EUROPEAN ORGANISATION FOR THE SAFETY OF AIR NAVIGATION

EUROCONTROL

THE EUR RVSM PRE-IMPLEMENTATION SAFETY CASE

RVSM 691

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Abstract

This document constitutes the EUROCONTROL RVSM Pre-implementation Safety Case (PISC) for the EUR RVSM Programme. The aim of this document is to show by means of argument and supporting evidence that the application of the ICAO RVSM Concept in the European Region, and the Implementation of RVSM by the Participating States, satisfy the criteria defined in the EUR RVSM Safety Policy.

The EUR RVSM Safety Policy encompasses the ICAO requirements concerning the Target Level of Safety for the vertical collision risk and is compliant with the requirements of the EATMP Safety Policy and with the Safety Objectives of the ATM 2000+ Strategy.

Version 1.0 of the document was submitted to the Safety Regulation Commission (SRC) for evaluation in order to give advice to the Provisional Council (PC) and to the European Air Navigation Planning Group (EANPG) on the safe implementation of RVSM. Version 2.0 contains, *inter alia*, modifications in response to the comments reveiced after the review by the SRC and updates related to the height monitoring, the Collision Risk Assessment and State preparedness.

Keywords

RVSM	Safety	Functional Hazard Assessment
Implementation	National Safety Plans	Separation
Collision Risk Assessment	Target Level of Safety (TLS)	Safety Case

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The following table records the complete history of the successive editions of the present document.

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0.2	26 Jan 2001	Working Draft for initial SRC Review	All
0.3	16 Mar 2001	Working Draft for internal DSA Review following further developments and first Independent Review	All
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2.0	14 Aug 2001	Proposed second Issue ➢ Modifications in response to SRC comments (for details see letter RVSM/WP3.3/A834) ➢ Updates of results concerning height monitoring, Collision Risk Assessment and State preparedness	All

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EXECUTIVE SUMMARY

All ICAO Member States agreed on the feasibility of the Implementation of RVSM, on a global basis following exhaustive studies undertaken by the ICAO Review of the General Concept of Separation Panel in the late 1980s (RGCSP/6) **[5]**. The primary justification for the implementation of RVSM in the European airspace is the requirement to provide additional airspace system capacity to meet the ever-rising number of aircraft movements.

During the five years, 1995 to 2000, improvements introduced by the EUROCONTROL European ATC Harmonisation and Integration Programme (EATCHIP) contributed to containing the duration, and frequency of occurrence, of ATC delays despite a yearly traffic increase of between 4% and 6%. However traffic forecasts have indicated that the number of movements will continue to rise, and will more than double by the year 2015 compared to the 1998 figures. It is accepted that major changes to the ATM systems will be necessary in order to cope with this continued traffic growth. Of the various measures under consideration, the implementation of RVSM is considered to be the most cost effective means in the short term of meeting this need through the provision of six additional flight levels for use in the highly congested airspace from FL 290 to FL 410 inclusive.

As required in other regions EUR RVSM has to demonstrate to the international aviation community that the Target Level of Safety (TLS) set out by ICAO **[2]** for the vertical collision risk will not be exceeded in the European RVSM Airspace.

However, during the initiation of the EUR RVSM Programme, it was felt, that to demonstrate the achievement of this criterion would be viewed as being necessary but not sufficient for the EUR RVSM airspace. At that stage the decision was taken to develop the EUR RVSM Safety Policy **[1]** in co-ordination with the EUROCONTROL Safety Regulation Commission in order to establish the basis for the safety assurance of the RVSM Concept and its Implementation in the EUR RVSM Airspace.

The three main deliverables of the RVSM Safety activities are (i) the Functional Hazard Assessment (FHA), (ii) the Collision Risk Assessment (CRA) and (iii) the National Safety Plans. These three deliverables form the major input to the development of the EUR RVSM Pre-Implementation Safety Case (PISC). In addition, the PISC contains those elements of the EUR RVSM Programme to be taken into account when addressing the safe introduction of RVSM in EUR RVSM airspace.

The PISC sets out the safety requirements broken down to the level of system elements. It establishes all the arguments and evidence necessary to demonstrate that the ICAO RVSM Concept as applied to the EUR RVSM Airspace, and the Implementation of RVSM by the participating States, will be tolerably safe when assessed against the requirements of the EUR RVSM Safety Policy **[1]**.

The PISC demonstrates that this aim has been achieved, by means of the following principal safety arguments:

(i) That a set of Safety Requirements has been specified for RVSM that fully address all the functionality, performance and integrity requirements necessary to ensure that the safety risks under RVSM will be tolerable.

(ii) That the RVSM Concept developed by EUROCONTROL for the European region has the potential to satisfy fully the RVSM Safety Requirements.

(iii) That the Implementation of the RVSM Concept by the individual participating States will fully satisfy the RVSM Safety Requirements.

(iv) That the Switch-Over from the current vertical separation minima of 2000 ft (600 m) to the RVSM value of 1000 ft (300 m) will not adversely affect the safety of the on-going air traffic operations.

Each of the above arguments is developed in the relevant section of the PISC, evidence is shown that all the arguments are valid and detailed conclusions are drawn, which can be summarised as follows:

(i) A sufficient set of safety requirements have been specified for EUR RVSM, including those generated by the Functional Hazard Assessments (FHA), and have been allocated to the respective RVSM system elements. Identified hazards are sufficiently controlled and/or mitigated except in two instances (i) Nuisance Alerts from ACAS/TCAS Version 6.04a and (ii) Level Busts. These issues are given particular attention in this document and are addressed at **5.12.2** and **5.12.1** respectively. The qualitative methodolology of the EUROCONTROL FHA process, in which the Risk Classification Scheme is based on operational assessments of the severity and probability of occurrence of identified hazards, does not provide the means for a direct comparison of the output of the FHA with the quantitative approach of the ICAO TLS. The qualitative argument of the FHA shows that the overall number of hazards/risks per severity class is acceptable. However, except for two hazards which relate to Aircraft Equipment (System Elements AC1 and AC2) and are bounded by the Technical TLS (2.5 x 10^{-9} fatal accidents per flight hour.); the consequences of all of the hazards identified by the FHA will be evidenced as Operational Errors and should be the subject of the ongoing study of Altitude Deviation Reports (Appendix M). As such they will be analysed and the quantified risk will be set against the total TLS of 5 x 10^{-9} fatal accidents per flight hour.

(ii) The RVSM Concept satisfies the safety requirements for each RVSM system element. It is argued why the two hazards referred to above are considered to be tolerable and the results of the monitoring and collision risk modelling programme are demonstrated. The technical TLS is met, however, the global system performance specification requirement related to the probability of vertical overlap is currently not met. This is due to a small number of aircraft types, which are currently not performing in line with the MASPS. Since this is a pre-requisite for sufficient confidence in the calculated technical vertical risk, action has been taken with the aim to meet those targets by 31 August 2001. The validation of the Safety Objective concerning the overall risk of an accident or serious risk-bearing incident will additionally be assessed through the post-implementation monitoring programme.

(iii) States within the RVSM programme are making steady progress towards safe Implementation. Eurocontrol has asked for a confirmation of State readiness from the DGCAs of all participating States concerning the safe implementation of RVSM; and implicitly the realisation of the commitments contained within the National Safety Plans. To date 33 DGCAs have replied confirming the readiness of their State. The RVSM Programme has obtained 37 RVSM National Safety Plans.

(iv) The identification, and implementation of measures to control and/or mitigate, hazards and risks associated with Switchover were identified through the Functional Hazard Assessment. The mitigating factors were identified and incorporated into a RVSM Countdown and Switchover Plan produced by EUROCONTROL.

Based on the conclusions drawn in each of the above arguments and subject to the conditions mentioned, the application of the ICAO RVSM Concept in the European Region, and the Implementation of RVSM by the participating States can be considered as tolerably safe and satisfying the criteria defined in the EUR RVSM Safety Policy **[1]**.

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1 INTRODUCTION

1.1 Background

Reduced Vertical Separation Minima (RVSM) is due to be introduced into European airspace in January 2002. This will reduce 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 40 States that are participating in the EUR RVSM Programme are listed in **Table 1**.

Albania	Austria	Belgium	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: States participating in RVSM

The key dates for the introduction of RVSM are given in **Table 2**.

Major Activity	Completion Month
Provisional Council approval of Master Plan	April 1999 - Completed
Start of Height Monitoring Programme	25 May 2000 - Commenced
Monitoring Infrastructure Fully Operational	November 2000 - Completed
Aircraft Prepared for EUR RVSM	31 December 2000 – On-going
Operators and their Aircraft Approved for RVSM Ops	31 March 2001 – On-going
Pre-Implementation Safety Assessment	May 2001
Go/Delay Decision	July 2001
Implementation Date	January 2002
Initial Post Implementation Safety Assessment	December 2002
Final Post Implementation Safety Assessment	December 2004

Table 2: Key Dates for RVSM

This document constitutes the EUR RVSM Pre-Implementation Safety Case (PISC), one of the main deliverables of the EUR RVSM Programme.

Version 1.0 was submitted to the Safety Regulation Commission (SRC) for evaluation in order to give advice to the Provisional Council (PC) and to the ICAO European Air Navigation Planning Group (EANPG) on the safe implementation of RVSM.

This second edition contains the changes made in response to the comments received from the SRC on the first edition. It provides the remaining information required to fulfil the conditions set for the Verification Committee (VC) – (see Appendix O for Terms of Reference of VC). In particular the results concerning height monitoring, Collision Risk Assessment and State preparedness have been revised.

1.2 Aim

The aim of this document is to show by means of argument and supporting evidence that the application of the ICAO RVSM Concept in the European Region, and the Implementation of RVSM by the participating States, satisfy the criteria defined in the EUR RVSM Safety Policy **[1].**

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

1.3 Scope

As required in other regions EUR RVSM has to demonstrate to the international aviation community that the Target Level of Safety (TLS) set out by ICAO **[2]** for the vertical collision risk will not be exceeded in the European RVSM Airspace.

However, it was felt – during the initiation of the EUR RVSM Programme – that to demonstrate the achievement of this criterion would be viewed as being necessary but not sufficient for the EUR RVSM airspace. At that stage the decision was taken to develop the EUR RVSM Safety Policy **[1]** in co-ordination with the EUROCONTROL Safety Regulation Commission in order to establish the basis for the approval process of the RVSM Concept and its Implementation in the EUR RVSM Airspace.

Therefore, the scope of the present EUR RVSM Pre-Implementation Safety Case (PISC) is defined by the requirements of the EUR RVSM Safety Policy Document (Edition 1.0) **[1],** sub-paragraph 6.4, which goes beyond the demonstration of meeting the ICAO TLS for the vertical collision risk:

*"The EUR RVSM Pre-Implementation Safety Case (PISC) shall provide the assurance that the objectives stated in the EUR RVSM Safety Policy Document are met. Evidence shall be provided that (i) all identified hazards and risks are managed and mitigated, (ii) the collision risk meets the ICAO Target Level of Safety and (iii) States show they will safely implement RVSM through the development of national safety documentation"***[1]**.

Consequently, the three main deliverables of the RVSM Safety activities were (i) the Functional Hazard Assessment, (ii) the Collision Risk Assessment and (iii) the National Safety Plans. These three deliverables form the major input to the development of the EUR RVSM PISC. In addition, the PISC contains those elements of the EUR RVSM Programme that are considered relevant and should be taken into account when addressing the safe introduction of RVSM in EUR RVSM airspace.

The PISC sets out the safety requirements broken down to the level of system elements. It establishes all the arguments and evidence necessary to demonstrate that the ICAO RVSM Concept as applied to the EUR RVSM Airspace, and the Implementation of RVSM by the participating States, will be tolerably safe when assessed against the requirements of the EUR RVSM Safety Policy **[1]**.

The structure of the present document is intended to explain to the reader the argument for safety of RVSM by combining an understandable, narrative approach (presented in the body of this document) with a structured and methodological approach (driven by diagrams in **Appendix A** and tables in **Appendix H**).

1.4 Structure of the Document

1.4.1 Overview

The EUR RVSM Pre-Implementation Safety Case (PISC) is constructed using a methodology known as Goal-Structuring Notation (GSN). This approach commences with the claim that the risk of collision under EUR RVSM will be tolerable safe. 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 four principal safety arguments form the four major **Sections 4-7** of the PISC. **Appendix A** gives a more detailed explanation of how the GSN Methodology was applied to RVSM. It contains the relevant diagrams, which illustrate the decomposition of the EUR RVSM Safety Argument into its different strands. Each of these individual strands finishes with references to where the relevant evidence can be found.

The application of this Methodology – ensuring the construct of a conclusive chain of arguments – is complemented by a rigorous derivation and decomposition of the individual safety requirements in **Section 4** and **Appendix H**. The EUR RVSM Safety Objectives **[1]** are expressed through seven ‘Attributes’, which are translated into nine ‘Overall RVSM Safety Requirements’. These nine ‘Overall RVSM Safety Requirements’ are allocated to different RVSM system elements and subsequently broken down into ‘Safety Requirements for System Elements’ against which the safety arguments are developed in **Sections 5** to **7**.

At this stage the relevant hazards, which were identified during the Functional Hazard Assessment **[33]**, are allocated to the ‘Safety Requirements for System Elements’ to ensure that they are appropriately addressed and their risk being managed. **Appendix H** lists the individual Safety Requirements, summarises how they are realised (based on material developed in **Sections 5** to **7**), and which actions result for EUROCONTROL and/or the individual Stakeholders participating in EUR RVSM.

1.4.2 Detailed Structure

Section 2 of this document provides important background material for the PISC relating to the RVSM Safety Policy, Safety Objectives and Safety Responsibilities.

The remainder of the document is set out in such a way as to reflect the structure of the safety argument, as follows:

Section 3 discusses the business need for RVSM and explains how the aim, set out in sub-paragraph 1.2 above, will be addressed by 4 principal arguments. Namely:

(i) That the safety requirements for vertical separation under RVSM are complete and correct;

(ii) That the safety requirements are fully realised in the EUR RVSM Concept;

(iii) That the safety requirements will be fully realised in the Implementation of the EUR RVSM Concept; and

(iv) That the ‘Switch-Over’ to RVSM will not endanger the ongoing ATS.

Sections 4 through **7** - address each of those arguments in turn by further decomposition of the arguments and the provision of evidence to show that each strand of the argument is valid.

Section 8 - provides the conclusion as to why the ICAO RVSM <u>Concept</u> as applied to the EUR RVSM Airspace, and the <u>Implementation</u> of RVSM will be tolerably safe.

Appendix A - shows the argument and evidence structure in Goal-Structuring Notation (GSN) format.

Appendix B – provides detailed supporting material concerning the ATC Simulation, which have been carried out to assess the operational impact and determine the implications and consequences of the implementation of RVSM on ATC and airspace issues.

Appendix C – contains details related to airspace design issues, such as a map of the area of applicability of EUR RVSM and Flight Level Orientation Schemes.

Appendix D – summarises the process adopted for the Functional Hazard Assessment and its major findings. A table is provided which contains descriptions of all relevant hazards. The detailed FHA Report can be found under **[33]**.

Appendix E – provides background material on the height monitoring activities of the EUR RVSM Programme.

Appendix F – presents the results of the Collision Risk Assessment, which aims at assessing the predicted levels of vertical risk that would pertain in the EUR RVSM airspace against the ICAO Target Level of Safety. The collision risk methodology used in the estimation process is detail fully in the European Mathematical Supplement **[34]**.

Appendix G – provides detailed supporting material on the development of National Safety Plans and the review of the States' safety preparedness.

Appendix H – presents the 'Overall RVSM Safety Requirements' that are allocated to different RVSM system elements and are subsequently broken down into 'Safety Requirements for System Elements'. Furthermore, the relevant hazards, which were identified during the Functional Hazard Assessment, are allocated to the 'Safety Requirements for System Elements'.

Appendix J – summarises the contents of the EUROCONTROL Air Traffic Control Training Package for the Introduction of Reduced Vertical Separation Minimum within the European RVSM Area **[36]**.

Appendix K – provides a summary of the Woodfield Report **[29]**, which assesses the potential hazard of wake vortices in the EUR RVSM airspace.

Appendix L – contains background material on ACAS/TCAS issues.

Appendix M – provides a summary of the Study on Operational Errors.

Appendix N – provides a List of Assumptions upon which the PISC and the FHA were developed.

Appendix O – provides the Terms of Reference of the Verification Committee (VC).

Evidence may be presented in one of three ways, as appropriate:

1) As text within the relevant section.

2) As an appendix to the PISC where the evidence is bulky.

3) By reference to a separate published document.

The primary purpose of evidence is to show, in a direct manner, that a particular safety argument is valid. However, where appropriate, additional (so-called **Backing**) evidence is provided in order to show that the direct evidence is trustworthy.

1.5 The Phases of the Development of the Overall RVSM Safety Case

1.5.1 Pre-Implementation Safety Case

This is set out in this document.

1.5.2 Post-Implementation Safety Case.

The required contents of the Post-Implementation Safety Case will be developed as a result of the pre-implementation safety activities. However, the main objective will be to confirm assumptions and estimations being made in order to determine whether, in an operational RVSM environment, the safety objectives can be met. It is expected that the document will demonstrate *inter alia* that safety is continuously ensured, that the aircraft approval process is effective, that the target levels of safety are being met, that operational errors do not increase and that ATC procedures introduced for RVSM remain effective.

The initial version of the Post-Implementation Safety Case is planned to be issued before the end of 2002, to be followed by the final version before end-2004.

2 RVSM SAFETY MANAGEMENT

Objectives

1) To outline the development of the RVSM Safety Policy, the High Level Safety Statement and the RVSM Safety Objectives, from which the safety requirements were derived.

2) To describe the major deliverables of the RVSM safety management programme.

3) To explain the relative safety responsibilities of EUROCONTROL and the States, in ensuring that RVSM will be safe.

2.1 ICAO RVSM Target Level of Safety (TLS)

In ICAO Doc. 9574 (2nd Edition) – Manual on the Implementation of a 300M (1000ft) Vertical Separation Minimum between FL 290 and FL 410 inclusive - **[2]** ICAO introduces the Target Level of Safety of 5×10^{-9} fatal accidents per aircraft flight hour resulting from a loss of vertical separation due to any cause for the vertical collision risk within RVSM airspace. This TLS was adopted for, and has been used in, the NAT Region since 1997.

In accordance with the NAT Region precedent the TLS was not partitioned into separate components for different types of risk. However, assessments of technical height keeping performance would need to be conducted with reference to a safety constraint of 2.5×10^{-9} fatal accidents per flight hour, as this was the value that had been used in the ICAO RVSM Manual **[2]**.

2.2 ATM 2000+ Safety Objective

At the 5th Meeting of the ECAC Transport Ministers, Copenhagen, 14 February 1997, the Ministers requested that a comprehensive, ‘gate to gate’ orientated ATM Strategy for the years 2000+ should be developed. The resulting document – ATM Strategy for 2000+ **[4]** was published in November 1999.

The document also defines 8 Major Strategic Objectives for the future ATM network. The first of these, at sub-paragraph 5.2.1, is:

“Safety

> ***To improve safety levels by ensuring that the number of ATM induced fatal accidents and serious or risk bearing incidents do not increase and where possible decrease.***
>
> Safety is of the highest priority in aviation. The main purpose of ATM services is to ensure the safe separation of aircraft, both in the air and on the ground, while maintaining the most efficient operational and economic conditions.”

2.3 EATMP Safety Policy

As a means of meeting the above on-going objectives of a high level of safety, through the adoption and implementation of a common safety policy, initially the EATCHIP, and now the EATMP, Safety Policy was developed. The EATMP Safety Policy **[3]** defines the foundation of, and specifies the general requirements for, a harmonised approach to Safety Management in the different ECAC States participating in EATMP.

The EUR RVSM Programme is an essential part of EATMP and in consequence the RVSM Safety Policy Document (Edition 1.0) **[1]** has been developed to satisfy the requirements of the EATMP Safety Policy. The RVSM Safety Policy Document sets out the Safety Policy, the Safety Objectives, the means of achieving the Safety Objectives of RVSM Implementation and the RVSM Safety Deliverables.

2.4 RVSM Safety Policy

The Safety Policy for RVSM implementation has been established to meet the requirements of ICAO Standards and Recommended Practices and Guidance Material on managing collision risk consequent on the implementation of RVSM. The European RVSM Programme is fully compliant with the EATMP Safety Policy and the ATM 2000+ Strategy **[4]**.

The following statements, taken from the RVSM Safety Policy Document (Edition 1.0) **[1]**, define the Safety Policy of the RVSM Programme:

(i) The European RVSM Programme uses an explicit, pro-active approach to safety management in the development, implementation and continued operation of RVSM.

(ii) The responsibility of management for the safety performance of the RVSM Programme is recognised. The RVSM Programme Manager is responsible for the overall management of the Programme. The RVSM Safety Sub-Programme Manager is responsible to the RVSM Programme Manager for ensuring the compliance of the Programme with EATMP Safety Policy and appropriate international standards and requirements. The RVSM Safety Sub-Programme Manager is also responsible for liaison with the EUROCONTROL Safety Regulation Commission.

(iii) The implementation of RVSM shall be conducted in accordance with the requirements of the EATMP Air Navigation System Safety Assessment Methodology (Edition 1.0) **[9]**

(iv) The safety of air navigation has been given the highest priority in the development of the RVSM operational concept and the Implementation Programme

(v) The RVSM Programme shall minimise the programme’s contribution to the serious or risk bearing incidents or aircraft accidents as far as is reasonably practicable.

It is the function of the EUR RVSM Safety Objectives to ensure that these safety statements have been complied with.

2.5 RVSM Safety Objectives

The following statements, taken from the RVSM Safety Policy Document (Edition 1.0) **[1]**, define the Safety Objectives of the RVSM Programme:

(i) The RVSM Programme shall conduct a full Functional Hazard Analysis looking at the whole system including air and ground segments and the proposed operational concept. This analysis shall adopt a total aviation system perspective and a risk based approach to the classification of hazards. The analysis shall include, but not be restricted to, those risks already identified by ICAO for RVSM implementation.

(ii) The RVSM Programme shall, as its principal safety objective, minimise the programme's contribution to the risk of an aircraft accident. The RVSM Programme recognises the Safety Objectives of the ATM 2000+ Strategy **[4]**, in particular the general objective to 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 implementation of RVSM shall not adversely affect the risk of en-route mid-air collision.

(iii) The RVSM Programme shall establish an explicit Safety Sub-Programme to ensure that Programme's contribution to the risk of an aircraft accident is minimised in accordance with the principal safety objective.

(iv) In accordance with ICAO Guidance Material the management of vertical collision risk within RVSM airspace shall meet the Target Level of Safety of 5×10^{-9} fatal accidents per flight hour.

(v) In accordance with ICAO Guidance Material, 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.

(vi) Guidance shall be given to the States to explain the necessary activities to provide evidence about the safe implementation of RVSM on the national level and subsequently assure the preparedness of the States.

Safety Objectives (ii), (iv) and (v) together define the tolerable level of risk for RVSM and for the basis for the Safety Requirements derived for RVSM discussed in paragraph 4.2 below.

The decision to adopt the TLS of 5×10^{-9} fatal accidents per flight hour was taken by EUROCONTROL in accordance with the principles established in ICAO Doc. 9574 (2nd Edition) – Manual on the Implementation of a 300M (1000ft) Vertical Separation Minimum between FL 290 and FL 410 inclusive **[2]**, and in conformance with the recommendations of the ICAO Doc. 009 (To be issued) – Guidance Material on the Implementation and Application of a

300M (1000ft) Vertical Separation Minimum in the European RVSM Airspace **[30],** and with ICAO NAT Doc. 002 – Guidance Material on the Implementation of a Vertical Separation Minimum of 300M (1000ft) between FL290 and FL410 inclusive in the NAT Region **[8].** This TLS was adopted for, and has been used in, the NAT Region since 1997.

In accordance with the NAT Region precedent, it was also decided that the TLS would not be partitioned into separate components for different types of risk. However, assessments of technical height keeping performance would need to be conducted with reference to a safety constraint of 2.5×10^{-9} fatal accidents per flight hour, as this was the value that had been used in the ICAO RVSM Manual **[2]** in the development of the Minimum Aircraft System Performance Specifications (MASPS) necessary for aircraft operations in RVSM airspace, on a global basis.

2.6 Deliverables of the EUR RVSM Safety Policy

In order to demonstrate that the RVSM Concept and the Implementation of RVSM in the European environment are i) tolerably safe and that the level of risk is as low as is reasonably practicable, and ii) that the requirements of the RVSM Safety Statement have been achieved: the EUR RVSM Safety Policy Document has defined three deliverables that support the Pre-Implementation Safety Case:

a) Report on the RVSM Functional Hazard Assessment (FHA)

In order to demonstrate compliance with the EATMP Safety Policy a detailed Functional Hazard Assessment (FHA) has been conducted to provide assurance that all hazards and risks associated with RVSM have been identified and classified. The FHA addresses three separate scenarios:

(i) the situation whereby RVSM has been operational for one year, is fully operational and all introductory problems have been resolved.

(ii) the particular situation in States that have to ensure the transition between RVSM and non RVSM airspace, and

(iii) the change-over on the day of RVSM introduction.

b) Report on the Collision Risk Assessment.

A Collision Risk Assessment has been carried out in order to provide evidence that the collision risk in RVSM airspace meets the quantitative Target Level of Safety required by ICAO.

c) National Safety Plans.

High-level guidance has been given to the States to explain the activities necessary to permit the safe implementation of RVSM at the national level. Using the guidance material, National Safety Plans have been produced by the States and submitted to the appropriate National Regulator.

2.7 Safety Responsibilities

2.7.1 European RVSM Concept

The EUROCONTROL Agency is responsible for ensuring that the application of the RVSM Concept in the European environment is tolerably safe and that, where possible, the risk is reduced to a level that is as low as is reasonably practicable. The role of the Agency in meeting these responsibilities can be summarised as:

- Overall Management of the RVSM Programme;
- Provision of a Height Keeping Performance Monitoring Infrastructure, from development to operation;
- Analysis of Height Keeping Performance data;
- Facilitation of ATS readiness for RVSM Operations;
- ATC Procedure Development and Validation;
- Definition and provision of specialised Integrated Flight Planning Service (IFPS) requirements for RVSM operations within the Central Flow Management Unit (CFMU);
- Support to Aircraft Operators and ATS Providers;
- Overall Safety Case development (excluding National Safety Plans);

2.7.2 Implementation of RVSM

The responsibility for ensuring that the Implementation of the RVSM Concept is safe, rests with the individual Participating States that together constitute the EUR RVSM Area. Each State is responsible for the safe implementation of RVSM in the airspace for which it has jurisdiction. The State Programme Managers will be responsible for providing assurance through National Safety Plans or other, equivalent documentation that their responsibilities have been met. The RVSM Programme has assumed the responsibility of providing guidance to the States on how to develop these National Safety Plans. In addition the results of the Functional Hazard Analysis (FHA)/Preliminary System Safety Assessment (PSSA) have been made available to the States for local adaptation.

Subsequently, it is the task of the RVSM Programme to review the National Safety Plans and to summarise the review findings in the States' preparedness report, which is presented in section 6 with supporting material in **Appendix G**.

2.8 Conclusions

It has been shown in this section that:

(i) The RVSM Programme is a key part of EATMP, and the approach to safety management taken on RVSM complies with the safety policy for EATMP.

(ii) Safety Objectives have been specified for RVSM that are consistent with the ATM 2000+ Safety Objective and with the ICAO-specified Target Level of Safety (TLS).

(iii) The respective safety responsibilities of EUROCONTROL and the participating States have been defined, with EUROCONTROL responsible for the safety of the RVSM Concept (and a few specific aspects of implementation) and the States responsible for the safety of the Implementation of the Concept.

3 BUSINESS JUSTIFICATION AND OVERALL SAFETY ARGUMENT for RVSM

Objectives

1) To justify the introduction of RVSM into European airspace.

2) To establish high-level arguments as to why the operational environment under RVSM will be ‘safe’ – i.e. the level of safety risk will be tolerable and, where possible, as low as is reasonably practicable, as defined herein.

3) To state the assumptions on which the safety arguments are based.

The structure of the safety arguments and supporting evidence which address these objectives is shown in **Appendix A, Figure A -1**.

3.1 The Business Justification for RVSM in Europe

3.1.1 Global Acceptance

All ICAO Member States have agreed on the feasibility of the Implementation of RVSM, on a Global basis following the exhaustive studies undertaken by the ICAO Review of the General Concept of Separation Panel in the late 1980s. This work resulted in the Report of the Sixth Meeting of the RGCSP (RGCSP/6) **[5]** and the distribution of the ICAO RVSM Guidance Material **[6]**.

3.1.2 Capacity Requirement

The primary justification for the implementation of RVSM in the European airspace is the requirement to provide additional airspace system capacity to meet the ever-rising number of aircraft movements. During the five years, 1995 to 2000, improvements introduced by the EUROCONTROL European ATC Harmonisation and Integration Programme (EATCHIP) contributed to containing the duration, and frequency of occurrence, of ATC delays despite a yearly traffic increase of between 4% and 6%. However traffic forecasts have indicated that the number of movements will continue to rise and more than double by the year 2015 compared to the 1998 figures. It is accepted that major changes to the ATM systems will be necessary in order to cope with this continued traffic growth. Of the various measures under consideration, the implementation of RVSM is considered to be the most cost effective means in the short term of meeting this need through the provision of six additional flight levels for use in the highly congested airspace from FL 290 to FL 410 inclusive.

The EUR RVSM Programme is fully supported by the Operators and by the User Organisations.

3.1.3 Cost Benefit Assessment

The implementation of RVSM in the European Airspace will also provide a positive Benefit/Cost Ratio.

In 1995, an Initial Cost Benefit Study of the Implementation of RVSM in Europe was conducted by external contractors and presented to the EATCHIP Air Navigation Team (ANT). This study was subsequently updated and refined, and the results were presented to the ANT in June 1997. This refined analysis – PA Consulting Group, EUROCONTROL Contract C/1.248/HQ/BE/96 – Update to the Initial Cost Benefit Assessment of Reduced Vertical Separation Minima **[12]** took into account:

(i) ATC Capacity enhancements;

(ii) Cost for Aircraft Altimetry Upgrades;

(iii) Cost for ATM Systems Upgrades;

(iv) Cost for Height Monitoring systems and operation;

(v) Fuel Efficiency Gains;

(vi) Costs of Delay.

The original RVSM programme allowed for re-validations of the Cost Benefit Analysis (CBA) as part of its business case. In January 1999, EUROCONTROL undertook to re-validate the RVSM business case using updated assumptions and forecasts to reduce potential uncertainties in the original study, and thereby increase the robustness' of the re-validated case. The revised CBA – (Ref. **[13])** concluded, in summary, that: the refined overall cost benefit case for RVSM is positive with a Benefit/Cost ratio of 14 and a large positive Net Present Value.

