

Finally, using traffic growth forecast, it has been estimated that the technical vertical risk will continue meeting the technical TLS until 2010.

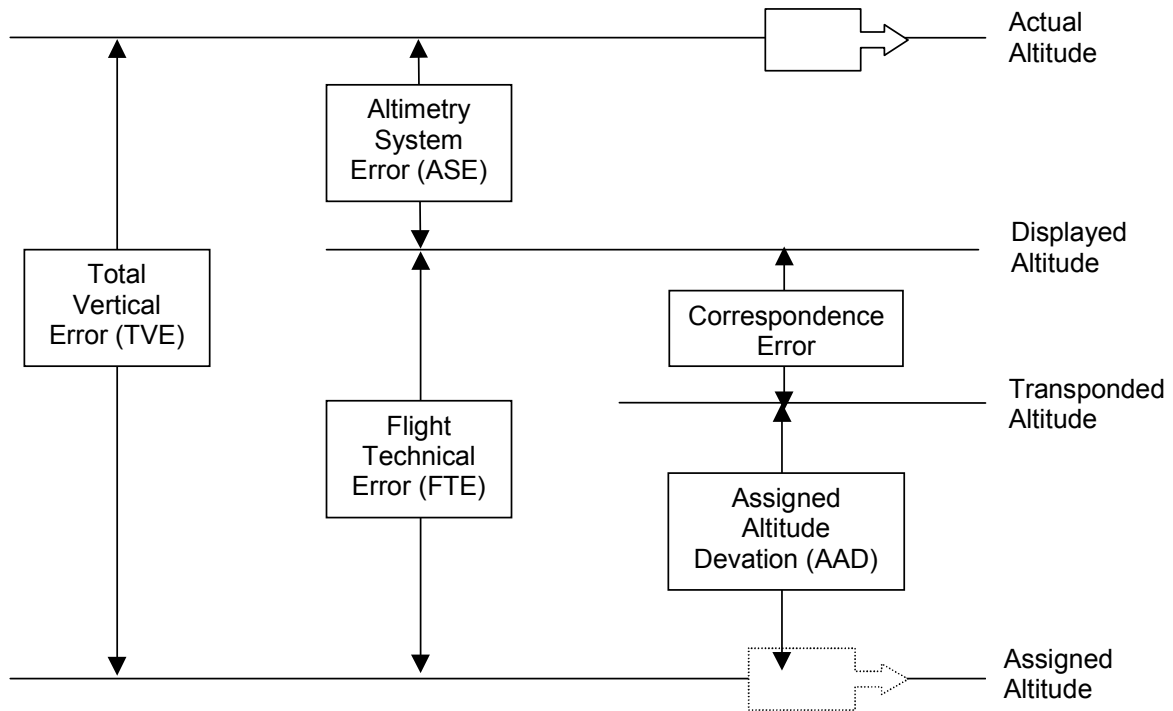
### **C.6. Recommendations**

The scrutiny group recommended to the MID RMA, in coordination with concerned States, assure that incidents and altitude deviations occurring over the Red Sea Area are reported in a continuous basis and copy of those reports are sent to the MID RMA in due time for their operational assessment in future safety analysis.

MID RMA to continue monitoring RVSM operations in the whole Middle East RVSM airspace over the months by the collection of altitude deviation reports from the participating States. Those reports should describe the nature, duration and length of the altitude deviation itself.

MID RMA to use a form based on the Eurocontrol altitude deviation report form to ensure that the appropriate operational information is collected.

