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THE EUR RVSM SAFETY MONITORING REPORT 2004

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Abstract

This document constitutes the EUROCONTROL RVSM Safety Monitoring Report for the EUR RVSM Programme in 2004.

The aim of this document is to show by means of argument and supporting evidence that the implementation of RVSM in the European Region continues to satisfy the criteria defined in the EUR RVSM Safety Policy and the RVSM Pre-Implementation Safety Case.

Keywords

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Aircraft monitoring Classification	Safety	Monitoring Targets	Total Vertical Error
Target Level of Safety (TLS)	Altimetry System Error	Safety Case	Aircraft Classifications

Contact Person(s)	Tel	Unit
M. I. Izquierdo	+32 (0)2 729 4714	Airspace/Flow Management & Navigation Business Division (DAS/AFN)

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EATMP Infocentre
EUROCONTROL Headquarters
96 Rue de la Fusée
B-1130 BRUSSELS

Tel: +32 (0)2 729 51 51
Fax: +32 (0)2 729 99 84
E-mail: eatmp.infocentre@eurocontrol.int

Open on 08:00 - 15:00 UTC from Monday to Thursday, incl.

DOCUMENT APPROVAL

The following table identifies all management authorities who have successively approved the present issue of this document.

AUTHORITY	NAME AND SIGNATURE	DATE
Safety Expert - Author (DAS/AFN)	M.I. IZQUIERDO	
Manager Navigation Domain (DAS/AFN)	R. RAWLINGS	
Safety Management (DAP/SAF)	Dr. B. TIEMEYER	
Head of Business Division DAS/AFN	A. HENDRIKS	
Head of Business Division DAP/SAF	Dr. E. MERCKX	
Director DAS	B. REDEBORN	

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EXECUTIVE SUMMARY

This document constitutes the second annual EUR RVSM Safety Monitoring Report and demonstrates, as far as data is related, that the key Safety Objectives set out in the EUR RVSM Safety Policy **[1]** in accordance with ICAO Doc 9574 (2nd Edition) **[2]** continue to be met in operational service.

The report demonstrates that this aim has been achieved, by means of satisfying the following principal safety objectives:

Objective #1 That the vertical collision risk in RVSM airspace due solely to technical height-keeping performance meets the ICAO TLS of 2.5×10^{-9} fatal accidents per flight hour.

Objective #2 That the vertical collision risk – i.e. the risk of mid-air collision in the vertical dimension - in RVSM airspace meets the ICAO overall Target Level of Safety (TLS) of 5×10^{-9} fatal accidents per flight hour.

Objective #3 That the continuous operation of RVSM has not adversely affected the overall risk of en-route mid-air collision.

Objective #4 That all issues that were active when the 2003 Safety Monitoring Report **[7]** was issued have been addressed satisfactorily.

Each of the above objectives is developed in the relevant section of the report, evidence is shown that the objectives are achieved, as far as data is related and based on the initial assumptions, and detailed conclusions are drawn, which can be summarised as follows:

Objective #1 The computed vertical collision risk due to technical height-keeping performance (2.93×10^{-11}) meets the TLS of 2.5×10^{-9} fatal accidents per flight hour and amounts to almost four times smaller than the risk estimated in the 2003 Safety Monitoring Report **[7].** This can be explained by a larger amount of data now available, which allows a better estimation of the tails of the distribution and have a large influence on the vertical risk value. This is supplemented by coordinated actions with Operators and Equipment Manufactures to correct aircraft not meeting (TGL6) requirements.

In addition, it is important to remark that most monitoring classifications (100 out of 107) are showing compliance with technical height keeping requirements and the quality of the height-monitoring data is satisfactory.

Objective #2 The overall vertical collision risk ($0.81 \times 10^{-9} \div 1.97 \times 10^{-9}$) meets the ICAO overall TLS of 5×10^{-9} fatal accidents per flight hour. The same Collision Risk Model (CRM) as in the 2003 Safety Monitoring Report **[7]** was used in order to ensure comparability.

It is important to note that available operational error data is still not complete and presents some differences with respect to the 2003 operational data in terms of participating States and reporting rates, in the case of NIL reports. To duly account for those differences, estimates have been made for a range of values of operational vertical risk (from 7.84x10-10 to 1.87x10-9), resulting in an estimate of maximum and minimum overall vertical collision risk.

The highest overall vertical risk value for this year amounts to more than three times bigger than the overall vertical risk estimated in 2003. This can be explained by an increased number of participating States during the data collection campaign and a significant number of vertical deviations higher than or equal to 1000 ft.

Objective #3 Available valid Altitude Deviation Reports sent by the States shows that, in terms of rate of occurrences, there is no significant difference in safety in those States from before the RVSM implementation. Although for specific types of errors the occurrence frequency has decreased with respect to previous periods, in general, the occurrence frequency is similar before and after the implementation.

Objective #4 All of the issues outstanding when the 2003 RVSM Safety Monitoring Report **[7]** was released, have either been resolved or are addressed as ongoing issues in this report.

Main concerns

However, in addition to the on-going issues there are concerns related to the nature of the data itself which affect the validity of these objectives and are raised in this document. These can be summarised as follows:

(i) The operational risk has been calculated with new operational error data sent by the States during a 4-month period campaign. Despite the short period used in the analysis, there is an increasing trend in the operational risk value over time. There are several reasons for this, such as the increased number of States who sent Altitude Deviation Reports in this year’s campaign and a significant number of vertical deviations higher than or equal to 1000 ft.

(ii) As a consequence, the overall vertical risk also shows an increasing trend over the years.

(iii) Moreover, extrapolation beyond the observed limits of the operational error data is not possible due to the limitations and uncertainties in the applied current Collision Risk Model and the still existing under-reporting problem.

(iv) Objective #3 evidence is provided by comparing the reporting rates of RVSM-related incidents at different periods. However, after two years of the implementation of RVSM, a clear distinction between RVSM-related and non RVSM-related incidents doesn’t exist any more.

(v) Therefore, it can be concluded that the available operational information is not enough as to ensure that Objectives #2 and #3 are met within overall European RVSM airspace with an appropriate level of confidence.

Proposed recommendations

To cope with those concerns and shortcomings, specific recommendations have been made in this document with view to be implemented in the 2005 report:

Recommendation #1 Ensure the collection of post-implementation operational-error data and monitor the ADR reporting rates. Therefore a new operational error data collection campaign is planned to be launched (starting November 04 until June 05) in order to allow comparison and assessment of the operational vertical risk trend.

Recommendation #2 Develop, under the aegis of the Safety Improvement Sub-Group, an electronic format of Altitude Deviation Report to be implemented by the ANSPs facilitating the operational error data collection.

Recommendation #3 Review the current Collision Risk Model to provide a better modelling of the human errors under different scenarios and account for NIL reports.

Recommendation #4 Extend the assessment of Objective #3 to any type of vertical incident in the RVSM airspace, providing a generic overview of safety in EUR RVSM airspace for vertical operations.

Conclusions

In summary, subject to the results of the monitoring and collision-risk assessment work obtained from the available information and, considering the limited new operational qualitative error data, the operation of RVSM in EUR airspace can be considered as tolerably safe.

However, in the light of the concerns and shortcomings (i.e. under-reporting problem) raised in the document, confidence in current operational performance cannot be fully built and the high level of uncertainty must be considered when interpreting data in the report concerning the safety of RVSM vertical operations.

Should those shortcomings not be overcome in the future, monitoring of safety levels and safety trends in the EUR RVSM airspace cannot be ensured, the identification of problem areas and associated mitigations cannot be addressed and safety improvements cannot be implemented in a continuous and effective way.

Long term monitoring activities are therefore necessary to ensure that aircraft are performing according to the specifications, assess the increasing trend of the risk, identify the factors, further investigate safety improvements and follow-up actions to offset the effects and implement those actions to solve potential safety issues on time.

Acknowledgements

The results and outcomes of this report have been achieved thanks to all the States that have actively participated by sending Altitude Deviation Reports on time.

We would like to encourage those other States who, for one or other reasons, couldn't send any information before, to participate in the new campaign for the 2005 report. The Agency is keen to support States, wherever possible, on the collection of data and the clarification of any issues.

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1. INTRODUCTION

1.1 Background

Reduced Vertical Separation Minima (RVSM) was introduced into European airspace at 0001 hrs UTC on 24 January 2002, 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 41 States participating in the EUR RVSM Programme are listed in Table 1–1.

Albania	Austria	Belgium	Belarus	Bosnia & Herzegovinia
Bulgaria	Croatia	Cyprus	Czech Republic	Denmark
Estonia	FR of Yugoslavia	Finland	France	Germany
Greece	Hungary	Ireland	Italy	Latvia
Lithuania	Luxembourg	Malta	Moldova	Monaco
Morocco	The Netherlands	Norway	Poland	Portugal
Romania	Slovak Republic	Slovenia	Spain	Sweden
Switzerland	FYR of Macedonia	Tunisia	Turkey	Ukraine
United Kingdom				

Table 1–1: States participating in RVSM

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

Amsterdam	Ankara	Athinai	Barcelona	Beograd	Berlin	Bodo
Bratislava	Brindisi	Bruxelles	Bucuresti	Budapest	Canarias	Casablanca
Chisinau	France	Hannover	Istanbul	Kaliningrad	Kharkiv	Kobenhavn
Kyiv	Lisboa	Ljubljana	London	L'viv	Maastricht	Madrid
Malta	Milano	Minsk	Munchen	Nicosia	Odesa	Oslo
Padova	Praha	Riga	Rhein	Roma	Rovaniem	Sarajevo
Scottish	Shannon	Simferopol	Skopje	Sofia	Stavanger	Sweden
Switzerland	Tallinn	Tampere	Tirana	Trondheim	Tunis	Varna
Vilnius	Warszawa	Wien	Zagreb			

Table 1–2: FIRs/UIRs representing the EUR RVSM airspace

1.2 Aim

This report responds to the official ICAO request to Eurocontrol, acting as the European RMA, to show by means of argument and supporting evidence that the implementation of RVSM in the European region continues to satisfy the criteria defined in the EUR RVSM Safety Policy.

The report will be issued for endorsement to the ICAO European Air Navigation Planning Group (EANPG) to be held at the end of November 04. Prior to that, the report will be also submitted to the Safety Regulation Commission (SRC) for advice.

1.3 Scope

This EUR RVSM Safety Monitoring Report (SMR) follows on from the POSC **[6]** and the EUR RVSM Safety Monitoring Report 2003 **[7]** to demonstrate that the key Safety Objectives set out in the EUR RVSM Safety Policy **[1]** continue to be 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 and in discharging the outstanding issues addressed in previous reports as well as proposing new safety-related issues.

The EUR RVSM Safety Policy is compliant with the requirements set out by ICAO Document 9574 **[2]**, the EATMP Safety Policy **[3]** and the Safety Objectives of the ATM 2000+ Strategy **[4]**.

1.4 Structure of the Document

The report is constructed using an approach that claims that the <u>risk of collision under EUR RVSM will be tolerably safe</u>. This claim is broken down into four principal safety arguments, which represent a necessary and sufficient condition for the above claim to be true. These principal safety arguments are discussed and assessed in **Sections 4, 5, 6 and 7** of this report. **Section 8** summarises all the conclusions and recommendations raised in the aforementioned sections to assess whether the risk of collision can be considered as tolerably safe.

Section 2 of this document discusses the four RVSM Safety Objectives that relate directly to the ongoing safety of EUR RVSM.

Section 3 compares the current results of the Collision Risk Assessment of the estimated levels of vertical collision risk that would pertain in the EUR RVSM airspace, against the ICAO Target Level of Safety of 5×10^{-9} accidents per flight hour for overall vertical risk and 2.5×10^{-9} accidents per flight hour for risk due to technical height-keeping performance. It also contains an explanation of how the safety objectives, set out in section 2, have been satisfied.

APPENDIX A - provides an update on, and the current results of, the height monitoring activities of the EUR RVSM Programme.

1.5 Future activities

At the end of 2005 a new RVSM SMR is planned to be issued. Provided sufficient data are available, this continuous effort of monitoring and data analyses will provide clarification, consolidation and better understanding of the criteria, arguments and performances initially exposed and assumed in the RVSM project.

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2. RVSM SAFETY OBJECTIVES

A key issue for the assessment of RVSM safety is the satisfaction of a number of Safety Objectives defined in the Safety Policy for RVSM and compliant with the ATM Strategy 2000+. The following four objectives remain directly relevant to the ongoing safety of RVSM:

Objective #1 In accordance with ICAO Guidance Material [2], the risk of mid-air collision in the vertical dimension within RVSM airspace, due to technical height keeping performance, shall meet a Target Level of Safety of 2.5×10^{-9} fatal accidents per flight hour.

Objective #2 In accordance with ICAO Guidance Material [2]**,** the management of overall vertical collision risk within RVSM airspace shall meet a Target Level of Safety of 5×10^{-9} fatal accidents per flight hour.

Objective #3 Improve safety levels by ensuring that the number of ATM induced accidents and serious or risk bearing incidents do not increase and, where possible, decrease. Therefore, the continuous operation of RVSM shall not adversely affect the risk of en-route mid-air collision.

Objective #4 Discharge all recommendations made in previous RVSM Safety Monitoring Reports and address any new safety related issues coming up since the issue of the latest report. In this particular case, the 2003 RVSM safety Monitoring Report **[7]** will be considered the previous reporting document.

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3. COLLISION RISK ASSESSMENT

3.1 Introduction

The level of vertical collision risk within European RVSM airspace shall satisfy the following quantitative safety objectives set up in section **2**:

Objective #1 In accordance with ICAO Guidance Material [2], the risk of mid-air collision in the vertical dimension within RVSM airspace, due to technical height keeping performance, shall meet a Target Level of Safety of 2.5×10^{-9} fatal accidents per flight hour.

It is an update to the information provided in Appendix F of the POSC **[6]** and section 3 of the RVSM Safety Monitoring Report 2003 **[7]**, using for the first time in the analysis a complete 2-year period RVSM data.

Objective #2 In accordance with ICAO Guidance Material [2], the management of the overall vertical collision risk within RVSM airspace shall meet a Target Level of Safety of 5.0×10^{-9} fatal accidents per flight hour.

This section presents the results of the collision risk estimation process which aims at assessing the vertical collision risk in RVSM airspace against the target levels of safety detailed above.

This information is primarily concerned with:

- The traffic distribution over the RVSM flight levels;
- Technical height keeping performance[1]; and
- Frequency of operational vertical errors.

Without changes to the collision risk model itself, the information leads to new estimates of the parameters of the model and thus to a new estimate of vertical collision risk.

3.1.1 Initial Assumptions

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

i) That the collision risk model (CRM) is mathematically correct.

ii) That the Altimetry System Error (ASE) for RVSM-approved aircraft is stable with time.

3.1.2 Vertical Collision Risk – General Concept

The mathematical model described in **[13]** has essentially two components:

[1] More detailed information on technical height-keeping performance is included in Appendix A.

- One is the frequency with which aircraft flying at the vertical separation minimum pass directly overhead of each other. 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 estimate of 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.

3.2 Technical Vertical Risk Estimation

3.2.1 Frequency of Horizontal Overlap

Methodology

Table 3–5 lists all the relevant data used in the current calculations. A summary of the methodology is given in the following paragraph and additional details on this methodology can be found in **[13]**.

The estimate of the frequency of horizontal overlap is 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. Based on the range of different geometries and relative velocities seen across the set of proximate events, 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, is calculated. This probability, combined with the proximity frequency, gives the horizontal overlap frequency.

Data

The three European HMUs continuously record information on proximate events occurring between FL290 to FL410. All the data is passed through quality control checks before being considered in the assessment. The frequency of horizontal overlap has been derived from proximate events recorded between 1st December 2003 and 31st May 2004 that have passed all quality control checks.

Weighted averages for aircraft dimensions were calculated based on actual aircraft dimensions and the estimated number of flight hours of each aircraft group in the RVSM airspace. The updated aircraft dimensions are presented in Table 3–6. The relative aircraft velocities and the classification used for the different proximity event geometries are shown in Table 3–6 and Table 3–7 respectively.

Weighting Factors

The most accurate way of determining the horizontal overlap frequency would be to set R equal to the dimension of the average aircraft, that is, about 0.02 nm. However, since this type of event is rare, it would be necessary to sample data over a very long period of time to ensure an accurate estimate so a larger value of R is used to ensure sufficient data is available.

Figure 3–3 through **3–5** present the observed proximate events versus the predicted number of events for a given R based on the current data set. These figures confirm that 0.5 nm is a reasonable value for R and that the distribution of same and crossing events is not uniform between R = 0 and 0.5 nm.

To account for this non-uniformity weighting factors have been calculated as 4.30 for same direction events and 1.31 for crossing events. The values used to determine these weighting factors are presented in Table 3–8 (note: HCPA means Horizontal Closest Point of Approach).

It should be noted that **Figure 3–3** through **3–5** present all proximate events on both adjacent and non-adjacent flight levels to allow for the maximum number of observations. Caution should be taken when comparing these figures to the data presented in **Table 3–5**, which presents data only for adjacent flight levels.

Results for frequency of horizontal overlap

Based on the current data set the frequency of horizontal overlap in the European RVSM airspace is estimated to be 8.09×10^{-3} for aircraft in level flight and 9.51×10^{-3} for aircraft in non-level flight at adjacent flight levels.

3.2.2 Probability of Vertical Overlap Due to Technical Height Deviations

The probability of vertical overlap has been derived from the data set as described in APPENDIX A - , section A.3.

The components approach has been used to estimate the probability of vertical overlap due to technical height keeping performance (see 3–6). The component approach is based on the convolution of an overall ASE (Altimetry System Error) distribution and a typical AAD (Assigned Altitude Deviation) performance distribution.

The overall ASE distribution is a combination of ASE distributions for each aircraft monitoring classification, weighted by the proportion of flights made by that classification. 'Typical' AAD performance has been taken to be that which is not greater than 350 ft in magnitude. Any AAD greater than this value would be considered 'atypical', and thus would be modelled following the approach detailed for atypical AADs and assessed for its contribution towards the total vertical risk. Full details of the approach can be found in the EUR Mathematical Supplement **[13].**

The ASE fits for each aircraft monitoring classification that have been derived for the current collision risk analysis are shown in Table 3–9. In most cases the performance appears to fit a mixture distribution curve. If no measurements were available for an aircraft classification, a default GDE distribution based on the total set of measurements was assumed. This distribution was also used for a couple of classifications for which only very few measurements were available.

Table 3–11 presents the currently observed proportions of typical AAD. The distribution chosen to model the typical AAD is a DE, with mean 0.035ft and standard deviation value of 39.80ft. The closeness of the fit is shown in Figure 3–7. It should be noted that this figure presents all measurement data values rounded to the nearest 100.

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

The value of $P_z(1000)$ based on the currently observed ASE and typical AAD data is estimated to be 3.62×10^{-9}.

This value satisfies the Global System Performance Specification that the probability that two aircraft will lose procedural vertical separation of 1000 ft should be not greater than 1.7×10^{-8}. It was this probability value that was used as a basis for the derivation of the MASPS. A detailed discussion on aircraft height-keeping performance can be found in APPENDIX A - , Section A.5.

3.2.3 Results for Technical Vertical Risk due to Technical Height-Keeping Performances

Combining the probability of vertical overlap with the horizontal overlap frequency for level flight gives an estimated vertical risk due to technical height-keeping performance for European RVSM airspace of 2.93×10^{-11}.

This is the risk due solely to errors in technical height keeping performance, and does not include the risk due to other sources. These are covered in the next section.

3.3 Total Vertical Risk Estimation

In assessing the risk due to all causes, the risk due to technical height keeping performance must be combined with the risk due to all other sources of deviation from the assigned altitude. These deviations are referred to as atypical.

3.3.1 Analysis of the Operational Data Collected

From 1st January 04 until 1st May 04, a campaign was initiated to collect ADRs from the States participating in RVSM. Since then, 51 ADRs have been received and evaluated to proceed with the estimation of the operational risk. This represents a change with respect to the RVSM Safety Monitoring Report 2003 **[7]** where, due to the lack of reports, POSC **[6]** atypical errors and error rates were applied.

Another change with respect to the POSC **[6]** and 2003 **[7]** reports is that the number of regions under analysis has been extended. Data from 7 regions, representing 11 ACCs, has been analysed in comparison with data from the 5 core regions used in the POSC. In addition, 4 additional regions representing another 10 different ACCs, which reported NIL events, have been taken into account in the analysis.

The estimated total flight time for the overall 11 regions over the reporting period is of 63,916 hours.

In relation to the reports, only 29 reports out of 51 have been used in the analysis. The rest describe errors no greater than 300ft, errors outside the RVSM airspace or errors not related to altitude deviations.