3.1.4 Global RVSM Technical Requirements

ICAO has foreseen that RVSM will be implemented on a Region by Region basis, the first one being the NAT Region (March 1997). To enable global introduction of RVSM in an effective and safe manner, ICAO developed the aircraft "Global Height Keeping Performance Specification", derived from the safety objective associated with the technical aircraft height keeping (Ref.**[2]**). From this specification, the RVSM technical aircraft requirements were derived, expressed as the RVSM Minimum Aircraft Performance Specification (MASPS).

The RVSM MASPS are therefore the globally applicable aircraft technical requirement as basis for the safe operation of RVSM. Since RVSM has already been introduced in the NAT Region, most aircraft crossing the NAT region and also operating in the EUR region already meet the technical RVSM requirements, thus obviating the need for this proportion of aircraft to be modified. Also the introduction of RVSM in the PAC Region (February 2000) provides a proportion of aircraft to be already RVSM MASPS compliant. Therefore, for a significant proportion of aircraft that will operate in EUR RVSM there will be no additional cost for upgrading the aircraft equipment as they already meet the global RVSM requirements.

3.2 Development of Safety Arguments

As noted in sub-paragraph 1.2 above, the overall aim is to show by means of argument and supporting evidence that the safety risks under RVSM will be tolerable and, where possible, that the level of risk is as low as is reasonably practicable.

The PISC demonstrates that this aim has been achieved, by means of the following principal safety arguments:

(i) That a set of Safety Requirements has been specified for RVSM that fully address all the functionality, performance and integrity requirements necessary to ensure that the safety risks under RVSM will be tolerable and that, where possible, risk has been reduced to a level as low as reasonably practicable. – see **Section 4.**

(ii) That the RVSM Concept developed by EUROCONTROL for the European region has the potential to fully satisfy the RVSM Safety Requirements - see **Section 5.**

(iii) That the Implementation of the RVSM Concept by the individual participating States will fully satisfy the RVSM Safety Requirements - see **Section 6.**

(iv) That the Switch-Over from the current vertical separation minima of 2000 ft (600 m) to the RVSM value of 1000 ft (300 m) will not adversely affect the safety of the on-going air traffic operations – see **Section 7**.

Each of the above arguments is further developed in the relevant section of the PISC, together with evidence showing that all the arguments are valid.

3.3 Assumption on Current Levels of Risk

The above safety arguments are based on the assumption that the current levels of safety risk experienced in European airspace between FL 290 and 410 are accepted as tolerable and, where possible, as low as is reasonably practicable.

Such an assumption is justified on the basis that it is not a primary aim of ATM 2000+ to improve safety absolutely but rather to maintain at least the total number of incidents at current levels (see 2.1 above), despite the forecast increase in traffic. As ATM 2000+ represents EUROCONTROL's fundamental strategy for the development of the European ATS, it is reasonable to infer that the current level of risk in the ATS is accepted as being tolerable and has, where-ever possible, been reduced to a level as low as is reasonably practicable.

3.4 Conclusions

It has been shown above that:

(i) The introduction of RVSM is justified on the basis of the additional airspace capacity that it enables and the associated substantial positive financial benefit.

(ii) The global applicability of the RVSM aircraft requirements (RVSM MASPS) allows that those aircraft already modified for RVSM in regions where RVSM is already introduced (NAT and PAC regions), to also meet the requirement for EUR RVSM without any additional modifications and associated cost.

(iii) The key assumption regarding the tolerability of the current level of collision risk has been validated.

4 RVSM SAFETY REQUIREMENTS DETERMINATION

Objective

To set out the arguments and evidence that a set of safety requirements have been specified for RVSM that address fully all the functionality, performance and integrity requirements necessary to ensure that the safety risks under RVSM will be tolerable and, where possible, as low as is reasonably practicable.

The structure of the safety arguments and supporting evidence which address this objective is shown in **Appendix A**, **Figures A-2** and **A-3**.

4.1 Introduction

This section presents the high-level safety requirements for RVSM and shows that these are a complete and correct interpretation of the key Safety Objectives for RVSM that are described in section 3 above.

It shows how those safety requirements have been broken down into more detailed safety requirements, which have been allocated to the various elements of the RVSM system, along with the safety integrity requirements that emerged from the RVSM FHA.

It then presents so-called Backing evidence, relating to the quality of the safety requirements determination process, in order to show that the RVSM Safety Requirements themselves are trustworthy.

4.2 High-level Safety Requirements

The overall, high-level safety requirements, which describe the function, performance and reliability required of RVSM are as follows (**Table H-1 of Appendix H**):

RVSM1 - Provide safe vertical separation of aircraft by assigning aircraft to different flight levels (as in RVSM 4 below).

RVSM2 -Provide safe transition to and from CVSM (feet and metric systems)/RVSM flight levels within the defined transition airspace.

RVSM3 - Prevent non-approved civil aircraft from entering RVSM airspace.

RVSM4 - Nominal separation of flight levels shall be:

a) 300m (1000 ft) between RVSM approved aircraft.

b) 600m (2000 ft) between:

i) non RVSM approved State aircraft and any other aircraft operating within the EUR RVSM airspace.

ii) all formation flights of State aircraft and any other aircraft operating within the EUR RVSM airspace.

iii) non RVSM approved aircraft and any other aircraft operating within the defined RVSM transition airspace.

RVSM5 - The accuracy of the Aircraft (technical) height keeping performance (i.e. the performance bounded by the requirements of the MASPS) shall be sufficient to ensure that the risk of mid-air collision in the vertical dimension, in RVSM airspace, shall meet a Target Level of Safety of $2.5x10^{-9}$ fatal accidents per flight hour.

RVSM6 – Provide facilities for safe operation under abnormal conditions – eg aircraft on-board emergencies.

RVSM7 – The probability of any system failure leading to a mid-air collision shall be sufficiently low to ensure that the overall risk of mid-air collision due to the loss of vertical separation, from all causes, is within the TLS of $5x10^{-9}$ fatal accidents per flight hour.

RVSM8 – The system shall be sufficiently reliable to ensure that the number of ATM-induced accidents and serious or risk-bearing incidents, under RVSM, shall not increase from current (pre-RVSM) levels and shall, where possible, decrease.

RVSM9 – The performance and reliability of the system shall not deteriorate in service.

Constraint

Although there are no explicit RVSM safety requirements associated with capacity, in order that the benefits of RVSM are realised, the introduction of RVSM shall not prevent the capacity goals of the ATM 2000+ Strategy from being achieved.

4.3 Validation of High-level Safety Requirements

In the absence of any established precedent, the general approach employed in this document for deriving the RVSM Safety Requirements was based on the approach used in International Safety Management Standard IEC 61508, Part 1 **[31]**. This Standard addresses those aspects to be considered when electrical/electronic/programmable electronic systems are used to carry out safety functions, and is not (yet) recognised as a means of compliance to any Safety Regulation Commission (SRC) regulation. Nonetheless it was considered to be an acceptable and relevant methodology. The standard calls for the requirements of a safety function to be specified in terms of both functionality and integrity, according to the amount of risk reduction that the safety function has to provide. It is argued that ‘Vertical Separation’ is a safety function (since its role is to reduce the risk of collision due to overlap in the vertical plane) and therefore adopting the IEC 61508 approach is entirely appropriate.

In order to ensure that all aspects of the behaviour of Vertical Separation have been considered; a set of *behavioural attributes* derived from those specified in UK CAA document CAP 670 - ATS Safety Requirements **[32]** – was used. The list of attributes is more comprehensive than those implied in IEC 61508 and therefore more likely to yield a complete set of safety requirements.

Table H-1 of Appendix H shows the high-level safety requirements relevant to each attribute and the source of each requirement. A comparison of the safety requirements with the relevant RVSM Safety Objectives specified in paragraph 2.5 above shows that all of three key objectives have been captured in the high-level Safety Requirements.

Therefore, on the basis that the method of achieving Vertical Separation has not changed, that the current ATS is 'safe' (see Assumption at sub-paragraph 3.3) and that the three key safety objectives for RVSM have been fully addressed, it is concluded that the high-level Safety Requirements for RVSM are sufficient as specified.

4.4 Safety Requirements Decomposition and Allocation

For the purposes of decomposition of the high-level Safety Requirements, the RVSM system was considered to comprise the following elements:

(i) Airspace Design;

(ii) Flight Crew Procedures;

(iii) Flight Crew Training;

(iv) Aircraft Equipment;

(v) ATC Procedures;

(vi) ATC Training;

(vii) ATC Equipment;

(viii) System Monitoring.

A mapping between the RVSM high-level Safety Requirements and the safety requirements for each system element (except for those derived from the Functional Hazard Assessment (FHA) discussed in sub-paragraphs 4.5 below) is shown in **Table H-2 of Appendix H**.

It should be noted that, for the reasons explained in **Table H-2**, it is not possible to allocate high-level Safety Requirements **RVSM7** and **RVSM8** to specific system elements; therefore, they are retained as system-level safety requirements and will be addressed on that basis in section 5 below.

4.5 Hazard & Risk Analysis

4.5.1 Functional Hazard Assessment

A detailed Functional Hazard Assessment (FHA) has been conducted to provide assurance that all hazards and risks associated with RVSM have been identified. The FHA addresses three separate scenarios:

(i) the situation whereby RVSM has been operational for one year, is fully operational and all introductory problems have been resolved;

(ii) the particular situation in States which have to ensure the transition between RVSM and non RVSM airspace; and

(iii) the Switch-Over on the day of RVSM introduction.

The results of the FHA are presented in the EUR RVSM Programme – Functional Hazard Assessment **[33]**.

A complete list of hazards identified in the FHA is presented in the Hazard Logs contained in **[33]**. Analysis in **[33]** indicates that of these some hazards are safety significant in the context of the introduction of RVSM – i.e. either the hazard is new or the level of risk is potentially higher than already present in the ATM system.

For each of the safety-significant hazards, a safety integrity requirement was derived, using the risk-classification scheme described in **Appendix D**, in order to restrict the probability of occurrence of the hazard to a tolerable level according to the severity of the hazard. These safety integrity requirements are presented in **Table D-1 of Appendix D**. The prefixes H_M, H_T and H_S are used in Table D-1 to identify hazards defined for the mature situation in RVSM airspace, for the mature situation in Transition airspace, and for Switch-Over (from CVSM to RVSM), respectively.

4.5.2 Control and Mitigation of Hazards and Risks

The allocation of the FHA-derived safety integrity requirements to the appropriate elements of the system is also presented in **Table D-1** of **Appendix D**, together with an indication of what (if any) mitigation is available to reduce the effect, and/or probability of occurrence, of the hazard concerned.

Where mitigation is available, an explicit functional safety requirement was derived for the relevant system element(s), in order to specify clearly the mitigation required. Where mitigation is <u>not</u> available, the safety integrity requirement from the FHA is allocated to the relevant system element(s), in order to limit the risk to a tolerable level.

The resulting safety requirements (of both types) are shown in **Table H-3 of Appendix H**.

4.6 RVSM Safety Requirements Traceability

Examination of **Tables H-1**, **H-2** and **H-3** shows complete traceability from the high-level RVSM safety requirements through to the safety requirements placed on each system element. Furthermore, examination of the hazards and safety integrity requirements identified in the FHA **[33]**, and of **Tables D-1** and **H-3**, show that all safety-significant hazards and safety integrity requirements are traceable to a mitigating (or at least controlling) safety requirement.

4.7 Backing Evidence

The Safety Requirements evidence is considered to be trustworthy on the basis that:

(i) The concept of operations for RVSM is known and derived in a competent manner.

(ii) The scope of RVSM has been clearly defined.

(iii) The ICAO Target Level of Safety (TLS) and its application are appropriate for EUR RVSM.

(iv) The Hazard and Risk analyses were carried out by competent staff.

(v) The Hazard and Risk analysis process would have ensured that, within reason, all significant failure modes were identified.

(vi) The failure modes identified were representative of the operational environment and the pilot and controller workloads that will be encountered in EUR RVSM airspace.

(vii) The risk-classification scheme used to derive the safety integrity requirements was appropriate for the RVSM programme.

Evidence to support these arguments is provided in the following paragraphs.

4.7.1 RVSM Concept of Operations

The ICAO RVSM concept of operations has been developed for the European operational environment within the working structures of EATCHIP and EATMP in collaboration with the ICAO European and North Atlantic Office and EANPG, by appropriately technical and operational expertise, with representation from most States where RVSM is to be implemented. The expertise and decision making processes have ensured that the RVSM concept is manageable EUR wide, thereby providing an essential element in preparing for an effective and safe implementation of RVSM in EUR RVSM airspace.

The RVSM concept is the reduction of the vertical separation minimum between RVSM-approved aircraft from 600M (2000ft) to 300M (1000ft) between the Flight Levels FL290 and FL410 inclusive. This will provide six additional cruising levels to air traffic, increase the capacity of the Air Traffic Management system and facilitate the task of Air Traffic Services in maintaining a safe, orderly and expeditious flow of traffic. It can be expected that the capacity and system benefits of RVSM will, by facilitating the Air Traffic Control function, also have the potential for safety benefits.

All aircraft, excluding State Aircraft, intending to operate in the EUR RVSM airspace must be equipped in compliance with the MASPS as specified in JAA

TGL 6 (or in similar State Documentation based on Reference [2] and [6]) and have received appropriate certification/approval from the State of Registry or from the State of the Operator. The reduced vertical separation minimum will be applied between RVSM approved aircraft within the designated EUR RVSM airspace

Therefore, all operators proposing to operate across the lateral limits of the RVSM airspace shall be required to indicate on Filed Flight Plans their RVSM status. Except within the European RVSM Transition Airspace non-RVSM approved aircraft, other than State aircraft, shall not be permitted to operate within RVSM airspace.

The designated RVSM airspace, including the transition airspace and the changes in Airspace Design necessary to accommodate the new Flight Level Orientation Scheme, are shown in **Appendix C** – RVSM Table of Cruising Levels.

Specific ATC procedures will be used to facilitate the safe transition of aircraft to/from RVSM and non-RVSM airspace and whilst operating in the RVSM airspace. The transition tasks shall be accomplished within the designated RVSM airspace so as to make RVSM operations transparent to adjacent non-RVSM regions.

The RVSM Programme also requires that specific training of ATC staff and Flight Crew shall be performed prior to the start of RVSM operations. Furthermore the Programme requires that ATC and IFPS equipment and procedures to be modified according to specific Programme requirements prior to the start of RVSM operations.

4.7.2 Scope of RVSM

RVSM will apply to all RVSM-approved aircraft operating between FL 290 and FL410 inclusive, except to State aircraft and except in Transition Areas. The proposed area of applicability comprising 40 States is shown on the map in **Appendix C**.

4.7.3 Target Level of Safety

The ICAO TLS has been successfully applied to RVSM in the NAT region as a means to quantitatively manage risk of collision. The technical TLS associated with the aircraft technical height keeping, is directly related to the global RVSM MASPS and is therefore globally applicable. The overall TLS associated with risk due to any cause, has been successfully applied for NAT RVSM and there is currently no information available on the basis of which a different overall TLS should be applied for EUR RVSM.

4.7.4 The FHA Staff Competence

The competence of the staff who carried out the Functional Hazard Analysis process is justified in **Appendix D** and in **[33]**.

4.7.5 Validation of FHA and Risk-Assessment Techniques

The FHA was carried out in accordance with EUROCONTROL EATMP Air Navigation System Safety Assessment Methodology **[9]**.

The derivation of safety integrity requirements, from the assessed hazard severity, used the Probability and Risk-classification schemes described in **Appendix D**.

Examination of **Figure 20** and **Figure 21** of **Appendix D** shows that a probability of a collision (i.e. Hazard Severity 1) of $<10^{-9}$ would be 'not tolerable', and yet the ICAO TLS allows for the probability of a collision to be as high as $5x10^{-9}$. Because a tolerable level of risk for Hazard Severity 1 is not specified it is not possible to relate the Risk-Classification scheme to the TLS quantitatively, but it is reasonable to argue that the basis of the Risk-Classification scheme may be conservative with respect to the ICAO TLS by up to an order of magnitude.

4.8 Compliance of Safety Requirements with RVSM Safety Objectives

In considering whether the complete set of RVSM safety requirements (including those derived from the FHA) meet the RVSM Safety Objectives, four questions need to be answered:

(i) Whether the technical vertical collision risk represented by the RVSM safety requirements relating to height-keeping accuracy is within that portion of the TLS allocated to height-keeping performance.

(ii) Whether the total vertical collision risk represented by the complete set of RVSM safety integrity requirements is within the remainder of the TLS.

(iii) Whether the overall level of risk, of an accident or serious risk-bearing incident, is no greater than exists prior to the introduction of RVSM.

(iv) Whether there are specific safety benefits accruing from the introduction of RVSM, which could offset the increase in risk that is inherent in any reduction of separation standards.

4.8.1 TLS Technical Height-Keeping Requirements

Inspection of **Tables H-1** and **H-2** shows that the TLS Technical Height-keeping requirements are captured fully in high-level safety requirement **RVSM5** and allocated entirely to Aircraft safety requirement **AC1**. Therefore, **AC1** is a correct and sufficient interpretation of this Safety Objective.

4.8.2 TLS Operational-Risk Requirements

The assessment of risk associated with technical and operational aspects against the TLS of $5x10^{-9}$, does not take into account events initiated by ACAS/TCAS resolution advisories, except where those advisories were the result of operational errors. Where a potential conflict due to an operational error was resolved by an ACAS/TCAS resolution advisory, the operational error is taken into account in the risk assessment as though ACAS/TCAS was not available. The rationale for this approach is provided in Paragraph **5.12.2**

Inspection of **Tables H-1** and **H-2** shows that the portion of TLS, which is concerned with risks not related to Technical Height-keeping, is captured fully in high-level safety requirement **RVSM7**.

It must be borne in mind that this element of the TLS applies to the total vertical collision risk, whereas the EUROCONTROL FHA methodology considers each hazard separately. The question that needs to be addressed, therefore, is whether the aggregate effect of the risks identified in the FHA (post mitigation) is compliant with **RVSM7**, even though those risks may be individually tolerable. This question is addressed in two ways:

(i) As discussed in sub-paragraph 4.7.5 above, the EUROCONTROL FHA methodology and Risk-classification scheme do not provide the means of linking quantitatively the output of the FHA with the TLS. Therefore, a more qualitative argument is employed, which shows that the overall number of hazards / risks per severity class is acceptable.

The FHA identified a total of 33 hazards related to the mature (i.e. post-Switch-Over) situation for RVSM, the safety integrity requirements for which are shown in **Appendix D**, **Table D-1**.

None of the hazards was assessed as Severity Class 1 – i.e. none are capable of directly causing an accident.

Only one hazard (failure of the altimetry equipment on an RVSM-approved aircraft) has been assessed as Severity Class 2, and its probability of occurrence has been estimated to be sufficiently low for the risk to be considered tolerable according to the methodology used. In any event the performance of aircraft altimetry equipment will continue to be addressed in the Height-Monitoring Programme explained in paragraph 5.9 below.

Of the other 32 hazards, five were assessed as Severity Class 3, some 24 as Severity Class 4 and three as Severity Class 5.

For the 33 hazards, mitigations of the effect and/or probability of occurrence have been identified, and have been captured as safety requirements in their own right; satisfaction of these safety requirements would result in 31 of the 33 risks being considered tolerable. There are two risks - due to pilot-induced “level busts” and TCAS nuisance alerts – which have been assessed as not tolerable, according to the FHA methodology. These two risks are discussed in Sub-Paragraphs **5.12.1**-“Level Busts” and **5.12.2**-ACAS/TCAS Nuisance Alerts below.

As explained in sub-paragraph 4.7.5 above, the risk assessment methodology used is conservative by one or two orders of magnitude compared with the TLS. Therefore, it can be argued that (apart from the two “intolerable” risks) the total number of hazards/risks associated with RVSM is reasonably consistent with safety requirement **RVSM7** (provided the required mitigations are put in place) and, therefore complies with the related Safety Objective.

(ii) It can be seen from Table H3 that, with the exception of the Hazards H_M1.3 and H_M1.4 which relate to Aircraft Equipment (System Elements AC1 and AC2) and are bounded by the Technical TLS (2.5 x 10^{-9} fatal accidents per flight hour.); the consequences of all of the hazards, identified by the FHA and included the Table (H3), will be evidenced as Operational Errors. As such, and assuming the full co-operation and diligence of States, they should be reported to EUROCONTROL as Altitude Deviation Reports. The reports will be scrutinised and analysed and the quantified risk will be set against the overall TLS of 5 x 10^{-9} fatal accidents per flight hour (RVSM7) Additionally the on-going nature of the ADR Studies will indicate the causes of Operational Errors, establish error rates and trends, and enable remedial action to be taken to satisfy the overall TLS, minimise system risk to as low a level as is reasonably practical, and to avoid any increase in risk (RVSM8).

4.8.3 Overall Risk and Safety Benefits from RVSM

Inspection of **Tables H-1** and **H-2** shows that the RVSM Safety Objective relating to total vertical risk is captured fully in high-level safety requirement **RVSM8**.

In addition there are a number of features of the RVSM Programme which will provide a reduction of risk. These are as follows:

Air Traffic Control

(i) The six additional flight levels will reduce controller workload (and potential for errors) by:

- facilitating the general task of the resolution of potential traffic conflicts, and provide additional flexibility / options to controllers in busy sectors;
- easing the problem of resolution of traffic conflicts at congested crossing points;
- reducing radar vectoring with subsequent potential reduction in R/T traffic;
- providing compatibility with cruising levels used in the NAT Region, thereby eliminating Transition tasks at the NAT/EUR interface.

(ii) The reduction in radar vectoring and R/T traffic will also reduce pilot workload.

(iii) The six additional flight levels will also reduce the volume of traffic at each flight level, thereby reducing the horizontal collision risk.

(iv) Improved communications failure procedures have been developed and are expected to be approved by the ICAO Council before RVSM implementation.

Note: The new communications failure procedures apply to all airspace (RVSM and CVSM) and are intended to enhance operational efficiency They are not considered to be safety critical in terms of their date of applicability.

Aircraft

(v) MASPS/RVSM Approval Process will result in improved height keeping equipment and maintenance standards, and the height keeping performance accuracy of RVSM approved aircraft in all operations.

(vi) The introduction of RVSM will provide the motivation for an earlier development and operational use of more sophisticated ACAS/TCAS systems.

(vii) RVSM will provide financial and operational incentives to Aircraft Operators to modernise their aircraft fleets.

Flight Crew

(viii) Flight Crew RVSM Training programmes should result in a raised awareness of the importance of adherence to cleared level (thus reducing incidences of “level busts”), the significance of Wake Vortices and other potential causes of Operational Errors (Assigned Altitude Deviations)..

(ix) Reduction in pilot workload through the reduced number of ATC initiated radar vectors for separation purposes.

Participating States

(x) The requirements placed on the States will Increase focus on National Safety Management processes.

(xi) Greater degree of standardisation of procedures.

General Safety Issues

(xii) Operational height keeping performance of RVSM aircraft will be tracked by means of a European-wide database which will incorporate the data from the NAT RVSM database.

(xiii) Independent, passive and accurate measurements of the height keeping performance of RVSM aircraft will be conducted on an on-going basis by HMU/GMU

(xiv) The ongoing monitoring programme will provide unique data on the consistency and repeatability of Altimetry System Error (ASE).

4.9 Conclusions

It has been shown in this section that:

(i) A sufficient set of high-level safety requirements have been specified for RVSM, and have been completely and correctly allocated to the appropriate elements of the RVSM system.

(ii) Safety requirements have also been specified and allocated to the system elements, for each hazard identified in the FHA, sufficient to control and/or mitigate the hazard, in all but two cases, which are dealt with in section 5.

(iii) The safety requirements satisfy the TLS for technical height-keeping accuracy, and are broadly consistent with the remainder of the TLS.

(iv) There are additional aspects of the RVSM programme which will result in a reduction of collision risk.

(v) The processes used in deriving and allocating the safety requirements give further confidence that the safety requirements are complete and correct.

5 APPLICATION OF THE ICAO RVSM CONCEPT IN THE EUR AIRSPACE

Objective

This section sets out the arguments and evidence that the RVSM Concept will satisfy the RVSM Safety Requirements.

The structure of the safety arguments and supporting evidence that address this objective is shown in Appendix A, Figure A-4. Lower-level arguments are referenced in the appropriate paragraphs below.

5.1 Introduction

In this Section, each of the following elements of the system is considered in turn, and arguments and evidence presented to show that the Concept 'design' has been addressed by the EUROCONTROL Agency, and that it has the potential to satisfy fully the associated Safety Requirement(s):

(i) Airspace Design (AD);

(ii) Flight Crew Procedures (FC);

(iii) Flight Crew Training (FC);

(iv) Aircraft Equipment (AC);

(v) ATC Procedures (ATC);

(vi) ATC Training (ATC);

(vii) ATC Equipment (ATC);

(viii) System Monitoring (SM).

For each system element discussed, the purpose of the safety requirements is summarised, the general approach to satisfying the requirements is described, and then the specific arguments and evidence of requirements satisfaction are presented.

Arguments and evidence are also presented to show that the specified Safety Constraints have been met.

Next, arguments and evidence are presented to show all safety requirements are traceable to the Concept design.

Specific risks associated with the RVSM Concept are then highlighted.

Finally, the degree of compliance of the Concept with the RVSM Safety Objectives is discussed.

Assurance that the Safety Requirements, relating to the Implementation of RVSM, are satisfied by the participating States is covered in **Section 6.**

5.2 Airspace Design

5.2.1 Safety Requirements

The designated European RVSM airspace will need to accommodate safe RVSM operations using the 6 additional flight levels that the reduced separation minimum will provide. Thus it will be necessary to ensure that:

(i) at entry into and the exit from RVSM airspace the transition from/to CVSM flight levels is effected safely,

(ii) the characteristics of the use of the new flight levels are suitable for European operations, and

(iii) the airspace structures are designed to meet the operational requirements from both an Air Traffic Management and a Flight Operations perspective.

To achieve these requirements, the following formal Safety Requirements, applicable to Airspace Design, have been developed in order to:

(i) Provide Transition Airspace to enable the safe transition of aircraft to and from RVSM Flight Levels from and to the existing CVSM Flight Levels - both the Feet and Metric systems - (Safety Requirement **AD1**).

(ii) Enable the implementation and use of the six additional Flight Levels that the 300M (1000ft) RVSM provides - (**AD2**).

(iii) Make provision for any changes necessary to accommodate Contingency Procedures and/or measures arising from abnormal operating conditions or emergencies - (**AD3**).

5.2.2 Approach

These requirements will be met if:

(i) the areas just within the EUR RVSM airspace are designated transition airspace and changes to the route network are introduced, where necessary, to facilitate transition to/from RVSM airspace;

(ii) the Flight Level Orientation Scheme selected to incorporate the 6 additional flight levels has been assessed and validated as compatible with the European environment;

(iii) the changes to Route Networks, Sectorisation, and any other airspace structures necessary to accommodate RVSM operations, have been implemented.

The arguments and evidence, which show that the Airspace Design safety requirements have been met in the RVSM Concept, are summarised **in Figure A - 5 of Appendix A**, and are explained in the following sub-paragraphs.

5.2.3 Provision of Transition Areas (AD1)

The airspace or part thereof of the 14 RVSM States within the extremities of the RVSM airspace has been designated as Transition Airspace in Amendment 200 to ICAO Doc 7030/4 **[7]**, and as further amended after the inclusion of Tunisa FIR as part of the EUR RVSM airspace. Transition has to take place within this airspace so that all aspects of RVSM Operations are transparent to adjoining non-RVSM ATCs/UACCs. Transition procedures are applicable.

A further designation of airspace has been included in Doc 7030/4 at the interface between EUR RVSM airspace and NAT airspace. In this airspace the State may allow aircraft to climb to and descend from FL430 and above in the NAT.

Within transition airspace, RVSM approved aircraft entering RVSM airspace will need to change flight level to conform to the FLOS. Aircraft exiting may have to change flight level to conform to the FLOS outside EUR RVSM airspace. Also in transition airspace non-RVSM aircraft, except State aircraft, will be cleared to a non-RVSM level. These tasks have to be completed inside the designated airspace unless agreed otherwise through letters of agreement with the adjacent ACC.

There are ATC procedures applicable for this task. To facilitate their application, airspace design changes can be introduced in the designated transition airspace. These range from the introduction of unidirectional routes, unidirectional segments of routes and restricting the use of some flight levels. Which method is chosen depends on the traffic intensity and complexity, the ability to reach agreement with the adjacent non-RVSM State on new routes and other local factors. The RVSM Programme reviewed each route which could be used in the transition from RVSM to non-RVSM airspace, and vice-versa, and issued guidance on what, in the programme’s view, would be the best airspace design change (if any), given the traffic intensity and complexity. This Guidance Document was published in **[26]** after each state had been given the opportunity to comment. Once agreed by ANT, each Transition State was asked specifically to take the report into consideration and make a decision on the airspace design solution it would adopt. Confirmation of this activity was reported to the Programme.

The designated Transition Areas are illustrated on the map of the European RVSM Area at **Appendix C**.

5.2.4 Provision of New Flight Levels / Flows (AD2)

<u>Flight Level Orientation Scheme for European Region</u>

Annex 2 Appendix 3 of ICAO **[27]** specifies the Table of Cruising Flight Levels to be used when RVSM is applied. Given the transition complexities this Table of Cruising Levels introduces if adjacent regions are applying CVSM, the RVSM Programme established an RVSM Ops Task Force to look at whether other possible FLOS options should be pursed for adoption in the EUR RVSM airspace. The report of the task force recommended that the Table of Cruising Flight Levels in Annex 2 Appendix 3 of ICAO be adopted for EUR RVSM airspace.

The ANT accepted this recommendation and the RVSM Programme Master Plan was approved by the PC on this basis.

Studies were carried out on options for a Flight Level Allocation Scheme (FLAS) for the non-transition area and a real-time simulation RVSM5 (**Appendix B**) refers. There was no safety impact or operational benefit perceived and so no recommendation was made.

Route Network and Sectorisation

Except as explained above for transition airspace, the route network does not need to be modified for RVSM operations. However, for efficiency and capacity reasons, Version 4 of the ARN Route network will be introduced in Nov 2001 and will incorporate airspace changes both in the transition and in the rest of the EUR RVSM airspace. ANT approved version 4 in Feb 2001.

Sectorisation issues were also reviewed. Again there were no specific safety reasons for recommending changes to sectorisation except where the division flight level (DFL) per sectors before RVSM was a non-useable flight in CVSM but a useable flight level with RVSM. The study assessed how traffic patterns would change in the vertical plan with the 6 additional levels. A Guidance document was endorsed by ANT in November 2000 and sent to National Programme Managers during March 2001 as well as to airspace planners through the RNDSG of ANT.

States have been implementing elements of ARN Version 4 throughout 2001 and this has been confirmed in co-ordination with the AMN/RNDSG. LoAs have been agreed or finalised based on ARN V 4 proposals. The AIRAC date of 29 November 2001 has been agreed at ANT by all the States as the final date by which V4 Phase 2 changes should be implemented. There will be a subsequent Phase 3 to ARN V4 in April/May 02 following the initial experience of RVSM. Some States will implement airspace changes through ICAO which are not necessarily part of ARN V4.