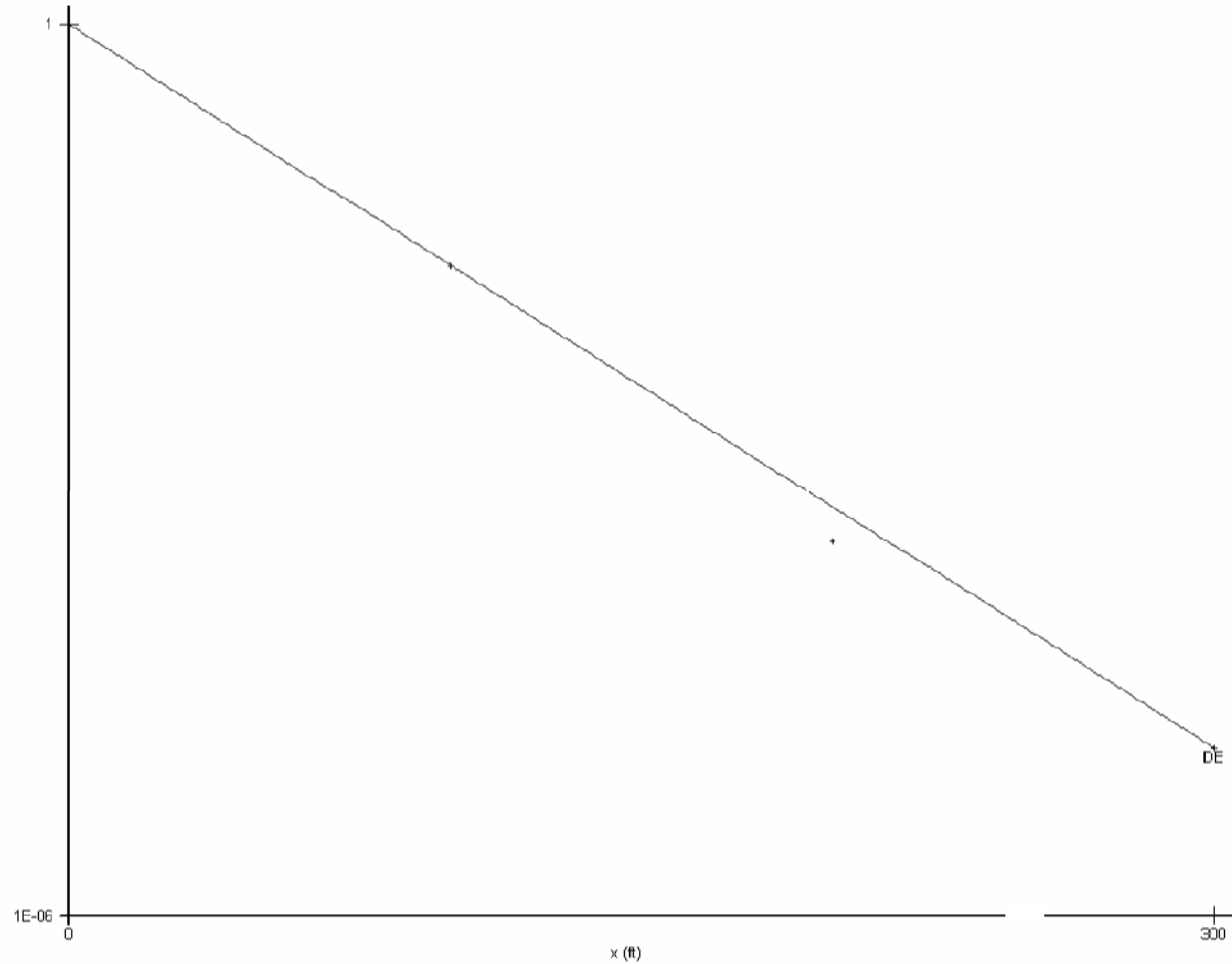
**Figure C-1: Components which combine to form the total vertical error (TVE)**



Note: TVE expresses the accuracy with which aircraft systems are able to maintain the assigned altitude. The FTE component approximates to AAD (on the assumption that correspondence error is relatively small) and includes autopilot performance (the so-called *typical* AAD) but excludes all operational sources of error (*atypical* AAD).

Figure C-2: Fit for typical AAD

abs(AAD) < 350 Rounded to the Nearest 100. Measurement Data: 01 Jan 2005 to 31 Dec 2006 (1041711 data points)



Empirical and five model one-minus-cumulative curves (logarithmic) showing the probability that an individual measurement deviates from the sample mean ASE by more than an amount x, i.e.  $\text{Prob}(|x_j - m| > x)$

**Table C- 1: Summary of proximate event parameters used to calculate horizontal overlap frequency**

	Days	Flt Hrs (F)	Number of proximate events	Total frequency (2n/F)
Bahrain SSR radar data	30 *	1.320	124	0.094
	Days	Flt Hrs (F)	Geometry factor	Horizontal overlap
HMU data	518	93.204,63	7.44E-02	8.68 E-03

\* NOTE: Recording time per day is 2 hours.