16 reports out of 29 correspond to errors caused by the pilot or pilot-controller loop errors.

9 reports out of 29 show deviations greater or equal than 1000ft. The main causes of those deviations were:

- Wrong TCAS indications.
- Unknown military aircraft operating outside the military areas.
- Confusion with ATC clearance.
- Pilot loop error.

In all the cases, no other aircraft was involved in the situation and, therefore, separation minimum was all the time maintained.

For completeness, reporting rates of PISC **[5]** and POSC **[6]** (the 2003 report **[7]** applied POSC values), have been compared with this year report (see Table 3–1). It has been noted that the reporting rates for this year report are the lowest ones, even when the 4 additional regions are not included.

Table 3–1: Comparison of the technical vertical risk

	Reporting rate
PISC V2.0 [5]	2.97×10^{-4}
POSC V1.0 [6]	1.95×10^{-4}
Current report	7.53×10^{-5}
Current report including NIL events	3.38×10^{-5}

Those differences can be considered as normal taking into account the following facts:

i. The reporting rate of those States that have continuously supported this activity has decreased with respect to previous years;

ii. The number of reporting States have increased in this campaign;

iii. Previous reports were collected for a longer period of time in comparison with the 4 month collection period for this year (from January 04 until May 04); and

iv. Previous reports were collected either before the RVSM implementation or few months after its implementation, in 2002.

Therefore, the 2004 Altitude Deviation Reports[2] represent a post implementation fully operational environment.

3.3.2 Probability of Vertical Overlap Due to Atypical Errors

Details of the methodology followed, to assess the risk associated with the ADRs collected for that period of time, can be found in section F.5 of the PISC **[5]**. Further details on the reports used in the analysis can be found in Table 3–12, Table 3–13 and Table 3–14.

In addition to ADRs, atypical AAD for level flight can be recorded by the height monitoring system. These AAD values (greater than 350ft) are considered together with any ADRs that indicated an aircraft had joined a wrong level.

Table 3–11 lists the estimated proportion of flight time spent at a given magnitude of deviation on all atypical data. The proportions are presented separately for aircraft in climb and/or descent and for aircraft in level flight.

In addition, to account for the effect of reporting no events in specific ACCs in the analysis, this report provides a range of operational risk values based on the different number of regions under consideration (e.g. core area, no ACCs with NIL reports).

Results for Probability of Vertical Overlap due to Atypical Errors

Using the methodology described in the POSC **[6]** and the data presented in Table 3-10, the estimated probability of vertical overlap has been computed for a range of probabilities, depending on the number of ACCs accounted for, in the analysis. The result ranges from 1.13×10^{-7} to 4.34×10^{-8} for climbing/descending deviations and from 1.07×10^{-7} to 4.59×10^{-8} for level flight deviations.

3.3.3 Frequency of Horizontal Overlap

The frequency of horizontal overlap used to estimate the risk from the atypical altitude deviations using the model from **[13]** are the same as those values used to estimate the risk from technical height keeping errors, namely 8.09×10^{-3} for aircraft in level flight and 9.51×10^{-3} for aircraft in climb/descent.

3.3.4 Total Vertical Risk Results

The value of the probability of vertical overlap due to atypical errors combined with the appropriate values of horizontal overlap frequency gives the collision risk estimate based only on atypical data.

This is estimated to be within the range of 4.12×10^{-10} and 1.07×10^{-9} for climbing/descending deviations and 3.71×10^{-10} to 8.66×10^{-10} for level flight

[2] As explained in this document and the 2003 RVSM Safety Monitoring Report, not enough Altitude Deviation Reports were received during 2003 to allow the calculation of the operational risk in a fully RVSM operational environment. As this is the first time that the operational risk is being computed for that scenario, results have to be treated with caution as they have been obtained for a limited period of time and number of ACCs.

deviations.

The total vertical risk is then the sum of the aforementioned risks due to atypical performance (from 7.84×10^{-10} to 1.94×10^{-9}) and the risk due to technical vertical height-keeping performance (2.93×10^{-11}).

The total vertical risk is estimated to be a value between 8.13×10^{-10} and 1.97×10^{-9}. As mentioned in previous paragraphs, a range of results is provided in order to show the effect of including NIL reports and ACCs outside the core area in the analysis.

It is interesting to note that, if all the operational error data collected during the RVSM post implementation period were used in the analysis, then the reporting rates and overall vertical risk estimate for 2004 would have been within the same range (from 5.8×10^{-10} to 7.7×10^{-10}) as in the POSC **[6]** and 2003 **[7]** reports. A bigger set of data for a longer period used in those reports explains the small effect of the 2004 reports in the final value. However, those estimates cannot be considered representative of the operational risk during the RVSM post implementation period, as data was not continuously collected for the same number of regions.

3.3.5 Uncertainties

The total vertical risk has been estimated based on some initial assumptions and limited operational error data. This extrapolation beyond the observed limits of the data leads to considerable modelling uncertainty, the main causes of which are thought to be:

(i) The difficulty of ensuring that the probability of distributions fitted to ASE data provide a realistic model for the large deviations that occur very rarely;

(ii) Serious errors are rare so the risk estimate is constructed from small samples, which results in statistical uncertainty.

(iii) The collision risk model for operational errors needs further refinement. Especially with respect of how to model the highly complex human errors which are not properly implemented at the moment.

(iv) Despite the increased commitment from States to provide operational error data, the underreporting problem still exists. In addition, four months has been proved not to be sufficient amount of time to collect operational errors. Therefore, the sample of collected data is not enough to be considered representative of the European RVSM area and hence enable to extrapolate an overall vertical risk value for RVSM operations in Europe.

In conclusion, although the estimate of collision risk is below the TLS, it cannot be stated with high level of confidence that the real risk is actually below the TLS.

3.4 The Effect of Future Traffic Growth

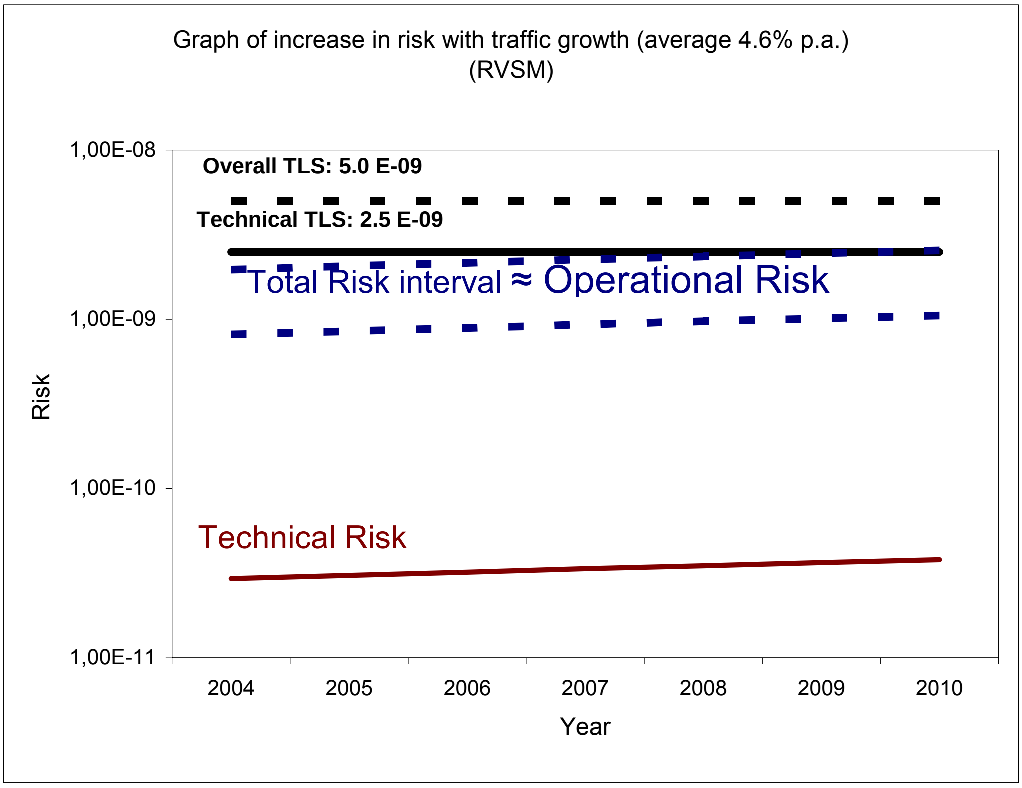
The effect of future traffic growth on the vertical collision risk can be evaluated on the basis of suitable assumptions on the relationship between traffic growth and frequency of horizontal overlap, and on the course with time of technical height-keeping performance and operational errors.

A number of assumptions have been made for the current evaluation, providing an estimation for the technical and total vertical risks up to the year 2010. Longer term estimations, up to 2015, have not been made considering the current operational data limitations and aforementioned uncertainties.

Figure 3–1 shows that both, the technical and the overall TLS, continue to be met in 2010. However, due to degree of uncertainty expressed in the previous section, it is not possible to state with a high level of confidence that the true risk meets the TLS.

For instance, if an under-reporting rate of 1 out of 5 is taking into account, the TLS would not be met this year in the worst case scenario, whereas 2010 is the limit for the best case scenario.

Figure 3–1: Effect of traffic growth in the risk calculation.



3.5 Comparison with Previous Results

A comparison is made between the results obtained in the current assessment and the previous ones, i.e. the POSC **[6] ,** the PISC **[5]** and the 2003 report **[7]**, to examine how changes in risk, if any, may be related to changes in risk model parameter values.

The following tables compare the technical vertical risk estimates presented in this chapter, with those presented in the POSC **[6]**, PISC **[5]** and 2003 report **[7]**.

Table 3–2: Comparison of the technical vertical risk

	Estimated frequency of horizontal overlap	Estimated probability of vertical overlap, Pz(1000)	Estimated technical vertical risk
PISC V2.0 [5]	9.01×10^{-3}	2.22×10^{-8}	0.20×10^{-9}
POSC V1.0 [6]	8.55×10^{-3}	0.58×10^{-8}	0.05×10^{-9}
2003 report [7]	8.26×10^{-3}	1.36×10^{-8}	0.11×10^{-9}
Current report	8.09×10^{-3}	0.36×10^{-8}	0.03×10^{-9}

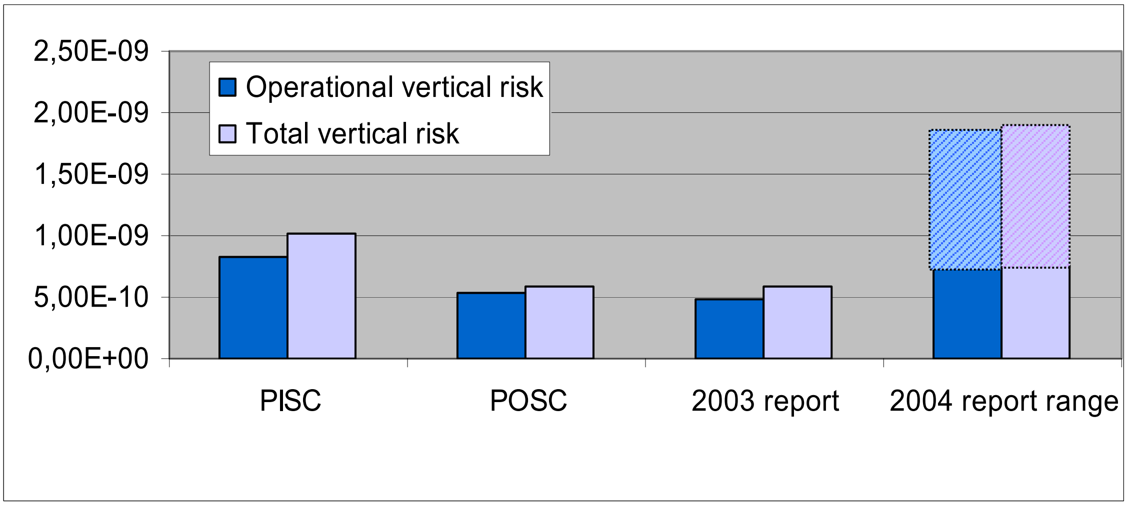
Table 3–3: Comparison of overall vertical risk

	Estimated technical vertical risk	Estimated operational vertical risk	Estimated overall vertical risk
PISC V2.0 [5]	0.20×10^{-9}	0.82×10^{-9}	1.02×10^{-9}
POSC V1.0 [6]	0.05×10^{-9}	0.53×10^{-9}	0.58×10^{-9}
2003 report [7]	0.11×10^{-9}	0.49×10^{-9}	0.59×10^{-9}
Current	0.03×10^{-9}	$0.78 \times 10^{-9} \div 1.94 \times 10^{-9}$	$0.81 \times 10^{-9} \div 1.97 \times 10^{-9}$

Table 3–4: 2004 parameter value changes with respect to previous reports

Change in parameter value	**Estimated probability of vertical overlap, Pz(1000)**	**Estimated technical vertical risk**	**Estimated operational vertical risk (lower value)**	**Estimated operational vertical risk (upper value)**	**Estimated overall vertical risk (lower value)**	**Estimated overall vertical risk (upper value)**
PISC [5]	≈ 6.2 times smaller	≈ 6.7times smaller	similar	≈ 2.3 times bigger	≈ 1.2times smaller	≈ 1.9 times bigger
POSC [6]	≈ 1.6 times smaller	≈ 1.7times smaller	≈ 1.5 times bigger	≈ 3.5 times bigger	≈ 1.4times bigger	≈ 3.4 times bigger
2003 report [7]	≈ 3.8 times smaller	≈ 3.7times smaller	≈ 1.6 times bigger	≈ 4.0 times bigger	≈ 1.4times bigger	≈ 3.4 times bigger

Figure 3–2: Comparison of the operational and total vertical risk



As shown in Table 3–2 to Table 3–4, similar to any previous report, the operational vertical risk is the dominant component.

Despite the uncertainty expressed in the results, there seems to be an increasing trend in the operational risk value after the implementation of RVSM (see Figure 3–2). Reported large altitude deviations by some States within their RVSM airspace might be appointed as one important factor to that increase. Although apparently those cases did not represent a real danger, as no other aircraft were around, it is important to note that those errors are still occurring and their consequences in a denser airspace would be dramatic. Therefore, further investigation on safety improvements is necessary to offset the effects of an increasingly dense airspace.

To provide assurance that the system would continue to be safe, it is recommended that:

(i) An annual RVSM assessment of the height keeping performance and the risk associated with operational errors is ongoing;

(ii) Work on developing initiatives to collect more operational error data continues; and

(iii) The collision risk model applied for the computation of the operational risk is further refined to ensure that human errors and the operational environment are properly modelled.

On the other hand, the technical vertical risk has decreased up to almost four times with respect to last year report. The main causes of which are thought to be:

(iv) A sample of data that covers a 2-full year period of RVSM post-implementation.

(v) The mean ASE used in the analysis is associated to each specific airframe and/or aircraft-monitoring classification and is not a constant value over time. Many monitoring classifications used in this year report have been updated or new ones have been created.

(vi) Additional and more precise analytical tools applied during the decision making process for the derivation of the final ASE distribution.

Therefore, it can be concluded that deviations of several times in the probability of vertical overlap (and therefore the technical vertical risk) are considered as normal, as long as the mean ASE of the aircraft monitoring classifications meet the group requirements, as explained in Appendix A.5.2, and the vertical probability overlap is not greater than 1.7×10^{-8}.

A detailed discussion on aircraft performance can be found in paragraphs 3.2.2 and 3.2.3, and in APPENDIX A - , paragraph A.5.

Finally, the total vertical risk continues to increase as a consequence of the operational risk value. Although the total vertical TLS is met by some margin, it cannot be stated with confidence that this is the case.

3.6 Conclusions

This chapter has dealt with the estimation of the risk of collision, based on the currently observed data.

The estimate for the probability of vertical overlap based on currently observed ASE and typical AAD data satisfies the Global System Performance Specification that the probability of two aircraft losing procedural vertical separation of 1000 ft should be not greater than 1.7×10^{-8}. This probability value was used as a basis for the derivation of the MASPS.

When the observed frequency of horizontal overlap is taken into account, the technical TLS of 2.5×10^{-9} is also met.

The operational risk has been updated using a new set of ADRs collected for a period of 4 months. A range of operational risk values have been provided depending on whether reports from non core areas or NIL reports received from some States are considered in the analysis.

Finally, the estimated total vertical risk range of values satisfies the overall TLS of 5×10^{-9} fatal accidents per flight hour. However, those values are based on some initial assumptions and limited operational error data. This extrapolation beyond the observed limits of the data leads to considerable modelling uncertainty and certain lack of full confidence on the results. To cope with that, several actions have been initiated.

Finally, using traffic growth forecast and based on the limited available information, it has been estimated that the TLS will continue to be met in 2010. However, this is subject to revision due to the aforementioned uncertainties.

3.7 Recommendations

(i) The Collision Risk Model applied for the computation of the operational risk be further refined. Especially with respect of how to model highly complex human errors which are not properly modelled at the moment.

(ii) Since the operational risk is the most important contribution to the overall risk, work on developing initiatives to collect post-implementation operational error data should continue. This will allow the ADR reporting rates to be updated and provide confidence in the operational risk value.

(iii) Launch a new Altitude Deviation Report campaign for the 2005 report in order to collect as much data as possible, assess the increasing trend of the operational risk value, identify the factors and further investigate safety improvements to offset the effects.

Figure 3–3: **Observed number of proximity events and predicted number of overlaps for Same Direction Traffic**

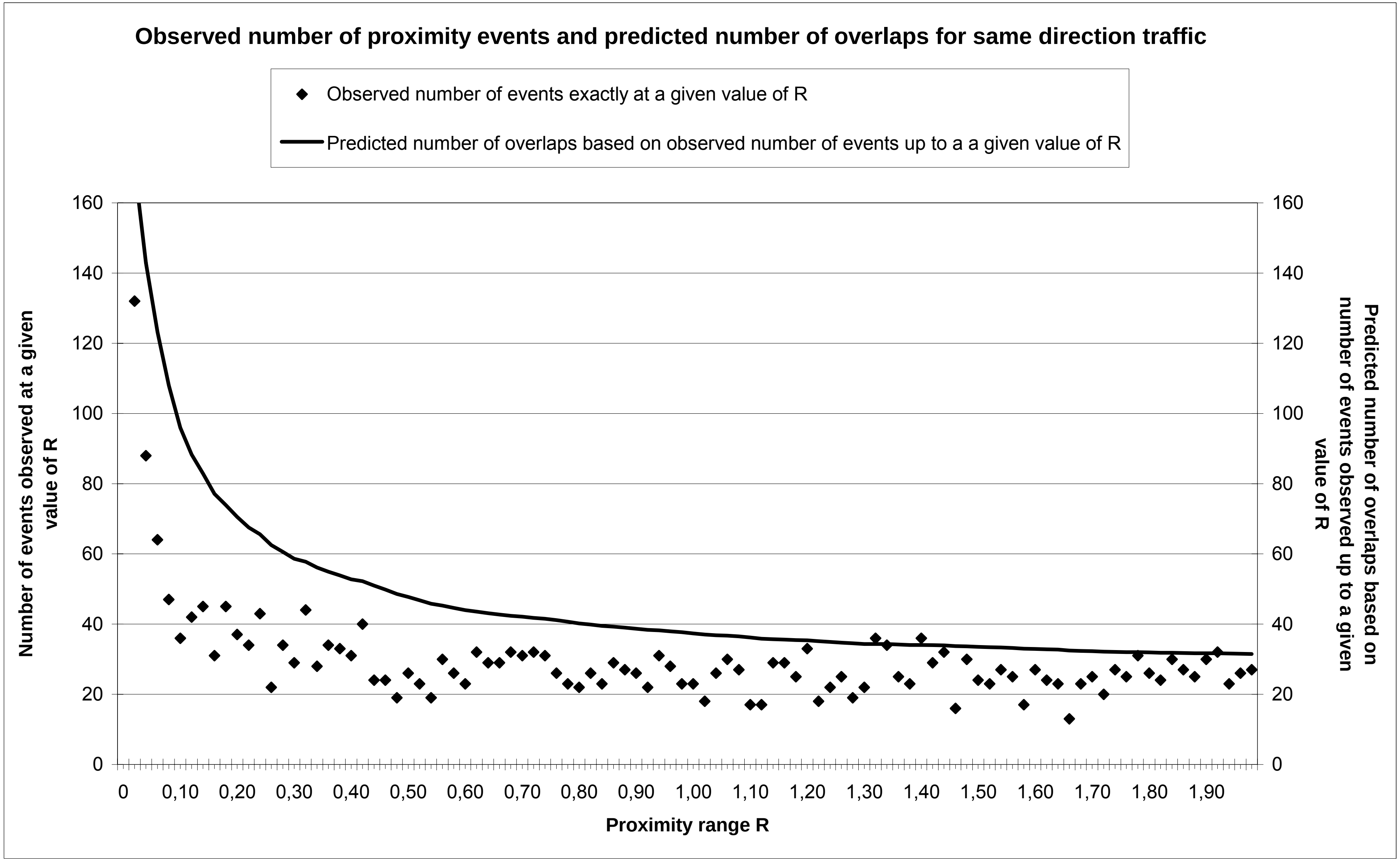


Figure 3–4: Observed number of proximity events and predicted number of overlaps for Opposite direction traffic