A series of tables and diagrammatic representations of the pre/post RVSM Cruising Levels and traffic flows, and the transition processes to/from RVSM/non RVSM airspace and to/from Feet/Metric Levels are provided in the ATC Manual for a Reduced Vertical Separation Minimum (RVSM) in Europe – ASM.ET1.ST13.5000 **[25]**. Copies are provided in **Appendix C**.

5.2.5 Provision of Contingency Facilities (AD3)

No Contingency Facilities, or specific changes to airspace design, should normally be necessary to handle contingency situations or to support the conduct of the RVSM Contingency Procedures described in the ATC RVSM Manual **[25]** However if for any reason it became necessary for a suspension of RVSM Operations, that is a discontinuance of the use of a 300M (1000ft) RVSM, appropriate measures for the application of a VSM of 600M (2000ft) are detailed in the ATC Manual **[25]**.

5.2.6 Backing Evidence

The above Airspace Design evidence is considered to be trustworthy on the basis that:

(i) The correct and safe operation of the Transition areas has been independently validated by means and staff independent of the Design work. Evidence to support this argument is provided in **Appendix B** - ATC Simulations.

The Simulations, which specifically addressed Transition Areas and Transition Procedures, were (using the references letters employed in **Appendix B**):

(e) Romanian Simulation at Constanta ACC in June 1998

(f) Fourth Continental RVSM Simulation (Transition) Simulation: Turkey – January 1999.

(g) Simulation of Latvian Airspace – Riga ACC September 1999. This simulation specifically addressed RVSM Feet/Metric transitions.

(i) Sixth Continental Simulation – EEC Bretigny in September 2000. This simulation addressed transition issues within the airspace of Cyprus and Greece.

(j) Simulation of Moroccan Airspace, Casablanca, October 2000.

(ii) The correct and safe operation of the six new Flight Levels / flows for RVSM airspace has been complied has been independently validated by means and staff independent of the Design work. Evidence to support this argument is also provided in **Appendix B** - ATC Simulations. The simulations that specifically addressed Flight Level Orientation Schemes (FLOS) were (using the reference letters of **Appendix B**):

(b) Second Continental RVSM Simulation, Hungary, May 1996

(c) Third Continental RVSM Simulation

In addition, after the decision on the FLOS was taken, a further Simulation was commissioned to determine the optimum Flight Level Allocation Scheme (FLAS):

(h) Fifth Continental RVSM Simulation – European Core Area, EEC – October 1999.

(iii) The correct and safe provision of Contingency facilities has been independently validated by means and staff independent of the Design work. Evidence to support this argument is referenced and summarised at **Appendix B** – ATC Simulations. The simulation, which specifically addressed Contingency facilities, was the Third Continental RVSM Simulation that examined the core area of Europe. This was the main objective of this simulation.

(iv) The Airspace Design work and validation thereof has been carried out by an approved agency, employing competent staff. Evidence to support this argument is provided as follows. The Airspace Design work was developed by, or co-ordinated through, the Route Network Development Sub-Group (RNDSG) and the associated ATC Procedures by the ATM Procedures Development Sub-Group (APDSG) of the EUROCONTROL Airspace and Navigation Team (ANT). The work was validated through ATC Simulations, and the Simulation Reports and recommendations were endorsed by the ANT. The ANT is made up of Senior Airspace and Navigation experts from the Member States, User Organisations, ICAO and the EUROCONTROL Agency.

5.2.7 Mitigation of Hazards and Risks

Five hazards, identified in the FHA, are shown in **Table H-3 of Appendix H** as being relevant to Airspace Design: The first four hazards were identified during the "Transition" Session and are mitigated through the adherence to the Transition Procedures, detailed in Sub-Paragraph 5.5 of the ATC Manual ([25], that are part of the ATC Training requirements highlighted in the Guidance Material provided to States [36]

H_T1.8– Two aircraft at same level in opposite directions

There are three possible causes for this hazard, all relating to the incorrect application of procedures :- the pilot fails to follow the FPL after a Comms failure; the pilot fails to execute correct clearance; or the ATCO gives the wrong clearance.

Where agreed, the use of unidirectional routes (Standard Routing Scheme) will further mitigate the hazard.

H_T1.10– Length of buffer area is too short

There is no defined "buffer area". However the process of ensuring that the transition to/from CVSM (Feet and Metric)/RVSM Flight Levels is completed within the area of responsibility of the first/final RVSM ACC on the aircraft route will mitigate this hazard. Furthermore, common recommendations to the States have been given to further mitigate the hazard. Finally, where agreed, the use of unidirectional routes (Standard Routing Scheme) will also mitigate the hazard.

H_T2.2 – ATCO fails to perform conversion to metric CIS system

This hazard is addressed under ATC Procedures in Sub-Paragraph 5.7.5.

H_T3.6 – Congestion at FL280 and below

The probability of occurrence of this hazard will be reduced by sectorisation and/or flow management as necessary to be used to prevent congestion. Recommendations to the States will be given to carry out the necessary simulations **[35]**.

The fifth hazard:

H_M1.11 – Sudden deviation from cleared FL and/or route due to Wake Vortex

The hazard is caused by vortices generated from a preceding aircraft normally flying above or crossing through the level of the encountering aircraft. This is especially considered to be a problem if the separation is only 1000 feet and/or when a smaller aircraft is following a heavier. However the normal Flight Level Orientation System (FLOS) in the EUR RVSM airspace will mean that aircraft cruising on routes in the same direction will be separated by at least 2000 feet (e.g for a Northbound flow the usable levels are FL 300, FL 320, FL 340, etc). Thus the probability of encountering hazardous wake vortices from preceeding traffic will be minimal. This is in contrast to the FLOS over the NAT where aircraft are flying in the NAT Organised Track Structure (OTS) which is uni-directional and uses all levels (eg FL300, FL310, FL320).

The RVSM Programme has undertaken an independent wake vortex study **[29]**. This study concludes that RVSM is not expected to increase the probability of a hazardous encounter with wake vortex, and the risk of collision remains tolerable. However, pilots and air traffic will be informed that nuisance encounters would increase.

5.2.8 Conclusions Regarding Airspace Design

The above evidence shows that the safety requirements allocated to Airspace Design have been addressed in the RVSM Concept and mitigations have been provided for four of the five related hazards. No mitigation has been identified for flight deviations arising from wake vortices but it has been concluded that the risk of a collision arising from such an incident is no greater under RVSM than it has been under CVSM and that such risk remains tolerable.

5.3 Flight Crew Procedures

5.3.1 Safety Requirements

In order to support safe operations in EUR RVSM airspace, appropriate Flight Crew procedures need to be available and Flight Crew Training (Sub-Paragraph 5.4) needs to include these RVSM specific procedures. The Flight Crew procedures will allow flight crew to comply with the normal, abnormal and contingency EUR RVSM operational procedures and will include the checking/assurance that for operation in EUR RVSM airspace, the Aircraft Equipment meets the RVSM MASPS requirements (see Sub-Paragraph 5.5).

The EUR RVSM Flight Crew Procedures have been developed to comply with ICAO Guidance material **[6]**, to be compatible with the EUR RVSM ATC Procedures **[25],** and to ensure that when operating in EUR RVSM airspace the aircraft is operated according its RVSM approval status.

The associated Safety Requirements, applicable to Flight Crew Procedures, are intended to ensure that the appropriate procedures are available, and are adhered to, during operation in EUR RVSM airspace:

(i) Operations in Transition Airspace, including the provision of compulsory reporting points to prevent late handover of aircraft from non RVSM airspace - (Safety Requirement **FC1**).

(ii) Operations in RVSM Airspace - (**FC3**).

(iii) Revised Flight Planning requirements, including notification of the aircraft's RVSM approval status - (**FC4**).

(iv) Aircraft Contingencies, including actions in the event of on-board emergencies and of loss of R/T communications - (**FC7**).

5.3.2 Approach

The Flight Crew Procedures safety requirements will be satisfied by the material, described above, promulgated by ICAO, the JAA and EUROCONTROL.

The arguments and evidence, which show that the Flight Crew Procedures safety requirements have been met in the RVSM Concept, are summarised in

Figure A-6 of Appendix A, and are explained in the following sub-paragraphs.

5.3.3 Provision of Procedures

Specialised Flight Crew Procedures for Operations in the EUR RVSM Airspace are provided/notified in ICAO Doc. 7030/4 Regional Supplementary Procedures (Amendment 200 dated 12 December 2000) **[7]** – European EUR Supps - Part 1- Rules of the Air, Air Traffic Services and Search and Rescue.

More detailed information on the procedures required for operations in any RVSM environment (currently NAT and PAC Regions and the future EUR RVSM airspace) is provided in JAA Temporary Guidance Leaflet No.6 Appendix 4 – Training and Operating Practices and Procedures **[11].** This material addresses the following safety requirements:

- Flight Crew Operating Procedures (satisfying **FC1** and **FC3**);
- Flight Crew Flight Planning Procedures (satisfying **FC4**);
- Flight Crew Contingency Procedures (satisfying **FC7**).

JAA TGL No.6 **[11],** at Appendix 4 sub-para 8.3, cross-refers to the EUROCONTROL Doc “The ATC Manual for a Reduced Vertical Separation Minimum (RVSM) in Europe” **[25]** for specialised operational matters for European Operations.

5.3.4 Operational Approval

As stated in ICAO Doc 7030/4 **[7],** in order to be granted an RVSM approval, the operator should satisfy the appropriate State Authority that, besides the aircraft meeting the RVSM MASPS requirements, “the operational procedures for operation in EUR RVSM airspace have been instituted”. Therefore, the approval process should ensure that the operator has performed the necessary steps to ensure that flight crew, operating in EUR RVSM airspace, are aware of, and trained regarding the EUR RVSM flight crew procedures. A Flight Operations Awareness Video **[50]** will be released on 10 August 2001. The video addresses the various issues relating to flight operations in RVSM airspace including flight crew procedures and training.

5.3.5 Applicability of existing RVSM Operational Approvals

ICAO states in Doc 7030/4 **[7]** that “an RVSM Approval is not limited to a specific region and is applicable globally, under the understanding that any operating procedures specific to a particular Region, in this case the EUR Region be stated in the Operations Manual or appropriate Crew Guidance”.

Because RVSM flight crew procedures for EUR RVSM operations are different from RVSM Procedures in other regions where currently RVSM is operated, it is required that flight crew, already approved for RVSM operation in other (existing) regions where RVSM is implemented, are fully aware of the specific EUR RVSM procedures. To this extent, State Authorities have been requested to ensure that, when considering the applicability of existing RVSM approval for operation in EUR RVSM airspace, flight crew are aware of the EUR RVSM specific procedures. When the RVSM Programme received notification of EUR

RVSM (operational) approval based on existing approval for RVSM operation in another region, it is assumed that the State Authority has fulfilled its responsibility regarding this aspect of the approval process.

The EUR RVSM approval notification process, instituted by ICAO through State Letter T 13/15.2E - L00-1160.ATM on 15 December 2000, provides a method (form) for Authorities to notify the EUR RVSM Programme of the applicability of existing RVSM approvals for EUR RVSM operations, taking into account the existence of EUR specific RVSM procedures.

5.3.6 Backing Evidence

The above Flight Crew Procedure evidence is considered to be trustworthy on the basis that:

(i) The Flight Crew Operating procedures governing Transition to/from RVSM/non-RVSM airspace (**FC1**) are not significantly different or additional to those used in existing practice.

(ii) The correctness and safety of the procedures for normal operations in RVSM airspace (**FC3**) have been demonstrated by three years of continuous application in the RVSM airspace of the NAT Region. The minor variations necessary for EUR Regional operations (e.g. RTF Phraseology) have been validated by means of the ATC Simulations summarised in **Appendix B**.

(iii) The correctness and safety of the new Flight Crew Contingency procedures for RVSM airspace (**FC7**) have been independently validated by means and staff independent of the procedure design work. Evidence to support this argument is summarised at **Appendix B** – ATC Simulations. The simulation that specifically addressed Contingency facilities was the Third Continental RVSM Simulation, which examined the core area of Europe. The main objective of this simulation was to evaluate Contingency Procedures.

(iv) The correctness and safety of the RVSM Flight-planning procedures (**FC4**), as detailed in Appendix 4 of JAA TGL No.6 **[11]**, have been demonstrated by three years of continuous application in the RVSM airspace of the NAT Region. The use and effectiveness of the letter “W” (to indicate that the aircraft is RVSM approved) in Field 10 of the Flight Plan is part of the IFPS evaluations described in sub-paragraph 5.8.4 below.

5.3.7 Mitigation of Hazards and Risks

Four hazards, identified in the FHA, are shown in **Table H-3 of Appendix H** as being relevant to Flight Crew Procedures (See also Sub-Para 5.4.8 (Below) – Mitigation of Hazards and Risks relating to Flight Crew Training)

H_T3.5 – Late hand-over of aircraft from non-RVSM airspace

The probability of occurrence of this hazard will be reduced by the introduction and use of compulsory reporting points (i.e. the pilots are obliged to report passing the points) as described in the ATC RVSM Manual **[25]** – Sub-Paragraph 7.2.6. In the event that a Pilot fails to make the expected report, ICAO Document 4444 **[48]** Part (ii) Para 14.1.5, requires Controllers to attempt to establish contact .

H_M1.8 – Pilot is deviating from clearance (‘Level Bust’)

This (severity class 3) hazard can only occur if existing mitigation factors fail. That is, normal procedures to prevent level busts include cross-check between pilots to ensure that the correct settings are made for altimeters and autopilot input. When an error is made, which results in a climb or descent through the cleared flight level, the air traffic controller can only react after the aircraft is shown to have gone through the cleared level.

The FHA estimated the probability to be ‘remote’, placing the hazard in the NOT TOLERABLE category according to the FHA methodology (described in **Appendix D**).

During the FHA, no RVSM specific mitigations were identified, although it was noted that this hazard currently exists in today’s environment below FL290.

Level busts have been recognised as aviation hazards by a number of States, and activities have been initiated by those States to reduce their occurrence (identifying causes and find remedies, providing awareness and training material). Although these activities are not RVSM specific, they are expected to be also beneficial for the safety of RVSM in this respect. In EUR RVSM guidance and awareness material, pilots are urged to be more vigilant to prevent level busts (See Para **5.12.1**). In addition an awareness campaign has been launched by the Agency resulting in the issue of a Safety Letter which was widely distributed throughout the Aviation community **[52].**

Given the above, mitigations against level busts are assumed to be sufficient so as to ensure that their occurrence is at least as manageable as in the current 1000ft environment below FL290 (see also para **5.12.1**).

It should be noted that the risk that level busts represent are included in the Collision Risk Assessment (see **Appendix F**).

H_M2.2 – ‘W’ indicated in the flight plan or the pilot claims aircraft as RVSM approved despite this is not the case

The probability of occurrence of this hazard will be reduced in part by Flight Crew Procedures requiring changes to the aircraft RVSM approval status to be notified via a change (CHG) message. In addition, random checks of what is declared by an operator in the flight plan and what is the information available in the EUROCONTROL database will be performed before start of RVSM operations. Discrepancies will be addressed to operators and certification authorities concerned. (Sub-Para 5.9.6 refers)

H_M1.15 – Air RX/TX unserviceable

To obtain an RVSM Approval, Flight Crews must receive training in RVSM Communication Failures and Contingency Procedures which are addressed in the Flight Crew Procedures **[11]** and in the ATC Procedures **[25]** The application of these procedures will minimise any risk resulting from this hazard.

The hazard is further mitigated by the introduction of compulsory reporting points at the entry and exit of RVSM airspace, from which aircrew and controller can calculate possible level changes as requested in the filed flight plan.

5.3.8 Conclusions Regarding Flight Crew Procedures

The above evidence shows that the Safety Requirements allocated to Flight Crew Procedures have been addressed in the RVSM Concept and mitigations have been provided for the four described hazards.

5.4 Flight Crew Training

5.4.1 Safety Requirements

The Safety Requirements applicable to Flight Crew Training and are intended to ensure that suitable provision is made for training in:

(i) Operations in Transition Airspace, including the mitigation of the hazards of late handover on entry to, and exiting at the incorrect level, from RVSM airspace - (Safety Requirement **FC2**);

(ii) Operations in RVSM Airspace, including mitigation of the hazards of loss of visual perspective and deviation from cleared flight level - (**FC6**);

(iii) Aircraft Contingencies, including the handling of on-board emergencies and loss of R/T communications - (**FC8**);

(iv) Revised Flight Planning arrangements - (**FC5**).

5.4.2 Approach

The Flight Crew Training safety requirements will be satisfied by the material promulgated by ICAO, the JAA and EUROCONTROL.

The arguments and evidence, which show that the Flight Crew Training safety requirements have been met in the RVSM Concept, are summarised in **Figure A-7 of Appendix A** and are explained in the following sub-paragraphs.

5.4.3 Provision and Validation of Training

The initial guidance on the additional training necessary for Flight Crews for operations in any RVSM Airspace was provided in the ICAO Doc 9574 – Guidance Material on the Implementation of RVSM **[6]** and**[2]**. This material was then incorporated into the ICAO Doc 002 – NAT RVSM Guidance Material **[8]** and has been validated through the successful use of the RVSM procedures over three years of application in the NAT Region.

The requirement to institute additional Flight Crew procedures for operations in EUR RVSM airspace is notified in ICAO Doc. 7030/4 Regional Supplementary Procedures (Amendment 200 dated 12 December 2000) **[7]** – European EUR Supps - Part 1- Rules of the Air, Air Traffic Services and Search and Rescue.

The responsibility for ensuring that Flight Crews are made aware of these procedures is placed upon the Operator through the requirement “that any operating procedures specific to a particular Region, in this case the EUR Region, be stated in the Operations Manual or appropriate Crew Guidance”. This requirement is expanded in JAA Temporary Guidance Leaflet No.6 Appendix 4 – Training and Operating Practices and Procedures **[11].**

The ultimate responsibility for ensuring that Flight Crews have received the necessary training in RVSM Procedures rests with the State that issues the RVSM Approval to the particular Operator. The Operational Approval aspect, as described in Sub-Paragraph 5.3.4 above, of the RVSM Approval requires that the approving State is satisfied that the Flight Crew are aware of the RVSM Operating Procedures. The procedures include

- RVSM Operations (satisfying **FC2** and **FC6**);
- Contingency Procedures (satisfying **FC5**);
- Flight Planning Procedures (satisfying **FC8**).

Additionally Flight Crew training should include relevant aspects of ACAS operation in RVSM airspace, and how wake vortex turbulence and mountain wave effects will affect RVSM operations.

5.4.4 Material for Flight Crew Training

To assist in the provision of training for Flight Crews, the EUROCONTROL Agency has provided awareness material and guidance on the contents of RVSM Flight Crew training in the form of training packages and information CD-ROMs. This material has been spread widely through airspace user organisations and aircraft operators to the pilot community to ensure that pilots are aware of RVSM specific aspects of flight deck procedures. In addition a Flight Operations Awareness Video [50] will be released on 10 August 2001. The video addresses the various issues relating to flight operations in RVSM airspace including flight crew procedures and training.

5.4.5 Backing Evidence

The above Flight Crew Training evidence is considered to be trustworthy on the basis that the Guidance on the training provided in ICAO Doc 9574 **[2]** ICAO Doc 002 **[8],** JAA TGL No. 6 **[10]** and publised by the Agency, has been validated through the successful use of the RVSM procedures over three years of application in the NAT Region.

5.4.6 Mitigation of Hazards and Risks

Six hazards, identified in the FHA, are shown in **Table H-3 of Appendix H** as being relevant to Flight Crew Training. (See also Sub – Para 5.3.8 (Above) – Mitigation of Hazards and Risks relating to Flight Crew Procedures). The probability of occurrence of all of the six hazards will be minimised through training in, and adherence to, the appropriate Flight Crew RVSM Procedures described in JAA TGL No. 6 **[10]** and in ICAO Document 7030/4 **[7]**, supported by the the application of the ATC Procedures set out in the ATC RVSM Manual **[25]**. Additional comments are provided under the headings of the last four hazards.

<u>H_T1.9 – Aircraft exiting at a non-existing CVSM level</u>

<u>H_T3.5 – Late hand-over of aircraft from non-RVSM airspace</u>

<u>H_M2.2 – ‘W’ indicated in the flight plan or the pilot claims aircraft as RVSM approved despite this is not the case</u>

The probability of occurrence of this hazard will also be reduced through spot checks on the integrity of the use of “W” in the Flight Plan, and by pilot-awareness training courses, focusing on the importance of correct notification of RVSM-approval status.

Additionally, Pilot Training in the RVSM Procedures **[7]** and **[10]** governing the notification of changes to the aircraft RVSM approval status, as discussed in sub-paragraph 5.3.7 above, is necessary..

H_M1.6 – The pilot will miss the visual perspective of other traffic from the flight deck and will deviate from cleared level/track

Though no special RVSM mitigation is identified for this hazard, general information and awareness of the consequences of the implementation of RVSM on the visual perception of the proximity of aircraft at 1000ft vertical separation, together with accumulated pilot experience of flying in a 1000ft environment below FL 290 and progressively in RVSM airspace, is expected to keep the risk within tolerable limits.

H_M1.8 - Pilot is deviating from clearance (‘Level Bust’)

As noted in sub-paragraph 5.3.7 above, the FHA did not identify a specific RVSM mitigation to reduce the severity or probability of the hazard. However the Flight Crew Training specified above, together with the Pilot Guidance and Awareness Material (due to be issued in August 2001) by the EUR RVSM Programme (Sub-Para 6.10 and Appendix J also refer): and the additional emphasis placed on adherence to CFL that the ongoing Studies of Operational Errors (detailed in Appendix M) provides; can be expected to reduce this hazard and ensure that the occurrence of level busts are at least as manageable in RVSM airspace as in the current 1000ft environment below FL290.

H_M1.15 –Air RX/TX unserviceable

To obtain an RVSM Approval, Flight Crews must receive training in RVSM Communication Failures and Contingency Procedures which are addressed in the Flight Crew Procedures and in the ATC Procedures specified above. These application of these procedures will minimise any risk resulting from this hazard.

5.4.7 Conclusions Regarding Flight Crew Training

Training in Flight Crew Procedures has been identified as the primary means of meeting the allocated Safety Requirements and of providing the necessary mitigation of all six hazards. Additional supporting means have been detailed against the individual hazards.

5.5 Aircraft Equipment

5.5.1 Safety Requirement

The safety of RVSM operations is critically dependent on the height keeping performance of the RVSM approved aircraft. As detailed in the Report of ICAO RGCSP/6 **[5],** ICAO agreed that the maximum tolerable level of risk caused by technical errors in aircraft height keeping in an RVSM environment should be defined by a technical Target Level of Safety (TLS), of 2.5×10^{-9} fatal accidents per aircraft flight hour. In order to meet this technical TLS, ICAO defined the RVSM "Global System Performance Specification" (GSPS). This GSPS sets limits to the parameter values associated with aircraft height keeping performance and horizontal overlap (related to frequency of aircraft pairs being separated only vertically). From this specification the "global height keeping performance requirement" was derived. This in turn was the basis of specification of the aircraft equipment necessary to achieve the required technical height keeping performance for RVSM operations. The equipment requirements were expressed as the RVSM Minimum Aircraft System Performance Specification (MASPS). These MASPS define the aircraft systems, which need to be available and operational during flight in RVSM airspace.

Thus the safety requirements regarding Aircraft Equipment are that all aircraft, which are provided a 1000 ft vertical separation minimum in RVSM airspace, need to meet the RVSM MASPS and that the risk associated with the technical aircraft height keeping performance meets the technical TLS.

Meeting the RVSM MASPS is to be ensured through the State RVSM approval processes for which the requirements are set out in the ICAO EUR Regional Supplementary Procedures, Doc 7030 **[7].** Meeting the TLS is ensured through monitoring of height keeping performance and the other relevant aircraft and airspace parameters (see 5.9) and Collision Risk Assessment (**Appendix F**).

The derivation of the RVSM Global System Performance Specification (GSPS) and the MASPS, is described in ICAO Document 9536 - Report of the Sixth Meeting of Review of the General Concept of Separation Panel (RGCSP/6) **[5]**. The RVSM requirements are set out in ICAO Doc 9574 **[6]**. The RVSM MASPS, as basis for required aircraft modification and RVSM approval, are amplified in regionally developed material such as JAA Temporary Guidance Leaflet (TGL) No. 6 (Rev.1) **[11]**.

All of the above material, which was subsequently adopted by all Contracting ICAO Member States, provides evidence that the performance requirements are sufficient to meet the technical TLS, thereby addressing the formal safety requirements **AC1** and **AC2**. that are set out in **Table H1**, namely to;

(i) Reduce errors in aircraft technical height keeping performance sufficiently to meet the technical TLS of 2.5×10^{-9} fatal accidents per flight hour due to loss of correctly established vertical separation - (Safety Requirement **AC1**).

(ii) Ensure that, after the initial upgrading, aircraft technical height keeping performance will continue to meet the technical TLS - (**AC2**).

5.5.2 Approach

The Safety Requirements applicable to Aircraft Equipment will be satisfied by requiring aircraft (other than State aircraft), intending to operate in RVSM airspace, to:

(i) Comply with the performance requirements of the Minimum Aircraft Systems Performance Specification (MASPS) **[11].**

(ii) Comply with the on-going maintenance requirements which form part of the MASPS **[11].**

The arguments and evidence that show that the Aircraft Equipment safety requirements have been met in the RVSM Concept are summarised in Figure A 8 of Appendix A, and are explained in the following sub-paragraphs.

5.5.3 Design of the MASPS

Evidence that compliance with MASPS is sufficient to meet safety requirements AC1 and AC2 is provided in ICAO Document 9536 – Report of the Sixth Meeting of Review of the General Concept of Separation Panel (RGCSP/6) **[5].**

Requirements for the height-keeping performance of aircraft for use in an RVSM environment can be determined by using the Collision Risk Model in a reverse manner. This requires two basic pieces of information, namely the TLS and the frequency of passing events involving horizontal overlap of the aircraft. The latter expresses that the level of height-keeping performance necessary to meet the TLS is dependent on other airspace parameters affecting the risk of collision should vertical separation be lost. As described, the technical TLS for the implementation of RVSM is 2.5×10^{-9} fatal accidents per flight hour. The frequency of passing events involving horizontal overlap is a measure of the number of times that aircraft on adjacent flight levels at the planned vertical separation are in overlap in the horizontal plane. This parameter reflects traffic densities and patterns as well as navigation performance in the horizontal plane. The larger the value of frequency of passing events involving horizontal overlap, the greater the collision risk per flight hour.

In order to ensure that the required height keeping performance would ensure the safe operation of RVSM in any region it was necessary to choose a value for the frequency of passing events involving horizontal overlap that would be unlikely to be exceeded in any airspace for some time. Based on this assumed large frequency, the probability of vertical overlap that would exactly satisfy the TLS of $2.5\text{x}10^{-9}$ was derived to be $1.7\text{x}10^{-8}$. Subsequently, the MASPS was derived to ensure that this probability of overlap would not be exceeded. Thus, if the MASPS is satisfied, then the TLS of $2.5\text{x}10^{-9}$ will also be satisfied, providing that the frequency of horizontal overlap does not exceed that value assumed for the derivation of the MASPS.

This shows that MASPS-specified performance is adequate to meet the TLS and therefore that safety requirements **AC1** and **AC2** have been addressed satisfactorily in the conceptual design.

5.5.4 Monitoring MASPS Effectiveness and Collision Risk Assessment

In order to ensure the effectiveness of the RVSM MASPS and that the technical TLS is being met, and to reinforce the foregoing evidence on meeting the Aircraft Equipment safety requirements for aircraft height keeping performance (**AC1** and **AC2**), a height keeping performance monitoring programme has been established. This independent monitoring is a requirement derived from ICAO RVSM Guidance Material **[2]** and **[6].** The main objective of the monitoring programme is to confirm the effectiveness of the RVSM MASPS, and to provide evidence, through Collision Risk Modelling, that the risk associated with aircraft height keeping performance is within the technical TLS.

Additionally, the monitoring data is used to address any poor height keeping performance by aircraft declared MASPS compliant, in order to assess and remedy the causes. The process in place includes contacting operators and aircraft manufacturers, and is done in consultation with other regions where RVSM is in operation.

When a measured height deviation is excessive, indicating an aircraft to be out of the MASPS tolerances, immediate action is taken towards the relevant operator and State Authority in order to correct the situation as soon as practicable.

The above actions have been proven to be effective, and will gradually improve the overall height keeping performance of aircraft expected to operate in EUR RVSM airspace. This will have a positive effect on the risk associated with aircraft height keeping performance.

The monitoring programme and the results are further dealt with under 5.9.

5.5.5 Backing Evidence

Backing evidence relating to the validity of the Collision Risk Assessment is provided in paragraph 5.9 below.

5.5.6 Mitigation of Hazards and Risks

Two hazards, identified in the FHA, are shown in **Table H-3 of Appendix H** as being relevant to Aircraft Equipment:

H_M1.3 – System error – altitude deviation

The whole purpose of the MASPS requirements is to reduce the extent of the deviation and the frequency of occurrence of this hazard to a tolerable level. That level being defined by the ICAO TLS as described in Sub-Paragraph **2.1**

It should also be noted that the on-going Height-monitoring Programme will continue to assess the compliance with MASPS and the ICAO TLS after implementation of RVSM, as described in paragraph 5.9 below.

H_M1.14 – Change of approval status during flight (downgraded). Pilot will not be able to control level

This (severity class 2) hazard is caused by an aircraft equipment failure associated with height-keeping for an RVSM approved aircraft. Apart from MASPS compliance, no specific mitigation has been identified (by the FHA). However, the probability of occurrence has been estimated to be “extremely improbable” and so, according to the FHA methodology, the risk is considered to be tolerable.

It may not be realistic to consider that the failure of some part of the MASPS equipment of an aircraft is “extremely improbable”. But should such a failure occur, any risk arising would be greatly minimised through the use of

Contingency Procedures (5.6.2(v) below) which are part of both the Flight Crew and ATC RVSM Procedures referenced in Sub-Para 5.3.7 above). These require that should the Pilot be in any doubt as to his ability to maitain his assigned level accurately he should advise ATC. The Controller is then required to take action to ensure safe separation from other aircraft

5.5.7 Conclusions Regarding Aircraft Equipment

The effectiveness of MASPS in meeting the technical part of the TLS is fundamental to the safety case for RVSM. MASPS was devised entirely for this purpose and has been proven thus far in the NAT Region. Furthermore, CRM has shown that the adoption of MASPS for EUR RVSM will be adequate to meet the technical TLS in this Region also. Further assurance will be gained from the on-going System Monitoring Programme described in paragraph 5.9 below.