**Table C- 2: Observed ASE performance for aircraft monitoring groups**

Type	Flight time proportion	Between-Airframe Density	Within-Airframe Density
A124	0.06%	G	G-DE
A300	0.81%	G	G-DE
A306	1.50%	G	GL-GL-GL
A310-GE	0.82%	G-DE	G-DE
A310-PW	0.35%	G-DE	G-DE
A320	31.00%	G-DE	G-G-GL
A330	3.78%	G-DE	G-G-GL
A340	3.35%	G-DE	G-G-GL
A345	0.07%	G	G-DE
A346	0.25%	DE	G-DE
AN72	0.00%	G	G
AVRO	0.67%	G	G-DE
B701	0.01%	G	G
B703NG	0.00%	G-DE	G-DE
B712	0.00%	G-DE	G-DE
B727	0.03%	DE	G
B732	0.10%	DE	G-DE
B737CL	11.81%	G-DE	GL-GL-GL
B737NX	15.26%	G	G-G-GL
B744-10	3.27%	G	G-G-GL
B744-5	1.01%	G	G-DE
B747CL	1.35%	G	G-DE
B747LCF	0.00%	G-DE	G-DE
B74S	0.10%	G	G
B752	4.57%	G-DE	GL-GL-GL
B753	1.53%	G	G-G-GL
B767	4.60%	G-DE	G-G-GL
B772	3.75%	G	G-G-GL
B773	0.89%	G	G-G-GL
BD100	0.02%	G	G-DE
BE40	0.12%	DE	G-DE
BE40-BEECH	0.01%	G	G-DE
C17	0.06%	G	G
C525	0.05%	DE	G
C550-B	0.35%	DE	G-DE
C550-II	0.02%	G	G-DE
C560	0.06%	G	G-DE
C56X	0.50%	G-DE	G-DE
C650	0.04%	G	G-DE
C680	0.00%	G	G
C750	0.05%	G	G-DE
CARJ	0.18%	G	G-DE
CL600	0.08%	G	G-DE
CL600NG	0.00%	G-DE	G-DE
CL604	0.24%	G	G-DE
DC10	0.29%	G	G-DE
DC86-7	0.02%	G	G-DE
DC86-7-1	0.01%	G	G-DE

Type	Flight time proportion	Between-Airframe Density	Within-Airframe Density
DC86-7NG	0.02%	G	G-DE
DC95	0.00%	G	G
E135-145	0.12%	G	G-DE
E170	0.25%	G	GL-GL-GL
F100	0.11%	G	G
F2TH	0.34%	G	G-DE
F900	0.35%	G	G-DE
FA10	0.05%	G	G-DE
FA20	0.04%	G	G-DE
FA50	0.18%	G	G-DE
GALX	0.03%	G	G
GLEX	0.06%	DE	G-DE
GLF2	0.00%	G-DE	G-DE
GLF2B	0.00%	G-DE	G-DE
GLF2B-G	0.00%	G-DE	G-DE
GLF2-G	0.00%	G	G
GLF3	0.01%	DE	G
GLF4	0.17%	G	G-DE
GLF5	0.09%	G	G-DE
H25B-700	0.00%	G	G
H25B-800	0.38%	G	G-DE
H25B-800NG	0.01%	G	G
H25C	0.01%	G	G
IL62	0.01%	G	G-DE
IL76	0.05%	G	G-DE
IL86	0.01%	G	DE
IL96	0.01%	G	G
L101	0.24%	G	G-DE
LJ31	0.02%	G	G
LJ31NG	0.00%	G-DE	G-DE
LJ35/6	0.09%	G	G-DE
LJ55	0.01%	G	G-DE
LJ60	0.12%	DE	G-DE
MD11	1.07%	G	G-DE
MD80	2.67%	G-DE	G-DE
MD90	0.26%	G-DE	G-DE
SBR1-65	0.01%	G-DE	G-DE
T134	0.00%	G	G
T154	0.12%	DE	G-DE
T204	0.02%	G	G-DE
VC10	0.07%	DE	G-DE
YK42	0.01%	G	G-DE

**Table C- 3:** Observed proportions of typical AAD for approved aircraft, as recorded by the height-monitoring systems

Magnitude of AAD	Observed number of AAD measurements
-350 to -251	11
-250 to -151	170
-150 to -51	12,508
-50 to 50	1,016,986
51 to 150	11,525
151 to 250	152
251 to 350	2