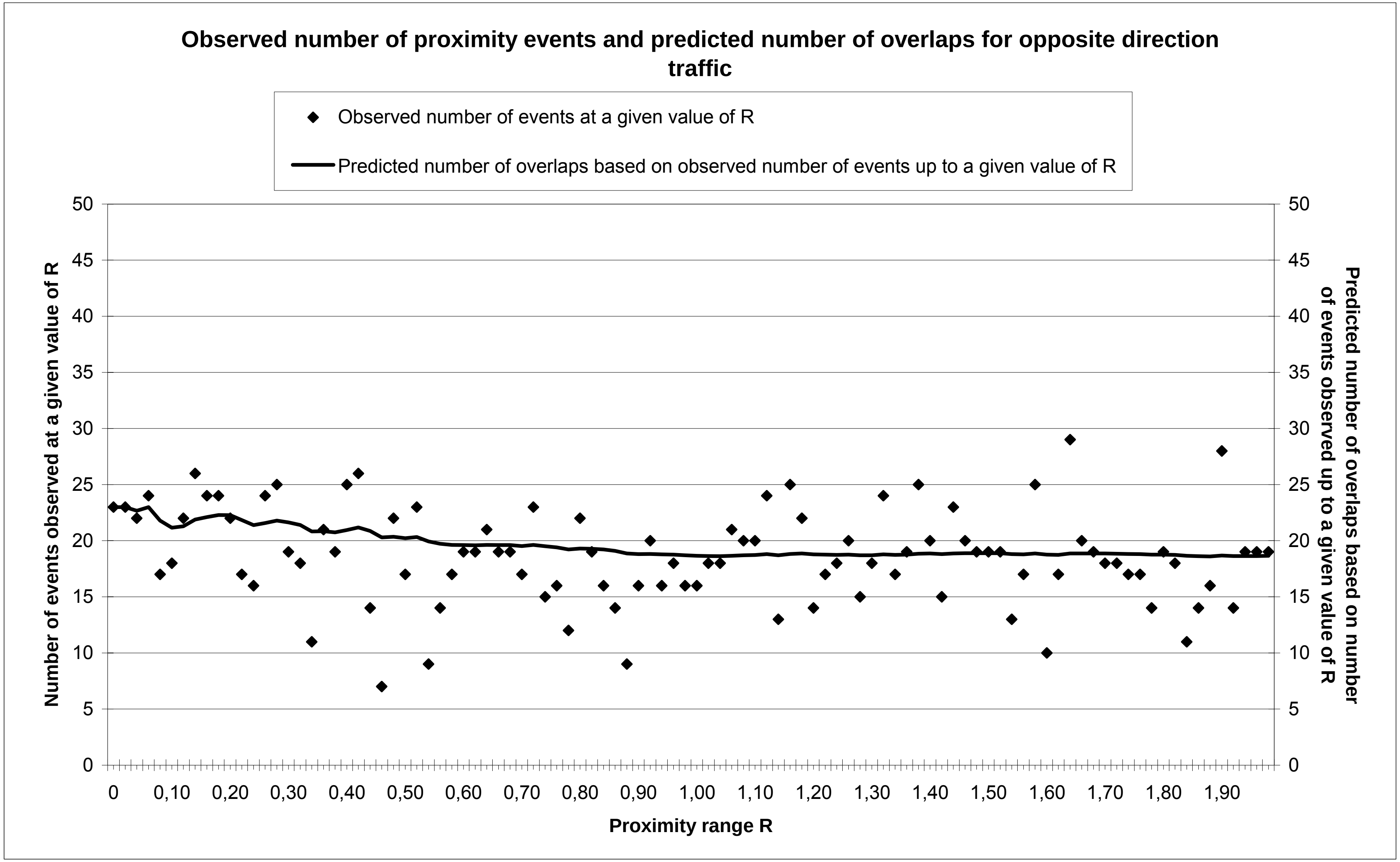


Figure 3–5: **Observed number of proximity events and predicted number of overlaps for Crossing traffic**

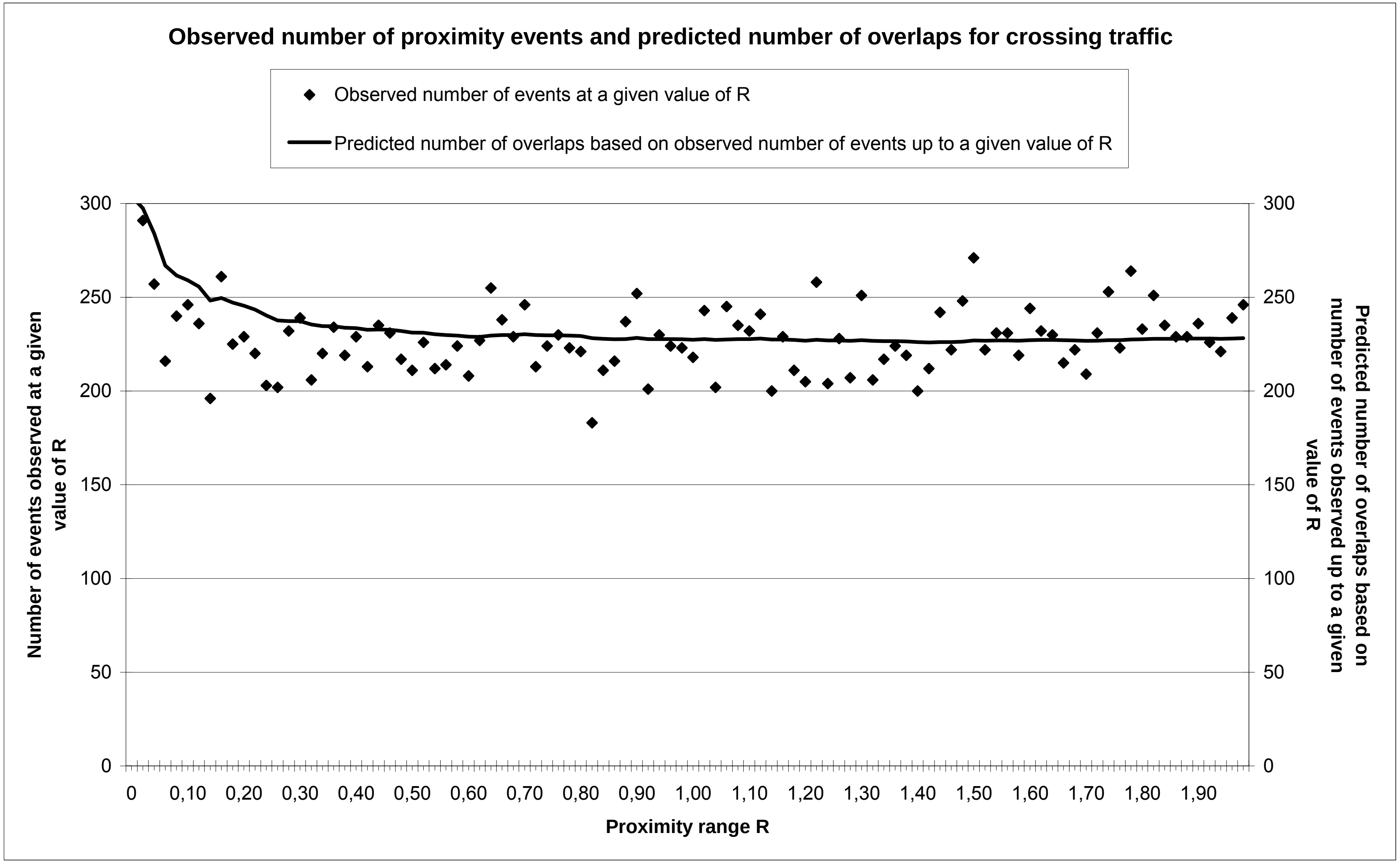
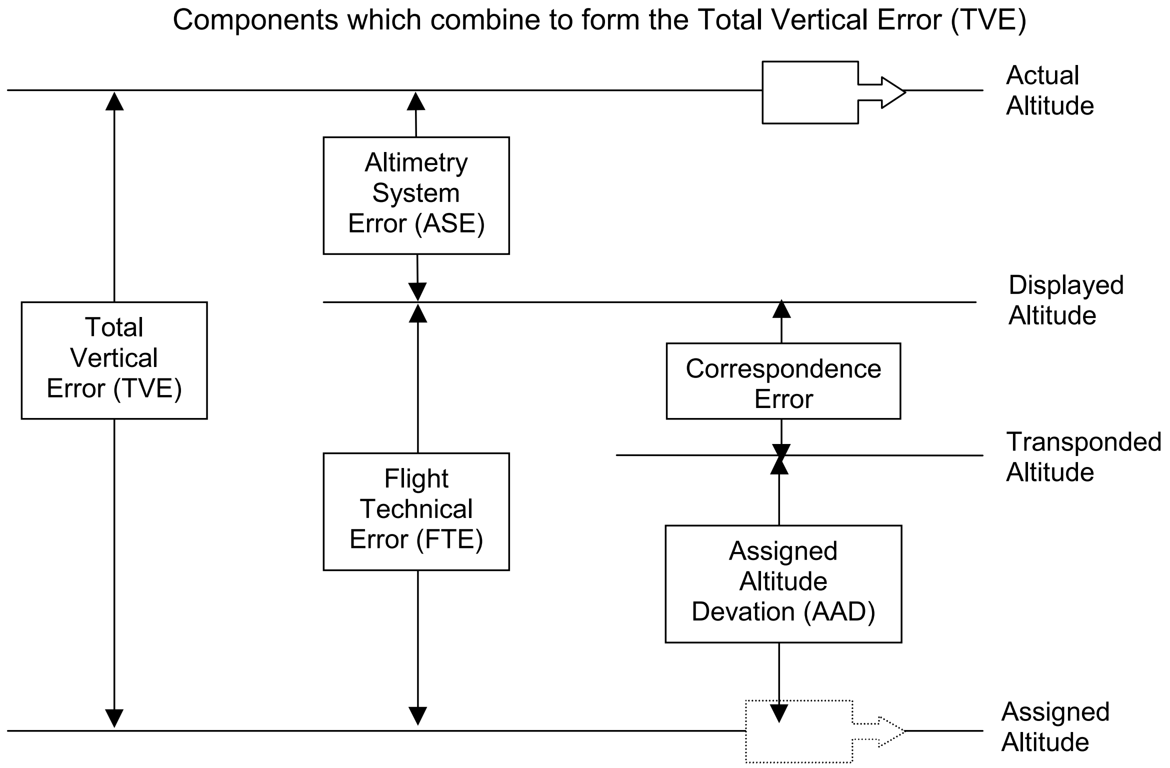


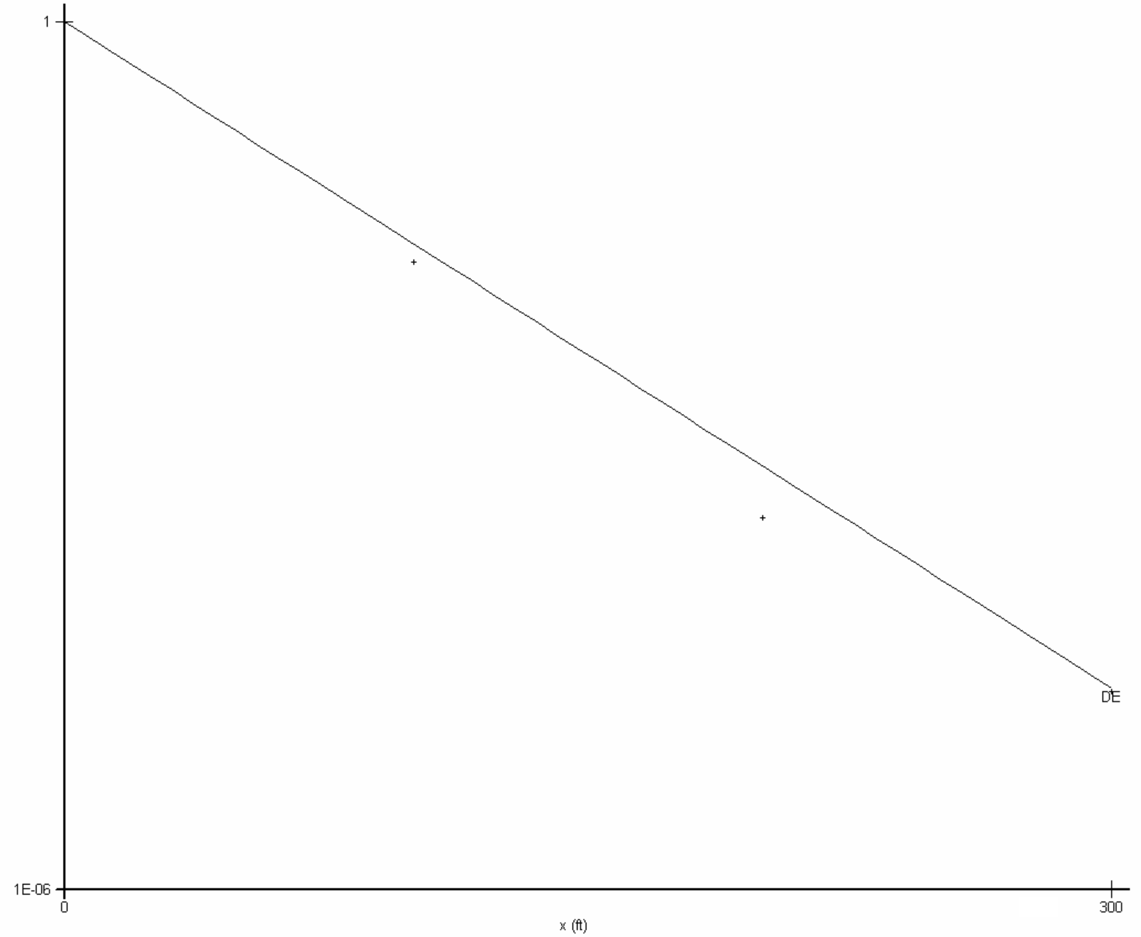
Figure 3–6: Components which combine to form the TVE



Note: TVE expresses the accuracy with which the 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 3–7: Fit For Typical AAD

abs(AAD) < 350 Rounded to the Nearest 100. Measurement Data: 31 May 2002 to 31 May 2004 Approvals Data: as of 21 June 2003 (1362114 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. Prob{|x_j - m_x| >= x}

Figure 3–8: Proportion of Flight Time Spent in Deviation

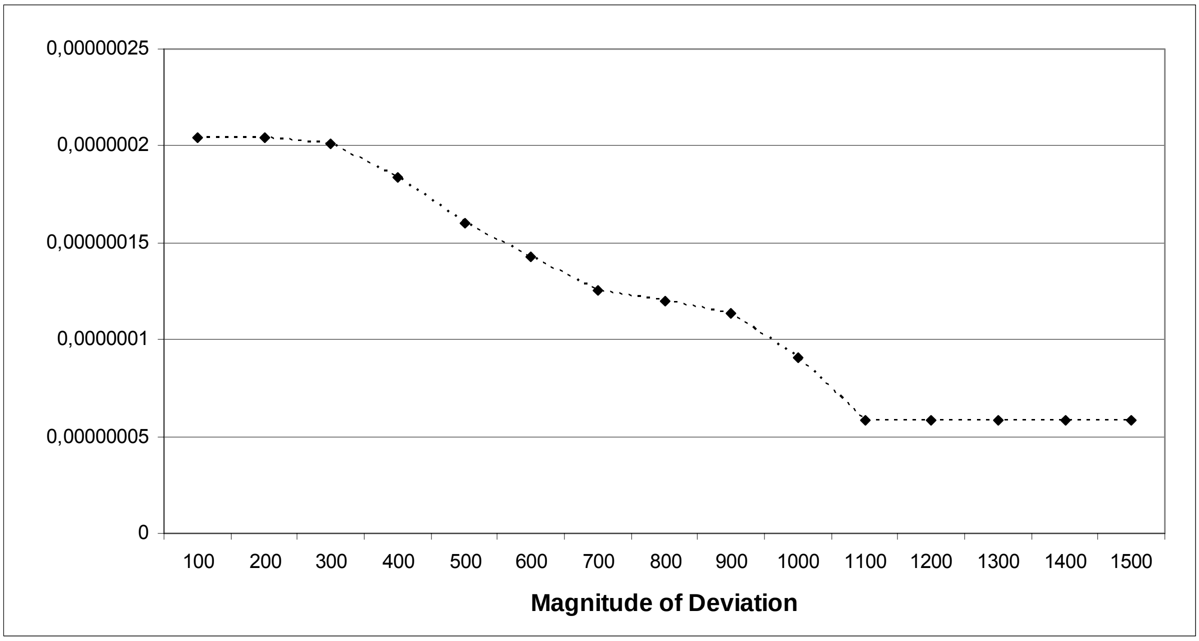


Table 3–5: Summary of Proximate Events Used to Calculate Horizontal Overlap Frequency[4]

			Number of Proximate Events					Geometry Factor		Horizontal Overlap	
HMU Site	Days	Flt Hrs (F)	Same	Opp	Cross	Total (n)	Total Frequency (2n/F)	level traffic	non-level traffic	level traffic	non-level traffic
Geneva	173	26,299.75	11	6	1,986	2,003	0.1523208	5.92E-02	7.22E-02	9.02E-03	1.10E-02
Linz	174	14,698.69	12	10	473	495	0.0673529	6.10E-02	6.92E-02	4.11E-03	4.66E-03
Nattenheim	166	21,918.14	25	439	1,359	1,823	0.1663462	5.79E-02	6.59E-02	9.63E-03	1.10E-02
Combined	513	62,916.58	48	455	3,818	4,321	0.1373564	5.89E-02	6.92E-02	8.09E-03	9.51E-03

[4] Total numbers are a subset of numbers presented in Table 3–8 and only represent events occurring on adjacent flight levels.