5.6 ATC Procedures

5.6.1 Safety Requirements

RVSM is a change to a fundamental ATC separation. Its application needs to be supported by the appropriate operational instructions and procedures which cover all possible scenarios encountered by controllers

The Safety Requirements applicable to ATC Procedures for RVSM are intended to ensure that the procedures cover the precise and clear description of the new vertical separation minimum, the criteria and requirements for its use, and enable the safe and expeditious flow of traffic throughout the EUR RVSM Airspace. The following procedures have been developed, validated, agreed and provided to ATC.

(i) Transition Procedures to allow for the safe transfer to/from the different flight levels prescribed at the interface of the RVSM and non–RVSM (feet and metric systems) airspace, including mitigation of specific hazards associated with entry to, and exit from, RVSM airspace - (Safety Requirement **ATC1**).

(ii) RVSM Operating Procedures, including mitigation of hazards associated with missing RVSM information, the use of mixed separation standards necessary for the handling of non-RVSM approved State aircraft operating both as GAT (General Air Traffic) and as Operational Air Traffic (OAT).and Inter centre co-ordination using both automated system support as well as direct verbal coordination and RTF phraseology (**ATC3**).

(iii) Clearance Procedures, including mitigation of hazards associated with aircraft immediately above or below RVSM airspace, and missing RVSM information - (**ATC8**).

(iv) Contingency Procedures including mitigation of hazards associated with aircraft on-board emergencies, severe turbulence and loss of R/;T communications - (**ATC5**).

5.6.2 Approach

The Safety Requirements applicable to ATC Procedures have been satisfied by procedures issued by EUROCONTROL in accordance with the following principles.

(i) New Vertical Separation Minimum

The New Vertical Separation Minimum to be applied by ATC, when spacing aircraft using a vertical separation, has been developed based on ICAO Annex 2 **[27].** It has been accepted by the Airspace and Navigation Team, formed the basis for the RVSM Programme Master Plan approved by Provisional Council, introduced as an amendment proposal to Regional Supplementary Procedures – Europe (Doc 7030/4) **[7]** and approved by the President of the ICAO Council in Dec 1999.

(ii) Criteria and requirements for use of RVSM

Applicable criteria for the application of RVSM have been approved by ICAO Council, promulgated in AICs and documented in detail in the ATC Manual **[25].** RVSM can only be applied between RVSM approved aircraft flying within the designated European RVSM airspace. ATC will refuse a clearance into RVSM airspace to non-RVSM approved except for State aircraft and aircraft entering the RVSM transition airspace. In such cases, the applicable VSM is 2000ft separation. ATC will apply the appropriate VSM based on the current flight plan. Flight Planning processing will have an initial checking and filtering function.

(iii) Handling of State aircraft

State aircraft i.e. aircraft used for military, customs and police, have been exempted from the requirement to be RVSM approved in order to fly in EUR RVSM airspace. This exemption has been notified in the ICAO DOC 7030/4 amendment for RVSM **[7].** Specimen text which set out the means of notification to ATC of State aircraft status has been has been provided to RVSM States for inclusion in National AIPs.

Based on this indication, ATC procedures have been developed for providing a 2000ft vertical separation minima between these aircraft (when flying as GAT) and all other aircraft. However State aircraft, when operating as OAT, will be considered as non-RVSM approved unless there is a specific co-ordination effected to the contrary. In addition all activities occurring within airspace restrictions and/or reservations are to be considered as being non-RVSM approved. The application of RVSM will continue to require that the same minimum vertical spacing be applied, to such activities and non-participating aircraft, as were being applied prior to RVSM implementation.

Real Time Simulations (see Appendix B) have demonstrated that the handling of non-RVSM approved State aircraft is feasible, but levels of 3% of such aircraft in a given sector would increase ATC workload and reduce the overall capacity of the sector, thus annulling the benefits expected from RVSM. This has resulted in a strong recommendation to military air forces to modify their transport fleets operating regularly above FL 285. There has been a positive response from a significant number of air forces and current studies indicate that the number of non-RVSM approved State aircraft will be approximately 1%.

Military Guidance for the Introduction of RVSM in Europe **[46]** was published in 2000 and amended in March 2001. A military workshop was organised in July 2000 to present the Guidance Document and to brief military representatives on the impact of RVSM on their operations.

(iv) Transition Procedures.

There are 2 different types of interface between the designated EUR RVSM airspace and adjacent airspace. The appropriate procedures for each are a pre-requisite for the safe operations in the airspaces adjoining. Where considered appropriate to simplify or facilitate transition, transition procedures can and should be supplemented by specific airspace design solutions.

The first interface addressed is between EUR RVSM and NAT. When RVSM starts in Europe, the current interface and transition procedures will be simplified. There are no generic procedures developed for this interface. However there is one significant operational procedure difference between the two adjacent RVSM regions. In the NAT, non-RVSM aircraft can climb through the level band FL 290-410. This is not permitted in EUR RVSM except in the transition airspace. In order to address this difference, FIRs currently in the NAT interface may designate airspace in which this transition is performed.

The predominant type of transition is between RVSM and non-RVSM Table of Cruising Flight Levels. In the interface between EUR RVSM and the airspace of the Russian Federation the transition involves an RVSM system based on 1000ft and a Russian Federation vertical separation minima based on a 500m VSM.

In this designated transition airspace

- ATC procedures have been developed to ensure that the minimum vertical separation is assured throughout. This separation will involve RVSM approved aircraft, State aircraft and non-RVSM approved civil aircraft entering RVSM airspace for the purpose of transition to non-RVSM airspace.
- The criteria for establishing the exact point of applicability of the two flight level systems have been detailed.
- ATC procedures have been established to also ensure that non-RVSM approved aircraft (except State aircraft) are cleared above or below RVSM airspace before the transfer of control point to the adjacent ACC.

In the Russian metric interface transition, two possible scenarios were developed, simulated and offered to the interface states. An Eastern Interface Working Group had five meetings to ensure that all the administrations which would be involved in LoA discussions had a clear understanding of the two scenarios.

(v) Contingency Procedures

In the EUR RVSM context, contingency procedures refer to a set of unforeseen circumstances that directly impact on the ability of a single aircraft, or group of aircraft, to operate as RVSM approved aircraft. Events addressed relate to:

- Degradation of aircraft equipment associated with height keeping;
- Occurrence of weather phenomenon resulting in turbulent conditions which directly affect the ability to maintain their cleared flight levels.

ATC procedures, which ensure that the reversion to 2000ft minimum separation as soon as the pilot informs ATC of equipment degradation to below RVSM MASPS compliance levels, have been developed. ATC will also manually update the radar display RVSM indication and coordinate the updated RVSM status to the next ACC.

Specific actions to be taken are directly related to the actual weather circumstances and traffic situation existing at the time. Guidance is provided for ATC in cases when there is no advance warning of impending met conditions that could create severe turbulence in area of responsibility. This Guidance forms part of the ATC Training Briefing Material for RVSM. **[36]**

(vi) Co-ordination Procedures

With the implementation of RVSM, a clear indication as to an aircraft's non-RVSM approval status and its request for special handling will be included as an integral part of the estimate message. The ATC Manual provides the exact intercenter coordination phraseology for verbal estimates. When the On Line Data Interchange (OLDI) system is used, the non-RVSM approval status will be transitted as an integral part of the automated estimate message. The EUROCONTROL OLDI Standard has been updated in Dec 2000 to support this requirement.

States have been asked to consider the requirement for stipulating increased pre-notification time parameters for the passing of estimate messages of non-RVSM approved aircraft intending to operate within RVSM airspace. ACCs are also invited to consider stipulating precise co-ordination procedures relating to RVSM within their LoAs with those ACCs which do not receive flight plan information from IFPS so as to ensure that the individual RVSM approval status of each individual aircraft is accurately communicated.

(vii) Phraseology

Specific Controller-Pilot RTF phraseology to cover indication of RVSM Approval status, denial of clearance into RVSM airspace, loss of RVSM capability due weather equipment and other related aspects have been developed, agreed and published in Doc 7030/4 **[7]** as well as in the ATC Manual **[25]** as well as ATC and Pilot Training Briefing material.

The arguments and evidence that show that the ATC Procedures safety requirements have been met in the RVSM Concept are summarised in **Figure A-9 of Appendix A**, and are explained in the following sub-paragraphs.

5.6.3 Provision of ATC Procedures

The ATC Procedures for use in the EUR RVSM Airspace are provided in the EUROCONTROL Manual for a Reduced Vertical Separation Minimum (RVSM) in Europe (Section 5), Edition 1, Amended 1 February 2001 **[25].** The procedures are as follows:

(i) Transition Procedures;

(ii) RVSM Operating Procedures;

(iii) Contingency Procedures;

(iv) Clearance Procedure;

(v) RTF Phraseology;

(vi) RCF Procedures.

The implementation of RVSM has implications with regard to air-ground communication failure procedures. The ICAO Regional Supplementary Procedures for Europe (Doc 7030/4) require that the applicable vertical separation minimum between an aircraft experiencing a communication failure in flight and any other aircraft, where both aircraft are operating within EUR RVSM airspace, shall be 2000ft (600m) unless an appropriate horizontal separation minimum exists.

In December 2000, the EANPG endorsed a proposal for the amendment of the ICAO Regional Supplementary Procedures for Europe with regard to air-ground communication failure. The proposed procedures are intended for application <u>throughout</u> the European Region, including EUR RVSM airspace (between FL 290 and FL 410 inclusive). The proposal for an IFR flight experiencing communication failure in IMC is to reduce from 20 mins to a period of 7 minutes the requirement to maintain the last assigned speed and level or the minimum flight altitude, if the minimum flight altitude is higher than the last assigned level. The appropriate procedures are included in Section 7 of the ATC RVSM Manual **[25],**

The need for the reduction in this period is particularly relevant where non-RVSM airspace is located adjacent to EUR RVSM airspace to ensure that the necessary air traffic control and co-ordination measures can be put in place. The establishment and location of compulsory reporting points, such as RVSM entry and exit points, may be strategically located to enhance ATC's ability to detect air-ground communication failures on a timely basis. The choice of 7 mins emerged from the RVSM simulation in Riga, which trialed both a 5 min and 10 min options. The proposal is subject to the ICAO processes and once approved will be promulgated in ICAO Doc 7030/4, the proposed revision has been incorporated within the RVSM ATC Manual Amendment 1.

An additional proposal to utilise additional SSR codes to provide further indicators of the pilot's intentions during radio communication failure was rejected by the ORCAM Users Group (OUG). The OUG, in light of the existing shortage of codes, had decided to formulate a position which opposed the use of SSR codes for communication failure purposes. The OUG further concluded that reserving such codes for the purposes described, was a "wasteful" procedure since the codes would require total EUR Region wide reservation, and this was for use only on rare occasions. In considering this position the Airspace and Navigation Team (ANT) agreed <u>not</u> to pursue the procedure whereby the pilot should convey his intent to ATC through the selection of prescribed Mode 3/A codes when experiencing communication failure.

5.6.4 Backing Evidence

The above ATC Procedures evidence is considered to be trustworthy on the basis that the correctness and safety of the ATC Procedures has been independently validated by means and staff independent of the procedure design work. Evidence to support this argument is provided in sub-paragraph 5.2.4 and 5.2.6 above, that relate to the Real Time Simulations of airspace design and procedures set out in **Appendix B**.

5.6.5 Mitigation of Hazards and Risks

Seventeen hazards, identified in the FHA, are shown in **Table H-3 of Appendix H** as being relevant to ATC Procedures:

<u>H_T1.1 – Non-RVSM approved aircraft adjusted to CVSM FL too early</u>

Procedures for the transitioning of non RVSM approved civil aircraft are set out at Sub-Paragraph 5.5 of the ATC RVSM Manual **[25].** The Guidance Material to States **[47]** cross refers to the ATC Manual and places a requirement on States that local instructions be in place for carrying out level changes for non-RVSM approved aircraft.

During the RVSM Simulations (Appendix B) Controllers were briefed that transition must take place within RVSM airspace, however, it was noted that following co-ordination with adjacent units, or if specified as part of L of A, that some flights were transitioned early when traffic conditions permitted.

<u>H_T1.2 – Non-RVSM approved aircraft given RVSM separation in transition airspace (application of two VSMs in the same airspace)</u>

The probability of occurrence of the hazard will be reduced in part by local instructions (to be produced by the States) anticipating and covering the problem – see also mitigation of the same hazard by modification to ATC equipment covered in sub-paragraph 5.8.8 below.

<u>H_T1.5 – Inability to provide longitudinal separation for RVSM-approved aircraft entering CVSM (congestion)</u>

The RVSM Programme, the CFMU and those Transition States that are not part of the IFPS region, have to developed contingency plans that will be introduced when it is not possible to achieve efficiently the required longitudinal separation into non-RVSM airspace.

<u>H_T1.8– Two aircraft at same level in opposite directions</u>

There are three possible causes for this hazard: the pilot fails to follow the FPL after a Comms failure; the pilot fails to execute correct clearance; or the ATCO gives the wrong clearance.

The use of offsets (where possible), and the freezing of FLs 310,350 and 390 for specified distance in Transition areas, will partially mitigate the hazard.

H_T1.9 – Aircraft exiting at a non-existing CVSM level

This hazard is valid for the area around Tunis where the routes are eastbound.

The probability of occurrence of the hazard will be reduced first, by Pilot Training and Awareness Material (provided under local arrangements) and second, by adherence to ATC **[25]** and Flight Crew Procedures **[11]** which will ensure that the Controller issues, and the Pilot accepts, clearances to valid CVSM flight levels. Effective co-ordination between the States will provide further support.

H_T2.2 – ATCO fails to perform conversion to metric CIS system

The principle of the conversion to/from Feet/Metric levels is already well established at the relevant boundaries. The probability of occurrence of this hazard, after RVSM is implemented, will be reduced by the adherence to the ATC RVSM Procedures which are designed to ensure that the controller performs the correct conversion.

Furthermore, the introduction of uni-directional routes will remove the hazard where they are agreed.

H_T3.5 – Late hand-over of aircraft from non-RVSM airspace

The probability of occurrence of this hazard will be reduced by the use of compulsory reporting points (i.e. the pilots are obliged to report passing the points). ATC Procedures also require controllers to prompt the pilots for reporting.

H_T3.6 – Congestion at FL280 and below

A study of the possibility of congestion at Flight Levels below RVSM airspace, due to the number of non-RVSM approved aircraft, is detailed at **[35]**. The study concludes at Sub-paragraph 5 – “In the worst case a 10% increase in the number of flights could be experienced by some sectors at peak periods. However, informed estimates suggest that this figure will be considerably less”.

The effect of this hazard will be reduced in part by the use flow management to prevent congestion.

H_M1.10 – RVSM Operations have to be suspended

This hazard can be caused by severe turbulence due to CB activity, Clear Air Turbulence (CAT) or Mountain Waves **(5.12)**.

The risk resulting from this hazard will be mitigated by adherence to the ATC Procedures enabling the ACC/UAC to suspend RVSM if appropriate – either within a specific level band or a specific area, as detailed in DOC 7030/4, 14.3.4 **[7]**. The Air Traffic Flow Management (ATFM) shall assist in reducing traffic and a SIGMET is expected to be issued.

H_M1.13 – Aircraft status has to be downgraded to Non-RVSM approved

This hazard may be caused by aircraft equipment failure or adverse weather.

The first exercise of RVSM Simulation SO8 **[17]** demonstrated that adherence to ATC Procedures in the ATC RVSM Manual [25] would mitigate any risk arising from this hazard. During the simulation individual aircraft declared that they were **"Unable RVSM due Equipment".** Each sector was given 1 aircraft with such a condition to handle. The majority of controllers correctly descended the aircraft below FL290 and the ATC Contingency Procedures for the change from RVSM to CVSM to RVSM were handled with few comments. Based on the recommendations of the Simulation, States were required to introduce such means as necessary to identify the Non-RVSM status of the affected aircraft.

$\underline{H_M2.1}$ – Aircraft with degraded RVSM status has to be accepted into RVSM airspace

This hazard may be caused by aircraft equipment failure before entry into RVSM sector.

Only in extremely rare circumstances e.g. emergency, will an aircraft with degraded RVSM status be allowed into RVSM airspace. On such occasions the effect of the hazard will be reduced by special ATC co-ordination procedures.

$\underline{H_M2.4}$ – Flight plan totally missing

There is no reason to believe that the introduction of RVSM will influence the. probability of occurrence of this hazard or that existing Flight Crew and ATC Procedures cannot resolve consequent difficulties. The heightened emphasis which RVSM has given to the adherence to Flight Crew and ATC Procedures, in particular the requirement for the Controller to obtain the necessary flight data including RVSM Approval status, will further mitigate any risk from this hazard. Unless the RVSM Status of an Aircraft (excluding non State aircraft) is not known then the aircraft will not be allowed into RVSM airspace.

$\underline{H_M2.5}$ – Potential loss of separation due to wrong application of separation standard for OAT and GAT

The probability of occurrence of this hazard will be reduced by a number of means, detailed in the ATC RVSM Manual **[25],** to highlight the presence of non-RVSM approved aircraft in the RVSM airspace, e.g. special Flight Planning Procedures, Inter-Centre Co-ordination Procedures and Communication and Phraseology Procedures in Section 5, with Radar Display Systems and Flight Strips (Paper and Electronic) addressed in Section 8..

$\underline{H_M1.9}$ – Aircraft unexpectedly encounters turbulence that affects RVSM operation

This hazard can be caused by CB activity, Clear Air Turbulence (CAT) or Mountain Waves **(5.12)**.

The effect of this hazard will be reduced by ATC Procedures enabling ACC/UAC to suspend RVSM if appropriate – either within a specific level band or a specific area, as detailed in DOC 7030/4, 14.3.4 **[7]**. The Air Traffic Flow Management (ATFM) shall assist in reduced future traffic and a SIGMET is expected to be issued.

H_M1.15 –Air RX/TX unserviceable

Contingency Procedures, which include Communication Failures, are addressed in the ATC RVSM Manual [25]. Furthermore to obtain an RVSM Approval, Flight Crews must receive training in RVSM Procedures which include Communication Failures.The application of these procedures will minimise any risk resulting from this hazard.

H_M2.17 – ATCO issued incorrect clearance to non-RVSM approved aircraft

The effect of this hazard is minimised by ATC RVSM Procedures covering the use of special R/T phraseology and special co-ordination procedures for non-RVSM approved aircraft.

H_M2.7 – RVSM status of aircraft operating immediately above and below RVSM airspace not known to ATCO

ATC RVSM Procedures include the use of radar labels for ascertaining the status of RVSM approval of aircraft operating immediately above and below RVSM airspace. Unless the RVSM Status of an Aircraft (excluding non State aircraft) is not known then the aircraft will not be allowed into RVSM airspace.

Specific co-ordination procedures will have to be developed by the States to cover situations in which the DFL is at FL295, in order to reduce the probability of occurrence of this hazard.

H_M2.9 – Changes to or missing RVSM approval status

The probability of occurrence of this hazard is reduced by ATC Procedures governing insertion into the system. Unless the RVSM Status of an Aircraft (excluding non State aircraft) is not known then the aircraft will not be allowed into RVSM airspace.

5.6.6 Conclusions Regarding ATC Procedures

The above evidence shows that the safety requirements allocated to ATC Procedures have been addressed in the RVSM Concept and mitigations have been provided for all of the 17 related hazards.

5.7 ATC Training

5.7.1 Safety Requirements

Controllers will have to apply new operating procedures appropriate to RVSM operations. The changes need to be introduced and explained to all controllers involved through a comprehensive training programme which covers all related aspects and prepares controllers to the new environment.

The safety requirements applicable to ATC Training are intended to provide assurance that appropriate training packages have been developed and that those responsible for the training have been properly briefed on the content of the training package:

(i) Transition Procedures, including mitigation of associated hazards - (Safety Requirement **ATC2**).

(ii) RVSM Operations, including mitigation of associated hazards - (**ATC6**).

(iii) Contingency Procedures, including mitigation of associated hazards - (**ATC7**).

(iv) Clearance Procedures, including mitigation of associated hazards - (**ATC9**).

5.7.2 Approach

The EUROCONTROL Air Traffic Control Training Package for the Introduction of RVSM within the European RVSM Area has been designed to support National ATC trainers in the design and conduct of National RVSM Implementation training programmes.

The Training Package provides guidance on the RVSM training requirements for Air Traffic Controllers at a national level, looking at different methods of conducting training, discusses the training methodology employed and lessons learnt from North Atlantic RVSM implementation.

The training package is based on the ATC Manual for RVSM in Europe **[25]** and includes RVSM General ATC Procedures, Procedures for State Aircraft, Flight Planning Contingency Procedures, Inter-Centre Co-ordination, Transition procedures and Phraseology. The Training Package thus is fully compliant with the commonly agreed operating procedures enabled through D0C. 7030/4 Regional Supplementary Procedures – Amendment No.100 **[7]**.

The training package enables National ATC trainers to understand the RVSM operational procedures, RVSM phraseology, airspace structure and the ATS system modifications needed for RVSM operations. It also provides them with an awareness of the historical development of RVSM in ICAO, the procedure for aircraft certification, height keeping monitoring requirements, flight planning elements and the safety case content. It provides both for RVSM in transition areas as well as non-transition areas to be used as appropriate.

The Safety Requirements applicable to ATC Training have been satisfied by procedures issued by EUROCONTROL. Delivery of the training is the responsibility of the individual States.

The arguments and evidence, which show that the ATC Training safety requirements have been met in the RVSM Concept, are summarised **in Figure A-10 of Appendix A** and are explained in the following sub-paragraphs.

5.7.3 Provision of Training

Five Briefing Sessions were organised by the RVSM Programme between Nov 1999 and Jan 2000. The sessions were attended by the RVSM Trainers from the Participating States except for Tunisia (joined EUR RVSM Programme later but provided subsequently with Training Package) and Ukraine. A separate briefing session was organised for Ukraine in February 2001. States were provided with the EUROCONTROL ATC Training Package (see **[36]** and **Appendix J** for Training Syllabus).

Each session included presentations on

- RVSM Concept;
- Detailed RVSM procedures and phraseology;
- An overview of the training package;
- Customisation of the training material; and
- Experience from NAT RVSM training.

A training workshop was provided for military planning staffs, aircrew and controllers together with military guidance material in July 2000. This workshop focussed on the implications of the implementation of RVSM for military operators.

A further Trainers Workshop, organised by the RVSM Programme, is scheduled for May 2001. The aim is to brief National ATC Training Experts on:

- the progress of the EUROCONTROL RVSM Programme;
- recent developments that will affect ATC training, trainers and co-ordinators;
- the latest changes that have been made to ICAO Doc 7030/4 and by means of Amendment List 1 to the RVSM ATC Manual;
- recent ATM developments of direct relevance to RVSM including Wake Vortex, ACAS/TCAS and State Aircraft.

The above material forms part of the Guidance Material provided to the Participating States as described in **Appendix J**.

The provision of training of ATC Personnel in the above RVSM procedures is the responsibility of the individual ATS Provider States in accordance with the provisos of ICAO Annex 2 - Rules of the Air **[27].**

5.7.4 Backing Evidence

The above ATC Training evidence is considered to be trustworthy on the basis that:

(i) The Training was based on experience and the lessons gained from the real-time Simulations described in **Appendix B**.

(ii) The ATC training material in respect of the specified procedures was developed by, or through, the APDSG and RNDSG Sub-Groups of the EUROCONTROL Air Navigation Team, comprised of experts in ATC and Navigation from the Member States.

5.7.5 Mitigation of Hazards and Risks

Training for ATC staff in the procedures identified in paragraph 5.6 above will be provided in order to achieve the required reduction in the effect and/or probability of occurrence of the following hazards.

(i) H_T1.1 – Non-RVSM approved aircraft adjusted to CVSM FL too early;

(ii) H_T1.2 – Non-RVSM approved aircraft given RVSM separation in transition airspace (application of two VSMs in the same airspace);

(iii) H_T1.5 – Inability to provide longitudinal separation for RVSM-approved aircraft entering CVSM (congestion);

(iv) H_T1.9 – Aircraft exiting at a non-existing CVSM level;

(v) H_T2.2 – ATCO fails to perform conversion to metric CIS system;

(vi) H_T3.5 – Late hand-over of aircraft from non-RVSM airspace;

(vii) H_M2.4 – Flight plan totally missing;

(viii) H_M2.5 – Potential loss of separation due to wrong application of separation standard for OAT and GAT;

(ix) H_M1.9 – Aircraft unexpectedly encounters turbulence that affects RVSM operation;

(x) H_M1.15 –Air RX/TX unserviceable;

(xi) H_M2.17 – ATCO issued incorrect clearance to non-RVSM approved aircraft;

(xii) H_M2.7 – RVSM status of aircraft operating immediately above and below RVSM airspace not known to ATCO;

(xiii) H_M2.9 – Changes to or missing RVSM approval status.

(xiv) H_M1.13 – Aircraft status has to be downgraded to Non-RVSM approved

(xv) H_M2.1 – Aircraft with degraded RVSM status has to be accepted into RVSM airspace

(xvi) H_T1.8– Two aircraft at same level in opposite directions

(xvii) H_M1.10 – RVSM Operations have to be suspended

5.7.6 Conclusions Regarding ATC Training

Training for ATC staff has been identified as required to meet the allocated safety requirements and enable the necessary mitigation of all 17 hazards. The attendance of controllers at the major simulations has been found to be a valuable adjunct to the training programme.

5.8 ATC Equipment

5.8.1 Requirements

ATC have to provide a 1000ft or 2000ft vertical separation minimum depending on the RVSM approval status of the aircraft concerned. The incidence of non-RVSM approved aircraft flying in RVSM airspace is expected to be minimal, consisting only of State aircraft (throughout the RVSM area) and non-RVSM approved aircraft (within the first transition ACC).

However the fact that there is a need to apply different separation criteria introduces a risk factor. Consequently there is a clear requirement, and this was raised by controllers during real time simulations, for an unambiguous, reliable, and continued indication to Controllers of the RVSM status of all aircraft operating in, or planning to enter, RVSM airspace.

ATC equipment, modified to provide this additional support to Controllers, will help to ensure that the correct separation minima is applied, that controller workload is reduced and that risks are mitigated and safety enhanced.

Thus the key safety requirement, applicable to ATC equipment, is to provide Controllers with a distinguishable feature that identifies the non-RVSM approved status of aircraft when flying in the RVSM airspace as reported in the current flight plan. This gives rise to the following specific safety requirements that are intended to:

(i) Provide indication, to Controllers and to other ATC systems and Centres, of the RVSM-approval status of aircraft in operating RVSM and Transition airspace, so the aircraft can be correctly separated and (internally and externally) co-ordinated (**ATC10.1**, **10.3**, **10.4** and **10.5**);

(ii) Provide indication, to Controllers, of the RVSM-approval status of aircraft operating immediately above and below RVSM airspace (**ATC10.2**).

(iii) Ensure that all back-up ATC equipment is compatible with RVSM (**ATC10.6**).

(iv) Ensure that, where provided, ATC 'alerting' systems (eg STCA and MTCD) meet the requirements specified in sub-paragraph 8.7 of the ATC Manual for RVSM in Europe [25] in that they will respond correctly to aircraft in RVSM, Transition and non-RVSM airspace, according to the separation and RVSM-approval status of the aircraft concerned (Safety Requirement **ATC4**);

(v) Display the requested flight level (RFL) on Flight Progress Strips and inter-system OLDI messages (**ATC11**).

5.8.2 Approach

The ATC Equipment safety requirements will be satisfied by modifications to:

(i) The vertical-separation parameters of STCA, MTCD where these systems are provided;

(ii) CFMU IFPS;

(iii) National RDPS and Radar Display equipment;

(iv) National FDPS and Flight-Strips (Paper or Electronic);

(v) OLDI.

The arguments and evidence, which show that the ATC Equipment safety requirements have been met in the RVSM Concept, are explained in the following sub-paragraphs and are summarised in **Figure A-11 of Appendix A**.

5.8.3 Vertical Separation Parameter Changes – STCA and MTCD

It is a fundamental aspect of RVSM policy that the application of RVSM should meet the agreed safety objectives without Short-term Conflict Alert (STCA) and Medium-term Conflict Detection (MTCD) systems, and that the presence of STCA/MTCD should be considered as an additional ‘safety net’ to prevent actual collisions in case the ‘system’ fails.

Where an ACC/UAC has an STCA/MTCD system, that system must meet the requirements specified in the sub-paragraph 8.7 of the ATC Manual for RVSM in Europe **[25]**:

Short -Term Conflict Alert

The parameters for current STCA systems must be modified for the proper operation of this supplementary safety net available in some ACCs. This will prevent excessive nuisance alerts and severe operational disruptions. The modifications should allow STCA systems to selectively apply a 1000ft or 2000ft vertical separation minima as determined by the current approval status of the aircraft concerned when operating in RVSM airspace.

Where STCA systems cannot selectively assess the appropriate separation VSM of either 1000ft or 2000ft for flights, then the norm of 1000ft separation shall be applied. This choice of 1000ft VSM ensures that the appropriate VSM separation is applied to approved RVSM aircraft which will form the overwhelming number of flights in an encounter where at least one non-RVSM approved aircraft was involved, where 1000ft VSM was applied by the STCA system, then the alert generated would still assist in the prevention of collision in keeping with the safety net concept.

Medium Term Conflict Detection

MTCD systems, where available, provide an important planning tool for controllers. The selective application of a 1000ft or 2000ft vertical separation minima, as determined by the current approval status of the aircraft concerned when operating in RVSM airspace, is thus a required modification to current system operational characteristics which has to be introduced for RVSM operations.

The application of the above, and modification to other alerting systems, by the States will therefore ensure that safety requirements **ATC4** is satisfied.

5.8.4 IFPS - Identification of RVSM-Approved Aircraft

The RVSM Programme and the CFMU agreed the technical specifications for IFPS modifications relating to RVSM and these were incorporated in the IFPS Version 7.0 software release implemented on 31 March 2001. As a result of the specified modifications IFPS:

- will reject those flight plans, filed within the IFPS zone that do not qualify for operation within the RVSM airspace on the basis of information filed,
- will suitably annotate those flight plans filed outside the IFPS Zone that do not qualify for operation within the RVSM airspace on the basis of information filed,
- will ensure the timely and accurate distribution of the relevant RVSM associated flight plan information

In order to monitor the number of flights by RVSM approved aircraft, and to validate the IFPS output to aircraft operators based on the flight plan information received, three phases of operational evaluation of IFPS Version 7.0 software will be completed before RVSM implementation.

The third phase of the operational evaluation is planned to begin on 5 October 2001 and at this stage the IFPS will insert warning messages applicable to all flight planning requirements for RVSM, as appropriate, in the acknowledgement message. This evaluation will essentially reflect the output of IFPS as of 24 January 2002 onwards and will therefore serve as a final check for IFPS processing with respect to flight plans intending to operate in the EUR RVSM airspace.

Successful completion of the operational evaluation will therefore ensure that safety requirement **ATC10.3** has been satisfied.

5.8.5 Radar Data Processing and Display

The main tool to assist controllers in providing the correct separation minimum is the modification to the radar data processing and radar display systems of the ACCs controlling RVSM airspace, The Radar Display will provide a clear indication of the current “non-RVSM approved” aircraft status operating in this airspace.