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**APPENDIX D - ABBREVIATIONS**

AAD	Assigned altitude deviation
ACAS	Airborne collision avoidance system
AD	Altitude deviation
ADR	Altitude deviation report
ASE	Altimetry system error
CFL	Cleared flight level
CRA	Collision risk assessment
CRM	Collision risk model
DE	Double exponential density
FIR	Flight information region
FL	Flight level
FTE	Flight technical error
GDE	Gaussian double exponential density
GMU	GPS height-monitoring unit
GPS	Global positioning system
HMU	Height-monitoring unit
ICAO	International Civil Aviation Organisation
JAA	Joint Aviation Authorities
MASPS	Minimum aircraft system performance specification
RMA	Regional Monitoring Agency
RVSM	Reduced vertical separation minimum
SMR	Safety Monitoring Report
TCAS	Traffic Alert and Collision Avoidance System
TLS	Target level of safety
TVE	Total vertical error
UIR	Upper Flight Information Region
VSM	Vertical Separation Minimum

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## **APPENDIX E - A DEFINITIONS/EXPLANATIONS OF TERMS**

Note: The following definitions are taken from ICAO Document 9574 (2<sup>nd</sup> Edition) [1] - Manual on Implementation of a 300m (1000ft) vertical separation minimum between FL290 and FL410 inclusive.

### **Collision Risk**

The expected number of mid-air aircraft accidents in a prescribed volume of airspace for a specific number of flight hours due to loss of planned separation.

### **Flight technical error (FTE)**

The difference between the altitude indicated by the altimeter display being used to control the aircraft and the assigned altitude/flight level.

### **Height-keeping Performance**

The observed performance of an aircraft with respect to adherence to cleared flight level.

### **Probability of vertical overlap (Pz(1000))**

The probability that two aircraft nominally separated by the vertical separation minimum are in fact within a distance of  $\lambda z$  of each other, i.e. in vertical overlap. This probability can be calculated from the distribution of total vertical error.

### **Target level of safety**

A generic term representing the level of risk which is considered acceptable in particular circumstances.

### **Technical height-keeping performance (or error)**

That part of the height-keeping performance (or error) which is attributable to the combination of ASE and autopilot performance in the vertical dimension.

### **Total vertical error (TVE)**

The vertical geometric difference between the actual pressure altitude flown by an aircraft and its assigned pressure altitude (flight level). TVE can be split into two components, altimetry system error (ASE) and flight technical error (FTE).  $TVE = ASE + FTE$ .

### **Vertical-collision risk**

That expected number of mid-air aircraft accidents in a prescribed volume of airspace for a specific number of flight hours due to loss of planned vertical separation. Note: one collision is considered to produce two accidents.

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**APPENDIX F - REFERENCES**

- [1]** ICAO Document 9574 (2<sup>nd</sup> Edition) - Manual on Implementation of a 300M (1000 FT) Vertical Separation Minimum between FL290 and FL410 inclusive
- [2]** JAA Administrative and Guidance Material, Section One: General Part 3: Temporary Guidance Leaflet No. 6, Revision 1 – Guidance Material on the Approval of Aircraft and Operators for Flight in Airspace above Flight Level 290 where a 300M (1000 ft) Vertical Separation Minimum is applied (October 1999)
- [3]** The European RVSM Mathematical Supplement, MDG/21-DP/01, September 2001
- [4]** Separation and Airspace Safety Panel – ICAO Handbook for a Regional Monitoring Agency Supporting Implementation and Continued Safe Use of the RVSM, version 2.2, February 2003
- [5]** EUR RVSM Pre-Implementation Safety Case (PISC), RVSM 691, Version 2.0, 14 August 2001
- [6]** EUR RVSM Post-Implementation Safety Case (POSC), RVSM A1190, Version 1.0, 27 January 2003
- [7]** EUR RVSM Safety Monitoring Report 2003 , Edition 1.2, 23 October 2003
- [8]** EUR RVSM Safety Monitoring Report 2004 , Edition 0.2, 22 November 2004
- [9]** EUR RVSM Safety Monitoring Report 2005, Edition 1.0, 10 December 2005.
- [10]** EUR RVSM Safety Monitoring Report 2006, Edition 1.1, December 2006.
- [11]** RMA Handbook, 2004.

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