Table 3–6: Average Aircraft Dimensions and Kinetic Data

Average aircraft vertical size	38.67 ft	0.00638 Nm
Average aircraft horizontal size	132.44 ft	0.02186 Nm
Average vertical relative speed for aircraft in level flight	150 ft/m	1.5 Kts
Average vertical relative speed for aircraft in non-level flight	1500 ft/m	15 Kts

Table 3–7: Classifications Used for Proximity Event Geometry

Geometry of Event	Angle of Intersection
Same Direction	Less than 5º
Crossing	Between 5º and 175º
Opposite	Greater than 175º

Table 3–8: Derivation of Weighting Factors Associated with the Estimation of Horizontal Overlap Frequency

	Same			Opposite			Crossing		
HCPA	Observed number	Predicted number of overlaps	Underestimation Factor	Observed number	Predicted number of overlaps	Underestimation Factor	Observed number	Predicted number of overlaps	Underestimation Factor
0.02	209	209.00	1.00	23	23.00	1.00	304	304.00	1.00
0.04	132	170.50	1.23	23	23.00	1.00	291	297.50	1.02
0.06	88	143.00	1.46	22	22.67	1.01	257	284.00	1.07
0.08	64	123.25	1.70	24	23.00	1.00	216	267.00	1.14
0.10	47	108.00	1.94	17	21.80	1.06	240	261.60	1.16
0.12	36	96.00	2.18	18	21.17	1.09	246	259.00	1.17
0.14	42	88.29	2.37	22	21.29	1.08	236	255.71	1.19
0.16	45	82.88	2.52	26	21.88	1.05	196	248.25	1.22
0.18	31	77.11	2.71	24	22.11	1.04	261	249.67	1.22
0.20	45	73.90	2.83	24	22.30	1.03	225	247.20	1.23
0.22	37	70.55	2.96	22	22.27	1.03	229	245.55	1.24
0.24	34	67.50	3.10	17	21.83	1.05	220	243.42	1.25
0.26	43	65.62	3.19	16	21.38	1.08	203	240.31	1.27
0.28	22	62.50	3.34	24	21.57	1.07	202	237.57	1.28
0.30	34	60.60	3.45	25	21.80	1.06	232	237.20	1.28
0.32	29	58.63	3.57	19	21.63	1.06	239	237.31	1.28
0.34	44	57.76	3.62	18	21.41	1.07	206	235.47	1.29
0.36	28	56.11	3.72	11	20.83	1.10	220	234.61	1.30
0.38	34	54.95	3.80	21	20.84	1.10	234	234.58	1.30
0.40	33	53.85	3.88	19	20.75	1.11	219	233.80	1.30
0.42	31	52.76	3.96	25	20.95	1.10	229	233.57	1.30
0.44	40	52.18	4.01	26	21.18	1.09	213	232.64	1.31
0.46	24	50.96	4.10	14	20.87	1.10	235	232.74	1.31
0.48	24	49.83	4.19	7	20.29	1.13	231	232.67	1.31
0.50	19	48.60	**4.30**	22	20.36	**1.13**	217	232.04	**1.31**

Table 3–9: Observed ASE Performance for Aircraft Classifications

Type	Flight Proportion	Use Default Density	Non-compliant aircraft	Density	Mean (ft)	s.d[7].(G[8] /DE[9] only)	s.d. 1 (GDE[10] only)	s.d.2 (GDE only)	Alpha[11] (GDE only)
A124	0.0004029	NO	NO	G	64.8	61.52668			
A225	1.2059E-05	NO	YES	GDE	-3.5		58.39929	87.52154	0.34202
A300	0.0101655	NO	YES	GDE	8.8		51.78794	58.03694	0.2
A310-GE	0.0068018	NO	YES	GDE	-58		47.40961	51.17690	0.2664
A310-PW	0.0006771	NO	YES	GDE	14.5		46.86872	48.57089	0.2283
A318	0.0016199	NO	NO	G	46.6	26.14717			
A320	0.2290140	NO	YES	GDE	37.5		43.57041	48.19218	0.1998
A330	0.0194165	NO	YES	GDE	47.1		38.78191	43.28563	0.1707
A340	0.0188562	NO	YES	GDE	-5.3		40.68946	58.84049	0.5893
A345	0.0001331	NO	NO	G	-13.8	27.29563			
A346	0.0019842	NO	NO	G	21.9	32.52050			
A3ST	0.0002758	NO	YES	GDE	36.7		37.58069	43.40382	0.1664
AN72	2.0098E-06	NO	NO	DE	10.7	40.13571			
ASTR-1	4.3836E-06	NO	NO	G	35.9	48.46509			
ASTR-SPX	0.0001006	NO	YES	GDE	57.5		54.77639	56.46612	0.1762
AVRO	0.0139199	NO	YES	GDE	29.7		49.78819	53.11856	0.2516
B701	0	NO	YES	GDE	53		60.67652	50.79266	0.289
B703	6.6326E-05	NO	NO	G	22.7	63.62519			
B712	0.0015229	NO	YES	GDE	37.5		40.12781	41.44297	0.3397
B727	0.0008486	NO	YES	GDE	55.7		56.43107	67.52966	0.5707
B732	0.0067396	NO	YES	GDE	-2.7		35.45663	55.07860	0.1637
B737CL	0.1549954	NO	YES	GDE	-40.1		45.42245	50.45453	0.2458
B737NX	0.1409367	NO	YES	GDE	11.5		41.20204	62.28882	0.3149
B744-10	0.0266067	NO	YES	GDE	-55.5		37.84900	47.14231	0.5394
B744-5	0.0069908	NO	YES	GDE	-60.9		51.85683	53.68979	0.2289
B747CL	0.0105725	NO	YES	GDE	-39		59.98429	64.39440	0.2883
B74S	0.0002643	NO	NO	G	-28.8	66.73759			
B752	0.0351966	NO	YES	GDE	-7		39.89582	45.98975	0.3643
B753	0.0032585	NO	YES	GDE	6.8		34.73241	41.70636	0.1777
B764	0.0007788	NO	NO	G	-13.2	40.87909			
B767	0.0339228	NO	YES	GDE	-60.9		44.10159	50.95368	0.6194
B772	0.0233468	NO	YES	GDE	28		32.60254	50.83903	0.4343
B773	0.0010647	NO	YES	GDE	12.3		18.07178	21.47749	0.2
BE20	0.0001045	NO	NO	G	27.7	38.05987			

[7] s.d. is the standard deviation for a single distribution, i.e. G or DE; s.d.1 and s.d.2 are the standard deviations of the G core and the DE tails within a GDE mixture respectively.

[8] G stands for a Gaussian distribution.

[9] DE stands for a Double Exponential distribution.

[10] GDE stands for a Gaussian Double Exponential mixture distribution.

[11] Alpha is a weighting factor for the tail distribution within a GDE mixture distribution.

Type	Flight Proportion	Use Default Density	Non-compliant aircraft	Density	Mean (ft)	s.d[7].(G[8] /DE[9] only)	s.d. 1 (GDE[10] only)	s.d.2 (GDE only)	Alpha[11] (GDE only)
BE40	0.0002508	NO	YES	GDE	-5.7		54.79675	50.28776	0.3817
BE40-BEECH	3.5019E-05	NO	NO	G	-34.7	37.37752			
C500	0.0002803	NO	NO	G	-9.9	53.80877			
C525	0.0024199	NO	YES	GDE	17.4		44.32301	44.88837	0.4417
C525-II	0.0007049	NO	YES	GDE	9.6		103.3355	104.6526	0.9999
C550-B	0.00199470	NO	YES	GDE	43.7		39.70765	59.55795	0.3733
C550-II	0.0004419	NO	NO	G	-0.7	44.82029			
C550-SII	2.25E-06	NO	YES	GDE	-54.2		41.59374	24.86762	0.036
C560	0.0012471	NO	YES	GDE	36.3		55.33797	58.15166	0.322
C56X	0.0025580	NO	YES	GDE	-20.1		38.18556	39.74749	0.2045
C650	0.0011556	NO	YES	GDE	13.4		50.09249	58.98634	0.2581
C750	0.0005657	NO	YES	GDE	-5.8		52.95362	92.42170	0.5805
CARJ	0.0485865	NO	YES	GDE	-23.1		48.42564	52.76377	0.229
CL600	0.0003609	NO	YES	GDE	-4.7		53.81264	105.0403	0.4161
CL600-1	2.2292E-07	NO	YES	GDE	-3.5		58.39929	87.52154	0.34202
CL604	0.0012188	NO	YES	GDE	-1.3		46.81904	51.55534	0.3253
CRJ-700	0.0117397	NO	YES	GDE	3.9		48.13476	50.02828	0.1823
D328	8.0395E-06	NO	YES	GDE	-3.5		58.39929	87.52154	0.34202
DC10	0.0032334	NO	NO	G	-10.8	61.07926			
DC85	0	NO	YES	GDE	-3.5		58.39929	87.52154	0.34202
DC86-7	0.0001472	NO	YES	GDE	-39		57.84132	54.92651	0.324
DC86-7NG	0.0001947	NO	YES	GDE	-0.6		70.09212	80.14098	0.2457
DC91	2.5123E-06	NO	YES	GDE	-3.5		58.39929	87.52154	0.34202
DC93	0	NO	YES	GDE	22.4		39.49744	42.97418	0.5166
DC95	0.0002537	NO	NO	G	-37.1	27.29642			
E135-145	0.0406213	NO	YES	GDE	-5.7		61.56397	72.14784	0.5092
E170	0.0004235	NO	YES	GDE	-3.5		58.39929	87.52154	0.34202
F100	0.0145319	NO	YES	GDE	-5.6		47.47980	50.60727	0.4618
F2TH	0.0030168	NO	YES	GDE	-59.1		57.78679	76.49081	0.2960
F70	0.0102453	NO	YES	GDE	-84.5		35.81348	39.92077	0.1589
F900	0.0030484	NO	YES	GDE	21.8		61.35922	80.09939	0.3533
FA10	0.0005452	NO	YES	GDE	15.3		54.30628	55.86480	0.2348
FA10NG	3.3182E-07	NO	YES	GDE	-3.5		58.39929	87.52154	0.34202
FA20	0.0005924	NO	YES	GDE	-14.5		47.80010	59.28035	0.214
FA50	0.0017943	NO	YES	GDE	50.5		64.34658	69.04695	0.228
GALX	0.0001818	NO	NO	G	2.1	60.44181			
GLEX	0.00073	NO	YES	GDE	26.6		60.88906	59.11744	0.2965
GLF2	2.319E-05	NO	YES	GDE	38.6		70.68679	77.31241	0.9994
GLF2B	1.4455E-05	NO	NO	G	14.5	61.39289			
GLF2B-G	1.2883E-08	NO	YES	GDE	-3.5		58.39929	87.52154	0.34202
GLF3	0.0002185	NO	YES	GDE	-40.6		56.85026	78.93982	0.0312
GLF4	0.0020696	NO	YES	GDE	-25.6		52.16530	55.20544	0.4583
GLF5	0.0011777	NO	YES	GDE	-2.9		57.34001	62.46855	0.42
H25B-700	6.7184E-06	NO	YES	GDE	3		66.38120	112.2142	0.0645
H25B-800	0.0024528	NO	YES	GDE	23.2		64.44523	68.34800	0.2
H25B-800NG	1.1936E-06	NO	NO	G	26.6	61.42458			
H25C	3.0618E-05	NO	NO	DE	52	85.46875			
H25CNG	7.2456E-05	NO	YES	GDE	-3.5		58.39929	87.52154	0.34202

Type	Flight Proportion	Use Default Density	Non-compliant aircraft	Density	Mean (ft)	s.d[7].(G[8] /DE[9] only)	s.d. 1 (GDE[10] only)	s.d.2 (GDE only)	Alpha[11] (GDE only)
IL62	0.0002215	NO	YES	GDE	55.9		46.01140	50.06894	0.9999
IL76	0.0003517	NO	YES	GDE	55		61.55723	64.87729	0.3219
IL86	0.0005014	NO	YES	GDE	12.4		92.49249	73.82005	0.855
IL96	0.0001904	NO	YES	GDE	62.5		55.51994	58.76943	0.999
J328	0.0004497	NO	YES	GDE	40.7		43.06612	45.08605	0.3048
L101	0.0003979	NO	YES	GDE	5.4		73.02204	76.13709	0.3386
L29B-2	3.0148E-06	NO	NO	G	11.6	103.6756			
LJ31	0.0005105	NO	YES	GDE	6.4		43.30334	37.15330	0.2923
LJ35/6	0.0012285	NO	NO	G	74.3	46.18193			
LJ45	0.0014064	NO	NO	DE	39.6	38.51837			
LJ55	0.0003879	NO	NO	G	33.9	63.45158			
LJ60	0.0012139	NO	YES	GDE	27.1		40.09052	51.41714	0.9999
MD11	0.0059181	NO	YES	GDE	-10.1		52.98762	57.65188	0.4577
MD80	0.0678708	NO	YES	GDE	1.4		38.21512	43.49921	0.202
MD90	0.0026234	NO	YES	GDE	37.5		35.74569	42.93622	0.999
P180	0.0002889	NO	YES	GDE	53.2		25.52749	60.2299	0.9325
PRM1	0.0001050	NO	NO	G	-19.3	30.07454			
SBR1-65	3.9192E-05	NO	NO	DE	-24.5	75.61905			
T134	0.0002602	NO	YES	GDE	12.4		36.246	68.02501	0.7835
T154	0.0053593	NO	YES	GDE	-0.9		48.72344	64.11073	0.1518
T204	0.0006366	NO	YES	GDE	-42.5		86.39436	87.68536	0.1416
YK42	0.0002291	NO	NO	DE	48	55.99323			

Table 3–10: Observed Typical[12] Performance for MASPS Approved Aircraft, as Recorded by the Height Monitoring Systems

Magnitude of Deviation	Observed number of deviations	Observed Proportion
-350 to -251	29	2.129 E-05
-250 to -151	287	2.107 E-04
-150 to -51	14326	1.052 E-02
-50 to 50	1332454	9.782 E-01
51 to 150	14828	1.089 E-02
151 to 250	187	1.373 E-04
251 to 350	3	2.202 E-06

[12] 'Typical' AAD performance is defined to be not greater than 350ft in magnitude.

Table 3–11: Proportions of Atypical AAD of Given Magnitude

Deviation	Climbing/Descending Traffic	Level Traffic
100	2.04E-07	0
200	2.04E-07	0
300	2.01E-07	1.17E-07
400	1.84E-07	1.08E-06
500	1.60E-07	1.27E-06
600	1.43E-07	2.51E-07
700	1.25E-07	0
800	1.20E-07	5.83E-08
900	1.14E-07	3.64E-08
1000	9.04E-08	3.02E-07
1100	5.83E-08	0
1200	5.83E-08	0
1300	5.83E-08	0
1400	5.83E-08	0
1500	5.83E-08	0

Table 3–12: Summary of Atypical Altitude Deviations by Error Type

Type of event	Number of Occurrences
Errors no greater than 300ft	1
Errors in transponder altitude	1
Below FL290	14
TCAS nuisance or false events	2
TCAS real (actual collision avoidance)	4
Altitude deviations due to other technical error (e.g. autopilot failure)	3
Altitude deviations due to other operational error (e.g. pilot error, pilot-controller loop error)	16
Other errors not related to altitude deviations	7
Unknown errors	3
Total number of errors	51

Table 3–13: Description of the ADRs used in the Risk Calculations

Ref#	Date	#	Type of Error	Description	Remarks
2004/001	4 Jan 04	6	Unknown	• A/C 1 cleared at FL330, controller observed A/C 1 at FL334. • A/C 2 at FL340, received TCAS RA and climbed to FL343.	• N/A
2004/002	11 Jan 04	1	Pilot error	• A/C cleared at FL290, controller observed A/C at FL299.	• N/A
2004/004	17 Jan 04	4	A/C equipment failure	• A/C cleared at FL330, controller observed A/C at FL336.	• A/C unable to maintain height-keeping required for RVSM. Pilot advice having instrument problems.
2004/005	21 Jan 04	5	TCAS	• A/C cleared at FL260, controller observed A/C at FL300.	• Pilot notified that TCAS indications probably wrong, not first time for this aircraft.
2004/006	28 Jan 04	1	Pilot error	• A/C cleared at FL350, controller observed A/C at FL353.	• Pilot intentionally deviated by 300 ft from cleared FL.
2004/007	28 Jan 04	1	Pilot error	• A/C climbing to cleared FL350, received TCAS TA, disengaged autopilot, controller observed A/C at FL353.	• Level bust
2004/008	4 Feb 04	5	TCAS	• A/C cleared at FL370, reported at FL375 (due to TCAS RA).	• N/A
2004/009	2 Jan 04	5	TCAS	• A/C cleared at FL330, climbed to FL339 due to TCAS RA.	• A/C climbed due to TCAS RA
2004/010	2 Jan 04	1	Pilot error	• A/C cleared at FL340, instructed to climb to FL340 due to traffic, controller observed A/C at FL349.	• Level bust

Ref#	Date	#	Type of Error	Description	Remarks
2004/011	12 Jan 04	6	Unknown	• A/C cleared at FL400, A/C was handed of to a military unit to maintain FL400 until inside designated military area, controller observed A/C at FL382 descending before entering the military area.	• The military unit (ACU) could not explain why the A/C descended before entering the military area.
2004/012	22 Jan 04	1	Pilot error	• A/C cleared at FL330, observed by ATC at FL340.	• Flight crew certain cleared to FL340, voice recordings revealed A/C cleared to FL330 and pilot read-back FL330.
2004/013	4 Feb 04	4	A/C equipment failure	• A/C cleared at FL340, controller observed at FL337 to FL341.	• Indicator problem.
2004/014	18 Feb 04	1	Pilot error	• A/C cleared at FL290, controller observed at FL281.	• Pilot reported "finger trouble". • Possible TCAS RA
2004/015	19 Feb 04	4	A/C equipment failure	• A/C cleared at FL310, controller observed A/C at FL320.	• Transponder problem (wrong Mode c)
2004/016	26 Feb 04	6	Unknown	• A/C operating in military flying area which had a ceiling of FL350, controller observed A/C at FL390.	• A/C operated outside of the military flying area without clearance to do so.
2004/017	1 Mar 04	3	ATC/Pilot loop error	• A/C cleared at FL340, pilot read-back FL350, missed by ATC, controller observed at FL350 and re-cleared A/C at FL350.	•
2004/018	15 Jan 04	1	Pilot error	• A/C cleared from FL360 to FL320 due to opposite direction traffic at FL310. A/C descended to FL316.	• Pilot misunderstood cleared level despite correct read-back. Climbing rate of 1500 ft / min.
2004/021	26 Feb 04	5	TCAS	• A/C 1 at FL310. A/C 2 high climb rate causing A/C 1 to receive TCAS RA. A/C 1 climbed to FL316.	•

Ref#	Date	#	Type of Error	Description	Remarks
2004/022	27 Feb 04	1	Pilot error	• A/C cleared to FL330. Controller observed A/C at FL334.	• Pilot thought cleared to FL350.
2004/023	12 Apr 04	3	ATC/Pilot loop error	• A/C cleared at FL360. Controller observed A/C at FL355.	• Pilot read-back wrong cleared level (FL260) and the controller missed the incorrect read-back.
2004/024	18 Apr 04	5	TCAS	• A/C cleared at FL320. Received TCAS RA and descended to FL317.	•
2004/025	21 Apr 04	5	TCAS	• A/C cleared at FL340. Controller observed A/C at FL335.	• A/C reacted to TCAS RA. Most likely equipment problem.
2004/027	27 Apr 04	1	Pilot error	• A/C cleared to FL330. A/C kept climbing to FL338 before descending to FL330.	•
2004/028	4 Jan 04	1	Pilot error	• A/C cleared to FL350. Subsequently cleared to FL300. Controller observed A/C at FL350.	• It appears pilot misinterpreted a climb clearance to FL350 to another (same company) A/C.
2004/029	12 Jan 04	1	Pilot error	• A/C cleared to FL280. Controller observed A/C at FL287.	• Level bust
2004/030	28 Feb 04	1	Pilot error	• A/C cleared at FL290. Controller observed A/C at FL296	• Level bust
2004/031	14 Mar 04	1	Pilot error	• A/C cleared at FL300. Controller observed A/C at FL310.	• Pilot misunderstood cleared level despite correct read-back.
2004/032	23 Mar 04	1	Pilot error	• A/C cleared at FL340. Controller observed A/C at FL260	• Pilot descended without clearance. Pilot misunderstood a direct routing clearance from ATC.
2004/033	1 Apr 04	4	A/C equip failure	• A/C cleared at FL350. Controller observed A./C at FL354	• Pilot informed of autopilot failure.

Table 3–14: AAD for ADRs used in the Risk Calculations

Ref#	Date	AAD event for the report
2004/001	4 Jan 04	A/C1 400ft deviation, join wrong FL during 25 sec, 400ft deviation, join FL330. A/C2 only reacted. It is not an operational error.
2004/002	11 Jan 04	900 ft dev, join wrong FL during 20 sec, 900 ft dev, join FL290.
2004/004	17 Jan 04	Atypical AAD. 600ft dev, join FL336 for 5 min, 600ft dev (descending outside RVSM)
2004/005	21 Jan 04	1000ft dev, join FL300 during 3 min 25 sec.
2004/006	28 Jan 04	300ft dev, join FL353 during 2 min, 300ft dev, join FL350.
2004/007	28 Jan 04	300ft dev, join FL353 during 20 sec, 300ft dev, join FL350.
2004/008	4 Feb 04	500ft dev, join FL375 for 30 sec, 500ft dev, join FL370.
2004/009	2 Jan 04	900ft dev, join FL339 for 10 sec, 900 ft dev, join FL330.
2004/010	2 Jan 04	900ft dev, join FL349 for 10 sec, 900 ft dev, join FL340.
2004/011	12 Jan 04	2200ft dev, duration at FL382 unknown but joined a military area.
2004/012	22 Jan 04	1000ft dev, join FL340 for 90 sec, 1000ft dev, join FL330.
2004/014	18 Feb 04	900ft dev, join FL281 for 10 sec, 900 feet dev, join FL290.
2004/015	19 Feb 04	Technical error. 1000ft dev, join FL320 for unknown time.
2004/016	26 Feb 04	4000ft dev, join FL390 for 120 sec, 4000ft dev, join FL350.
2004/017	1 Mar 04	1000ft dev, join FL350.
2004/018	15 Jan 04	400ft dev, join FL316 for 15 sec, 400 ft dev, join FL320
2004/021	26 Feb 04	600ft dev, join FL316 for 45 sec, 600ft dev, join FL310
2004/022	27 Feb 04	400ft dev, join FL334 for 40 sec, 400ft dev, join FL330
2004/023	12 Apr 04	500ft dev, join FL355 for 15 sec, 500ft dev, join FL360
2004/024	18 Apr 04	300ft dev, join FL317 for 20 sec, 300ft dev, join FL320
2004/025	21 Apr 04	Atypical AAD. 500ft dev, join FL335 for 20 sec, 500ft dev, join FL340.