The operational specifications for this functionality including the conditions for possible derogation with respect to the automatic application of this distinguishing feature are detailed in the ATC Manual **[25]** –Section 8.3. The key requirements are:

(i) In a radar environment, the radar position symbols and/or radar labels associated with aircraft operating within the EUR RVSM Airspace shall provide a clear indication of the current non-RVSM approval status;

(ii) Where radar is used as the primary tool for providing separation, the radar position symbols and/or radar tools should provide a clear indication of the current non-RVSM approval status of aircraft operating within such level bands above and below the EUR RVSM Airspace, as defined by the local ATS provider;

(iii) The means by which the distinguishing feature is applied to the radar position symbols and/or radar labels of the aircraft concerned shall be automatic;

(iv) The possibility for the manual manipulation of the radar position symbols and/or radar labels of aircraft shall be available.

Note: The integrity of the display and use of RVSM status is enhanced by the requirement for IFPS to reject any FPL, for operations in RVSM airspace, which does not include a “W” in field 10.

Successful completion of the above will therefore ensure that those parts of safety requirement **ATC10.1** allocated to RDPS/Radar Display Systems, and all of safety requirement **ATC10.2**, have been satisfied.

5.8.6 Flight Progress Strips

Local Flight Data Processing Systems will provide appropriate indications on the flight progress strips of “non-RVSM approved” aircraft and State aircraft. In addition, the local ACC level FDPS and/or procedures have to provide the same functionality as regards checking of flight plans, annotation and distribution of details when the ACC is not part of the IFPS Zone.

When these functionalities are not achieved by automatic data processing, manual evaluation and insertion procedures need to be in place.

5.8.7 OLDI Messages

When On Line Data Interchange is available between ACCs forwarding of RVSM related information, such as the current RVSM approval status, information on State aircraft and requests for special handling will reinforce the correctness of flight plan data, mitigate in the case of flight plan unavailability and address information exchange in the case of degradation of RVSM capability of an aircraft in flight. The OLDI standard as amended in **[39]** includes the RVSM related specifications.

The operational requirements applicable to automated OLDI messages are set out in the ATC Manual **[25]** –Section 8.5.

5.8.8 Back-up Equipment

The safety requirements placed on many ATC systems assume the existence of a Back-up system to be used in the event of failure of the Primary system. Wherever a Primary system has been (or is to be) modified to accommodate RVSM it is essential that the equivalent Back-up system is also modified in order to maintain its effectiveness. The necessary changes are detailed in the ATC RVSM Manual **[25]** and the requirement to complete these changes is placed upon States in Chapter 4 of the Guidance Material provided to States **[47]**.

5.8.9 Backing Evidence

The above ATC Equipment evidence is considered to be trustworthy on the basis that the equipment changes described:

(i) Meet the recommendations made on ATS System modifications at RVSM3 (see **Appendix B**).

(ii) Have been used in all real time simulations after RVSM3 (see **Appendix B**). In each case, the simulation conclusions confirmed that the availability of these RVSM features facilitated controllers’ task in RVSM approval status awareness, assisted the planner and executive controller, improved co-ordination of this information and generally was a significant risk mitigation against the wrong application of the correct vertical separation minima between aircraft irrespective of their approval status. The recommendations of the Simulations (**Appendix B)** were used in the development of the ATC RVSM Manual **[25]** and the Guidance Material provided to States **[47].** The extent to which the findings have been implemented by States is the responsibility of the particular State. In three instances however, the findings related to specific States which have acknowledged the recommendations in writing.

5.8.10 Mitigation of Hazards and Risks

Eleven hazards, identified in the FHA, are shown in **Table H-3 of Appendix H** as being relevant to ATC Equipment:

H_M2.6 – STCA functionality not able to discriminate between RVSM approved aircraft and non-RVSM approved aircraft

Modification to the vertical-separation parameters of STCA (where provided) described in sub-paragraph 5.8.3 above will reduce the probability of occurrence of this hazard to a tolerable level.

H_M2.5 – Potential loss of separation due to wrong application of separation standard for OAT and GAT

The modifications to the radar display and flight progress strips, described in sub-paragraphs 5.8.5 and 5.8.6 above will in part provide the necessary reduction in the probability of occurrence of this hazard.

H_M2.17 – ATCO issued incorrect clearance to non-RVSM approved aircraft

The modifications to the radar display and flight progress strips, described in sub-paragraphs 5.8.5 and 5.8.6 above will also in part provide the necessary reduction in the probability of occurrence of this hazard.

H_T1.2 – Non-RVSM approved aircraft given RVSM separation in transition airspace (application of two VSMs in the same airspace)

The modifications to the radar display and flight progress strips, described in sub-paragraphs 5.8.5 and 5.8.6 above will also in part provide the necessary reduction in the probability of occurrence of this hazard.

H_M2.7 – RVSM status of aircraft operating immediately above and below RVSM airspace not known to ATCO

The modifications to the radar display, described in sub-paragraph 5.8.5 above will also in part provide the necessary reduction in the probability of occurrence of this hazard.

H_M2.8 – Missing IFPS checks of FPLs coming from states inside RVSM

The modifications to the IFPS, described in sub-paragraph 5.8.4 above will provide the necessary reduction in the probability of occurrence of this hazard.

H_M2.13 – RVSM status has to be transmitted manually to succeeding unit, if information is missing on flight plans

ATS system requirements allow for taking into account manual input in case of missing or changed flight plans.

H_M2.10 – ATC systems are not able to exchange OLDI messages containing data about RVSM approval status

The ATC RVSM Manual [25] places a requirement on States to modify equipment for RVSM operations. The modifications to the OLDI-based systems, described in sub-paragraph 5.8.7 above will also provide the necessary reduction in the probability of occurrence of this hazard. In the event of any failure in the OLDI system to exchange messages it will be necessary to revert to existing back-up communications systems.The indication of RVSM Status (Letter W in Field18) is not expected to increase demand on the OLDI system capacity.

H_M2.11 – ATC systems are not able to internally distribute data about RVSM approval status

It is a requirement on the States to identify and modify local systems to support data exchange of RVSM information in order to remove this hazard. See mitigation detailed at H_M2**.**10 above.

H_T1.9 – Aircraft exiting at a non-existing CVSM level

It is a requirement on the States to identify and modify local systems to ensure that the flight progress strips and OLDI messages contain the RFL, in order to reduce the probability of occurrence of this hazard.

H_M2.27 – Computer Failures

The failure of ATC Computers is not specifically related to the introduction of RVSM and no requirement for additional facilities has been generated by the RVSM Programme. Existing ATS equipment, including any backup facilities, must be modified as described in Section 8 of the ATC RVSM Manual **[25]**. A requirement to implement these changes has been placed upon States in Section 4 of the Guidance Material to States **[47]**.

5.8.11 Conclusions Regarding ATC Equipment

The ATC equipment operational features specified for RVSM operations satisfy the safety requirements allocated to ATC equipment, including the necessary mitigation of all 11 risks identified in the FHA.

5.9 System Monitoring

5.9.1 Requirements

The safety requirements applicable to System Monitoring are intended to ensure that:

(i) The achieved and on-going Technical Height Keeping Error of MASPS-approved aircraft meets MASPS requirements - (Safety Requirement **SM1**);

(ii) Data on operational errors is collected and analysed to demonstrate that the size and frequency of occurrence of Operational Errors is sufficiently low to enable the non technical portion of the TLS to be met - (**SM2**);

(iii) Data on the Horizontal Overlap Frequency is obtained in order to validate the values for the relevant parameters used in the CRM - (**SM3**);

(iv) Support measures are provided to exclude non-MASPS approved aircraft from RVSM airspace – including mitigation of the hazard of a non-MASPS aircraft (incorrectly) indicating RVSM approval status - (**SM4**).

(v) ACAS/TCAS TAs and RAs in RVSM airspace are monitored - (**SM5**).

5.9.2 Approach

The safety requirements applicable to System Monitoring are satisfied by:

(i) Measurement of Technical Height-keeping Error, including monitoring for non-compliance by aircraft claiming MASPS approval, as part of the Height-Monitoring programme;

(ii) Analysis of Altitude Deviation Reports (ADRs) to obtain operational error rates;

(iii) Determination of Aircraft Horizontal Overlap Frequency as part of the Height-Monitoring programme;

(iv) Maintenance of a EUROCONTROL database of aircraft RVSM approvals;

(v) Use of the CRM to relate height-keeping performance and operational error rate to the appropriate parts of the TLS;

(vi) Assessment of data obtained from the ACAS programme.

The arguments and evidence, which show that the System Monitoring safety requirements have been met in the RVSM Concept are summarised in **Figures A-12 and A-13 of Appendix A**, and are explained in the following sub-paragraphs.

5.9.3 Measurement of Technical Height-keeping Error

For EUR RVSM, the measurement of height keeping performance of aircraft intended for operation in EUR RVSM airspace, was performed by a height monitoring infrastructure developed on the basis of ICAO requirements and NAT RVSM experience.

The height monitoring took place in order to:

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

In the context of EUR RVSM, ICAO has agreed that EUROCONTROL acts as Regional Monitoring Agency (RMA). The responsibilities of an RMA in the context of RVSM are set out in ICAO Doc 9574 **[2]**, which have been covered in the EUR RVSM Programme. The approach and requirements for EUR RVSM monitoring are described in the EUR RVSM Monitoring Policy **[40]**.

The EUR RVSM height monitoring infrastructure consists of three new ground based Height Monitoring Units (HMUs), 25 portable GPS Monitoring Units (GMUs), post-processing equipment, and is managed from a Monitoring Cell (MC) based at the EUROCONTROL Experimental Centre (EEC) in Bretigny, France. Height keeping data is also obtained from the Regional Monitoring Agencies (RMAs) of other regions where RVSM is implemented.

Further details of the EUR RVSM Monitoring Infrastructure, its design principles and operation can be found in **Appendix E**.

The height monitoring results are stored in the monitoring data base and checked against the requirements for a valid measurement. The correlation and validation techniques are described in **Appendix E**.

The validated height keeping data is used:

i) as input in the Collision Risk Assessment (CRA), see **Appendix F**;
ii) to assess the MASPS effectiveness of aircraft and aircraft types **(Appendix E)** ; and
iii) to provide follow-up as required in case a measurement shows poor height keeping performance, in order to assess and remedy the causes.

In order for the CRA to be based on a sufficiently representative sample of EUR RVSM air traffic, monitoring targets have been set which are outlined in the EUR RVSM Monitoring Policy **[40]** and **Appendix E**. The ongoing a monitoring programme is aimed at meeting the monitoring targets by 31 August 2001. Other elements of the use of the height keeping data in the CRA is described in **Appendix F**.

Conclusions concerning the height monitoring system are summarised in paragraph 5.9.11 and detailed in **Appendix E.**

The follow-up process, referred to at Sub –paragraph (iii) above, to determine the cause of height deviations of 300 feet or more and to initiate remedial measures, is conducted through consultation and co-operation with State Authorities, Operators and Aircraft Manufacturers, and with other regions where RVSM is in operation. This type of follow-up action has already been proven to be effective in the NAT Region, and is expected to improve the overall height keeping performance of aircraft that operate in EUR RVSM airspace.

5.9.4 Analysis of Altitude Deviation Reports (ADRs)

The RVSM Programme commenced its collection of operational data on 1 April 2000. National Programme Managers were provided with an Assigned Altitude Deviation (AAD) Report Form together with guidance for its completion. These forms were distributed in turn to ACCs for their subsequent action. Each state set up a national data collection process to ensure that reports were forwarded to the RVSM Programme. A full description of the ADR collection and analysis is given in **Appendix M**.

The AAD reports once categorised are provided for the CRA. The data used in the current CRA presented herein pertained to the period April 2000 – October 2000, as detailed in **Appendix F**. In subsequent updates of the Safety Case, the remaining ADRs as detailed in **Appendices M** and **F** and will also be assessed for their contribution to the collision risk.

5.9.5 Measurement of Aircraft Horizontal Overlap Frequency

The HMU system is primarily designed to collect data on height-keeping performance. However, since each height-keeping measurement is accompanied by horizontal position information, the data can also be used to provide estimates of the horizontal overlap frequency. The horizontal overlap frequency is a measure of the rate at which aircraft flying at the vertical separation minimum pass directly overhead of each other. The required data has been calculated automatically by each of the European HMUs.

The required date relates to the number of proximity events observed in the HMU regions. A proximity event is defined as occurring between two aircraft on adjacent flight levels when their separation in the horizontal plane is less than a pre-defined distance. The horizontal overlap frequency is estimated from the number of proximate events, taking into account the geometry of each event, and the total number of flight hours observed in the region.

The relationship between horizontal overlap frequency and the risk of collision is referred to further in **Appendix F**, and explained in full detail in **[34]**.

5.9.6 Monitoring of Aircraft RVSM Approvals

Data on MASPS approval is obtained from three sources:

(i) the Airworthiness Authority of the State of registration;

(ii) the Airworthiness Authority of the State in which the Operator is based;

(iii) the Operator.

The data is held in the RVSM database which is maintained by the AMN User Support Cell (USC). This data is used for cross-checking against the CFMU flight plan data. A W in the flight plan indicates that the aircraft/operator has been approved for RVSM by the responsible State Authority. Operators whom filed W in the flight plan, who according to the RVSM approval data base had not yet been approved by their State Airworthiness Authority are then contacted to determine the reason for claiming RVSM approval. This cross-checking of data and follow-up activities towards aircraft operators and State Authorities (see also para **5.3.7**) will ensure that the chances of a non-approved aircraft being admitted into RVSM airspace is minimised.

5.9.7 Collision Risk Modelling

The collision risk model used in the assessment process is detailed fully in the European Mathematical Supplement **[34]**. It has been developed by the Mathematics Drafting Group (MDG), a group which reports through its parent body the Navigation Sub-Group to the EUROCONTROL Airspace and Navigation Team.

The mathematical model has essentially two components. One is the horizontal overlap frequency, as described in 5.9.5. The other component is the probability of aircraft that are nominally separated by the vertical separation minimum actually being, for reasons of error, at the same altitude.

This is termed the probability of vertical overlap. The data used to estimate the probability of vertical overlap are the measurements of the technical height keeping error and the analysis of ADRs as detailed in 5.9.3 and 5.9.4.

The product of these two components results in the estimate of collision risk in the vertical dimension. The collision risk assessment process is detailed in **Appendix F**. The full derivation of the model itself can be found in **[34]**.

5.9.8 Monitoring of ACAS/TCAS Equipage and Alerting Rates in RVSM Airspace

As stated in Sub-Paragraph 4.8.2 and detailed in Sub-Paragraph 5.12.2, one of the two “non-tolerable” risks identified by the FHA Process related to RAs and TAs issued by un-modified ACAS/TCAS equipment (Version 6.04a) in RVSM airspace. The equipage rate for ACAS/TCAS is closely monitored by the EUROCONTROL ACAS Programme in the context of the ACAS mandatory carriage time scales and associated exemptions, and data is made available to the EUR RVSM Programme as required.

The operations of ACAS in European airspace is also closely monitored in the context of the activities of the ACAS Programme to assess actual ACAS performance, including its performance in RVSM airspace. This comprises the rate of ACAS alerts, their effectiveness and consequences. The results are applied to identify the possibility for (operational and technical) improvements, and are shared with the EUR RVSM Programme as required.

Additionally, the Altitude Deviation Reporting (ADR) process, which has been set up to collect data for the calculation of operational risk (see **Appendix M**), will continue to provide information on altitude deviations, including those related to ACAS resolution advisories.

The equipage rate to date does not provide an indication that the number of flights operating TCAS V6.04a in RVSM airspace will be more than the flights made by aircraft not mandated to carry ACAS (for TCAS V6.04a relation, see para 5.12.2)

5.9.9 Backing Evidence

The above System Monitoring evidence is considered to be trustworthy on the basis that:

(i) The operation of the height-monitoring facilities has been validated. 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. Further evidence to support this argument is provided in **Appendix E**.

(ii) The original CRM, and the results therefrom, have been validated by successful application of the CRM to operations in the NAT Region. Evidence to support this argument comes from the use of the CRM to monitor the levels of Lateral collision risk in the NAT Minimum Navigation Performance Specification (MNPS) airspace since 1979. The same model, with only minor adjustments, has been employed to monitor vertical collision risk in the NAT RVSM airspace since 1997.

(iii) The adaptation of the NAT CRM for use in EUR RVSM airspace has been validated. Evidence to support this argument is as follows.

The CRA was based on a mathematical model derived under the auspices of ICAO and adapted for application to a European environment. The adaptation accounts for the prevalence of aircraft flying on crossing tracks within European airspace.

The validation of the mathematical correctness of the adapted model was performed by a peer review of mathematicians from a number of ECAC member states, as outlined in **Appendix F**. The process of applying the model to the analysis of data has also been subject to peer review by the same group of mathematicians.

Validation of the software used in the collision risk estimation has been performed in two ways. First, by inputting data of known behaviour and assessing whether the results of the software are in line with that behaviour. Second, the results have been compared with those produced from independently produced software by UK NATS.

Validating the results of the collision risk assessment against empirical data is not feasible: fortunately collisions are rare events and so do not occur at a rate that would make this possible. The method of validation rests on assessing how well the modelling reflects observable events, such as deviation from flight level, and estimating the probability that such deviations would result in collisions, based on other, measurable, system parameters such as traffic density.

(iv) The CRM scenarios and assumptions are representative of the operational conditions that will be encountered in the proposed European RVSM airspace. Evidence to support this argument is provided by the satisfaction of safety requirement **SM3** as described in sub-paragraph 5.9.5 above.

(v) CRA Staff Competence. Evidence of the competence of the staff who carried out the CRA process is provided in **Appendix F**.

5.9.10 Mitigation of Hazards and Risks

Two hazards, identified in the FHA, are shown in Table H-3 of Appendix H as being relevant to System Monitoring:

$\underline{H_M}$<u>2.2 – ‘W’ in indicated in the flight plan or the pilot claims aircraft as RVSM approved despite this is not the case</u>

The probability of occurrence of this hazard will be reduced in part by the maintenance of RVSM-approval records and monitoring of non-approved aircraft in RVSM airspace, as described in sub-paragraphs 5.9.6 and 5.9.7 above.

$\underline{H_M}$<u>1.1 - Aircraft with MTOW < 15.000kg or <30 pax might not be carrying ACAS V7.0</u>

The probability that the proportion of aircraft, not mandated to carry ACAS V7.0 but operating TCAS V6.04a in RVSM airspace (see 5.12.2 for detailed description of this issue) is higher than expected, is reduced by the monitoring of ACAS equipage rates by the ACAS Programme, as described in 5.9.8. The proportion of V6.04a flights in RVSM will be further reduced by awareness activities highlighting operational issues the flight crew of V6.04a aircraft will be faced with when operating in RVSM.

5.9.11 Conclusions Regarding System Monitoring

Monitoring of height-keeping performance, operational error rates, the presence of non-RVSM aircraft in RVSM airspace, and ACAS/TCAS equipage and rate of TAs and RAs form important input to the RVSM Programme. The monitoring provisions described above will meet all the safety requirements allocated to them, including the necessary mitigation of risks identified in the FHA.

Regarding the height keeping performance monitoring and monitoring of risk due to operational errors, the following conclusion can currently be drawn (see also **Appendices E** and **F**):

Achievement of Monitoring Targets

The Monitoring Policy **[40]** requires that pre-implementation monitoring can be terminated when 90% of the flights in EUR RVSM airspace are made by operator/types that have met their monitoring targets. Using the initial monitoring targets, the assessments detailed in **Appendix E** show that during the period January to June 2001, An estimated 89% of flights in EUR airspace above FL280 are made by operator/types that have met their monitoring targets.

MASPS Verification

Performance regarding entire aircraft population: Taking into account all (validated) measurements to date applicable to aircraft expected to operate in EUR RVSM airspace, it can be concluded that the height keeping performance for the aircraft population as a whole is within the Global Height Keeping Performance Specification which has been set by ICAO as the basis for the RVSM MASPS **[2]**, **[6]**, **[11]**.

'Group' Performance regarding Aircraft Monitoring Classifications (See Appendix E7): Performance requirements have been specified by ICAO **[2]**, **[6]**, **[11]**, saying which aircraft need to meet as a 'group' and also as the basis for the RVSM MASPS. The Groups have been considered in terms of Monitoring Classifications. Out of a total of 95 aircraft monitoring classifications, 70 have been shown to meet these performance requirements, 12 have shown not to meet these requirements (A124, BA46-AVRO, C560, DC8, E135, E145, F200, FA50, H25B-800-1, H25C-1, IL76, IL86). Work is ongoing vis-à-vis operators and manufacturers to identify and remedy the causes. For the remaining 13 classifications there is not yet sufficient data available.

Individual aircraft performance: Out of the total of 6912 airframes, which have been monitored by July 2001, 2 non-compliant measurements have been recorded in the context of EUR RVSM monitoring. They have been acted upon through official notifications to operators and State Authorities. Scrutiny and consultation with operators is ongoing regarding aircraft which have been measured to perform within MASPS compliance limits, but which show a performance below average.

Technical Vertical Risk

The vertical risk due to technical height-keeping performance estimated to pertain in European RVSM airspace is thus estimated to be 2.00x10-10 , compared with the TLS of $2.5x10^{-9}$.

It must be noted that a small number of aircraft are demonstrating Altimetry System Errors (ASE) which exceed the to limits set in the MASPS. At present the number of measurements involved are not sufficient to come to final conclusions. From the data presently available it seems that, whilst the individual measurements show compliance with the MASPS, the ensemble of nominally identical aircraft to which these aircraft belong are not going to meet the ‘aircraft group’ requirements. This issue is being brought to the attention of the manufacturers.

Total Vertical Risk

The total vertical risk is the sum of the risks due to atypical performance (e.g. operational errors) and the risk due to technical vertical height-keeping performance. It.is estimated to be 1.02x10-9 ,compared with the TLS of 5x10-9 fatal accidents per flight hour.

Appendix F has dealt with the estimation of the risk of collision, based on the currently observed data. However, it must be noted that the assessment has been based on the following assumptions:

(i) The risk of collision in an RVSM environment with TCAS will be lower than the risk of collision without TCAS.

(ii) The frequency and magnitude of operational errors will not be affected by RVSM implementation.

(iii) The frequency and magnitude of operational errors is independent of the proximity of other aircraft.

(iv) The type of operational errors observed in the set of 5 States used for the present analysis is representative of Europe as a whole.

(v) The set of reports for the 5 States used in the present analysis is complete. That is, there is no under-reporting. Based on the current risk estimates, it would appear that if the level of under-reporting is greater than 80% (ie only 1 out of every 5 atypical altitude deviations is reported) then the current level of risk may be in excess of the overall TLS of 5x10-9 fatal accidents per flight hour.

(vi) That the implementation of RVSM will not affect the frequency of horizontal overlap.

(vii) The lack of data on atypical (greater than 300ft) deviations from the HMU system is not sufficient to invalidate the current risk estimates.

System Monitoring will be ongoing, providing increasing confidence of the conclusions regarding RVSM system safety and update results will be presented in due time. Regarding the height monitoring, the shortfall in monitoring data is primarily caused by late aircraft MASPS compliance. Appropriate action by aircraft operators is required to meet the monitoring targets within the remaining time scales.

Post-Implementation monitoring will provide confirmation of the conclusions which were derived from pre-implementation data and expectations.

5.10 Safety Constraints

5.10.1 Approach

It is argued that the constraint placed on RVSM, in meeting its safety objectives, shall not restrict the capacity objectives of ATM 2000+. This can be shown to have been satisfied by demonstrating that:

(i) The CRM work, by which compliance with the TLS is demonstrated, was based initially on 2001 traffic levels;

(ii) Increases in traffic levels commensurate with ATM 2000+ will not significantly degrade RVSM safety.

5.10.2 CRM Traffic Assumptions

For the current collision risk assessment 2001 traffic levels were assumed. This was done so that the effect of RVSM of the level of risk could be assessed independently of traffic growth. The effect of traffic growth on the level of collision risk is dealt with in **Appendix F**.

5.11 Traceability of Safety Requirements to RVSM Concept

Table H-3 (columns 3 and 4), supplemented by the text above, provides traceability from the RVSM safety requirements to the corresponding aspect of the RVSM Concept, and shows that each safety requirement has been addressed.

5.12 Residual Risks

This paragraph expands on specific risks that were highlighted by the FHA. The first two being assessed as “non-tolerable”. Each topic has been the subject of a detailed study to determine how the forseen risk could be mitigated.

5.12.1 “Level Busts”

The risk of Level Bust (see 5.3.7) has been assessed as “not tolerable”, according to the FHA, and may arise from a number of causes. It could be a human error (e.g. a misreading of clearance, incorrect level input into the Flight Management System (FMS) in the flight deck or call-sign confusion).

However, this hazard can only occur if already implemented mitigation factors fail. That is, normal procedures to prevent level busts include cross-check between pilots to ensure that the correct settings are made for altimeters and autopilot input. When an error is made resulting in a climb or descent through the cleared flight level the air traffic controller can only react after the aircraft is shown to have gone through the cleared level.

During the FHA, no RVSM specific mitigations were identified, although it was noted that this hazard currently exists in today's environment below FL290 and one of the basic assumptions of this document (Appendix N – Assumption No 1) is that operations throughout the CVSM airspace are tolerably safe.

Level busts have been recognised as aviation hazards by a number of States and activities have been initiated by those States to reduce their occurrence (identifying causes and finding remedies, providing awareness and training material). Although these activities are not RVSM specific, they are also expected to be beneficial for the safety of RVSM. In this respect, in the RVSM Guidance Material Material to States [47], the Flight Crew Procedures in JAA TGL No 6 [11] and ICAO Doc. 7030/4 [7], and in the Flight Crew Awareness Video [50] , Flight Crew are urged to be exercise the greatest care and vigilance to prevent level busts.

A relevant proportion of reported level busts are caused by over- or under-shooting when levelling off at the assigned flight level. These events often involve older aircraft (types) which will not be approved for operation in RVSM airspace and which do not have an automatic capture (acquisition) feature. Therefore, with those aircraft excluded from RVSM airspace, this category of level busts is expected to reduce.

Given the above, mitigations against level busts are assumed to be sufficient to ensure that their occurrence are at least as manageable in the RVSM airspace as in the current 1000ft environment below FL290.

It should be noted that the risk that level busts represent are included in the Collision Risk Assessment (see **Appendix F** and **Appendix M**).

5.12.2 ACAS/TCAS Nuisance Alerts

Key Aspects

A detailed review of the issue of ACAS in RVSM Airspace is discussed in **Appendix L**.

ACAS is currently generally accepted as a tool which enhances safety, and all available evidence (study reports, etc) supports the risk reducing effect of ACAS, both in the 1000 ft environment below FL290 and the 2000ft environment above FL290. ACAS thereby provides an effective safety net, which prevents actual collisions in case the 'system' fails.

It is shown through ACAS Programme assessments **[53],** that in an RVSM environment ACAS II still provides an equally effective safety net, considerably reducing the risk of collision compared to the situation without ACAS.

Any manoeuvre based on ACAS Resolution Advisories (RAs), is based on the vicinity of any other (third party) aircraft and is co-ordinated accordingly. Therefore, when adhered to by the pilot, these manoeuvres do not induce a risk, but are actually taking place in the context of collision avoidance, reducing the potential for a collision. It is important to note that this is also the case when the manoeuvre is based on a 'nuisance' RA.

Although any ACAS manoeuvre takes into account any (third party) aircraft, and thereby will not cause any increase in risk regarding those other aircraft, it is recognised that (nuisance) ACAS events may constitute a risk, e.g. in particular situations which result from pilots not following the ACAS RA. This has been identified in the FHA in relation to additional ATC workload. However, this risk is far outweighed by the ACAS safety benefits **[53]**.

Because ACAS is considered an additional safety net, it is a fundamental aspect of RVSM policy that the application of RVSM should meet the agreed safety objectives without taking advantage of the risk reducing effect of ACAS.

Therefore given the safety benefit that ACAS provides, the actual risk of collision in RVSM airspace (including the ACAS benefit) will be lower than the risk calculated in the RVSM risk assessment (without the ACAS benefit). On this basis the ACAS events have not been taken into account in the CRA uinless they are caused by genuine operational errors (see Appendix M).

The EUR ACAS implementation programme requires that all aircraft with a MTOW of 15000kg or more than 30 passenger seats carry ACAS II (i.e. TCAS V7.0) when operating in EUR airspace. Aircraft which are not required to carry ACAS, may carry TCAS V6.04a. TCAS V6.04a, in contrast to TCAS V7.0, is not operationally compatible with RVSM operations, as it's logic is based on a 2000ft VSM above FL290. This may cause crew operating a TCAS V6.04a aircraft in RVSM airspace to experience a higher rate of nuisance TA's and RA's.

Regarding the operation of TCAS V6.04a in RVSM airspace, the ACASA study **[37]** has shown that with up to 10% of flights, the overall nuisance alert rate is similar to a full V7.0 environment. The actual number of TCAS V6.04a equipped flights in RVSM airspace, based on information regarding the aircraft types and operators expected to operate in RVSM airspace, is estimated to be lower than 3%. As the crew of an TCAS V6.04a equipped aircraft operating in RVSM airspace may experience a higher number of nuisance TA's and RA's, awareness activities include the strong recommendation to upgrade to V7.0 when operating in RVSM. In this context two aspects are important to note:

(i) The experience obtained with the early introduction of RVSM operations since 19 April 2001 in the United Kingdom, Germany and Austria, has not indicated the presence of any issue regarding V6.04a equipped in flights operating under RVSM conditions.

(ii) Regarding the general impact on risk of 6.04a equipped flights in RVSM airspace, the ACAS logic regarding third party aircraft (see above) also applies in the case of 'nuisance' alerts by V6.04a. I.e. a manoeuvre based on TCAS V6.04a RA's is not risk increasing, given the implicit co-ordination of the manoeuvre with aircraft in the vicinity.

Further Approach

In order to make ATC and Flight Crews aware of all aspects associated with the operation of ACAS, including its operation in RVSM airspace ACAS Workshops are being organised across Europe to take place in the period April 2001 - November 2001. This is expected to support the operational acceptability of ACAS aspects and further increase ACAS effectiveness, also in an RVSM environment.

Actions have been initiated in ICAO and in several States to reduce the occurrence of ACAS nuisance alerts, by addressing the main cause: high rates of climb and high rates of descent shortly before reaching the cleared flight level. Aircraft Operators and pilots are recommended to reduce a high rate of climb/descent when approaching the cleared level. This advice is further emphasised through awareness activities by the RVSM and ACAS Programmes (including the above mentioned Workshops), and is expected to reduce the rate of nuisance alerts, both in RVSM and non-RVSM airspace.

Regarding the impact on ATC workload by ACAS nuisance alerts in RVSM airspace, information is provided above indicating that any workload increase compared to operations in the band FL245-285, especially regarding TCAS V6.04a, will be minimal and workable. Therefore the impact of any potential workload increase on safety is expected to be minimal. The indicated actions regarding reducing the cause of nuisance alerts and making pilots and controllers more aware of ACAS operational aspects, are expected to further reduce the safety impact of nuisance alerts.

Further, the above issue needs to seen in the light of the overall risk reducing effect of ACAS and the ATC workload reducing effect of RVSM implementation. Therefore, it is considered that the above approach provides a sufficient mitigation regarding safety implications of ACAS nuisance alerts in RVSM airspace. In case the amount of flights operating TCAS V6.04a in RVSM airspace is significantly higher than expected, the increased impact of nuisance alerts on ATC workload and safety may need to be re-assessed.

It should be noted that in the context of the EUR ACAS Programme, the performance of ACAS II in EUR airspace is monitored on an ongoing basis in order to confirm the outcome of above mentioned studies and identify any possible improvements, either technically or operationally. The operation of ACAS in those European airspaces where an early application of RVSM is in use, is already providing useful information on the operation of ACAS in a full EUR RVSM environment (see above).

Summary of Main Points

1) Operation of ACAS V6.04a in RVSM airspace will provide a safety benefit.

2) Manoeuvres by ACAS V6.04a aircraft based on Nuisance Alerts will not be risk increasing

3) There will be an increase in the number of Nuisance Alerts experienced by ACAS V6.04a equipped aircraft.

4) Nuisance Alerts will create some increased ATC workload. Experience gained from the early implementation (April 2001) of RVSM in Austria, Germany and UK indicate that this is not an issue.

5) Less than 3% of the RVSM aircraft population are expected to be equipped with V6.04a.

6) Awareness activities by the ACAS and RVSM Programmes are expected to reduce the number of Nuisance Alerts.

5.12.3 Wake Vortices

The issue of wake vortices in RVSM airspace is discussed in **Appendix K**.

Experience gained from the implementation of RVSM in the NAT Region indicated that the turbulence created by the Wake Vortex of aircraft operating at the same Flight Level/Track could present operating difficulties. In order to evaluate the extent and possible consequences of these difficulties, in the EUR RVSM Airspace, an independent study was commissioned by the EUROCONTROL Agency. Woodfield Aviation Research undertook the study in March 1998. The RVSM Programme accepted the recommendations (inter alia) of the Study (Appendix K refers) which concluded that:

- RVSM is not expected to increase the probability of a hazardous encounter with wake vortices, but pilots and air traffic should be informed that nuisance encounters would increase;

- Before the introduction of RVSM, an effective system should be established for reporting, collecting and analysing reports from pilots and air traffic of significant wake vortex encounters.

The RVSM Programme commenced the collection of wake vortex encounters in EUR RVSM airspace from 1 Aug 2000. There have been some further 20 reports to date. Woodfield Aviation Research are analysing these later reports in order to confirm that the conclusions of the earlier study are still valid.

This further study has still to be concluded but the indications are that the Report recommendations are valid with the additional reminder that as traffic increases within European airspace, wake vortex encounters are also likely to continue to increase.

5.12.4 Mountain Wave Effects

The RVSM Programme has been gathering safety related data as part of its safety case preparations. In particular, assigned altitude deviation reports have been collected since 1 April 2000. Additionally, there has been a specific independent study on wake vortices, detailed in para 5.12.3 and **Appendix K**.

The Altitude Deviation Report (ADR) Form is required to be completed by controllers when there has been an assigned altitude deviation of 300ft or more resulting from TCAS, turbulence, operational error (whether pilot or controller related) or any event which causes the aircraft to deviate from its cleared flight level. It does not apply, however, for circumstances where an aircraft has requested an alternate flight level for passenger comfort because of encountered turbulence. The wake vortex report form is specifically addressed at wake turbulence. The effects of mountain waves can be very similar and the report form requests why wake vortex was suspected as the cause of the incident.

It has been brought to the attention of the RVSM Programme that Alpine centres such as Marseille, Geneva, Rome, Zurich, Padova, Munich and Vienna can experience Mountain Wave phenomena during Autumn, Winter and Spring in which aircraft cannot maintain the assigned flight level. Earlier studies on mountain wave effect prior to the RVSM Programme had failed to produce any conclusive evidence that there was a safety issue in Europe. Nevertheless, a reminder was distributed to Aircraft Operators to include any encounters with mountain wave on the wake vortex report form. However, since the collection of information programme began there have been no specific reports of a departure from a CFL as a result of mountain wave effects either in an altitude deviation report or a wake vortex report. Further, the safety manager of one of these States has since indicated that mountain wave effect is not regarded by them as a safety critical issue.

In the context of turbulence and mountain wave effects, there is specific phraseology provided in the Flight Crew Information Notice for pilots to indicate severe turbulence or other weather related phenomena and an inability to maintain RVSM operations. There is also guidance within the ATC manual on the procedures applicable for individual aircraft reporting severe turbulence, as well as procedures for multiple aircraft in adverse weather-related conditions.

In order to provide further information on Mountain Wave effects, GMU flight trials have been initiated that will concentrate on flight operations in the European Alpine region. Because of the rare occurrence of these effects, it is foreseen that through these ongoing measurements more data will become available. Detection of mountain wave effects was also a reason for siting one HMU in Geneva. However, this has proven non-conclusive as meteorological data for the upper airspace in the area was not reliable enough.

5.12.5 Operational Errors

Most of the hazards identified in the FHA are manifestations of human-induced operational errors. In recognition that the FHA process is heavily dependent on the (imperfect) estimation of the likely occurrence rate for such hazards, EUROCONTROL has instigated a programme to monitor the actual rate of occurrence (**See Appendix M**). The monitoring will continue well beyond the introduction of RVSM and the findings will be addressed in the Post-Implementation Safety Case.

5.13 Compliance of Concept with RVSM Safety Objectives

As discussed in paragraph 4.8 above, the key RVSM Safety Objectives are addressed by the RVSM safety requirements, as follows:

(i) The TLS technical height-keeping requirements are covered entirely by Aircraft Equipment safety requirement **AC1**;

(ii) The "operational" portion of the TLS – i.e. that part not governed by technical height-keeping performance - is covered entirely by system-level safety requirement **RVSM7**;

(iii) The overall level of risk of an accident or serious risk-bearing incident, due to loss of vertical separation, is covered entirely by system-level safety requirement **RVSM8**.

Satisfaction of the above three safety requirements would therefore ensure achievement of the Safety Objectives, as discussed in the following sub-paragraphs.

5.13.1 Technical Height-Keeping Requirements

In paragraph **5.5.3** above, it was shown that the probability of vertical overlap that would exactly satisfy the TLS of 2.5×10^{-9} was derived to be 1.7×10^{-8}, based on certain assumptions about the frequency of horizontal overlap. Subsequently, the MASPS was derived to ensure that this probability of vertical overlap would not be exceeded.. However in **Appendix F** the vertical overlap probability for the EUR RVSM airspace has been calculated as 2.22×10^{-8}. The reason for this is that a few individual group types are not achieving the height keeping performance required to satisfy the MASPS. However because the calculated horizontal overlap frequency is less than that assumed in the ICAO Global Height Keeping Specification, the resulting techical risk estimate is 2.00×10^{-10}, which satisfies the technical TLS of 2.5×10^{-9}.

To summarise:

(i) The observed height-keeping performance of the majority of RVSM-approved aircraft is within the MASPS requirements.

(ii) The observed height-keeping performance of a small number of aircraft types is not currently within the MASPS requirements.

(iii) The current estimate of vertical overlap probability does not satisfy the Global System Performance Specification requirement.

(iv) The level of technical vertical collision risk estimated for RVSM airspace is within the technical TLS.

Remedial action will be instigated regarding the small number of aircraft types which currently do not appear to meet the MASPS, as identifed in point (ii). Thus it is argued that the Technical Height-Keeping Safety Objective will be met in the RVSM Concept.

5.13.2 Operational-Risk Requirements

In paragraph 4.8.2 above, it was acknowledged that it was not practicable to link the individual risks identified in the FHA (post mitigation) directly to that operational-error part of the TLS - i.e. that part not covered by technical height-keeping performance.

However, it was argued that the total number and severity of those risks was broadly consistent with the TLS. Furthermore, the above discussion on the Concept has shown that:

(i) All the necessary risk-mitigation measures identified in the FHA have been incorporated in the Concept;

(ii) Analysis of Altitude Deviation Reports to date has shown that the recorded rate of operational errors results in a total risk estimate which is within the TLS (see sub-paragraph 5.9.4).

The operational-error monitoring must (and will) continue well beyond the Switch-Over to RVSM, in order to obtain sufficient data and to validate the analysis under actual RVSM conditions. However, it is reasonable to argue at this stage that the RVSM Concept is consistent with achievement with the operational Safety Objective.

5.13.3 Total Vertical Risk from RVSM

It can be seen from Table H3 that, with the exception of the Hazards $H_M1.3$ and $H_M1.4$ which relate to Aircraft Equipment (System Elements AC1 and AC2) and are bounded by the Technical TLS (2.5×10^{-9} fatal accidents per flight hour.); the consequences of all of the hazards, identified by the FHA and included the Table (H3), will be evidenced as Operational Errors. As such, and assuming the full co-operation and diligence of States, they should be reported to EUROCONTROL as Altitude Deviation Reports. The reports will be scrutinised and analysed and the quantified risk will be set against the Total Vertical TLS of 5×10^{-9} fatal accidents per flight hour (RVSM7) Additionally the on-going nature of the ADR Studies will indicate the causes of Operational Errors, establish error rates and trends, and enable remedial action to be taken to satisfy the Total Vertical TLS, minimise system risk to as low a level as is reasonably practical, and to avoid any increase in risk (RVSM8).

5.14 Conclusions on the RVSM Concept

It has been shown in this section that:

(i) For each of the eight elements of the RVSM system (Airspace Design, Flight Crew Procedures, Flight Crew Training, Aircraft Equipment, ATC Procedures, ATC Training, ATC Equipment, System Monitoring), the RVSM Concept fully satisfies the safety requirements set out in Section 4 above;

(ii) The Concept includes mitigation of the hazards identified in the FHA, and explicit safety requirements have been derived as a means of ensuring that the mitigations will be addressed in the RVSM Implementation;

(iii) The safety constraint on RVSM, relating to airspace capacity considered by the Collision Risk Assessment, has been satisfied in the Concept;

(iv) All the RVSM safety requirements, derived as described in section 4 herein, are traceable to the RVSM Concept;

(v) Although the FHA process deduced that the risks from Level Busts and ACAS/TCAS Nuisance Alerts are “not tolerable”, two points were relevant: neither risk is unique to RVSM Operations; and both risks are in being addressed in the context of the on-going monitoring of Operational Errors in the RVSM airspace. Additionally regarding Level Busts, ongoing activities by States, the issuing of (RVSM) awareness material by the RVSM Programme, and the emphasis given to the need for strict adherence to Flight Crew Procedures, are specifically aimed at reducing the occurrences of 'level busts', and as such can be considered appropriate mitigations. For ACAS nuisance alerts, primarily the comparability with the current environment in FL 245-295 and the low percentage of V6.04a flights in EUR RVSM airspace were seen as mitigating factors. On that basis, it was argued that the risks should be deemed as tolerable risks at this stage, subject to subsequently satisfactory results from the monitoring programme;

(vi) The inclusion in the Concept of on-going monitoring of key parameters – i.e. height-keeping performance (technical and operational), RVSM approval (including infringement of RVSM airspace), ACAS/TCAS alerts, and CRM input values – provides an important "safety net" for the above analysis and conclusions regarding the safety of the RVSM Concept (and, subsequently, its Implementation);

(vii) The results to date of the monitoring / collision-risk modelling programme show that it is likely that the two RVSM Safety Objectives concerning the TLS will be met. In this respect it should be noted that the assumptions on which these estimations were based need to be confirmed (see **Appendix F**), especially regarding (1) further monitoring of height keeping performance in order to meet the monitoring requirement set by the Monitoring Policy, and (2) consultation with aircraft operators and manufacturers regarding specific aircraft types;

(viii) Validation of the Safety Objective concerning the total vertical risk of an accident or serious risk bearing incident will be assessed through the Post Implementation Monitoring Programme.

6 IMPLEMENTATION OF THE RVSM CONCEPT

Objective

This section sets out the arguments and evidence that the Implementation of the RVSM Concept will satisfy fully the RVSM Safety Requirements.

The structure of the safety arguments and supporting evidence which address this objective is shown in **Figures A-15 and A-16 of Appendix A**.

6.1 Approach

6.1.1 Responsibilities of the States

States are ultimately responsible for the implementation of RVSM. To this end all participating States have prepared Safety Plans for the implementation of RVSM within their national airspace. These Safety Plans show in detail how the respective State responsibility is discharged, what activities it is undertaking to assure the quality of the changes it is making in order to implement RVSM, and how risks to aircraft are identified and managed.

Implementation of the RVSM Concept by the States is – *inter alia* - to be achieved by:

(i) The guidance provided by EUROCONTROL and ICAO for RVSM Implementation;

(ii) The production, by each State, of a specific, detailed Safety Plan to address the Guidance requirements;

(iii) Each State carrying out its own Hazard & Risk Analysis and incorporating the results as additional safety requirements in its Safety Plan;

(iv) Validation of each State's Safety Plan, against the Guidance requirements, by EUROCONTROL RVSM staff;

(v) Confirmation by each DGCA of the State readiness for the safe implementation of RVSM .

6.1.2 Responsibilities of EUROCONTROL

EUROCONTROL has four roles to play in the successful implementation of RVSM:

(i) To develop the RVSM concept within the context of the situation in the EUR region (see chapter 5 for details);

(ii) To provide guidance, co-ordination and support to the participating States and other parties in their preparation for the implementation of RVSM (chapter 5 describes and references this). This also includes the safety guidance provided to States and the development of the overall Safety Case for RVSM and, in particular, to demonstrate that the safety requirements identified in this Safety Case are traceable from Concept through to Implementation;

(iii) To successfully adapt the services provided by MUAC and CFMU for the implementation of RVSM. MUAC has been an active participant within the RVSM PMM, and has prepared a safety plan in line with the guidelines provided to the States. Information on the CFMU activities can be found in sub-paragraph 5.8.4;

(iv) To provide independent verification and validation of the implementation of RVSM, EUROCONTROL will monitor overall performance in terms of altitude deviations before and after implementation (both technical height keeping and actual operational error rates). In addition information of aircraft approval status will be obtained from States to provide verification of the RVSM approval status within the filed flight plans. Information on the actual number of RVSM approved aircraft, which is a key parameter in the go/delay decision process,will also be obtained.

6.1.3 Generation of National Safety Plans

The following process was established:

(i) Within the RVSM Programme guidance material was developed to support the States in their production of national safety plans **[26]**;

(ii) Each State has prepared its National Safety Plans;

(iii) The RVSM Programme has provided feedback to each State that has submitted draft or approved Plans. Comments have been made on the conformance of the Safety Plans against the guidelines and completeness of the Plans in regard to implementation issues, known to the RVSM Programme that are local to the State or a group of States;

(iv) In particular each State is expected to review the EUROCONTROL FHA and - where appropriate - incorporating additional local hazards and mitigation activities as additional safety requirements in its Safety Plan;

(v) Approval of the National Safety Plans by the appropriate State Authorities;

(vi) Confirmation from DGCA of the State readiness for the safe implementation of RVSM.

6.2 Specification of Implementation Requirements

High-level guidance has been given by EUROCONTROL to the States to explain the activities necessary to permit the safe implementation of RVSM at the national level.

This guidance is available on the web at www.eur-rvsm.com. The framework used for this guidance is that of an example Safety Plan. The guidance was developed within the EUROCONTROL RVSM Programme and has been extensively reviewed within the Programme, by the National Programme Managers (RVSM PMM) and the RVSM Programme Steering Group (RVSM PSG).

The guidance (example safety plan) was developed within the following concept framework:

(i) That States are sovereign and are responsible and accountable for:

- The approval of aircraft and operators based within the State;
- The provision of an appropriate Air Traffic Service;
  Thus the conduct of States in their safety preparedness is primarily an internal matter for the States.

(ii) States that are members of EUROCONTROL have agreed to work towards common, harmonised safety regulatory standards. Standards have recently been developed and approved by the SRC. It is unrealistic to expect States to have regulatory systems that conform to these requirements and to show that the RVSM Implementation by the State would meet these requirements within the timescales of the RVSM Programme. Only States that have established, comprehensive regulatory systems are likely to be in a position to show this;

(iii) States within the RVSM programme have nevertheless agreed to provide evidence of their safety preparedness with respect to RVSM Implementation. Further to this they have agreed to provide this evidence within a common framework, which has been developed by EUROCONTROL RVSM Programme as indicated above;

(iv) The framework is based around that evidence that would show that a State is meeting those established obligations within ICAO, namely:

- That the State has aircraft airworthiness and operator approval processes;
- That the State is responsible for the provision of an appropriate air traffic service;

(v) The framework used for the ATS aspects asks for evidence;

- That an appropriate ATS is provided. – the evidence here is that changes required for RVSM implementation have been identified, and implemented (or planned to be implemented);
- That the changes to the ATS have been (or will be) approved by appropriate authorities within the State;
- That there are appropriate quality checks that the proposed changes have been properly and effectively implemented;
- That safety risks associated with the State Implementation of RVSM have been identified, controlled and where practical reduced;

(vi) A similar framework is used for the aircraft and operator approval aspects;

(vii) The framework provided to States is supplemented by additional guidance material in the form of footnotes to the example text. This material provided further detail on:

- The type of evidence required;
- On how to develop and document the evidence;
- On the options available to the States; as States may differ in the way they meet these obligations.

6.3 State Safety Plans

The current status of the States in their development of national safety plans is given in **Appendix G Table G-1**.

In summary: there has been an excellent response from States in producing national safety plans in conformance with the supplied guidelines. The current status in the development of these plans is:

(i) Four States have been exempted form the production of a safety plan. Bosnia & Herzegovina, Luxembourg, and Monaco are exempted because responsibility for the upper airspace has been delegated to other Authorities. Ireland is exempted because it is currently a NAT RVSM transition region and has little additional changes for the EUR Implementation of RVSM.

(ii) All of the remaining States have produced Safety Plans.

6.4 Validation of State Safety Plans

The process for the review by EUROCONTROL of each of the State's Safety Plan is described in Appendix G.

The EUROCONTROL RVSM Programme has, in addition to providing review comments to the States on their provided National Safety Plans, formed a view on the overall safety preparedness of the States. There are four major components to this evidence:

(i) Conformance of safety plan with supplied guidance material;

(ii) Inclusion within the Safety Plan of National risk factors that are known to the EUROCONTROL RVSM Programme. These factors are either included or are being considered by the States for inclusion. What matters is that the Safety Plan reflects the issue and provides an action plan and contingency plan, where appropriate, to manage and mitigate the risk;

(iii) Continued development of the Safety Plans: to complete and report on activities detailed within the plan.

(iv) The institutional arrangements within the State for the provision of the regulation of safety. This factor is only to be used if there is insufficient information within the national safety plans.

6.5 State Confirmation of Readiness for the Safe Implementation of RVSM

An essential item in the Go/Delay decision is the requirement that all Director Generals of the National CAAs must confirm the readiness of the State to safely implement RVSM on 24 Jan 2002. This confirmation will be required by

August 2001. States in producing their national safety plans are aware that approval of such safety plans gives a commitment to make best endeavours to implement those plans. However, formal confirmation from the DGs has been requested. The current status of the receipt of DGs' confirmation is at **Appendix G**.

6.6 CFMU IFPS

The CFMU became involved in the EUR RVSM programme at a very early stage. At the outset, CFMU highlighted two important points. Firstly that the EUR RVSM area was not co-incident with the IFPS Zone thus, for certain States, IFPS could not guarantee a 100% flight plan capture. Secondly the IFPS software would classify airspace as either RVSM or non-RVSM. Therefore processing within the "EUR RVSM transition airspace" would be treated as RVSM airspace. A document entitled "RVSM Requirements for IFPS" was developed and accepted as the formal agreement between CFMU and the RVSM team in respect of RVSM implementation within the CFMU.

Throughout the development programme CFMU and the RVSM Programme have kept in regular contact. The CFMU User Relations Bureau (URB) is the focal point of co-ordination between the RVSM Programme and CFMU and the Head of the CFMU Flow Management Division (FMD) is a member of the RVSM Programme Steering Group. Where issues have arisen, ad hoc meetings have been held to resolve the problems within the context of the "RVSM Requirements for IFPS" document.

CFMU manages a rolling programme for the development and implementation of software releases. The complete cycle for a specific software release takes about eighteen months and this exercise is closely co-ordinated with the external users of the CFMU systems through the EAG Systems Sub-Group (SSG). Major aspects of the RVSM requirements for CFMU were included in the CFMU software release for 2001 (CFMU 7.0) and CFMU is confident that the software is behaving in accordance with the 'RVSM Requirements for IFPS' document. Because there are still some questions concerning the definition of certain EUR RVSM entry/exit points, effort has been reserved within the CFMU 8.0 development to allow for potential reworking of RVSM processing in the light of operational experience. The implementation of EUR RVSM in the CFMU was also included as an objective in the CFMU Development Plan approved by the European ATFM Group (EAG).

A series of Systems Acceptance Testing (SAT) using a dedicated test team and the CFMU Quality Assurance section have been undertaken. Three operational evaluations were run during February and March 2001 using personnel from 12 States, IATA and Eurocontrol. Training of States' operatives on the new system functionality has been carried out by means of presentations and hands-on experience.

The IFPS Users Manual, as part of the CFMU Handbook, has been updated to reflect processes for the checking of the EUR RVSM requirements. The Handbook has a wide circulation to external clients. The internal IFPS Operations Manual will be updated as appropriate to the relevant RVSM Phases, to reflect the required correction procedures for IFPS operators.

The CFMU and the RVSM programme have established a close working relationship during the programme development. This has allowed potential problems to be addressed as they occurred. Major aspects of the RVSM requirements for CFMU were included in the CFMU software release for 2001 (CFMU 7.0) and allowance has been made within the 2002 release (CFMU 8.0) for any reworking of RVSM processing that becomes necessary. There are not considered to be any adverse risks to the RVSM programme within the CFMU's area of operation.

6.7 CFMU Flow Control

See sub-paragraph 5.6.5.

6.8 Continuation of Monitoring Programme

In accordance with the objective stated in paragraph 6.5 of the RVSM safety Policy document **[1]**, EUROCONTROL will continue the System Monitoring Programme described in section 5 above in order to show that in the post-implementation RVSM environment the RVSM Safety Objectives are being met. The results of these activities will be documented in the Post-Implementation Safety Case.

6.9 Safety Requirements Traceability

The traceability of these safety requirements is demonstrated in **Appendix H Table H-3** where the safety requirements are linked to implementation activities and, where appropriate actions, have been identified to ensure that the safety requirements will be met.

6.10 Backing Evidence

The above Implementation evidence is considered to be trustworthy on the basis that:

(i) Information on RVSM has been widely disseminated among the States, ATS providers and airspace users;

(ii) The Guidance requirements for RVSM Implementation require all Safety Requirements to be met;

(iii) Each States is required to review the EUROCONTROL FHA and - where appropriate - incorporating additional local hazards and mitigation activities as additional safety requirements in its Safety Plan;

(iv) The Guidance requirements for RVSM Implementation were produced by competent staff;

(v) The Guidance requirements for RVSM Implementation are based on a recognised safety standard;

Evidence to support these three arguments is provided in the following paragraphs.

6.10.1 Dissemination of Information and Publicity Material

In order to inform, advise and assist all of the many elements of the World-wide Aviation Community of the above requirements and changes, and to prepare for the implementation of RVSM, the following documents have been prepared and published under the auspices of the RVSM Programme:

(i) ATC Manual for a Reduced Vertical Separation Minimum (RVSM) in Europe – ASM.ET1.ST13.5000 **[25]**) This manual was intended as a reference document for the use of ATS personnel involved in the planning, implementation and application of RVSM in Europe. It addresses:

- Background, History of, and Need for, RVSM;
- Description of the EUR RVSM Airspace;
- Provision of Service to Non-RVSM Approved State Aircraft;
- Flight Operations within the EUR RVSM Airspace;
- ATC Procedures (including State Aircraft, Communications, Inter-Centre Co-ordination, Phraseology, Transition and Contingency);
- Vertical Spacing from Prohibited, Restricted, Danger and Temporary Segregated Areas (TSAs);
- Communications failure in flight;
- ATS Systems Support;
- ATC Considerations;
- ACAS;

(ii) ICAO Document 009: Guidance Material on the Implementation of a 300M (1000 ft) Vertical Separation Minimum in the European RVSM Airspace **[30]**. This document was intended to provide a basic guidance to State Aviation Authorities(e.g. on the provision of ATS Services, airworthiness approvals, and monitoring of the airspace), and to Operators (e.g. on compliance with the requirements for RVSM Operations, and to assist in the development of Operating Manuals and Flight Crew Procedures);

(iii) Joint Aviation Authorities – Administrative and Guidance Material, Section One: General – Part 3 Temporary Guidance Leaflets – Leaflet N0. 6, "Guidance Material on the Approval of Aircraft and Operators for Flight above FL 290 where a 300M (1000 ft) Vertical Separation Minimum is applied" (JAA Leaflet No. 6) **[11]**. This is the basic reference document for the approval of Aircraft and Operators for operations in the EUR RVSM Airspace;

(iv) Amendment 200 to ICAO Document 7030/4 – Regional Supplementary Procedures – EUR Part 1**[7]**. This amendment constituted the formal

ICAO global notification, and legal enabler, of the area of applicability of, and aircraft and operational requirements for, EUR RVSM operations;

(v) EUROCONTROL Guidance Material – Adaptation of ECAC Airspace for EUR RVSM Implementation. **[26]**. This document details the measures necessary to adapt the ECAC airspace for RVSM operations. It sets out the procedures necessary for operations in the transition interface to/from the EUR RVSM and the adjacent non-transition airspace and for operations in the EUR RVSM airspace. The guidance material encapsulates the conclusions, recommendations and lessons gained from the series of ATC simulations and evaluations outlined in Appendix B;

(vi) Periodic circulation, to all elements of the aviation community, of RVSM Brochures, News Letters and Display Material;

(vii) Periodic issue of Specimen EUR RVSM Aeronautical Information Circulars (AICs) to States. These AICs provide an update on the progress, time-scales, requirements, and implications of the implementation of RVSM in the EUR Region. It is intended that States should then issue their own AIC, based on the specimen, within the area for which they are responsible.

To further ensure that the concept of operations under RVSM was understood, RVSM Seminars were conducted in Luxembourg (April 1998) and in Brussels (October 1999). A further Seminar, which specifically addressed the impact of RVSM on Military Operations, was held in Brussels in July 1999, and a series of RVSM Technical Briefings to operators and certification authorities were given in Tallinn, Johannesburg, Beirut, Paris (European Regional Airlines) and Athens.

6.10.2 Satisfaction of RVSM Safety Requirements

Evidence that the Guidance (generic requirements) for RVSM Implementation require all Safety Requirements to be met is shown in **Appendix H Table H-3**, which makes the link between the safety requirements in this Safety Case and the National Safety Plans, which implement the national aspects of these requirements.

6.10.3 States' Hazard & Risk Analysis

The status of the States' hazard and risk analysis is shown in the respective National Safety Plans. The progress being made on this is described in **Appendix G**. In summary many States. have developed a National Hazard Log and have reported on this in their National Safety Plans. A few States are still in the process of developing their hazard log. With the exceptions of France and Morocco, these latter States have not yet provided a recent update to their Safety Plan. Until these updates have been received, it is not possible to form any definitive conclusions on the status of the hazard and risk analysis within these States. The National Programme Managers of both France and Morocco have been approached to clarify their status concerning their hazard and risk analysis.

6.10.4 Generic Requirements – Staff Competence

The competence of the Eurocontrol Staff engaged on these tasks is assured through the pre-requisite background, experience and expertise of the postholders engaged on the RVSM Programme and/or in DSA/AMN. Furthermore all work and and recommendations of the EUROCONTROL Staff are subjected to an extensive peer and Stakeholder review and agreement process through expert bodies/groups consisting of specialist representatives of Member States and User Organisations.

6.10.5 Source of Generic Requirements

ICAO documentation is the source of the generic requirements. In particular Annex 11 is used as the starting point for the example National Safety Plan. The details within the example Safety Plan provide an amplification of the basic requirements within Annex 11 (see **Appendix G** for details).

6.11 Outstanding Actions

As indicated in **Appendix H**, **Table H-3**, evidence of the satisfactory implementation of RVSM depends on the completion of the listed actions.

6.12 Conclusions on the Implementation of the RVSM Concept

States within the RVSM programme are making steady progress towards safe implementation. Evidence for this is found within the National Safety Plans. States need to continue to put effort in and implement the commitments contained within their plans.

All States have provided second editions (June updates) of their Safety Plans, except five States – Estonia, FYROM, Greece, Moldova and Morocco – who have not yet provided updated and approved second editions of their Safety Plans. However, these States are in the process of approving their Safety Plans and copies of these approved plans will be sent to the RVSM Programme Office as soon as they are available.

Eurocontrol has asked for a confirmation of State readiness from the DGCAs of all participating States concerning the safe implementation of RVSM; and implicitly the realisation of the commitments contained within the National Safety Plans. To date 33 DGCAs have replied confirming the readiness of their State.

The CFMU will be ready to implement the changes to flight planning processes in line with the published schedule.

Operators are making steady progress in MASPs equipage and obtaining RVSM approval for their aircraft and operations. EUROCONTROL is closely monitoring this progress. Such progress is a key factor in the Go/Delay decision process.

EUROCONTROL has in place several monitoring mechanisms to validate and verify the safe and effective implementation of RVSM.

Evidence of the successful Implementation of RVSM depends on the satisfactory completion of the actions listed **Appendix H**, **Table H-3**.

7 SAFETY OF SWITCH-OVER FROM CVSM TO RVSM

Objective

This section sets out the arguments and evidence that the Switch-Over from the current vertical separation minima of 2000 ft (600 m) to the RVSM value of 1000 ft (300 m) will not adversely affect the safety of the on-going air traffic operations.

The structure of the safety arguments and supporting evidence that address this objective is shown in **Figures A-17 and A-18 of Appendix A**.

7.1 Approach

The safe Switch-Over from CVSM to RVSM will be effected by :

(i) The production and implementation of a plan for Switch-Over;

(ii) The identification, and implementation of measures to control and/or mitigate, hazards and risks associated with Switch-Over;

(iii) The preparation of Contingency plans to revert to a 'safe' state in the event of unforeseen problems.

7.2 Switch-Over Planning

In November 2000, a Functional Hazard Assessment was held at EUROCONTROL which specifically addressed the switchover period. The principal concerns of the participants, pilots and ATC controllers, were addressed through the FHA. The switchover from CVSM to RVSM requires specific attention to ensure a safe and effective changeover with the minimum disruption to the flow of air traffic. At the time of switchover, the whole of the RVSM airspace will be transition airspace for controllers and aircrews

<u>Airspace</u>

It is essential that there is a stable airspace environment for the implementation of RVSM. Version 4 of the ARN has been developed to be compatible with the implementation of RVSM and to maximise the capacity enhancement potential of RVSM. The implementation of Phase 2 ARN V4 is scheduled for 29 Nov 01 but, in the event, some states may implement their changes prior to that date. The intent is to provide a stable airspace structure and to separate route and sectorisation changes from the procedural changes wherever practicable.