Ref#	Date	AAD event for the report
2004/027	27 Apr 04	800ft dev, join FL338 for 1min 20 sec, 800ft dev, join FL330.
2004/028	4 Jan 04	5000 ft dev, join FL350 for unknown duration, unknown whether A/C returned to FL300.
2004/029	12 Jan 04	700 ft deviation, join FL287 for unknown time, 700 ft deviation, join FL280.
2004/030	28 Feb 04	600 ft deviation, join FL296 for unknown duration, 600 ft deviation, join FL290.
2004/031	14 Mar 04	1000 ft dev, join FL310 for unknown duration, 1000 ft dev, join FL300.
2004/032	23 Mar 04	8000 ft dev. up to FL260, 6000ft dev up to FL280, join FL260 for unknown duration, A/C re-cleared at FL260
2004/033	1 Apr 04	Atypical AAD. 400 ft dev, join FL354 for unknown duration, 400 ft deviation, join FL350

4. ASSESSMENT OF THE TECHNICAL VERTICAL RISK AGAINST THE TLS OF $2.5X10^{-9}$ 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 Target Level of Safety (TLS) of 2.5×10^{-9} fatal accidents per flight hour.

4.1 Direct Evidence of Compliance with TLS for Technical Height Error

The results show that the vertical collision risk due to technical height-keeping performance is estimated to be 2.93×10^{-11} fatal accidents per flight hour, compared with the TLS of 2.5×10^{-9}.

4.2 Backing 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 to be trustworthy 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) Pz(1000) - the probability of vertical overlap between RVSM-approved aircraft due to technical height-keeping performance – will be less than the ICAO requirement of 1.7×10^{-8}.

(iii) All RVSM-approved aircraft using EUR RVSM airspace meet the ICAO Global Height Keeping Performance specifications for RVSM.

(iv) All RVSM-approved aircraft using EUR RVSM airspace meet the individual ICAO performance specification for the components of Total Vertical Error (TVE).

(v) The monitoring targets for the EUR RVSM height-monitoring programme have been met.

(vi) The input data used by the CRM is valid.

(vii) 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 four European HMUs between 1st December 2003 and 31st May 2004.

The current values of $8.09x10^{-3}$ for aircraft in level flight and $9.51x10^{-3}$ for aircraft in non-level flight at adjacent flight levels indicate that the horizontal overlap frequencies have decreased slightly - by 2% and 7.7% for aircraft in level and non-level flight at adjacent flight levels respectively. This is caused by a higher increase of the flight hours (19%) against the number of proximate events (15%).

It is concluded therefore that the estimated value of the frequency of horizontal overlap, used in the computations of technical vertical collision risk, doesn't change significantly within a range and the process is valid.

(ii) Pz(1000) Compliance

Evidence concerning Pz(1000) shows in section 3.2.2 that the estimated value of Pz(1000) is 3.62×10^{-9} compared with the ICAO requirement of 1.7×10^{-8}.

(iii) Compliance with ICAO Global Height Keeping Performance Specification

Evidence concerning the achievement against the ICAO Global Height Keeping Performance Specification is presented in APPENDIX A - **,** paragraph A.5.1.

As explained in this paragraph, four requirements exist:

(a) the proportion of TVE beyond 90 m (300 ft) in magnitude must be less than 2.0×10^{-3};

(b) the proportion of TVE beyond 150 m (500 ft) in magnitude must be less than 3.5×10^{-6};

(c) the proportion of TVE beyond 200 m (650 ft) in magnitude must be less than 1.6×10^{-7}; and

(d) the proportion of TVE between 290 and 320 m (950 and 1050 ft) in magnitude must be less than 1.7×10^{-8}.

The results show that all but requirement (b) and (c) are satisfied. Meeting the requirements constrains the error distribution function and, therefore, gives increased confidence that the TLS will be satisfied particularly when the amount of data available is small. On the other hand, not meeting one or more of the requirements (a) - (c) does not necessarily imply that the TLS will not be met.

As shown in APPENDIX A - , a lot of height monitoring data has become available from the European height monitoring programme and has allowed a reliable modelling of the aircraft height keeping distributions, effectively providing the type of confidence aimed at by requirements (a) - (c). The critical requirement is (d), which is, in fact, equivalent to the ICAO requirement that the probability of vertical overlap is less than 1.7×10^{-8}, and is met.

(iv) Compliance with ICAO Individual TVE Component Requirements

Evidence concerning achievement against the ICAO TVE Component requirements is presented in APPENDIX A - **,** paragraph A.5.2.

Three requirements have to be met:

(a) The mean ASE for any aircraft group shall not exceed ± 25m (± 80 ft).

(b) The sum of the absolute value of the group mean ASE and three standard deviations of group ASE shall not exceed 75m (245 ft).

(c) Errors in altitude keeping shall be symmetric about a mean of 0 m (0 ft), shall have a standard deviation not greater than 13 m (43 ft) and be such that the error frequency decreases with increasing error magnitude at a rate which is at least exponential.

This paragraph presents the results for ASE against (a) and (b), which show that the majority of aircraft monitoring classifications satisfy requirements (a) and (b). However, the following aircraft monitoring classifications currently fail to meet (a) and/or (b):

(a) E170 and F70;

(b) A124, E170, GLF2, H25C, L29B-2, SBR1-65 (≈ 245ft) and T204.

This paragraph also presents the results for height keeping against requirement (c), which show that, on the basis of the data currently available, this requirement has been satisfied for the standard deviation and the mean (see also paragraph A.5.2).

(v) Compliance with EUR RVSM Height-Monitoring Targets

Evidence concerning achievement against the Height-Monitoring Targets for the EUR RVSM Programme is presented in APPENDIX A - **,** paragraph A.4.

The derivation of applied monitoring targets and aircraft groupings for the Safety Monitoring Report is discussed in APPENDIX A - , paragraphs A.4.1 to A.4.3.

Paragraph A.4.4 presents the results up to 31st May 2004. As discussed below, these results show that at least 94% of the RVSM flights were made by operator monitoring/classification combinations that meet the current monitoring targets, consequently, meeting the 90%-requirement. More than 4% of flights remain still unmatched as a consequence of the differences between both sources of data: area of coverage (ECAC vs HMU coverage area), data management in the case of code sharing companies or aircraft type similar to others within the same group. Therefore the final figure might potentially increase up to 98%.

(vi) Validity of CRM Input Data

Evidence of the validity of the CRM input data, obtained from the RVSM Height Monitoring Programme (other than satisfaction of the monitoring targets), is based on the following:

(i) The quality and reliability of the monitoring infrastructure and its output data are ensured through the specification of the systems and through verification of performance (APPENDIX A - , paragraph A.1)

(ii) The requirement that all data from the HMUs or GMUs used in the CRM has satisfied quality control requirements.

Details of the sources of the data used in the assessment described above are given herein in APPENDIX A - **,** paragraph A.1, which shows that these two conditions have been satisfied.

(vii) Corrective Action

The means by which instances of poor technical height keeping performance by RVSM-approved aircraft are followed up is described in APPENDIX A - **,** paragraph A.7.

4.3 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. This is the smallest value predicted since the beginning of the monitoring activities with the PISC **[5]**

(ii) The quality of the height monitoring data is satisfactory. (More than 90% of the flights were made by operators that met their monitoring targets)

(iii) Most monitoring classifications are showing compliance with technical height keeping requirements. There are however a few classifications that show cause of concern. Nevertheless, the User Support Cell continues to ensure that problems are identified as they arise and associated corrective actions are applied.

4.4 Recommendations

(i) The technical height-keeping analysis and follow-up process should continue to ensure that all aircraft perform to the specifications and verify the performance for those classifications that have no data.

5. SATISFACTION OF SAFETY OBJECTIVES FOR OVERALL VERTICAL TLS

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 meets the ICAO overall Target Level of Safety (TLS) of 5×10^{-9} fatal accidents per flight hour due to all causes.

5.1 Direct Evidence of Compliance with Overall TLS

The results show that the overall vertical collision risk, due to the combination of technical height-keeping and operational errors, is estimated to be within a range from 0.81×10^{-9} to 1.97×10^{-9} fatal accidents per flight hour, compared with the TLS of 5×10^{-9} fatal accidents per flight hour.

Although the overall TLS of 5×10^{-9} fatal accidents per flight hour is met currently, the three following points should be noted:

- The results have been achieved using the same collision risk model as used for the results in the PISC **[5],** POSC **[6]** and 2003 **[7]** Safety Monitoring reports for reasons of comparison. However, as it is mentioned in the following paragraphs, this model needs further refinement.

- The overall vertical collision risk has been obtained using a new computed operational risk value based on a set of ADRs sent by the States for the period from 1st January 04 up to 1st May 2004.

- This is a short period when compared with the 2-year height monitoring data used in the analysis of the technical-height keeping performances. In fact, no 2003 reports have been used in the analysis as a consequence of the small number of reporting States and low reporting rates.

5.2 Backing Evidence of Compliance with Overall TLS

The above evidence concerning vertical collision risk due to all causes is considered to be trustworthy if it can be shown that:

(i) The number of altitude deviation reports (ADRs) is sufficiently representative of the true situation.

(ii) The method of analysing ADRs for input to the CRM is valid and the method by which operational errors are modelled in the CRM is valid.

(iii) Expected future traffic growth affecting EUR RVSM airspace is fully taken into account in the collision risk analysis.

(i) Validation of ADRs

Since 1st April 2000, Eurocontrol has collected ADRs from the participating States in order to assess the operational risk within the RVSM airspace before and after the implementation of RVSM in Europe. The fact that the operational error data has not always been available for a sufficient number of States and on a continuous basis has increased the uncertainty in the error rate used in the analysis.

Despite the great interest shown and the invaluable support provided by some States during this year's collection campaign, the number of ADRs continues to be insufficient to provide a full picture of the operational side in the European RVSM airspace.

Therefore, even when the number of reporting States has increased in comparison with previous reports, there are still two important issues to be addressed in relation to the ADRs validity:

- Ensure the continuous reporting of ADRs from a representative number of States every year. In consequence, a new collection campaign for the 2005 report has been launched. The campaign will start in November 04 and last until June 05, in order to cover a period of time of at least 8 months. Additional initiatives are under development to facilitate the elaboration and collection of those reports by implementing specific applications in the ANSPs. This initiative intends to overcome current problem when during long periods of time (i.e. the whole 2003 year) just few reports from a few number of States were received.

- Based on that information, assess the risk of any vertical event occurred within the EUR RVSM airspace regardless of either that being or not an RVSM induced error.

(ii) Validation of ADRs analysis for input to the Collision Risk Modelling

(a) Validation of ADR Analysis Method

The validity of the method of processing ADRs prior to input to the CRM was established in the PISC **[5]** (Appendix M and Appendix F, paragraph F.4.3).

(b) Validation of Operational Error Modelling

The validity of the method of modelling operational errors in the CRM was established in the PISC **[5]** (paragraphs 5.9.9 (ii) and (iii)). This method was applied also in the POSC **[6]** and the 2003 report **[7]** allowing comparison of the final results and validation of the initial assumptions.

However, this CRM presents some shortcomings that need to be overcome in order to provide a true picture of the operations in RVSM airspace. In particular, it is likely that the risk is under-estimated. In the POSC **[6]**, it was proposed to apply an additional model (i.e. "Conditional Model"), to overcome these short-comings.

Therefore, under the aegis of the Maths Drafting Group, a decision has been already taken to review, refine, as much as is feasible the Collision Risk Model. This revised model would be applied in future reports.

(iii) Future Traffic Growth

The effect of future traffic growth on the vertical collision risk was assessed based on estimated annual growth rate between 4.1% and 5.2% for the period 2005 - 2010 (see section 3.4).

The analysis shows that the overall TLS would continue to be met in 2010 (see **Figure 3–1**) However, the level of uncertainty in the results due to the under-reporting problem and the need to refine the CRM, does not provide full confidence in this statement.

5.3 Conclusions

It has been shown in this section that:

(i) Based on the new collected ADRs, the operational vertical risk has been recalculated. However, the number of reporting States and the reporting period is still considered insufficient to be representative of the true operational situation in RVSM airspace.

(ii) Nevertheless, the overall vertical collision risk meets the ICAO overall TLS of 5×10^{-9} fatal accidents per flight hour even for the highest value of the range obtained for the operational vertical risk.

(iii) The effect of future traffic growth has been assessed, expecting that the TLS will continue to be met until 2010.

(iv) A firm conclusion on the previous statements can not be drawn and a high degree of statistical confidence cannot be built in the results as long as the under-reporting problem exists and the current CRM limitations are not overcome to provide a better human error modelling.

5.4 Recommendations

It is recommended:

(i) Through continued contacts with States, efforts to monitor the ADR reporting rates will be undertaken and a new ADR collection campaign for the 2005 report covering at least 8 months of operational error data will be launched.

(ii) Assess any ADR occurred within the RVSM airspace regardless whether that being or not an RVSM induced error.

(iii) Facilitate the elaboration and collection of those reports by implementing specific applications in the ACCs. This initiative is under development.

(iv) Review and refine the EUR CRM for its future application in order to improve current human error modelling and the analysis of NIL reports, providing a more realistic estimate of the risk associated with the current operations. The model should be also applied to data from previous reports.

6. ASSESSMENT OF THE EFFECT OF RVSM ON THE OVERALL RISK OF EN-ROUTE MID-AIR COLLISION

Objective #3

The objective of this section is to set out the arguments and evidence that the continuous operation of RVSM has not adversely affected and will not adversely affect the overall risk of en-route mid-air collision.

6.1 Direct Evidence of Risk Mitigation

The approach is to show that risks associated with RVSM have been mitigated as far as practical because:

(i) The number of incidents in RVSM airspace is not increasing.

(ii) Any effect of traffic excluded from RVSM airspace on traffic below FL290 is not safety significant. This effect was assessed in previous reports concluding that RVSM does not appear to have a marked effect in traffic below FL290.

(i) RVSM-related Incidents in RVSM Airspace

A process to investigate and prevent recurrence of RVSM-related incidents raised by the Area Control Centres and Aircraft Operators was put in place when RVSM was implemented. However, as reporting of altitude deviations has been maintained at low response rates and not on a continuous basis, the statement that the operation of RVSM has not adversely affected the overall risk of en-route mid-air collision, is difficult to be validated within overall European RVSM airspace with an appropriate level of confidence.

An additional difficulty arises when trying to identify and analyse only RVSM-related incidents. A clear distinction doesn't exist and, on the other hand, it is considered that this report should provide a general analysis of the operations in the EUR RVSM airspace.

Based on that, this section reports on an analysis of incident data in which reporting rates from different periods are compared to determine whether the implementation of RVSM has had an effect on the frequency with which different types of errors occur. These errors make an important contribution to collision risk and the analysis serves to identify potential future problems.

<u>Technical errors</u>

Between 1st April 00 and 31st July 01, before RVSM was implemented, there were 3 reports, in the RVSM airspace, of vertical deviations occurring as a result of technical errors other than TCAS nuisance Resolution Advisories or TCAS real. This compares to 2 reports of events just after the implementation period (21st January 02 until May 02) and 3 reports following full Implementation between 1st January 04 and 1st May 04. Table 6–1 shows these figures converted into a rate of occurrence (per 10^5 flight hours). Rate has been also calculated in the case that no NIL reports are accounted for.

Table 6–1: Rate of deviations due to Technical Errors (x 10^5 flight hours)

Pre-RVSM	Early RVSM	Full RVSM (all reports)	Full RVSM (without NIL reports)
0.56	0.78	0.35	0.79
Reference	≈ 1.4 times bigger	≈ 1.6 times smaller	≈ 1.4 times bigger

It seems that post-implementation rates are bigger in comparison with the rate for the pre-implementation period. However, differences are not so big as to consider that there is a significant change in the rate of technical errors. On the other hand, there is no reason to believe that the technical error rate should be negatively affected by a change in the vertical separation minimum, as the height-keeping performances have improved since the implementation of RVSM.

<u>TCAS Nuisance Alerts</u>

49 vertical deviations in response to TCAS nuisance alerts were reported in the period prior to RVSM Implementation. This compares to 0 reports in the following Early Implementation period and 2 reports since the Full Implementation of RVSM. Table 6–2 shows these figures converted into a rate of occurrence (per 10^5 flight hours)

Table 6–2: Rate of deviations due to TCAS Nuisance RAs (x 10^5 flight hours)

Pre-RVSM	Early RVSM	Full RVSM (all reports)	Full RVSM (without NIL reports)
9.20	0	0.23	0.52
Reference		≈ 40 times smaller	≈ 18 times smaller

There is a significant reduction in the rate of TCAS nuisance RAs in the months since Full Implementation. Furthermore, there is no evidence that TCAS nuisance alerts are a significant issue in RVSM airspace.

<u>ATC and Pilot Errors</u>

The number of reports of vertical risk-bearing events with a primary cause of either ATC or pilot errors in the three periods were: 25 vertical deviations prior to RVSM Implementation, 8 reports in the following Early Implementation period and 16 reports since the Full Implementation of RVSM. Table 6–3 shows these figures converted into a rate of occurrence (per 10^5 flight hours)

Table 6–3: Rate of deviations due to Pilot and ATC Errors (x 10^5 flight hours)

Pre-RVSM	Early RVSM	Full RVSM (all reports)	Full RVSM (without NIL reports)
4.7	3.1	1.8	4.1
Reference	≈ 1.5 times smaller	≈ 2.6 times smaller	≈ 1.1 times smaller

The rate of ATC errors prior to the implementation of RVSM is higher than the rates observed following both Early and Full Implementation. Nevertheless, it is not significantly different. However, care should be taken when interpreting these figures because they do not represent a like-for-like comparison, as already explained.

Although, the number of ATC errors that are reported seems to fall, the events are of serious nature and need to be followed-up. The increased number of Flight Level options available has aided controllers and reduced the chance for them making an error. However, the reduction itself has not been so important.

6.2 Conclusions

(i) Based on current available information, it can be considered that there is no significant difference in safety, in those States which reported events, from before the RVSM implementation, according to the rate of occurrences.

(ii) Therefore, it might be concluded that RVSM has not adversely affected and will not adversely affect the overall vertical risk of en-route mid-air collision, according to the assumptions.

(iii) Nevertheless, considering the under-reporting problem, not sufficient arguments can be built to that respect as to give satisfactory evidence of that statement.

(iv) Two decisions have been taken in order to support future risk assessments: to consider any incident occurring in RVSM airspace regardless of its nature and initiate a longer data collection campaign.

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7. OUTSTANDING ISSUES FROM POSC RECOMMENDATIONS.

Objective #4

The objective of this section is to discharge all recommendations related to actions made in the previous 2003 Safety Monitoring Report **[7]** and address any new safety related issues arising since the issue of the latest report.

7.1 ADR programme.

The ADR programme continues in order to gather more post-implementation operational-error data.

Whilst it is recognised that the greatest contribution to the overall risk is the operational risk based on new a-typical AAD values, a meaningful number of reports is necessary to allow the update of the operational vertical risk and gain confidence in the results.

The 2004 ADR collection campaign has been demonstrated to be quite successful in terms of participating States and number of received reports. Based on that information, the operational vertical risk has been recalculated in this year report. As a consequence, an increasing trend of the operational risk has been identified along the years.

In order to assess that trend and continue monitoring the operations within the RVSM airspace to gain confidence in the results, it is necessary to continue collecting quantitative error data on a continuous basis.

In consequence, a new collection campaign for the 2005 report is proposed as well as some initiatives are under development to facilitate the elaboration and collection of that information in the ACCs .

Status

This matter is ongoing and is discussed in detail herein from paragraph 3.3.1.

7.2 Consistency and reliability of ADR reporting rates.

The consistency and reliability of the ADR reporting rates be reviewed regularly with the aim of extending the set of core regions from which the data can be used.

The consistency and reliability of the additional ADRs collected from January until May 2004 have been regularly reviewed. That information has allowed the extension of the original set of core regions under analysis.

However, that information is still not fully representative of the European RVSM airspace. Hence the launch of a new collection campaign for a longer period of time which will hopefully continue to be supported by those States that already participated in the 2004 campaign and will encourage the others to join it as an additional opportunity to help Eurocontrol to provide risk values based on consistent and reliable information.

Status

This matter is ongoing as, despite the extension of the set of core regions under analysis that number still needs to increase in order to become consistent and fully representative of the European RVSM airspace.

7.3 Conditional Model

A decision is required to be taken on the application of the validated "Conditional Model" as part of the CRM for future analysis.

After revision of this document from the Maths Drafting Group members, a decision has been taken to review the current CRM, taking into account the "Conditional Model", and apply it in future assessments. The original idea to make use of the 3-D CRM has been postponed until the model is fully developed and validated.

It is planned that the model will be applied to this and previous reports to allow comparison between results. To support this initiative, it is essential that sufficient operational error data is received from the States.