<u>Flight Planning</u>

There has been extensive preparation between the RVSM Programme and CFMU on the RVSM requirements for IFPS. Briefly, within the Countdown period there will be increased contact between Aircraft Operators and IFPS that will raise the overall awareness as to the necessary flight planning and approval requirements for entry into RVSM airspace. From Phase 2 (IFPS Schedule) 19 April 01– 03 October 01, warnings will be provided to non-RVSM approved aircraft that would incorrectly penetrate EUR RVSM airspace. In Phase 3 (IFPS Schedule) 04 October – 23 Jan 02, there will be additional warnings if there are potential violations of the IFPS checking rules against flight within RVSM. The detailed flight planning requirements will be the subject of a separate AIC. A draft AIC 4 will be prepared by the RVSM Programme.

<u>IFPS</u>

The IFPS checking for full RVSM will be activated by means of a switch in the IFPS software. This switch will be activated at 2100hrs 23rd January 2002 (switch off and switch on will take place 15 mins either side 2100hrs). Flight Plans processed by IFPS prior to that time will not have been validated by IFPS against full RVSM checking even though the EOBT may be for time a later than 0001hrs 24th January 2002. Potentially, therefore, flight plans that would be rejected if filed after 23/01/02 would be accepted with a warning message in the ACK message. It is desirable to limit the number of such flight plans. Therefore, the IFPS parameter, which controls the length of time that flight plans to be filed in advance of EOBT, will be adjusted. Currently, this parameter is set to 144 hrs (6 days). The timing of this adjustment will be further considered by the RVSM Programme and CFMU during Phase 3.

<u>State Preparations</u>

- The preparation of training for controllers, the modifications to air traffic systems and the update of national and local documentation are recognised;

- States will consider whether the sectors within RVSM airspace, and immediately below, require protection during switchover. This topic will be part of the regular exchange of discussions on capacity and remain within the existing FMP structure and is scheduled for October 2001;

- The changes in structure and systems may require that both internal and external testing of data exchange should take place prior to the implementation of RVSM. This will require co-ordination with adjacent centres and the use of offline testing. The intention is to provide a high degree of assurance that when systems go live at switchover with new environments that they have already been tested and demonstrated as working satisfactorily in advance of that date;

- States are reviewing their Letters of Agreement LOAs to reflect any changes in sectorisation (vertical/lateral boundaries or DFL), ATS routes, COPs or FLAS as a result of the implementation of RVSM.

<u>Switchover</u>

A prime activity of Countdown will be the switchover plan from the conventional vertical separation standard to reduced vertical separation minima. Contact will be established with users to seek a “clean” airspace environment as far as practicable:

- Non-approved flights airborne in the immediate period prior to switchover may be adjusted to their new levels subject to ATC considerations e.g. non-RVSM approved aircraft getting airborne shortly before the change and intending to operate within EUR airspace could be restricted to a climb below FL 290;

- Following switchover, it will be the intention for aircraft to be adjusted to their new levels at that time subject to air traffic considerations;

- Users will have to consider the fuel implications for non-RVSM approved aircraft in flight which will be descended below FL 290 as a result of the implementation of RVSM;

- The RVSM Programme has conducted a traffic analysis to determine a quiet period which confirmed the suitability for the changeover at 0001 hrs (UTC) 24 January 2002.

Aircraft in Flight

The RVSM approval status of each aircraft under control will need to be established at switchover so that a comparison can be made with flight plan information, and the information shown on the radar display as to their individual approval status.

The sequence of events at switchover will be:

- Warning of Change

- Implementation of Changeover

- Verification of Aircraft approval status

- Level Changes where appropriate

Flow Management

Traffic levels will have to be considered by States and consideration given to some initial flow restrictions for the switchover period and the days immediately after. There is a study of the numbers and nature of the traffic constrained to operate below FL 290 by the implementation of RVSM [35]. Also traffic constrained to fly below RVSM airspace will require attention as far as numbers and the existing vertical sectorisation is concerned. These sectors may require ATFM protection until traffic flow and numbers are more assured.

Manning at Switchover

ACC manning will be a major focus of attention with a possible need for back-up headquarters staff, engineering staff and in particular software support.

- Last minute briefings will be needed for staff coming on duty that night, morning staffs and staff coming on for the first time over the days immediately following implementation. Handovers may become extended for the initial period.

- EUROCONTROL will provide a response cell established within CFMU for about a 24/48 hour period. The specific representatives and ToRs have yet to be determined but it can be anticipated that RVSM Programme, CFMU staffs, PSG state and user representatives will be in attendance.
- In preparation for the introduction of RVSM and the first weeks of RVSM operations across Europe, the planning and execution of military exercises impacting on ATC capacity in the European RVSM airspace will be kept to a strict minimum during the period from 24th January to 31st March 2002.

7.3 Switch-Over Hazard and Risk Analysis

The means of identifying hazards and risks relating specifically to Switch-Over is the same FHA process as used for the longer-term aspects of RVSM described in sub-paragraph 4.5 above. That process led to 20 hazards being identified in the FHA.

It is clear that the some elements of the majority of these hazards will continue to exist, beyond the strict definition of the "Switchover Period", until such time as the operation of RVSM has become sufficiently familiar to be accepted as the norm. Similarly the relevant mitigations detailed against these hazards, together with adherence to the Flight Crew Procedures, Training and Awareness programmes referenced in Sub-Paragraphs **5.3** and **5.4,** and the ATC Procedures and Training (**5.6** and **5.7**) for the "mature" scenario, will serve to minimise any consequent risk from these hazards.

Wherever possible, mitigation of the effect, and/or probability of occurrence, of the hazards was identified, the means of mitigation being specified as safety requirements, SP 1 to 14, as follows:

H_S1.1 – Aircraft fuel shortage due to an ATC-enforced level change

The probability of occurrence of this hazard will be reduced by issue of an AIC regarding level changes at Switchover (SP10) and by the Flight Crew Procedures, Training and Awareness programmes referenced in Sub-Paragraphs **5.3** and **5.4.** Furthermore, it is considered that any risk of accident as a consequence of this hazard is virtually eliminated by the application of standard Flight Crew Operating Procedures applicable to shortage of fuel.

H_S1.2 – Incorrect and unsafe commands issued by ATCO due to the inability of ATCO to adjust to RVSM procedures.

The probability of occurrence of this hazard will be reduced by the requirement placed upon States to provide Controllers with Training in ATC Procedures for RVSM Operations namely :

(i) ATC Training as part of the National Safety Plan, to be completed before Switch-Over (SP1);

(ii) A new ATC Procedure, detailed in the Switchover Plan **[49],** requiring controllers to obtain verbally the individual RVSM status of the aircraft under their control (SP2) at Switch-Over.

and by the heightened vigilance and awareness of Controllers experiencing the demands of the initial application of a new separation minimum.

H_S1.3 – Incorrect and unsafe commands issued by ATCO due to high ATCO workload due to simultaneous implementation of new ATC procedures/new ATS systems

The probability of occurrence of this hazard will be reduced by the training as detailed above and by :

(i) Freezing the route structure/sectorisation in the EUR RVSM airspace by October 2001 (Note: This is the latest publication date for ARN V.4 Phase 2 implementation on 29 Nov 2001) (SP3);

(ii) A EUROCONTROL recommendation that new ATS systems be in place by 24 January 2002 or, if this is not possible, an acceptable Contingency Plan shall be available (SP4);

(iii) The RVSM Programme, the CFMU and the States developing and implementing a suitable capacity planning to cover the Switchover period (SP5).

H_S1.4 – Incorrect and unsafe commands issued by ATCO due to misuse of Flight Level Allocation Scheme

This hazard is similar to hazard 1.2, analysed above, and the probability will be mitigated by:

(i) The requirement (SP1) for ATC Training to be completed before Switch-over;

(ii) A new ATC Procedure, introducing a hand-over process between two centres/sectors to act as a fallback for the hazard. During co-ordination, the receiving controller may reject to accept an aircraft not following the FLAS, unless otherwise stated in the LOA (SP6).

H_S1.5 – Incorrect and unsafe commands issued by ATCO due to ATC equipment or OLDI failure .

The probability of occurrence of this hazard will be reduced by:

(i) Contingency planning to cover ATC equipment/OLDI failure (SP11);

(ii) Use of alternative means of communication for co-ordination.

(iii) The EUROCONTROL recommendation (SP4) that new ATS systems be in place by 24 January 2002 or for an acceptable Contingency Plan to be available.

H_S1.9 – Excessive workload on ATCOs at Switchover due to traffic congestion below FL290.

The probability of occurrence of this hazard will be reduced by the additional flow control (SP7) implemented by the States and by the timing of Switchover to coincide with a period of low traffic demand.

H_S1.12 – Loss of separation as a result of not being able to get aircraft to climb/descend due to high traffic density.

The probability of occurrence of this hazard will be reduced by the additional flow control (SP7) implemented by the States and by the timing of Switchover to coincide with a period of low traffic demand.

H_S1.13 – Loss of separation as a result of re-routing/diverting due to in-flight contingency or bad weather .

The probability of occurrence of this hazard will be reduced by training in, and adherence to, Flight Crew Procedures (SP12) and ATC RVSM Procedures (SP1) referenced in Sub–Paragraphs **5.3** and **5.6**

H_S1.16 – Loss of separation as a result of aircraft not changing level when required to do so due to pilot unpreparedness or bad weather .

The probability of occurrence of this hazard will be reduced by training in, and adherence to, Flight Crew Procedures (SP12) and ATC RVSM Procedures (SP1) referenced in Sub–Paragraphs **5.3** and **5.6**

H_S1.17 – ATC systems not detecting RVSM status

This problem may be caused by inadequate ATC system support or by the pilot not using proper R/T phraseology. The probability of occurrence of this hazard will be reduced by:

(i) The EUROCONTROL recommendation (SP4) that new ATS systems be in place by 24 January 2002 or for an acceptable Contingency Plan to be available;

(ii) The new ATC Procedure (SP2), requiring controllers to obtain verbally the individual RVSM status of the aircraft under their control at Switch-over.

H_S1.18 – Wrong RVSM status indication on flight plan

The probability of occurrence of this hazard will be mitigated by:

(i) Ensuring (as part of SP4) that the modifications to CFMU IFPS are in place by 24 January 2002;

(ii) The new ATC Procedure (SP2), requiring controllers to obtain verbally the individual RVSM status of the aircraft under their control at Switch-over.

(iii) Normal RTF Procedures which may clarify correct RVSM status

H_S2.1 – Loss of separation due to incorrect use of the FLAS .

The probability of occurrence of this hazard will be reduced by:

(i) Ensuring ATC training is completed before Switchover (SP1);

(ii) Ensuring that LoAs are in place before Switchover (SP9);

(iii) Ensuring that LoAs address issues related to FL310, 350 and 390 (SP13).

H_S2.2 – Incorrect RVSM status indicated on FPL

This hazard is the reverse of H_S1.18 - ie a flight plan incorrectly shows an aircraft as not being RVSM-approved, resulting in the being instructed to descend below the EUR RVSM. The mitigations are as for H_S1.18.

H_S3.2 – Aircraft fuel shortage occurs due to an non-RVSM aircraft, departing from outside IFPS area and planning to fly in RVSM airspace

This hazard is similar to H_S1.1. The probability of occurrence of the hazard will be reduced by issue of an AIC regarding level changes at Switchover (SP10), and by the Flight Crew Procedures, Training (SP12) and Awareness programmes referenced in Sub-Paragraphs **5.3** and **5.4,** and by ATC RVSM training (SP1), before Switchover.

Furthermore, it is considered that any risk of accident as a consequence of this hazard is virtually eliminated by the application of standard Flight Crew Operating Procedures applicable to shortage of fuel.

H_S5.1 – Unsafe and incorrect commands issued by ATCO during high traffic density

This hazard may occur because of the increased workload of the controller, while adapting to the new environment. Throughout the day, new controllers will be exposed to the new environment and it may occur that they have to take over a busy sector, while having to operate RVSM for the first time.

The probability of occurrence of this hazard will be reduced by the following measures:

(i) The RVSM Programme, the CFMU and the States are to develop and implement a suitable capacity planning to cover the Switchover period (SP5);

(ii) All ACCs within States that are implementing RVSM are to provide special briefings and other arrangements to cover the switchover period (SP7);

(iii) Special briefings / extended handovers for on-coming watches (SP8);

(iv) The establishment, where agreed, by 24 January 2002, of the uni-directional route structures, as per safety requirement AD1.3, described in sub-paragraph 5.2.7 (hazard H_T 1.10) above.

H_S5.2 – Excessive level of R/T traffic due to a greater number of level changes at Switchover.

The probability of occurrence of this hazard will be reduced by:

(i) The additional flow control (SP7) implemented by the States;

(ii) Last-minute briefings on R/T procedures for Flight Crew and ATCOs before Switchover.

H_S5.10 – Inadequate procedures (ATC Manual and LoAs)

The probability of occurrence of this hazard will be reduced by:

(i) The additional flow control (SP7) implemented by the States;

(ii) Ensuring that LoAs are fully in place by 24 January 2002 (SP9). EUROCONTROL will assist the States in development of LoAs.

H_S6.1 – Potential loss of separation due to ATCO applying wrong separation standard

The probability of occurrence of this hazard will be reduced by:

(i) The EUROCONTROL recommendation (SP4) that new ATS systems be in place by 24 January 2002 or for an acceptable Contingency Plan to be available;

(ii) The new ATC Procedure (SP2), requiring controllers to obtain verbally the individual RVSM status of the aircraft under their control at Switch-over.

H_S6.5 – The FPL indicated that the State aircraft is RVSM approved, however being non-RVSM approved

The probability of occurrence of this hazard will be reduced by the new ATC Procedure (SP2), requiring controllers to obtain verbally the individual RVSM status of the aircraft under their control at the time of Switch-over.

H_S6.7 – Loss of separation occurs as a result of failure to identify formation flights due to ATCO error or wrong FPL

The probability of occurrence of this hazard will be reduced by the new ATC Procedure (SP2), requiring controllers to obtain verbally the individual RVSM status of the aircraft under their control at the time of Switch-over.

7.4 Implementation of Mitigations

Evidence that the mitigations of Switchover risks, identified in sub-paragraph 7.3 above, will be realised in the RVSM Implementation is provided in **Appendix H**, **Table H-3**, safety requirements references SP1 to SP14.

In general, as part of the application of the concept, Eurocontrol has developed a Switchover Plan **[49]** that provides detailed guidance on the planning requirements for Switchover and includes mitigation for all of the Switchover hazards.

The responsibility for ensuring that the mitigations are in place prior to Switchover rests with the individual States and the appropriate measures detailed in the Switchover Plan **[49]** should be addressed in their National Safety Plans

For details of the mitigation measures for specific hazards, refer to **Table H-3**, as above.

7.5 Contingency Planning

The EUROCONTROL RVSM ATC Manual **[25]** provides guidance on Contingency Procedures for degradation of aircraft equipment associated with height keeping or the occurrence of weather phenomena that directly affect the ability of aircraft to maintain their CFL. Such Contingency Planning form part of the Guidance provided to States **[47]** by the RVSM Programme and will have to be complete prior to RVSM implementation together with, if appropriate, Contingency FLAS determined in the LoAs. The importance of the provision of Contingency plans is emphasized in the at Sub Paragraph 2.6 of Switchover Plan **[49]**. ACCs should also predetermine such capacity figures for the purpose of permitting rapid co-ordination with the local FMP. These measures will be the responsibility of the individual States and should be addressed in their National Safety Plans

Equipment failure of varying scales of seriousness is a possible problem for any ACC at any time and the relevant contingency plans for the loss of a sector etc have to be in place. The switchover is, of course, a potential period of heightened tension as system modifications and procedures go “live”. This is the rationale for adequate testing to have taken place beforehand, nevertheless, consideration has to be given to a systems failure and the rapid application of procedural operations. The emphasis throughout is the implementation of RVSM; while 2000ft VSM may be put in place this does not imply the implementation of CVSM. This failure condition, if it happens at all, could also take place hours, days or weeks after the implementation of RVSM thus plans have to be in place for a possible fallback to 2000ft VSM. The conditions under which such an option would be considered should have been analysed as much as practicable in advance. The consideration of the introduction of a procedural service, the imposition of flow control and a contingency FLAS would be part of this process. This preparation is an on-going process and will be confirmed in national countdown plans.

7.6 ATFM and Switch-Over

During the key hours leading to switchover, and for a certain number of days afterwards, Air Traffic Flow Management measures will be implemented to ensure a safe Switchover. Sector capacities will be set at lower thresholds throughout the RVSM airspace and the CFMU and FMPs will manage flows in accordance with the revised capacity figures. This is a well established approach that was successfully implemented in the past when major route network modifications, 8.33kHz and recently UK RVSM early application were introduced. The good co-operation between the RVSM Programme and the CFMU throughout the pre-implementation phase will be intensified as implementation is approaching and during Switchover. EUROCONTROL will also provide a joint RVSM/CFMU response cell established within CFMU for the period immediately before and after the implementation of RVSM. Details of times, telephone numbers, e-mail addresses etc will be distributed closer to the event.

7.7 Backing Evidence

The above Implementation evidence is considered to be trustworthy on the basis that:

(i) The EUROCONTROL Switch-Over plan was prepared by competent staff. The competence of the Eurocontrol Staff engaged on these tasks is assured through the pre-requisite background, experience and expertise necessary for the post-holders engaged on the RVSM Programme and/or DSA/AMN. Furthermore all work and recommendations are subjected to an extensive peer and Stakeholder review process through expert bodies/groups made up of specialist representatives of Member States and User Organisations.

(ii) The EUROCONTROL Switch-Over plan has been independently validated;

(iii) The Hazard & Risk Analysis were representative of the operational environment and workload;

(iv) All possible failure modes were considered in the Hazard & Risk Analyses;

(v) The Hazard & Risk Analyses were carried out by competent staff;

(vi) The National Contingency plans will have beeen prepared by competent staff;

(vii) The National Contingency plans will have been independently validated.

Evidence to support these three arguments is provided in the following paragraphs.

7.7.1 Switch-Over-Planning Verification

The RVSM Programme has provided a Countdown Plan/Schedule **[38]** for States to adapt to their own local requirements. A matrix of major events and headline planning actions has been provided which can be adapted by States and reproduced in greater depth to reflect the individual actions at ACC level.

7.7.2 Hazard & Risk Analysis Verification

The techniques and staff employed in the hazard and risk analysis for Switch-Over is the same as that used for RVSM in general. Evidence of the completeness and correctness of the results may be found at sub-paragraphs 4.7.4 and 4.7.5 above.

7.7.3 Contingency-Planning Verification

States are scheduled to notify the RVSM Programme of the completion of their National Countdown Plans, which will include contingency planning, by 31 Aug 2001.

7.8 Outstanding Actions

As indicated in **Appendix H**, **Table H-3**, evidence of the satisfactory Implementation of RVSM depends on the completion of the listed actions related to Switch-over.

7.9 Overall Residual Risk at Switch-Over

After mitigation, the 20 hazards related to Switchover are distributed as follows: six in Severity Category 2, five in Severity Category 3, and nine in Severity Category 4.

Although it may seem that the number of the higher category hazards is greater than for the mature situation, this is not of such great concern because the ‘time at risk’ for Switchover is many orders of magnitude shorter. The important issue is that possible mitigations have been identified for at least all the category 2 and 3 hazards, and that heightened awareness of the hazards by operators, flight crew and ATCOs, implementation of the mitigations through thorough Switchover and Contingency planning should reduce the total vertical risk during the Switchover period to a tolerable level.

7.10 Conclusions on Switch-Over.

The preparation for Switchover has been focussed on the provision of assurance that the change from the current vertical separation minima of 2000 ft (600 m) to the RVSM value of 1000 ft (300 m) will not adversely affect the safety of the on-going air traffic operations, and be carried out in an effective manner with a minimum disruption to the aircraft operators.

The identification, and implementation of measures to control and/or mitigate, hazards and risks associated with Switchover were identified through a Functional Hazard Assessment (FHA 3). The mitigating factors were identified and incorporated into a RVSM Countdown and Switchover Plan produced by EUROCONTROL. **[38]**

The States are to prepare their national countdown plans, which will incorporate the preparation for switchover and any contingency plans. Confirmation of the completion of national countdown plans will be submitted to EUROCONTROL by August 2001. EUROCONTROL will also provide a response cell co-located with CFMU staffs for the period of the switchover. Appropriate ATFM measures will be in place to ensure a safe switchover.

While the preparations for Switchover are not yet complete as some actions are dependent on a Go decision, there are plans and processes in place or in preparation to ensure a safe and effective change to RVSM on 24 January 2002.

Switchover demands vigilant ATFM which will be managed by CFMU, with the RVSM States, through a well established process.

Evidence of the successful Implementation of RVSM depends on the satisfactory completion of the actions listed **Appendix H**, **Table H-3**.

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8 CONCLUSIONS

The aim of the EUR RVSM Pre-Implementation Safety Case is to show by means of argument and supporting evidence that the application of the ICAO RVSM Concept in the European Region, and the Implementation of RVSM by the participating States, satisfy the criteria defined in the EUR RVSM Safety Policy **[1]** (for additional background see 1.3. – Scope of the Safety Case).

The PISC sets out the safety requirements broken down to the level of system elements. It establishes all the arguments and evidence necessary to demonstrate that the ICAO RVSM Concept, as applied to the EUR RVSM Airspace, and the Implementation of RVSM, by the participating States, will be tolerably safe when assessed against the requirements of the EUR RVSM Safety Policy **[1]**.

The PISC demonstrates that this aim has been achieved, by means of the following principal safety arguments:

(i) That a set of Safety Requirements has been specified for RVSM that address fully all the functionality, performance and integrity requirements necessary to ensure that the safety risks under RVSM will be tolerable – see **Section 4**;

(ii) That the RVSM Concept developed by EUROCONTROL for the European region has the potential to satisfy fully the RVSM Safety Requirements - see **Section 5**;

(iii) That the Implementation of the RVSM Concept by the individual participating States will fully satisfy the RVSM Safety Requirements - see **Section 6**;

(iv) That the Switch-over from the current vertical separation minima of 2000 ft (600 m) to the RVSM value of 1000 ft (300 m) will not adversely affect the safety of the on-going air traffic operations – see **Section 7**.

It has been shown in **Section 4 – RVSM Safety Requirements Determination –** that:

(i) A sufficient set of high-level safety requirements have been specified for RVSM, and have been completely and correctly allocated to the appropriate elements of the RVSM system;

(ii) Safety requirements have also been specified and allocated to the system elements, for each hazard identified in the FHA, sufficient to control and/or mitigate the hazard, in all but two cases, which are dealt with in **Section 5**;

(iii) The safety requirements satisfy the TLS for technical height-keeping accuracy, and are broadly consistent with the remainder of the TLS;

(iv) There are additional aspects of the RVSM programme which will result in a reduction of collision risk.

(v) The processes used in deriving and allocating the safety requirements give further confidence that the safety requirements are complete and correct.

It has been shown in **Section 5 – Application of the ICAO RVSM Concept in the EUR Airspace –** that:

(i) For each of the eight elements of the RVSM system (Airspace Design, Flight Crew Procedures, Flight Crew Training, Aircraft Equipment, ATC Procedures, ATC Training, ATC Equipment, System Monitoring), the RVSM Concept fully satisfies the safety requirements set out in Section 4 above;

(ii) The Concept includes mitigation of the hazards identified in the FHA, and explicit safety requirements have been derived as a means of ensuring that the mitigations will be addressed in the RVSM Implementation;

(iii) The safety constraint on RVSM, relating to airspace capacity considered by the Collision Risk Assessment, has been satisfied in the Concept;

(iv) All the RVSM safety requirements, derived as described in section 4 herein, are traceable to the RVSM Concept;

(v) Although the FHA process deduced that the risks from Level Busts and ACAS/TCAS Nuisance Alerts are “not tolerable”, two points were relevant: neither risk is unique to RVSM Operations; and both risks are in being addressed in the context of the on-going monitoring of Operational Errors in the RVSM airspace. Additionally regarding Level Busts, ongoing activities by States, the issuing of (RVSM) awareness material by the RVSM Programme, and the emphasis given to the need for strict adherence to Flight Crew Procedures, are specifically aimed at reducing the occurrences of ‘level busts’, and as such can be considered appropriate mitigations. For ACAS nuisance alerts, primarily the comparability with the current environment in FL 245-295 and the low percentage of V6.04a flights in EUR RVSM airspace were seen as mitigating factors. On that basis, it was argued that the risks should be deemed as tolerable risks at this stage, subject to subsequently satisfactory results from the monitoring programme;

(vi) The inclusion in the Concept of on-going monitoring of key parameters – i.e. height-keeping performance (technical and operational), RVSM approval (including infringement of RVSM airspace), ACAS/TCAS alerts, and CRM input values – provides an important “safety net” for the above analysis and conclusions regarding the safety of the RVSM Concept (and, subsequently, its Implementation);

(vii) The results to date of the monitoring / collision-risk modelling programme show that it is likely that the two RVSM Safety Objectives concerning the TLS will be met. In this respect it should be noted that the assumptions on which these estimations were based need to be confirmed (see **Appendix F**), especially regarding (1) further monitoring of height keeping performance in order to meet the monitoring requirement set by the Monitoring Policy, and (2) consultation with aircraft operators and manufacturers regarding specific aircraft types;

(viii) Validation of the Safety Objective concerning the total vertical risk of an accident or serious risk bearing incident will be assessed through the Post Implementation Monitoring Programme.

It has been shown in **Section 6 – Implementation of the RVSM Concept –** that:

(i) States within the RVSM programme are making steady progress towards safe implementation. Evidence for this is found within the National Safety Plans. States need to continue to put effort in and implement the commitments contained within their plans.

(ii) All States have provided second editions (June updates) of their Safety Plans, except five States – Estonia, FYROM, Greece, Moldova and Morocco – who have not yet provided updated and approved second editions of their Safety Plans. However, these States are in the process of approving their Safety Plans and copies of these approved plans will be sent to the RVSM Programme Office as soon as they are available.

(iii) Eurocontrol has asked for a confirmation of State readiness from the DGCAs of all participating States concerning the safe implementation of RVSM; and implicitly the realisation of the commitments contained within the National Safety Plans. To date 33 DGCAs have replied confirming the readiness of their State.

(iv) The CFMU will be ready to implement the changes to flight planning processes in line with the published schedule.

(v) Operators are making steady progress in MASPs equipage and obtaining RVSM approval for their aircraft and operations. EUROCONTROL is closely monitoring this progress. Such progress is a key factor in the Go/Delay decision process.

(vi) EUROCONTROL has in place several monitoring mechanisms to validate and verify the safe and effective implementation of RVSM.

(vii) Evidence of the successful Implementation of RVSM depends on the satisfactory completion of the actions listed **Appendix H**, **Table H-3**.

It has been shown in **Section 7 – Safety of Switch-Over from CVSM to RVSM –** that:

(i) The preparation for Switchover has been focussed on the provision of assurance that the change from the current vertical separation minima of 2000 ft (600 m) to the RVSM value of 1000 ft (300 m) will not adversely affect the safety of the on-going air traffic operations, and be carried out in an effective manner with a minimum disruption to the aircraft operators.;

(ii) The identification, and implementation of measures to control and/or mitigate, hazards and risks associated with Switchover were identified through a Functional Hazard Assessment. The mitigating factors were identified and incorporated into a RVSM Countdown and Switchover Plan produced by EUROCONTROL;

(iii) The States are to prepare their national countdown plans which will incorporate the preparation for switchover and any contingency plans. Confirmation of the completion of national countdown planswill be submitted to EUROCONTROL by August 2001. EUROCONTROL will also provide a response cell co-located with CFMU staffs for the period of the switchover. Appropriate ATFM measures will be in place to ensure a safe switchover;

(iv) While the preparations for Switchover are not yet complete as some actions are dependent on a Go decision, there are plans and processes in place or in preparation to ensure a safe and effective change to RVSM on 24 January 2002;

(v) Switchover demands vigilant ATFM which will be managed by CFMU, with the RVSM States, through a well established process;

(vi) Evidence of the successful Implementation of RVSM depends on the satisfactory completion of the actions listed **Appendix H**, **Table H-3**.

Based on the conclusions drawn in this section the application of the ICAO RVSM Concept in the European Region and the Implementation of RVSM by the participating States can be considered as tolerably safe and satisfying the criteria defined in the EUR RVSM Safety Policy **[1]**.

APPENDIX A - PISC ARGUMENT AND EVIDENCE STRUCTURE

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Introduction

The attached diagrams show, in Goal-structuring Notation (GSN), the Argument and Evidence structure of the PISC.

GSN Methodology

GSN is based primarily on **Goals** (represented by rectangles, numbered G n.nn) and **Solutions** (represented by circles, numbered S n.nn).

A Goal should always take the form of a "predicate" – ie a statement that is either true or false. As the name suggests, GSN provides for the decomposition of Goals into smaller, sub-Goals – logically, a Goal is true (has been satisfied) if, and only if, its all sub-Goals are true. For the structure to be considered complete, every branch must be terminated in a Solution.

When GSN is used for safety case construction (as herein), Goals and Solutions are used to represent safety **Arguments** and **Evidence** respectively.

Other, symbology may be used in order to provide supporting information, as follows.

Strategies (represented by parallelograms, numbered St n.nn) are a useful means of adding 'comment' to the structure to explain, for example, how the argument will develop. They are not predicates, rather they are there purely for explanation of the Argument decomposition, and their use is optional.

Contextual symbology – including the **Assumptions**, **Justifications**, and **Criteria** symbols used herein - is also available.

Application to the PISC

Figure A-1 overleaf starts with the claim (G0), that the risk of collision under RVSM will be tolerable. This is broken down into four principal safety Arguments (G1 to 4) which represent a necessary and sufficient condition for G0 to be true.

The question as to what is tolerable is addressed by the Criteria (Cr0001) distilled from the RVSM Safety Objectives set out in Section 2 of the PISC.

Because a large part of the safety case for RVSM is argued on the basis that the risk is no greater that at present, an Assumption has been declared that the current level of risk is tolerable.

Finally, as far as G0 is concerned, J0001 provides a summary of the basic Justification for the introduction for RVSM.

In GSN terms, the rest of the PISC consists of a decomposition of Arguments G1 to 4, to a level at which clear Evidence of the validity of the Argument can be identified.

In many instances, exemplified by Figure A-2, the decomposition proceeds along two lines – direct Argument and Evidence that the higher-level Argument (in this example G1) is true, and supporting (or backing) Argument and Evidence that the direct Evidence itself is trustworthy. Strategies St1.1 and 1.2 are used here in order to highlight this distinction.

Evidence is identified in most instances by reference to the appropriate section of the main body of the PISC in which that Evidence (or a reference to the relevant Appendix or external document) may be found.