Status

A decision has been taken to review the current applied model; the Maths Drafting Group is in charge to refine it for the European airspace.

7.4 Future traffic growth

The effect of future traffic growth on the results be re-assessed once sufficient post-implementation data is available.

The effect of future traffic growth on the results has been re-assessed. According to the initial assumptions, the TLS will continue to be met in 2010.

However, if those values are compared with the estimated increase of the operational vertical risk over the years (more than 3 times) and the uncertainties in the values computation due to the under-reporting problem and the collision risk model limitations, it cannot be ensured that the true risk will always meet the TLS up until 2010.

Status

This matter is ongoing as long as there are under-reporting problems and the collision risk model is under refinement. It will be reviewed once the revised Collision Risk Model is applied.

7.5 Technical height-keeping analysis

The technical height-keeping analysis and follow-up process is continued to *ensure that all aircraft continue to perform to the specifications and to verify the performance for those classifications that have no data. For those classifications already identified as not meeting the requirements, additional data should be obtained to ensure the correctness of the results.*

Both matters have been addressed in APPENDIX A - . The Agency has continued the height-keeping analysis and follow-up process ensuring that all aircraft continue to perform to the specifications and verifying the performance for those classifications that have little or no data.

For those classifications already identified as not meeting the requirements, manufacturers and the original Type Certificate Airworthiness Authorities were contacted. Jointly corrective actions were undertaken with the result that most of the monitoring groups will comply with ICAO requirements in 2004 with the exception of A124, E170 and T204, where feedback is awaiting.

Status

This is a continuous activity and is discussed in detail herein Appendix A, paragraph A.4 to A.8.

7.6 RVSM operational data

More RVSM operational data to be obtained to confirm that the number of RVSM-related incidents in RVSM airspace is not increasing.

As was also observed in previous reports, in the new collected operational error data, it is often difficult to identify errors that are truly resulting from RVSM and separate them from errors that are not dependent upon the reduction in separation minimum.

On the other hand, the ultimate aim of this report is at providing assurance that the operations in the EUR RVSM airspace are safe. Therefore, it has been considered that any effort on identifying errors resulting from RVSM, should be better allocated to provide a generic assessment of the RVSM operations in Europe.

In addition, results from the RVSM incident analysis will be cautiously treated in order to draw conclusions, identify factors, derive safety improvements and follow-up actions and immediately implement them in the monitoring process.

Status

A decision has been taken to consider any type of incident in the analysis in order to provide a more generic picture of the EUR RVSM operations. Special attention will be paid in the analysis of data in order to derive safety improvements for the EUR RVSM airspace and implement them in the monitoring process.

7.7 Altimetry System Error Stability

Further work to be done to show that Altimetry System Error for RVSM-approved aircraft is stable with time.

Preliminary results on the analysis of Altimetry System Error stability for RVSM-approved aircraft show that RVSM-approved aircraft will not become non-compliant in the medium term as a consequence of ASE drifts.

Further work will continue focused on identifying factors affecting ASE stability, correlating altimetry system maintenance logs with ASE monitoring data, analysing the effect of ASE instability on the safety of RVSM and modelling the course of ASE over time.

Status

This matter is ongoing and is discussed in detail herein Appendix A, paragraph A.6.

8. CONCLUSIONS AND RECOMMENDATIONS

8.1 Conclusions

This section is intended to summarise all the different conclusions derived throughout the document, more precisely in sections 3 to 7:

(i) The current computed vertical collision risk due to technical height-keeping performance meets the ICAO TLS of 2.5 x 10^{-9} fatal accidents per flight hour (Objective #1) and amounts almost four times lower of the value predicted in the 2003.

(ii) The quality of the height monitoring data is satisfactory. (More than 90% of the flights were made by operators that met their monitoring targets).

(iii) Most monitoring classifications are showing compliance with technical height keeping requirements. There are however a few classifications that show cause of concern. Nevertheless, the Agency continues to ensure that problems are identified as they arise and associated corrective actions are applied.

(iv) The operational vertical risk appears to have increased compared to previous years.

(v) The overall vertical collision risk meets the ICAO overall TLS of 5 x 10^{-9} fatal accidents per flight hour (Objective #2).

(vi) The effect of future traffic growth has been assessed, estimating that the conclusion that the TLS will continue to be met until 2010.

(vii) However, the level of uncertainty in the obtained values, especially concerning the operational vertical risk value which is still affected by the under-reporting problem and the limitations of the applied model itself, doesn't provide high level of confidence on statements (vi) and (vii).

(viii) Based on current available information, it can be considered that there is not significant difference in safety in those reporting States from before the RVSM implementation, according to the rate of occurrences. As for Objective #2, a high level of uncertainty must be considered when interpreting the data in the report concerning the safety of RVSM Operations.

(ix) All recommendations related to actions made in the 2003 Safety Monitoring Report [7] have been discharged. Many of those actions keep on going as they are related to the monitoring of the height-keeping performances.

Subject to the results of the monitoring and collision risk assessment work obtained from the available information and considering the limited new operational qualitative error data, the operation of RVSM in EUR airspace can be considered as tolerably safe.

However, in the light of the concerns and shortcomings raised in the document, confidence in current operational performance cannot be fully built and the high level of uncertainty must be considered when interpreting data in the report concerning the safety of RVSM operations.

8.2 Recommendations

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

(i) Continue contacts with States and efforts to collect more RVSM operational error data using Altitude Deviation Reports to:

a. Continue monitoring the ADR reporting rates and hence gain more confidence in the results.

b. Continue reviewing regularly the consistency and reliability of the ADR reporting rates with the aim of to extending the set of core regions from which the data can be used.

c. Confirm that the number of incidents in RVSM airspace is not increasing.

(ii) Initiate as soon as possible a new operational error data campaign (November 04 – June 05) to obtain sufficient reports for next year's report. The campaign should collect any type of events within the RVSM airspace.

(iii) Implement any derived actions, conclusions, lessons learnt or proposed safety improvements derived from the operational error data analysis.

(iv) Refine the current Collision Risk Model to be applied in future analysis with retrospective character.

(v) Continue the technical height-keeping analysis and follow-up process to ensure that all aircraft perform to the specifications and verify the performance for those classifications that have no data.

(vi) Continue activities on ASE stability.

APPENDIX A - TECHNICAL HEIGHT-KEEPING PERFORMANCE

A.1. Introduction

ICAO Document 9574 **[2]** 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 technical TLS of 2.5 x 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 the MASPS and on the effectiveness of altimetry system modifications; and

iii. evidence of altimetry system error (ASE) stability.

To meet these requirements and objectives, the EUR RVSM Programme established a height monitoring infrastructure, based on ICAO requirements **[2]** and NAT RVSM experience.

The RVSM Height Monitoring infrastructure is based on the use of two systems:

1. Ground based Height Monitoring Units (HMUs) located at Linz, Nattenheim, Geneva and Strumble; and
2. Portable GPS Monitoring Units (GMUs) carried on selected flights.

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 through flight testing.

A.2. Scope

This appendix discusses the technical height-keeping performance of aircraft that use EUR RVSM airspace, in relation to ICAO requirements **[2]**. In particular it:

i. sets out the ICAO targets for height monitoring and shows the extent to which these targets have been achieved.

ii. summarises the results of the EUR RVSM Height-Monitoring Programme to date concerning compliance with the MASPS for the overall aircraft population, specific aircraft groups and individual airframes.

iii. presents results to date concerning the long-term stability of ASE.

iv. explains the follow-up action that is taken in the event of poor height-keeping performance by supposedly MASPS-compliant aircraft.

v. concludes with a summary of the position to date and recommendations for further action where appropriate.

The results contained herein are based solely on data as described in Section A.4. It should be noted that collision risk calculations based on this information are discussed in Section 3 of the main body of the report.

A.3. Data Used in the Performance Assessment

All results presented in this appendix were calculated based on height measurement data that was;

- Recorded between 31-May-2002 and 31-May-2004, and
- Recorded by the Linz, Nattenheim, Geneva and Strumble HMUs as well as the different GMUs, and
- Fully correlated to a MASPS approved aircraft.

As of 15 July 2004, 10,069 aircraft were known to be RVSM approved and flying in the European RVSM airspace (from 2,115 operators). Height correlated measurement data was available for 7,650 of these RVSM approved aircraft (1,545 operators) and were included in this assessment. The total number of measurements can be broken down as displayed in Table A-1.

Table A- 1: Total number of measurements by region

	Other Regions (NAT)	EUR
Number of measurements	29,739	1,332,384

A.4. Applied Monitoring Targets and Aircraft Classifications

A.4.1. Monitoring Aircraft Classifications

As a result of harmonisation between the different Regional Monitoring Agencies (RMAs) around the world, a set of revised monitoring aircraft classifications have been established and documented in the ICAO RMA handbook **[16]**. All results presented in the following sections are discussed based on the monitoring aircraft classifications.

A.4.2. Monitoring Targets Determination

In January 2004, each monitoring classification was assessed against target reduction criteria to determine if the monitoring target set for that classification could be reduced[13]. Monitoring target reduction alleviates the impact on the airspace users, while ensuring the collection of sufficient data to demonstrate the technical performance of the monitoring group.

The four criteria applied to determine current monitoring targets are:

1. *The value of the* $|mean| + 3stdev \leq 200$ *feet*

[13] Monitoring target sets are reduced to have a minimum impact on the airspace users, while ensuring the collection of sufficient data to demonstrate the technical performance of the monitoring group.

TGL 6 [10] paragraph 7.2.3 states that the ASE for an aircraft group[14] when the aircraft are operating in the basic flight envelope should meet the criteria of |mean| + 3stdev ≤ 200 ft. This performance standard is stricter than that set for aircraft in the total flight envelope (|mean| + 3stdev ≤ 245 ft). It should be noted that the latter is also the ICAO group requirement.

It is assumed that all monitoring data was collected while aircraft were flying the basic flight envelope. In addition, it is also assumed that if observed ASE monitoring data shows that a monitoring group is meeting the standard for the basic flight envelope then they are likely to satisfy |mean| + 3stdev ≤ 245 feet when operating in the total flight envelope. As such, when deciding whether or not a target can be reduced the stricter criteria for the basic flight envelope is applied.

2. Percentage of operator population with at least one measure.

In addition to the first criteria, it is necessary to ensure that the monitoring data is representative of the total population. It is assumed that it is necessary for at least 75% of the total operators to have at least one of their aircraft monitored to provide a good representation of the entire operator population. In addition, the operator population must contain measures that are from the European monitoring programme.

3. Individual aircraft performance must be consistent with the group.

For each monitoring classification, the individual aircraft means are compared to the classification mean +/- 1.96 times the between airframe standard deviation with a correction factor[15]. Therefore, the individual aircraft means should fall within these upper and lower bounds in 95% of the cases.

An additional examination is made of the plots of individual aircraft standard deviation against the pooled estimate of the within airframe standard deviation with 95% likelihood bounds. This is based on the assumption that the within airframe variation of ASE is the same for all the aircraft of a classification.

4. Each Operator Has a Fleet that is Meeting Individual Measurement Requirements

TGL 6 states that the absolute ASE of any measure for a non-group aircraft must not exceed 160 ft for worst case avionics (see section 7.3.6 of TGL 6). On the assumption that a group aircraft should perform equal to or better than a non-group aircraft, the absolute maximum ASE value was examined for all operator-monitoring group combinations. To account for any measurement system error, an additional 30 ft was considered when examining measures.

It was accepted that some of the fleet would be outside of these limits

[14] Group aircraft 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

[15] The correction factor is dependent on the number of repeated samples and corrects for any bias in the estimation of standard deviation

however if this grew to greater than 10% of the fleet then it is considered not appropriate to reduce the monitoring requirement to as low at 10%. To cater for small fleets, an operator that has at least 2 aircraft showing performance worse than 190 ft and these constitute at least 10% of the operator's measured fleet is considered to have failed this criteria.

Based on the results of the monitoring target reduction assessment, the monitoring targets have been modified by reducing the targets to 30% in the case of the monitoring classifications A310-GE, AVRO, BE40 and C56X, reducing to 10% the monitoring classifications A330, A340, A346, B737CL, B744-10, B764, CRJ-700, LJ31 and T154, increasing to 60% the monitoring classifications H25C and 100% for the monitoring classifications IL76, IL86 and YK42. Finally the following new monitoring classifications have been set up: ATR, CL600-1, D328, DC86-7-1, GLF2B-G, B463 and BA11.

A.4.3. Current Monitoring Targets and Classifications

The following two tables list the currently applied monitoring classifications and targets for group and non-group aircraft. The column entitled *Monitoring Classification* specifies the name used for analysis purposes; *Target* indicates the current target set for the classification; and *A/C ICAO, A/C Type*, and *A/C Series* list the respective ICAO indicators, aircraft types and aircraft series that are considered as part of the classification.

Table A- 2: Applied Monitoring Classifications for Group Aircraft (Updated)

Monitoring Classification	Target	A/C ICAO	A/C Type	A/C Series
A124	100%	A124	AN-124 RUSLAN	ALL SERIES
A300	10%/2	A306 A30B	A300 A300	600, 600F, 600R, 620, 620R, 620RF B2-100, B2-200, B4-100, B4-100F, B4-120, B4-200, B4-200F, B4-220, B4-220F, C4-200
A310-GE	30%/2	A310	A310	200, 200F, 300, 300F
A310-PW	30%/2	A310	A310	220, 220F, 320
A318	60%	A318	A318	All Series
A320	10%/2	A319 A320 A321	A319 A320 A321	CJ , 110, 130 110, 210, 230 110, 130, 210, 230
A330	10%/2	A332, A333	A330	200, 220, 240, 300, 320, 340
A340	10%/2	A342, A343	A340	210, 310
A345	60%	A345	A340	540
A346	10%/2	A346	A340	640
A3ST	60%	A3ST	A300	600R ST BELUGA
AN72	60%	AN72	AN-74, AN-72	ALL SERIES
ASTR	60%	ASTR	1125 ASTRA	ALL SERIES
ASTR-SPX	60%	ASTR	ASTR SPX	ALL SERIES
ASTR -1	60%	ASTR	1125 ASTRA, 1125 ASTRA SPX	Serial No. 001 to 072 and 074 to 078 incl.
ATR	60%	AT43, AT44, AT45,	ATR-42,	200,300,320,400,500, ALL

Monitoring Classification	Target	A/C ICAO	A/C Type	A/C Series
		AT72	ATR-72	
AVRO	30%/2	RJ1H, RJ70, RJ85	AVRO	RJ70, RJ85, RJ100
B712	30%/2	B712	B717	200
B727	60%	B721, B722	B727	100, 100C, 100F, 100QF, 200, 200F
B732	60%	B732	B737	200, 200C
B737C	60%	B737	B737	700C
B737CL	10%/2	B733, B734, B735	B737	300, 400, 500
B737NX	10%/2	B736 B737 B738 B739	B737	600 700,700BBJ 800,800BBJ 900
B744-10**	10%/2	B744	B747	400, 400D, 400F Serial Numbers: 24312, 24956- 24958, 25213, 25214, 25292, 25308, 25344, 25351, 25356, 25366, 25379, 25380, 25395, 25406, 25413, 25422, 25427, 25432, 25434, 25435, 25452, 25544-25547, 25560, 25561, 25564-25566, 25599-25602, 25605, 25628-25630, 25632, 25639-25645, 25647, 25699-25705, 25777-25784, 25809-25814, 25817-25823, 25866-25874, 25879-25883, 26055, 26056, 26062, 26255, 26326, 26341-26353, 26355, 26356, 26359, 26360, 26361, 26362, 26372, 26373, 26374, 26392, 26393, 26394, 26395, 26396, 26397, 26398, 26401, 26402, 26403, 26404, 26405, 26406, 26407, 26408, 26409, 26411, 26413, 26414, 26416, 26425, 26426, 26427, 26473, 26474, 26477, 26547, 26548, 26549, 26550, 26551, 26552, 26553, 26554, 26555, 26556, 26557, 26558, 26559, 26562, 26563, 26609, 26610, 26615, 26616, 26637, 26638, 26875, 26876, 26877, 26878, 26879, 26880, 26881, 26890, 26892, 26899, 26900, 26901, 26902, 26903, 26906, 26908, 26910, 27042, 27043, 27044, 27062, 27063, 27066, 27067, 27068, 27069, 27070, 27071, 27072, 27073, 27078, 27090, 27091, 27092, 27093, 27099, 27100, 27117, 27132, 27133, 27134, 27137, 27141, 27142, 27154, 27163, 27164, 27165, 27173, 27174, 27175, 27177, 27178, 27202, 27214, 27217, 27230, 27261, 27262, 27338, 27341, 27349, 27350, 27436, 27442, 27478, 27503, 27595, 27602, 27603, 27645, 27646, 27648, 27650, 27662, 27663, 27672, 27723, 27724, 27725, 27827, 27828, 27898, 27899, 27915, 27965, 28022, 28023, 28025, 28026, 28027, 28028, 28029, 28030, 28031, 28032, 28086, 28092, 28093, 28094, 28095, 28096, 28194, 28195, 28196, 28263, 28282, 28283, 28284, 28285, 28286, 28287, 28335, 28339, 28340, 28341, 28342, 28343, 28367, 28426, 28427, 28428, 28432, 28433, 28435, 28459, 28460, 28468, 28524, 28551, 28552, 28700, 28705, 28706, 28709, 28710, 28711, 28712, 28715, 28716, 28717, 28754, 28755, 28756, 28757, 28810, 28811, 28812, 28813, 28848, 28849, 28850, 28851, 28852, 28853, 28854, 28855, 28856, 28857, 28858, 28859, 28959, 28960, 28961, 29030, 29031, 29053, 29061, 29070, 29071, 29101, 29111, 29112, 29119, 29166, 29167,

Monitoring Classification	Target	A/C ICAO	A/C Type	A/C Series
				29168, 29170, 29219, 29252, 29253, 29254, 29255, 29256, 29257, 29258, 29259, 29260, 29261, 29262, 29263, 29328, 29375, 29406, 29492, 29493, 29729, 29730, 29731, 29732, 29733, 29868, 29869, 29870, 29871, 29872, 29899, 29906, 29950, 30023, 30158, 30267, 30268, 30269, 30322, 30400, 30401, 30454, 30455, 30558, 30559, 30607, 30608, 30609, 30729,30759-30765, 30766, 30767, 30768,30804, 30805, 30808-30810, 30811, 30812, 30885, 32338,32340, 32369, 32370, 32445,32571, 32745,32746, 32837, 32838, 32840, 32866, 32867, 32868, 32869, 32897, 32898,32909, 32910,32911, 32912, 32913,32914,33096, 33694, 33695, 33731,33732
B744-5**	60%	B744	B747	400, 400D, 400F Serial Numbers: 23719, 23720, 23814-23821, 23908- 23911, 23982, 23999-24001, 24047-24058, 24061, 24062- 24066, 24154, 24155, 24198-24202, 24222- 24227, 24285-24288, 24309- 24311, 24315, 24322, 24346- 24348, 24354, 24363, 24373, 24380-24386, 24405, 24406, 24423-24427, 24447, 24458, 24459, 24481- 24483, 24517, 24518, 24619, 24621, 24629, 24630, 24631, 24715, 24730, 24731, 24740, 24741, 24761, 24777, 24779, 24784, 24801, 24806, 24833, 24836, 24850, 24851, 24855, 24870, 24883, 24885- 24887, 24895, 24896, 24920, 24925, 24955, 24966, 24967, 24969, 24974, 24975, 24976, 24990, 24993, 24998, 25045-25047, 25064, 25067, 25068, 25074, 25075, 25082, 25086, 25087, 25126-25128, 25135, 25151, 25152, 25158, 25205, 25207, 25211, 25212, 25224, 25238, 25245, 25260, 25275, 25278, 25279, 25302, 25315, 25405
B747CL	60%	B741 B742 B743	B747	100, 100B, 100F, 200B, 200C, 200F, 200SF, 300
B74S	60%	B74S	B747	SP, SR
B752	10%/2	B752	B757	200, 200PF
B753	30%/2	B753	B757	300
B764	10%/2	B764	B767	400ER
B767	30%/2	B762 B763	B767	200, 200EM, 200ER, 200ERM
B772	30%/2	B772	B777	200, 200ER
B773	30%/2	B773	B777	300, 300ER
BE20	60%	BE20, BE30, B350	BEECH 200 SUPER KING AIR SUPER KING AIR 350 BEECH 300	ALL SERIES
BE40	30%/2	BE40	BEECHJET 400A	ALL SERIES
C500*	60%	C500	500 CITATION, 500 CITATION I, 501 CITATION I SINGLE PILOT	ALL SERIES
C500-1	60%	C500	500 CITATION	Serial No 193
C501-1	60%	C501	501 CITATION 1	
C525*	60%	C525	525 CITATIONJET,	ALL SERIES

Monitoring Classification	Target	A/C ICAO	A/C Type	A/C Series
			525 CITATIONJET I	
C525-II*	60%	C25A	525A CITATIONJET II	ALL SERIES
C550-552*	60%	C550	552 CITATION II	ALL SERIES
C550-B*	60%	C550	550 CITATION BRAVO	ALL SERIES
C550-II*	60%	C550, C551	550 CITATION II, 551 CITATION II SINGLE PILOT	ALL SERIES
C550-SII*	60%	C550	S550 CITATION SUPER II	ALL SERIES
C560	60%	C560	560 CITATION V, 560 CITATION V ULTRA, 560 CITATION V ULTRA ENCORE	ALL SERIES
C56X	30%/2	C56X	560 CITATION EXCEL	ALL SERIES
C650	60%	C650	650 CITATION III , 650 CITATION VI , 650 CITATION VII	ALL SERIES
C750	60%	C750	750 CITATION X	ALL SERIES
CARJ	30%/2	CRJ1, CRJ2	REGIONALJET	100, 100ER, 200, 200ER, 200LR
CRJ-700	10%/2	CRJ7	REGIONALJET	700, 700ER
CRJ-900	60%	CRJ9	REGIONALJET	900,900ER
CL600	30%/2	CL60	CL-600, CL-601	CL-600-1A11, CL-600-2A12, CL-600-2B16
CL600-1	60%	CL60	CL-600	CL-600-1A11 Serial No 1070
CL604	30%/2	CL60	CL-604	CL-600-2B16
BD100	60%	CL30	CHALLENGER 300	ALL SERIES
BD700	60%	GL5T	GLOBAL 5000	ALL SERIES
CONC	60%	CONC	CONCORDE	ALL SERIES
D328	100%	D328	328 Turboprop	100
DC10	30%/2	DC10	DC-10	10, 10F, 15, 30, 30F, 40, 40F
DC86-7*	60%	DC86, DC87	DC-8	61, 63, 71, 73
DC86-7-1	60%	DC86 DC87	DC-8	62,72
DC93*	60%	DC93	DC-9	30, 30F
DC95*	60%	DC95	DC-9	51
E135-145	60%	E135, E145	EMB-135, EMB-145	ALL SERIES
E170	60%	E170	EMB-170	ALL SERIES
F100	10%/2	F100	F-100	ALL SERIES
F2TH	60%	F2TH	FALCON 2000 FALCON 2000EX	ALL SERIES
F70	60%	F70	F-70	ALL SERIES
F900	60%	F900	FALCON 900, FALCON 900EX	ALL SERIES

Monitoring Classification	Target	A/C ICAO	A/C Type	A/C Series
FA10*	60%	FA10	FALCON 10	ALL SERIES
FA20	60%	FA20	FALCON 20, FALCON 200	ALL SERIES
FA50	60%	FA50	FALCON 50, FALCON 50EX	ALL SERIES
GALX	60%	GALX	1126 GALAXY	ALL SERIES
GLEX	60%	GLEX	BD-700 GLOBAL EXPRESS	ALL SERIES
GLF2	60%	GLF2	GULFSTREAM II (G-1159)	ALL SERIES
GLF2B	60%	GLF2	GULFSTREAM IIB (G-1159B)	ALL SERIES
GLF2B-G	60%	GLF2	GULFSTREAM IIB (G-1159B)	Serial No 102,166,199
GLF3	60%	GLF3	GULFSTREAM III (G-1159A)	ALL SERIES
GLF4	30%/2	GLF4	GULFSTREAM IV (G-1159C)	ALL SERIES
GLF5	10%/2	GLF5	GULFSTREAM V (G-1159D)	ALL SERIES
H25B-700*	60%	H25B	BAE 125 / HS125	700
H25B-800*	60%	H25B	BAE 125 / HAWKER 800XP, BAE 125 / HAWKER 800, BAE 125 / HS125	ALL SERIES/A, B/800
H25C*	60%/2	H25C	BAE 125 / HAWKER 1000	A , B
IL76	100%	IL76	IL-76	M,T
IL86	100%	IL86	IL-86	NO SERIES
IL96	60%	IL96	IL-96	M , T, 300
J328	60%	J328	328JET	ALL SERIES
L101	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)
L29B-2*	60%	L29B	L-1329 JETSTAR 2	ALL SERIES
L29B-731*	60%	L29B	L-1329 JETSTAR 731	ALL SERIES
LJ31	10%/2	LJ31	LEARJET 31	NO SERIES, A
LJ35/6	60%	LJ35, LJ36	LEARJET 35, LEARJET 36	NO SERIES, A
LJ40	60%	LJ40	LEARJET 40	ALL SERIES ,A
LJ45	60%	LJ45	LEARJET 45	ALL SERIES
LJ55	60%	LJ55	LEARJET 55	NO SERIES B, C
LJ60	10%/2	LJ60	LEARJET 60	ALL SERIES
MD10	60%	MD10	MD10	ALL SERIES
MD11	10%/2	MD11	MD-11	COMBI, ER, FREIGHTER, PASSENGER
MD80	10%/2	MD81, MD82, MD83, MD87, MD88	MD-80	81, 82, 83, 87, 88

Monitoring Classification	Target	A/C ICAO	A/C Type	A/C Series
MD90	30%/2	MD90	MD-90	30, 30ER
P180	60%	P180	P-180 AVANTI	ALL SERIES
PRM1	60%	PRM1	PREMIER 1	ALL SERIES
T134	60%	T134	TU-134	A, B
T154	10%/2	T154	TU-154	A , B, M, S
T204	60%	T204, T224, T234	TU-204, TU-224, TU-234	100, 100C, 120RR, 200, C
WW24	60%	WW24	1124 WESTWIND	ALL SERIES
YK42	100%	YK42	YAK-42	ALL SERIES

*Includes all aircraft of specified type except where otherwise specified in Table A- 3
**Both groups include same manufacturer/ type/ series but are serial number specific due to probe size (e.g. 5" or 10"). All aircraft are defaulted to the B744-10 unless confirmed otherwise.

Table A- 3: Applied Monitoring Classification for Non-Group Aircraft (Updated)

Monitoring Classification	Target	A/C ICAO	A/C Type	A/C Series	Serial #***
A225	100%	A225	AN-225 RUSLAN	ALL SERIES	
ASTRNG	100%	ASTR	1125 ASTRA		25
B463	100%	B463	BAE-146	300	E3001
B701	100%	B701	B707	100, 120B	
B703	100%	B703	B707	320, 320B, 320C	18928
B720	100%	B720	B720	720B	
B727NG	100%	B721, B722	B727	100,200	18935
B731	100%	B731	B737	100	
BA11	100%	BA11	BAC-111	ALL SERIES	
BE40-BEECH	100%	BE40	BEECHJET 400	ALL SERIES	
C500NG	100%	C500	500 CITATION, 500 CITATION I, 501 CITATION I SINGLE PILOT	ALL SERIES	116
C525NG	100%	C525	525 CITATIONJET, 525 CITATIONJET I	ALL SERIES	None Specified
C525-IING	100%	C25A	525A CITATIONJET II	ALL SERIES	None Specified
C550-552NG	100%	C550	552 CITATION II	ALL SERIES	None Specified
C550-BNG	100%	C550	550 CITATION BRAVO	ALL SERIES	None Specified
C550-IING	100%	C550	550 CITATION II, 551 CITATION II SINGLE PILOT	ALL SERIES	None Specified
C550-SIING	100%	C550	S550 CITATION SUPER II	ALL SERIES	None Specified
CL600	100%	CL60	CL-600,CL-601	CL-600-1A11, CL-600-2A12	1042, 1055, 1036 3055
DC85	100%	DC85	DC-8	50, 50F	
DC86-7NG	100%	DC86, DC87	DC-8	61, 62, 63,71, 72,73	46022, 46027,

Monitoring Classification	Target	A/C ICAO	A/C Type	A/C Series	Serial #***
					46071, 46067 46081, 46082, 46111, 46147, 46151, 46153
DC91	100%	DC91	DC-9	10	45740
DC92	100%	DC92	DC-9	21	
DC93NG	100%	DC93	DC-9	30, 30F	47700, 47475
DC94	100%	DC94	DC-9	41	
DC95NG	100%	DC95	DC-9	51	None Specified
FA10NG	100%	FA10	FALCON 10	ALL SERIES	128 157 168 201
FA20NG	100%	FA20	FALCON 20		455
H25A-100	100%	H25A	BAE 125 / HS125	100	
H25A-300	100%	H25A	BAE 125 / HS125	300	
H25A-400	100%	H25A	BAE 125 / HS125	400	
H25A-600	100%	H25A	BAE 125 / HS125	600	
H25B-700NG	100%	H25B	BAE 125 / HS125	700	257162 257195
H25B-800NG	100%	H25B	BAE 125 / HAWKER 800XP, BAE 125 / HAWKER 800, BAE 125 / HS125	ALL SERIES/A, B/800	258021 258022, 258028, 258037, 258061, 258130, 258283
H25CNG	100%	H25C	BAE 125 / HAWKER 1000	B	259008, 259028, 259037
IL62	100%	IL62	IL-62	NO SERIES , M	
L29A-6	100%	L29A	L-1329 JETSTAR 6	ALL SERIES	
L29A-8	100%	L29A	L-1329 JETSTAR 8	ALL SERIES	
L29B-2NG	100%	L29B	L-1329 JETSTAR 2	ALL SERIES	5211 5228 5236 5239
L29B-731NG	100%	L29B	L-1329 JETSTAR 731	ALL SERIES	5095
LJ23	100%	LJ23	LEARJET 23	ALL SERIES	
LJ24	100%	LJ24	LEARJET 24	NO SERIES , A, B, C, D, E, F	
LJ25	100%	LJ25	LEARJET 25	NO SERIES , A, B, C, D, F	
LJ31NG	100%	LJ31	LEARJET31	ALL SERIES	27
LJ55NG	100%	LJ55	LEARJET55		142

Monitoring Classification	Target	A/C ICAO	A/C Type	A/C Series	Serial #***
MU30	100%	MU30	MU-300 DIAMOND	ALL SERIES	
SBR1-40	100%	SBR1	NA-265 SABRELINER 40	ALL SERIES	
SBR1-60	100%	SBR1	NA-265 SABRELINER 60	ALL SERIES	
SBR1-65	100%	SBR1	NA-265 SABRELINER 65	ALL SERIES	11, 30, 32, 48, 58, 72, 74, 76,465, 8
SBR2	100%	SBR2	NA-265 SABRELINER 80	ALL SERIES	
T334	100%	T334	TU-334	ALL SERIES	
WW24ND	100%	WW24	1124 WESTWIND	ALL SERIES	270 352

*** Aircraft serial numbers excluded from the group classification and put into the non-group classification for the same manufacturer/type/series.

A.4.4. Achievement of Monitoring Targets

Operator Classification Targets

At the time of this report there was a total of 2,801[16] operator/monitoring classification combinations to consider for monitoring targets. Of these, the monitoring target requirements for;

2,048 Operator/monitoring classification combinations have been fully satisfied,

126 Operator/monitoring classification combinations have not been fully satisfied but have some aircraft monitored,

737 Operator/monitoring classification combinations have not been satisfied because no monitoring data was available.

It should be noted that the combinations with no data are mostly comprised (64 %) of operators with no aircraft monitored.

Ninety Percent of Flights Made by Operator that met their Monitoring Target

A sample of flight plan data for the Core European RVSM airspace between 1st December 2003 and 31st May 2004 comprising 2,067,625 flights, from operators with at least one RVSM approved aircraft, was matched against each operator/monitoring classification to assess if at least 90% of the flights are made by a combination that fully satisfied its monitoring targets.

Results are summarized in Table A- 4. This table shows that at least 94% of the flights were made by operator/monitoring classification combinations that meet the current monitoring targets, consequently, meeting the 90%-requirement. However, more than 4% of flights remain still unmatched as a consequence of the differences between both sources of data: area of coverage (ECAC vs HMU coverage area), data management in the case of

[16] This is a subset of the overall possible operator/monitoring classification combinations (3,193) where at least the operator has 1 aircraft approved to fly on RVSM.

code sharing companies or aircraft type similar to others within the same group. Therefore the final figure might increase up to almost 98%.

Table A- 4: Summary of matched flights against each operator/monitoring classification.

	Flights made by operator/monitoring classification combinations that:	**Met current monitoring targets**	**Did not meet monitoring targets**	**Could not be matched to an operator/monitoring combination**	Total
Flights matched from ICAO code operators	**Using operator ICAO code and aircraft type**	1,181,510	35,108	63,778	2,038,594
	Using aircraft type and full registration number[18]	17,837	4,609	12,508	
	Manually using operator codes	723,065	178		
Flights matched from IGA[20] ops.	**Using aircraft type and full registration number[18].**	23,406	4,448	1,053	28,907
	Flights from unknown aircraft code			124	124
	Total	1,945,818	44,344	77,463	2,067,625
	Percentage	94.11%	2.14 %	3.75%	

NOTE: 17,854 flights (0.85 %) made by ICAO aircraft codes couldn't be matched with the monitoring classification list provided in table A-3. Should this number of flights taken into account in the total, then the percentage of flights made by operator/monitoring classification combinations that met the monitoring targets would be 92.69%.

[18] As recorded in the flight plan Call Sign
[20] International General Aviation
[22] A definition of TVE can be found in section 3 of the main body of the text, figure 3–6.

A.5. Verification of the Aircraft Height Keeping Performance Requirements

The Global System Performance Specification defines the height-keeping performance necessary to meet the system safety goal. Compliance with the requirements of these specifications provides high confidence that the TLS of the guidance material is being met.

A.5.1. Performance Against Global Height-Keeping Requirements

Section 2.3.1 of ICAO document 9574 (2nd Edition)**[2]**, states that the aggregate of Total Vertical Error (TVE)[22] performance in the airspace simultaneously satisfies the following four requirements, constituting the Global Height-Keeping Performance Specification:

(a) the proportion of TVE beyond 90 m (300 ft) in magnitude must be less than 2.0×10^{-3};

(b) the proportion of TVE beyond 150 m (500 ft) in magnitude must be less than 3.5×10^{-6};

(c) the proportion of TVE beyond 200 m (650 ft) in magnitude must be less than 1.6×10^{-7}; and

(d) the proportion of TVE between 290 and 320 m (950 ft and 1050 ft) in magnitude must be less than 1.7×10^{-8}.

A TVE distribution was constructed based on a convolution of the fitted ASE and core AAD distributions. Predicted proportions of TVE with a magnitude as specified in requirements (a) to (d) were calculated based on this distribution. Results based on the current data set are presented in the following table:

Table A- 5: Predicted TVE Proportions

Magnitude of TVE (feet)	Requirement	Predicted Proportion	Meets Requirement
> 300	2.0×10^{-3}	5.36×10^{-3}	√
> 500	3.5×10^{-6}	5.83×10^{-6}	NO
> 650	1.6×10^{-7}	3.67×10^{-7}	NO
>= 950 & <= 1050	1.7×10^{-8}	2.83×10^{-9}	√

Table A-5 shows that the current TVE distribution meets two out of the four requirements of the Global Height-Keeping Performance Specification.

The Global Height-Keeping Performance Specification provides an alternative way of estimating $P_z(1000)$ on the basis of observed proportions of TVE without using an explicit analytical model for the probability distribution of TVE. The core of the Global Height-Keeping Performance Specification is requirement (d). This is based on the fact that, for very many probability distributions, the probability of vertical overlap $P_z(1000)$ can be approximated by a certain factor times the probability density of TVE at TVE = 1000ft.

Because the observed proportion of TVE between 950 ft and 1050 ft will be extremely small, it is difficult to accurately estimate the true proportion of such TVE. Therefore, requirement (d) has been supplemented with the requirements (a) to (c) inclusive which concern proportions of TVE that are easier to estimate due to their larger values.

However, these proportions are less directly related to the value of $P_z(1000)$. In fact, requirements (a) to (c) have been derived on the basis of a specific type of analytical probability distribution and ranges of parameter values. Although the range of distributions considered at the time was fairly broad, it does not necessarily cover each and every probability distribution that might occur in practice.

In the case of European RVSM, the extensive set of height monitoring data has allowed the development of an explicit model for the TVE probability distribution by means of the components approach and this model has been used to directly estimate $P_z(1000)$. This model has also been used to calculate the predicted proportions of TVE in Table A.5. The fact that the predicted proportion of TVE larger than 650 ft in magnitude exceeds the value of 1.6×10^{-7} shouldn't be considered a negative indication. The actual probability distribution of TVE looks like a Gaussian Double Exponential, which differs (slightly) from the range of distributions underlying the derivation of the requirements (a) to (c) of the Global Height-Keeping Performance Specification.

A.5.2. Performance Requirements for TVE Components

The following requirements describe the performance that aircraft types 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. They were the basis for development of the MASPS against which aircraft are to be approved.

i. The mean altimetry system error (ASE) of the group shall not exceed ±25 m (±80 ft).

ii. The sum of the absolute value of the mean ASE for the group and three standard deviations of ASE within the group shall not exceed 75 m (245 ft).

iii. Errors in altitude keeping shall be symmetric about a mean of 0 m (0 ft), shall have a standard deviation not greater than 13 m (43 ft) and be such that the error frequency decreases with increasing error magnitude at a rate which is at least exponential.

It is important to recognise that (i) and (ii) form the ICAO group requirements and then are applicable to monitoring classifications that are considered group[24] aircraft (i.e. presented in Table A- 2). Therefore, the following sections will only assess the performances of group classifications against the group

[24] Refer to JAA TGL No. 6 Para. 9.3.1 for a definition of group and non-group aircraft.

requirements and the derived conclusions will then be only applicable to these groups.

Nevertheless, it is important to note that in the collision risk assessment (Section 3) no distinction is made between group and non-group classifications.

Requirement (iii) sets performance limits on the errors in altitude keeping exclusive of human factors. This is interpreted to mean “allowable” altitude deviations as represented by the height monitoring data when the absolute value is less than 350 ft. Larger deviations are assumed to be due to human factors and are included in the risk assessment in section 3 of the main body of this report.

Figure 3–7 at the end of section 3 of the main body of this report, shows a one minus cumulative curve based on empirical AAD data rounded to the nearest 100 and a double exponential distribution with a standard deviation of 39.80 ft and a mean of 0.035ft. So the current data shows that the requirement for (iii) is being met on the standard deviation and the mean, as it is very close to 0.

A.5.3. ASE by Aircraft Monitoring Classification

The mean and standard deviation of each monitoring classification (for group aircraft) was calculated and a comparison was made against requirements (i) and (ii) listed in the above section. Table A- 6 shows the resulting means and standard deviations and the following paragraphs summarise the observed performance against the requirements. It should be noted that for a number of these aircraft the available data was limited to only a few measurements.

Aircraft Monitoring Classifications Meeting the Group Requirements

The following monitoring classifications 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 classification is meeting the ICAO Group performance requirements;

A300, A310-GE, A310-PW, A318, A320, A330, A340, A345, A346, A3ST, AN72, ASTR-1, ASTR-SPX, AVRO, B701, B703, B712, B727, B732, B737CL, B737NX, B744-10, B744-5, B747CL, B74S, B752, B753, B764, B767, B772, B773, BE20, BE40, BE40-BEECH, C500, C525, C525-II, C550-B, C550-II, C550-SII, C560, C56X, C650, C750, CARJ, CL600, CL604, CRJ-700, DC10, DC86-7, DC86-7NG, DC93, DC95, E135-145, F100, F2TH, F900, FA10, FA20, FA50, GALX, GLEX, GLF2B, GLF3, GLF4, GLF5, H25B-700, H25B-800, H25B-800NG, IL62, IL76, IL86, IL96, J328, L101, LJ31, LJ35/6, LJ45, LJ55, LJ60, MD11, MD80, MD90, P180, PRM1, T134,T154 and YK42

Aircraft Monitoring Classifications Not Meeting the Group Requirements

The aircraft monitoring classifications that currently are not meeting the group capability requirements according to current data are;

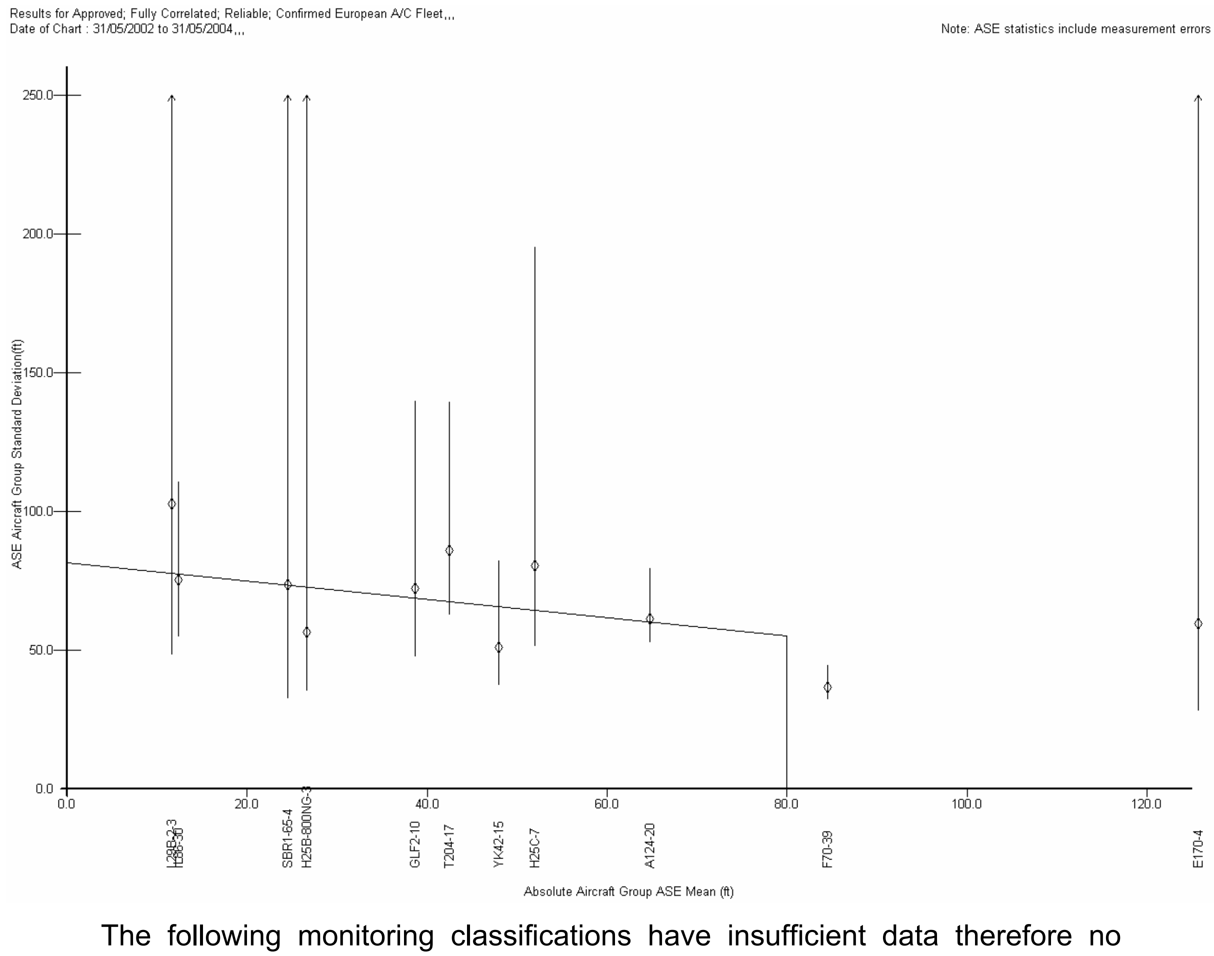
Requirement (i):E170 and F70

Requirement (ii): A124, E170, GLF2, H25C, L29B-2, SBR1-65 (≈ 245ft) and T204.

Figure A- 1 shows a graphical representation of these classifications against the ICAO group requirement (data is presented in order from left to right as it appears above). The diamonds represent the point estimates of the standard deviation of the overall ASE for the classification plotted against the overall |mean| (refer to Table A- 6 for exact values). The lines represent the 95% confidence intervals for the standard deviation.

Examination of individual measures shows that the measurements of only two classifications (F70, E170) are demonstrating Altimetry System Errors outside of the limits. Whilst in most cases the individual measurements show compliance with the requirements, the ensemble of these nominally identical (in most cases) aircraft results in some aircraft classifications not meeting requirements (i) and/or (ii). Actions taken against the aircraft classifications that are listed as not meeting the ICAO Group requirements are discussed in paragraph A.7.

Figure A- 1: Aircraft Classifications Not Meeting the ICAO Group Requirements



The following monitoring classifications have insufficient data therefore no conclusions can be made as to whether or not they are successful in meeting the specified capability requirements;

A225, CL600-1, D328, DC85, DC91, FA10NG, GLF2B-G and H25CNG.

The continued operation of some of these aircraft types in the RVSM Airspace is under investigation.

Table A- 6: ASE Parameters by Monitoring Classification for Group Aircraft

Monitoring classification	Group ASE mean[25]	Overall ASE standard deviation[26]	|Mean|+3*Stdev	#Mon_AC	#Measures
A124	64.8	61.2	248.4	20	770
A225	-3.5	58.9	180.2	1	20
A300	8.8	52.7	166.9	119	22,854
A310-GE	-58	48	202	77	15,642
A310-PW	14.5	46.3	153.4	40	5,010
A318	46.6	26.1	124.9	6	1,099
A320	37.5	44.3	170.4	867	305,918
A330	47.1	38.9	163.8	157	25,708
A340	-5.3	47.1	146.6	162	29,948
A345	-13.8	27	94.8	5	337
A346	21.9	30.2	112.5	23	236
A3ST	36.7	38.5	152.2	5	606
AN72	10.7	39.4	128.9	4	8
ASTR-1	35.9	42.6	163.7	3	74
ASTR-SPX	57.5	50.9	210.2	11	456
AVRO	29.7	50.2	180.3	83	17,864
B701	53	57.3	224.9	4	19
B703	22.7	62.1	209	5	157
B712	37.5	40.5	159	7	2,327
B727	55.7	58.7	231.8	43	708
B732	-2.7	38.5	118.2	44	9,156
B737CL	-40.1	46.4	179.3	607	211,677
B737NX	11.5	43.5	142	497	207,197
B744-10	-55.5	40.3	176.4	345	35,530
B744-5	-60.9	51.1	214.2	120	10,920
B747CL	-39	59.6	217.8	224	20,202

[25] The group mean is the mean of the individual aircraft means within the monitoring classification.

[26] The overall ASE standard deviation is a combination of the within airframe and between aircraft standard deviation. When no within aircraft standard deviation was available for a particular airframe then a default value of 59.4 was used.

Monitoring classification	Group ASE mean[25]	Overall ASE standard deviation[26]	|Mean|+3*Stdev	#Mon_AC	#Measures
B74S	-28.8	65.1	224.1	19	1,643
B752	-7	41.6	131.8	259	60,976
B753	6.8	35.9	114.5	22	10,283
B764	-13.2	40.8	135.6	11	193
B767	-60.9	46.1	199.2	405	44,417
B772	28	36.5	137.5	268	26,034
B773	12.3	18.8	68.7	12	6,131
BE20	27.7	35	132.7	2	12
BE40	-5.7	51.9	161.4	15	348
BE40-BEECH	-34.7	37.2	146.3	3	135
C500	-9.9	52.3	166.8	10	27
C525	17.4	42.9	146.1	76	1,180
C525-II	9.6	45.7	146.7	22	480
C550-B	43.7	43.6	174.5	48	2,619
C550-II	-0.7	43.2	130.3	23	530
C550-SII	-54.2	33.5	154.7	4	52
C560	36.3	54.3	199.2	40	1,185
C56X	-20.1	37.2	131.7	58	3,049
C650	13.4	51	166.4	22	1,171
C750	-5.8	60.2	186.4	44	510
CARJ	-23.1	49.3	171	163	66,141
CL600	-4.7	54.4	167.9	123	1,351
CL600-1	-3.5	58.9	180.2	1	27
CL604	-1.3	45.9	139	118	2,783
CRJ-700	3.9	48.4	149.1	35	18,446
D328	-3.5	58.9	180.2	1	5
DC10	-10.8	59.4	189	83	3,974
DC85	-3.5	58.9	180.2	1	11
DC86-7	-39	56.6	208.8	6	323
DC86-7NG	-0.6	72.5	218.1	9	1,203
DC91	-3.5	58.9	180.2	1	7
DC93	22.4	40.9	145.1	4	127
DC95	-37.1	26.8	117.5	2	14
E135-145	-5.7	64.3	198.6	148	34,780
E170	122.8	55.3	288.7	5	5
F100	-5.6	44.2	138.2	80	8,024
F2TH	-59.1	57.1	230.4	94	4,091
F70	-84.5	36.5	194	39	18,651
F900	21.8	59.8	201.2	192	4,383

Monitoring classification	Group ASE mean[25]	Overall ASE standard deviation[26]	|Mean|+3*Stdev	#Mon_AC	#Measures
FA10	15.3	50.9	168	13	366
FA10NG	-3.5	58.9	180.2	1	5
FA20	-14.5	49.7	163.6	21	1,011
FA50	50.5	62.7	238.6	109	3,136
GALX	2.1	54	164.1	22	322
GLEX	26.6	57.9	200.3	44	443
GLF2	38.6	72.4	255.8	10	60
GLF2B	14.5	60.2	195.1	4	17
GLF2B-G	-3.5	58.9	180.2	1	1
GLF3	-40.6	53.9	202.3	45	378
GLF4	-25.6	51.3	179.5	284	2,370
GLF5	-2.9	57.3	174.8	102	860
H25B-700	3	65.1	198.3	8	72
H25B-800	23.2	63.4	213.4	97	4,199
H25B-800NG	26.6	56.5	196.1	3	56
H25C	52	80.3	292.9	7	152
H25CNG	-3.5	58.9	180.2	1	297
IL62	55.9	50	205.9	16	162
IL76	55	61.4	239.2	25	470
IL86	12.4	75.2	238	30	64
IL96	62.5	57.3	234.4	10	243
J328	40.7	43.2	170.3	10	801
L101	5.4	70.6	217.2	28	1,355
L29B-2	11.6	102.7	319.7	3	32
LJ31	6.4	38.9	123.1	15	827
LJ35/6	74.3	43.6	205.1	22	568
LJ45	39.6	38	153.6	30	1,330
LJ55	33.9	61.6	218.7	8	222
LJ60	27.1	49.8	176.5	44	1,825
MD11	-10.1	53.8	171.5	160	12,475
MD80	1.4	38.8	117.8	295	71,847
MD90	37.5	42.1	163.8	27	213
P180	53.2	50.2	203.8	13	154
PRM1	-19.3	28.8	105.7	7	159
SBR1-65	-24.5	73.6	245.3	4	9
T134	12.4	46.7	152.5	17	31
T154	-0.9	48.8	147.3	135	4,672
T204	-42.5	86	300.5	17	939
YK42	48	51	201	15	216

A.6. ASE Stability

An important assumption underlying the MASPS concerns stability of ASE over time. Consequently, one of the objectives of the height monitoring programme is to provide supporting evidence for this assumption.

The various studies to date have indicated that many aircraft show some change in mean ASE over time, where both continuous drift and stepwise changes have been observed.

Work carried out by the NAT OPERATIONS/AIRWORTHINESS (OPS/AIR) SUB-GROUP into Altimetry System Error Stability, has concluded that Altimeter System Error can drift. The probable cause has been determined to be the drift characteristics of the pressure sensors. Investigations are to commence with the OEM's to review the data packages with particular reference to the error budget for the Air Data Computers and continued airworthiness.

Based on these findings, activities are continuing on identifying the factors affecting ASE stability, analysing the effect of ASE instability on the safety of RVSM and development of the appropriate modelling of ASE over time.

A.7. Overall Performance

As a result of the data collected for this report, a number of aircraft monitoring groups have been identified and continue to be identified as not complying with the group performance requirements as defined ICAO Doc 9574. As in the previous phases, manufacturers, Supplementary Type Certificate (STC) holders and the original Type Certificate Airworthiness Authorities have been contacted for these aircraft types and a number of actions have been undertaken to correct the performance. The following is a summary of these actions listed by aircraft monitoring classification:

a) **A124:** Following the issue of a letter from the European and North Atlantic Office of ICAO the Ukrainian Authorities (UKRAVIATRANS) have advised that a single aircraft was subjected to additional inspections. No information on the outcome of this inspection has been received. Further communications through the European and North Atlantic Office of ICAO has been initiated..

b) **E170**: EMBRAER have been advised of the demonstrated performance and are currently reviewing the data.

c) **F70:** The F70 group is continuing to show non-compliance with group requirements. Fokker Services have been informed and are currently assessing the results and are reviewing a possible change to the maintenance procedures to control skin/paint irregularities.

d) **GLF2:** After notification of the excess in performance and review by

Gulfstream, a number of aircraft were incorrectly attributed to the GLF2 group. These aircraft have been reassigned to the correct monitoring group and the additional aircraft are being reviewed by Gulfstream to ensure they have been modified correctly in accordance with the Gulfstream Service Bulletin.

e) **H25C:** Discussions between the FAA and Raytheon have resulted in the issue of service letter to remind H25C operators of the operating restriction in place on these aircraft when operating in RVSM airspace.

f) **L29B-2:** The STC Holder for the modification applicable to this group has been contacted. They have reviewed the data and are considering re-certifying each aircraft as a non-group aircraft due to the low numbers in the group.

g) **T204** A letter has been sent to the Russian Authorities, Tupolev Design Bureau and the manufacturing plant, advising them that the demonstrated performance exceed the ICAO group requirements. To date no response has been received.

A.8. Individual Aircraft Performance

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 270 ft (245 ft plus 25 ft allowance for measurement system error), since 31st May 2003. The information is summarised in the following table.

Table A- 7: Aircraft with Larger ASE Values.

Groups	#AC	ASE values
A300	1	-394.9
B737CL	1	-616
B744-5	3	-275.7; -278.2 ; -299.7
B747CL	4	-337.1; -273.1; -280.4; -275.3
B767	4	-277.7; -289.3; -292.1; -277.7
F900	2	-316.3; -304.4
FA10NG	1	-290.6
FA50	1	-281.2
L101	1	288
T154	5	288.8; 281.5; 276; 357.2; 341.8

A summary of the actions taken to date for each aircraft is given below by aircraft type.

a) ***A300 – AIRBUS A300-B4, ASE -394.9ft.*** After notification from the User Support Cell, an Air Data System and ATC System functional check was conducted, plus an inspection in accordance with that Service Bulletin requirement was carried out. No fault was found. However during the flight the crew reported that the autopilot was attempting to fly the aircraft 300ft from the clear flight level. Disengaging and reengaging the autopilot cleared the problem, no fault was found with the autopilot

b) ***B737CL – BOEING 737-300, ASE –616ft***. After notification from the User Support Cell, a system test of the ADC and visual inspection and leak check of the Pitot/Static system was carried out. No fault was found with the aircraft systems.

c) ***B747CL – BOEING 747-200, ASE -337.1ft, -273.1ft, -280.4ft, 275.3ft***. The operator of this aircraft was contacted by the User Support Cell. The aircraft under went a maintenance inspection Air Data and ATC transponder systems. No fault was found and the aircraft was returned to service.

d) ***B744-5 – BOEING 747-400, ASE -257.7ft, -278.2ft, -299.7ft.*** After notification from the User Support Cell, examination of the monitoring data showed that ADC no 2 was at fault. ADC no 2 was changed and the aircraft returned to service.

e) ***B767 – BOEING 767, ASE -277.6ft, -292.1ft, -289.ft -277.7ft***. After notification from the User Support Cell. The aircraft under went a maintenance inspection. No details of the faults found were reported.

f) ***FA10NG – FALCON 10, ASE -290.6ft***. After notification from the User Support Cell, the aircraft under went maintenance checks of the Air Data System in accordance with the STC inspection requirements. A leak in the Pitot and Static system was reported.

g) ***FA50 – FALCON 50, ASE -281.2ft.*** The User Support Cell has notified to the operator the current situation. No response has been received up to date, however subsequent measurements show the aircraft to be in compliance.

h) ***F900 – FALCON 900, ASE -316.3ft, -304.4ft***. After notification from the User Support Cell, the aircraft under went maintenance checks of the Air Data System and a skin inspection. A leak in the static system was discovered, plus the placards at the static ports were positioned incorrectly in front of the static ports. It should be noted that the static ports and placards were replaced during the preceding C-check and re-painted.

i) ***L101 – LOCKHEED L-1011, ASE +288ft***. Following investigations into a large altimeter split, at the same time as the aircraft was monitored, it as concluded that the static pressure system was at fault. The pitot probes were replaced and the system flushed, drained and leak check. Aircraft was returned to service.

j) ***T154 – TUPOLEV 154, ASE +341.8ft, +357.2ft, +276ft, +281.5ft, +288.8ft***. After notification from the User Support Cell, the aircraft under went a maintenance check. The captains “additional” altimeter was found to have a leak and was replaced. It should be noted that this leak could only be determined during a workshop inspection and not on the aircraft.

A.9. Conclusions

According to results, it is expected that most monitoring classifications show compliance with technical height keeping requirements.

The airspace monitoring and evaluation activities carried out for the elaboration of this report ensures that problems have been identified and follow-up actions will be taken in solving potential safety issues.

A.10. Recommendations

The User Support Cell regularly reviews both the individual and overall technical height keeping performance of aircraft and undertakes the corresponding actions. These actions help to ensure that the issues raised to date are remedied. However, it is necessary to continue this review and follow-up process to ensure that all aircraft continue to perform according to the specifications (TGL6).

APPENDIX B - ABBREVIATIONS

AAD	Assigned Altitude Deviation
ACAS	Airborne Collision Avoidance System
ACC	Area Control Centre
AD	Altitude Deviation
ADR	Altitude Deviation Report
AIC	Aeronautical Information Circular
ASE	Altimetry System Error
ATC	Air Traffic Control
ATM	Air Traffic Management
ATS	Air Traffic Service
CAA	Civil Aviation Authority
CFMU	Central Flow Management Unit
CFL	Cleared Flight Level
CRA	Collision Risk Assessment
CRM	Collision Risk Model
CVSM	Conventional Vertical Separation Minimum (2000ft at and above FL 290)
DE	Double Exponential density
DGCA	Director General Civil Aviation
EANPG	European Air Navigation Planning Group
EATMP	European Air Traffic Management Programme.
ECAC	European Civil Aviation Conference
EEC	EUROCONTROL Experimental Centre (Bretigny)
EUR	European Region (of ICAO)
FC	Flight Crew
FHA	Functional Hazard Assessment
FIR	Flight Information Region
FL	Flight Level
FLAS	Flight Level Allocation Scheme
FLOS	Flight Level Orientation Scheme
FPL	Flight Plan
FTE	Flight Technical Error
GAT	General Air Traffic
GDE	Gaussian Double Exponential
GMU	GPS Height Monitoring Unit
GPS	Global Positioning System
HCPA	Horizontal Closest Point of Approach.
HMU	Height Monitoring Unit
IFPS	Integrated Initial Flight Plan
ICAO	International Civil Aviation Organisation

JAA	Joint Aviation Authorities
LoA	Letter of Agreement
MASPS	Minimum Aircraft System Performance Specification
MTCD	Medium Term Conflict Detection
NAT	North Atlantic Region (of ICAO)
OAT	Operational Air Traffic
OLDI	On-line Data Interchange
PC	Provisional Council
PISC	Pre-implementation Safety Case
PSSA	Preliminary System Safety Assessment
RGCSP	Review of the General Concept of Separation Panel (of ICAO)
RMA	Regional Monitoring Agency
RVSM	Reduced Vertical Separation Minimum
SMR	Safety Monitoring Report
SRC	Safety Regulation Commission
STCA	Short Term Conflict Alert
TCAS	Traffic Alert and Collision Avoidance System
TLS	Target Level of Safety
TVE	Total Vertical Error
UAC	Upper Area Control Centre
UIR	Upper Flight Information Region
USC	EUROCONTROL User Support Cell
VSM	Vertical Separation Minimum

APPENDIX C - DEFINITIONS/EXPLANATIONS OF TERMS.

Note: The following definitions are taken from ICAO Document 9574 (2^{nd} Edition) - Manual on Implementation of a 300m (1000 ft) 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 λz 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.

Tolerably safe

This concept is derived from the ALARP (As-Low-As-Reasonably-Practicable) approach. This methodology classifies the risk as being in one of the three categories: intolerable, tolerable if ALARP and negligible.

If a system's risk falls into the tolerable category then it must be proven to be as low as reasonably practicable within that region for the system to be considered acceptable. In other words, tolerable risk is the willingness to live with a risk so as to secure certain benefits and in the confidence that it is being properly controlled.

In the ALARP approach the boundary lines between the risk categories need to be specified for the system to which they are being applied. In line with that approach and according to the RGCSP recommendations, the TLS value of $5x10^{-9}$ fatal accidents per flight hour, due to any cause, was considered the boundary line for tolerably safe in RVSM. Therefore, the risk assessment process for determining that the operation of RVSM is acceptably (or tolerably) safe in based on that TLS value.

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.

APPENDIX D - REFERENCES

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