Figures A-3 to A-18 continue the decomposition, to encapsulate the whole of the PISC Argument and Evidence structure, in the same way.

It is asserted that Figures A-1 to A-18 provide a well-structured Argument which is sufficient to show that G0 has been satisfied, and show that Evidence has been identified for every branch of the Argument structure.

Having established that, the adequacy of the PISC is dependent only on the quality of that Evidence in supporting the Argument.

A- 1 Overall argument

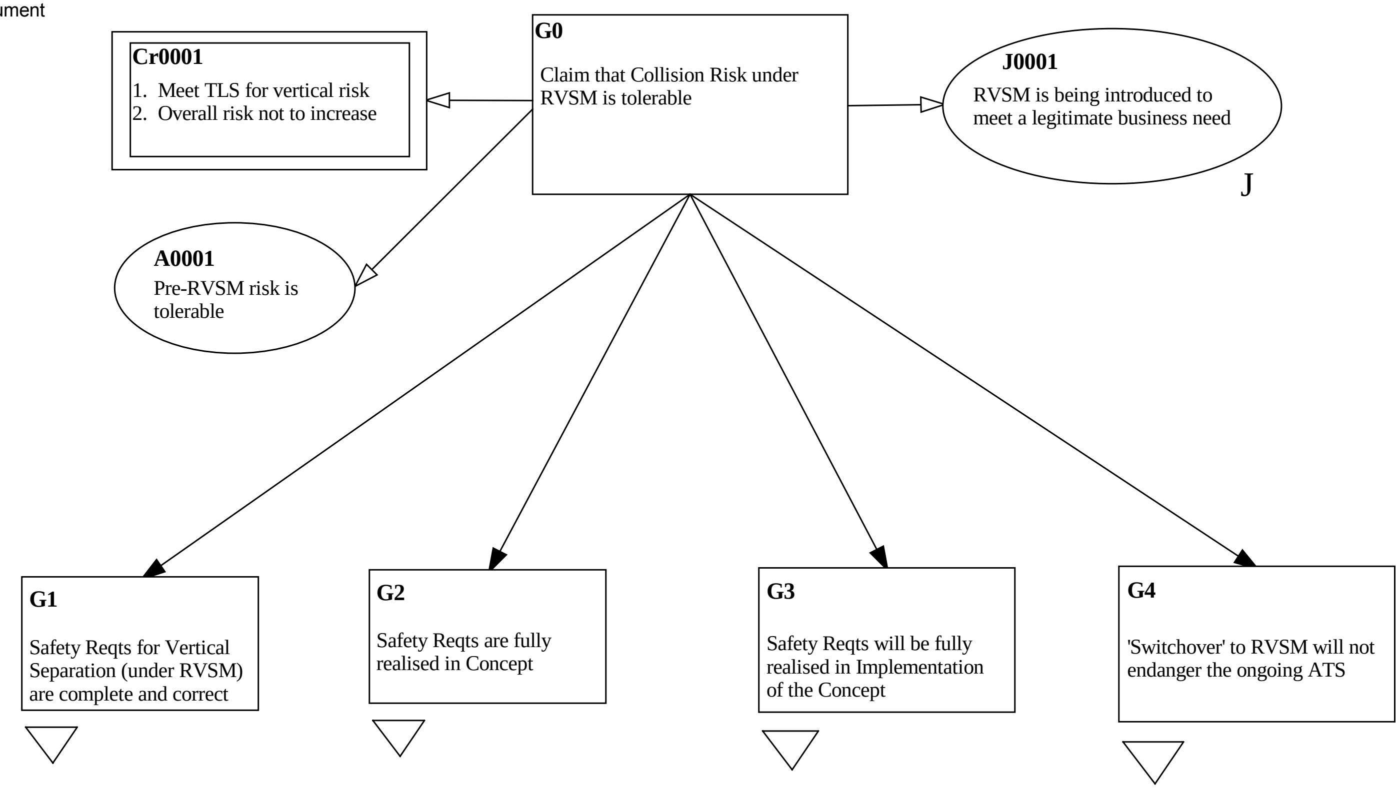


Figure 1: FIGURE A-1 / Overall Argument

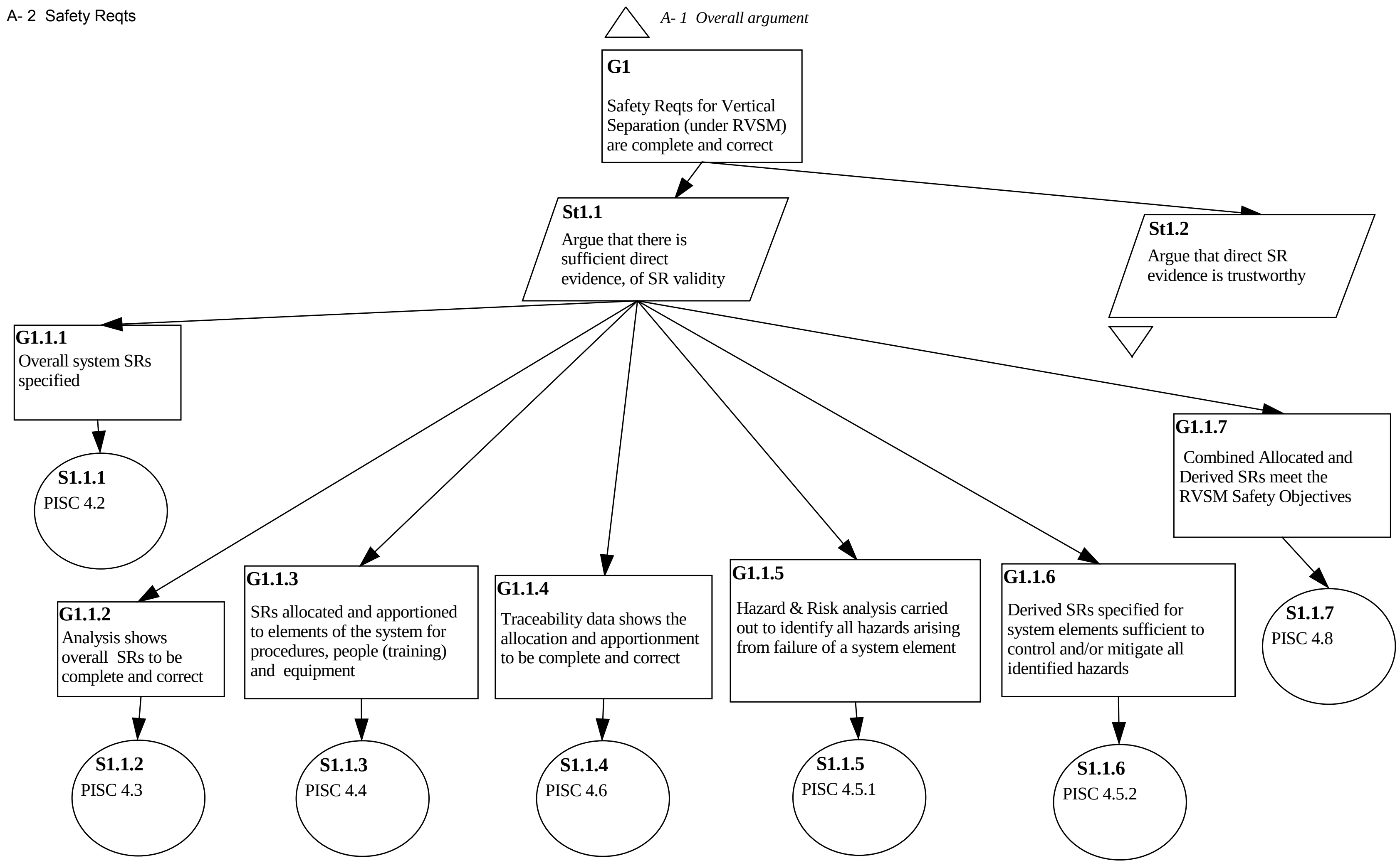


Figure 2: FIGURE A-2 / Safety Requirements

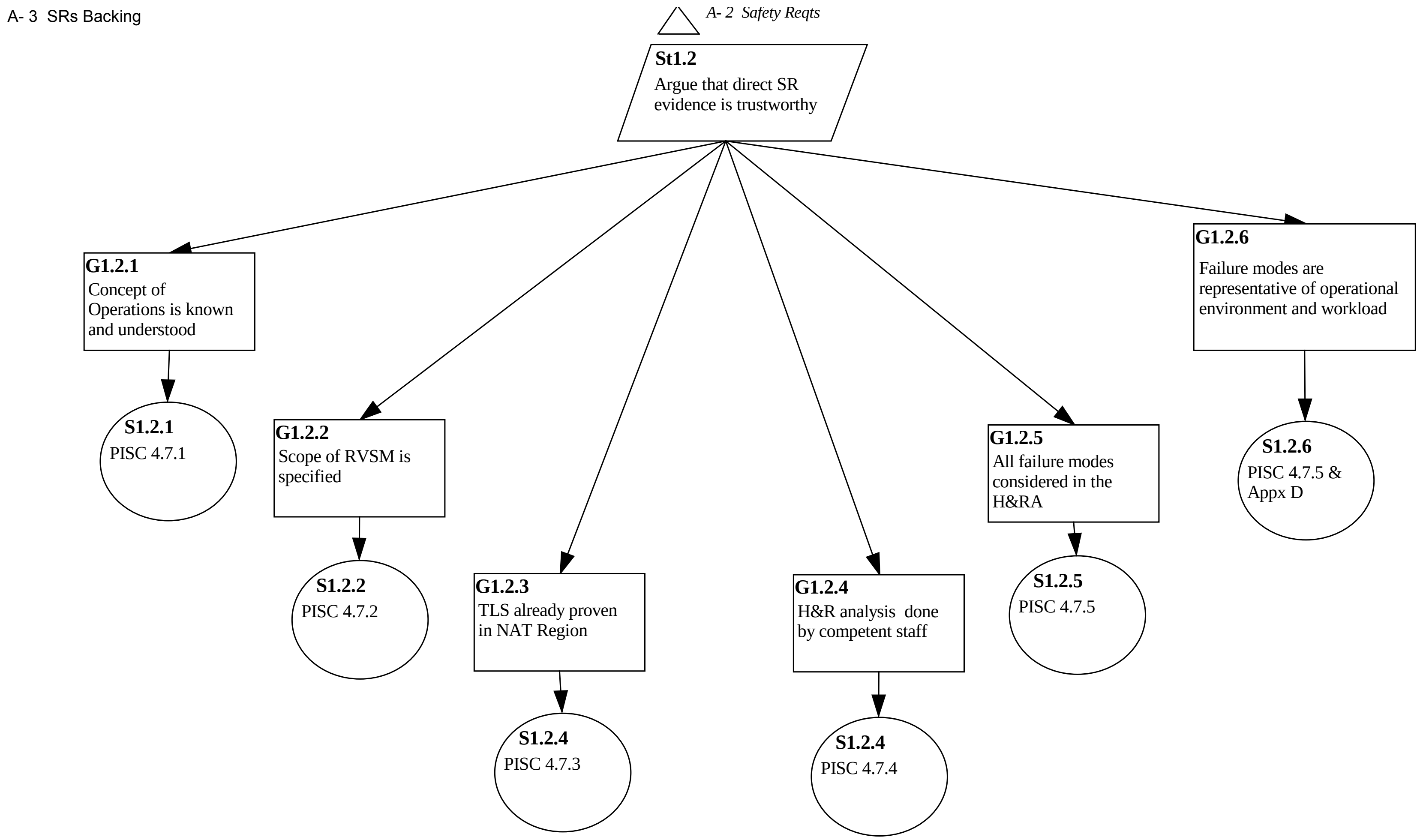


Figure 3: FIGURE A-3 / Safety Requirements Backing

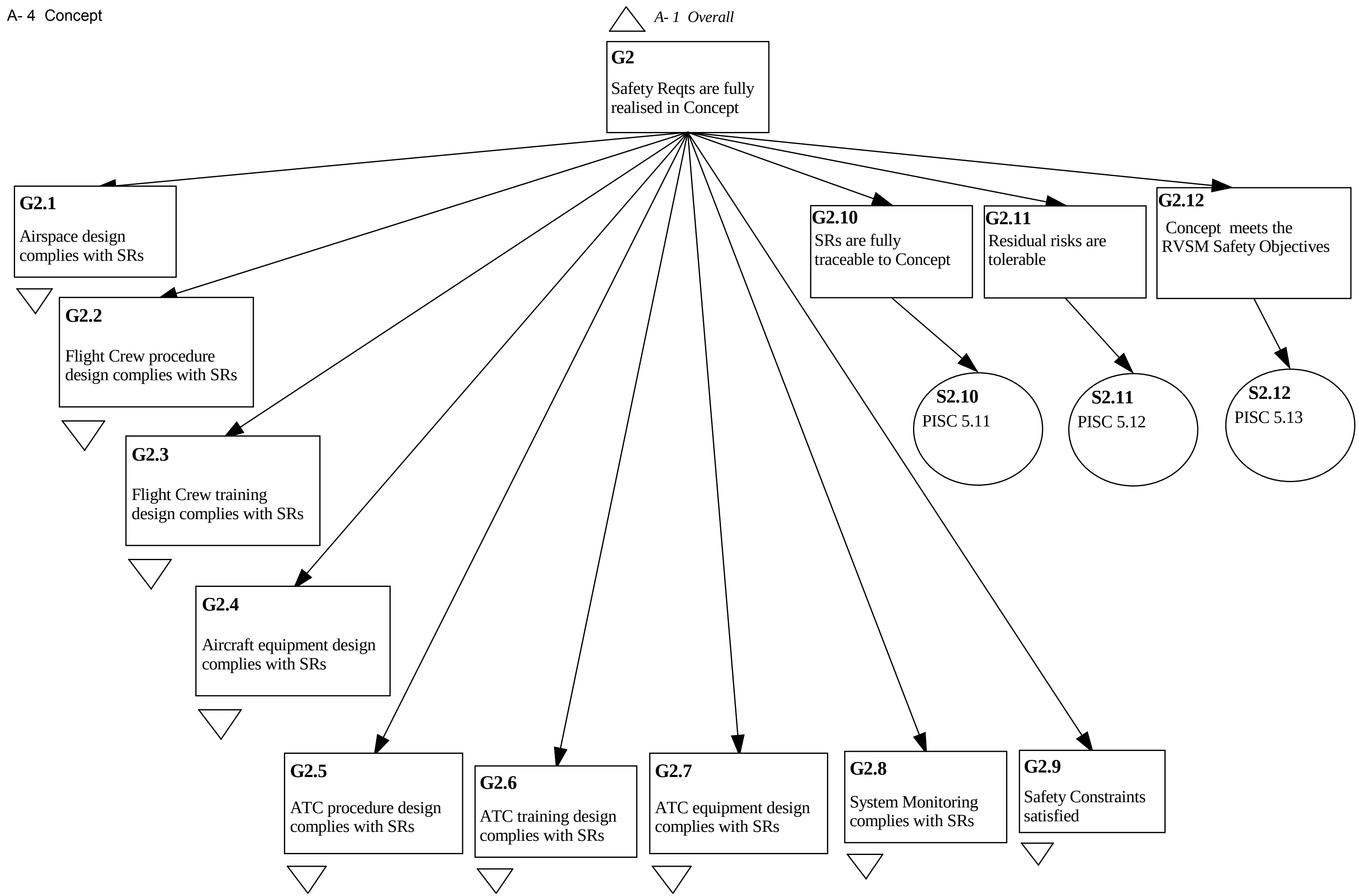


Figure 4: FIGURE A-4 / Safety Requirements Realisation in Concept

A- 5 Airspace Design

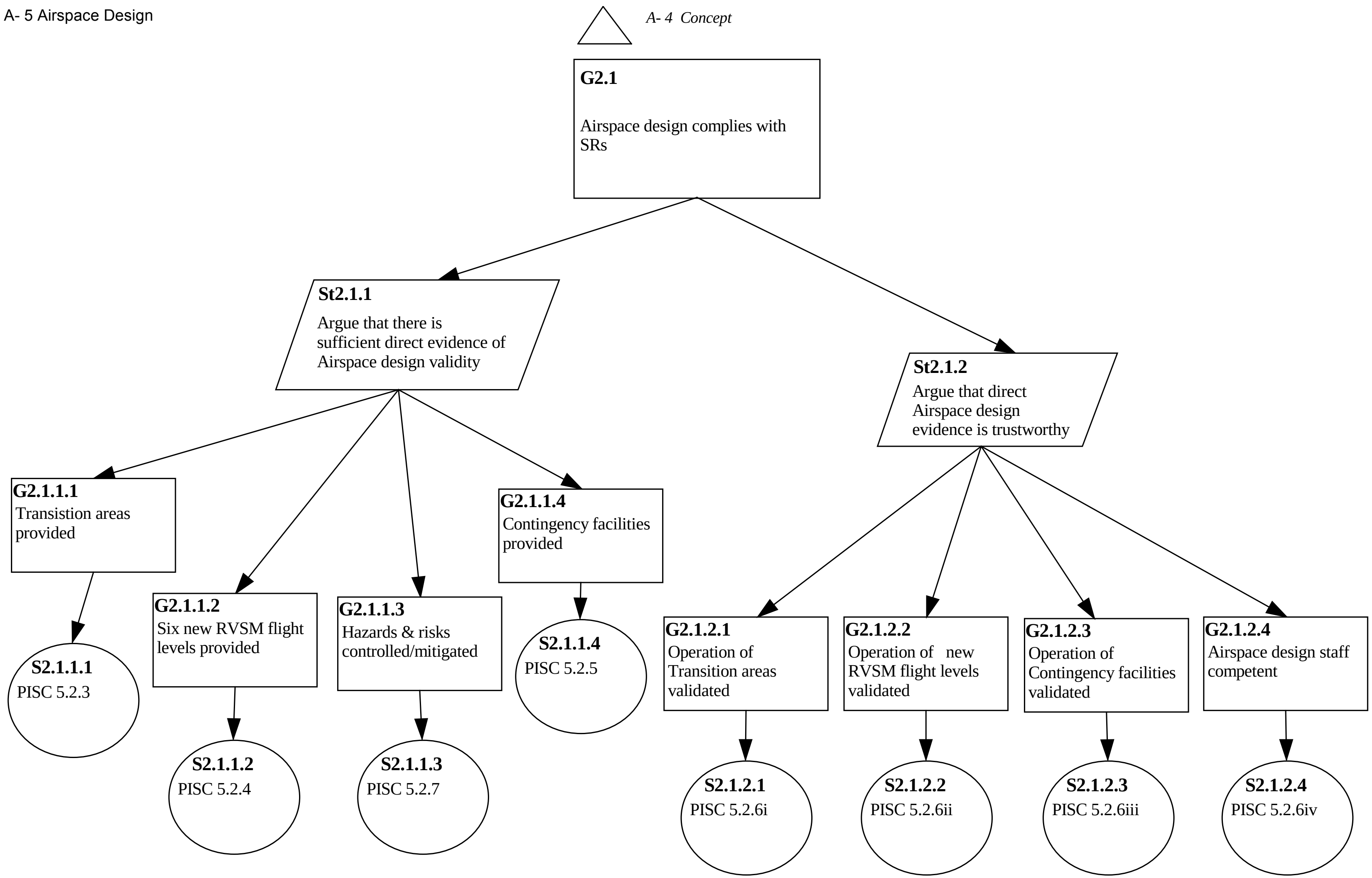


Figure 5: FIGURE A-5 / Airspace Design

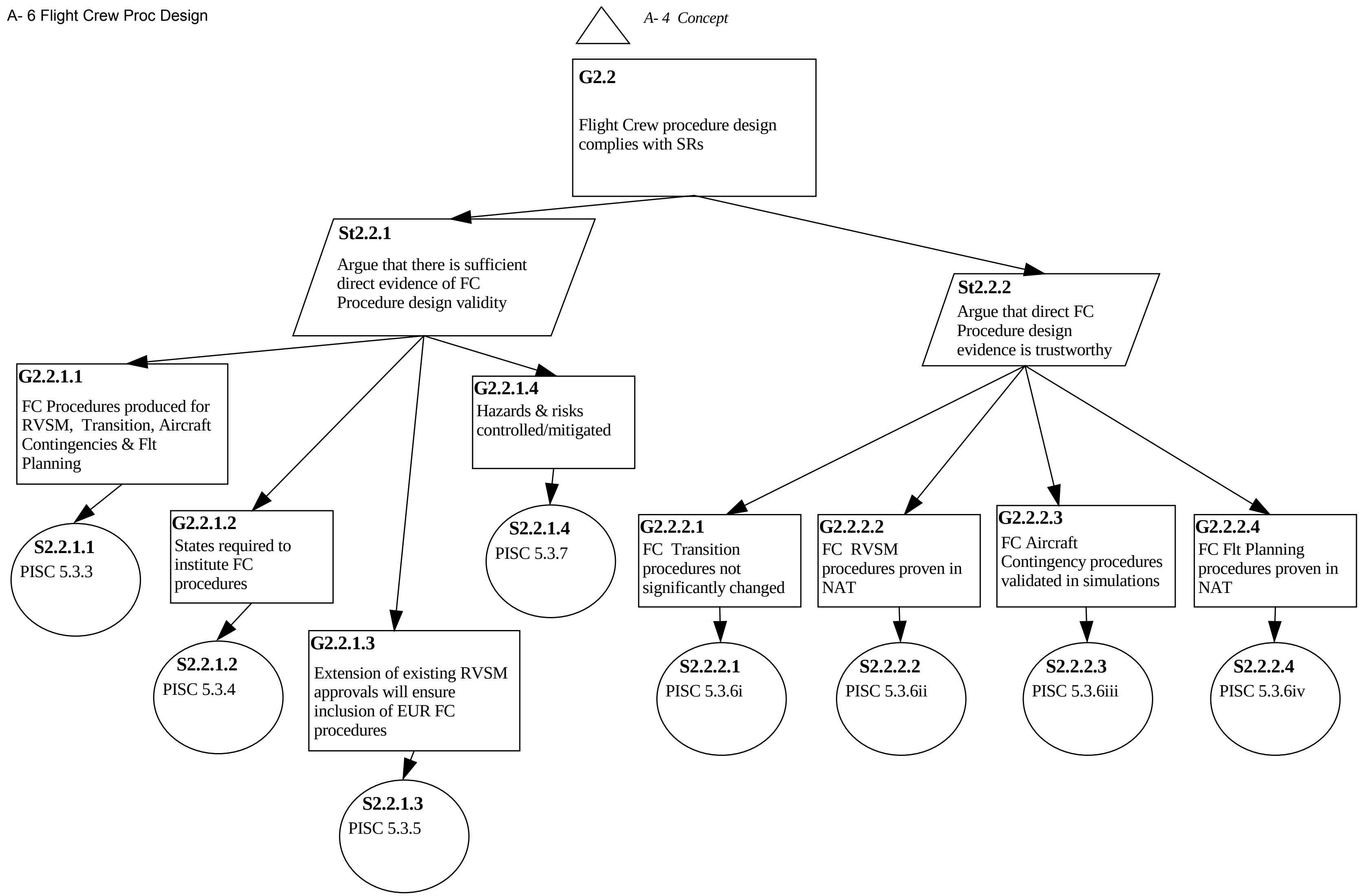


Figure 6: FIGURE A-6 / Flight Crew Procedure Design

A- 7 Flight CrewTrg Design

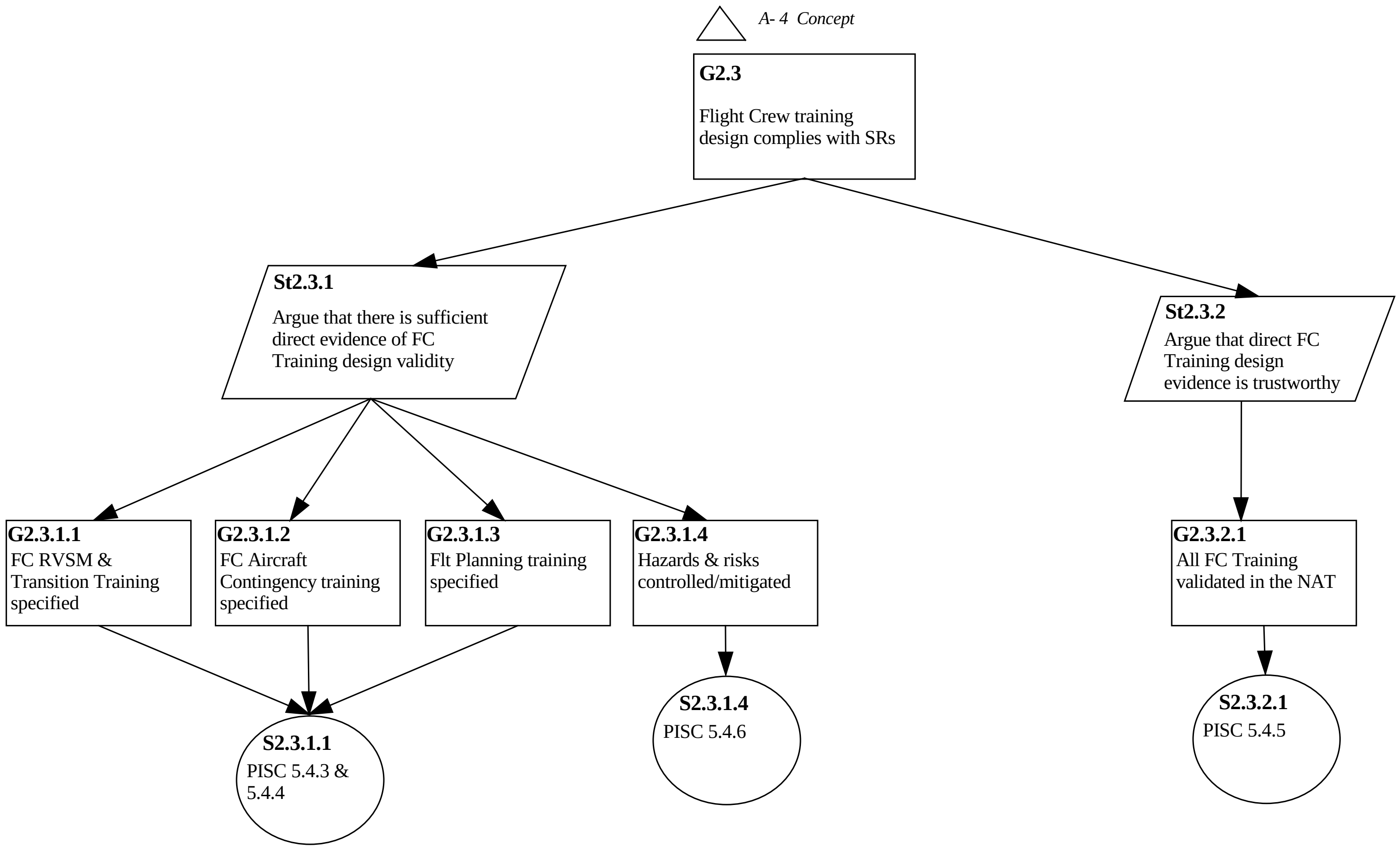


Figure 7: FIGURE A-7 / Flight Crew Training Design

A- 8 Aircraft Equipt Design

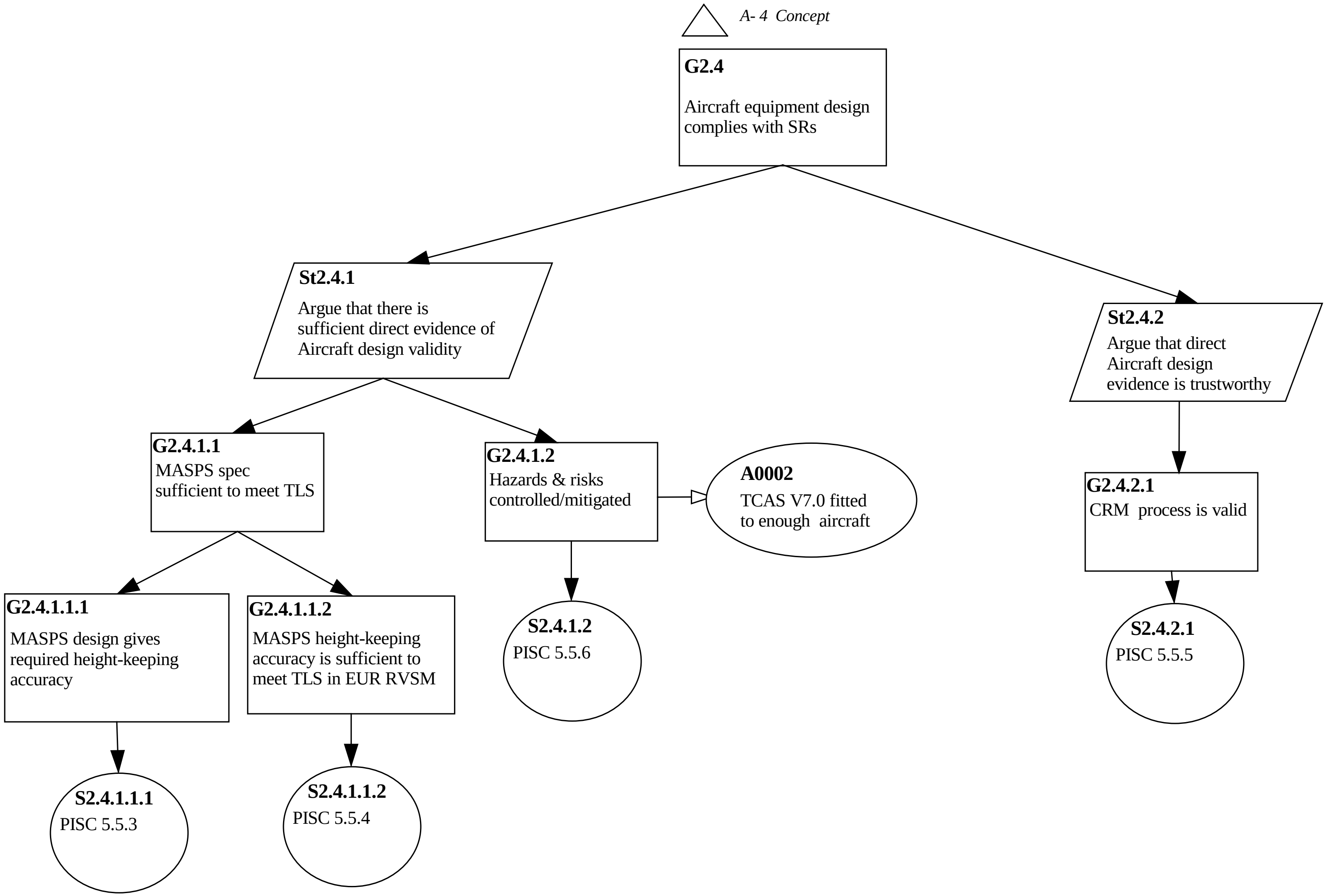


Figure 8: FIGURE A-8 / Aircraft Equipment Design

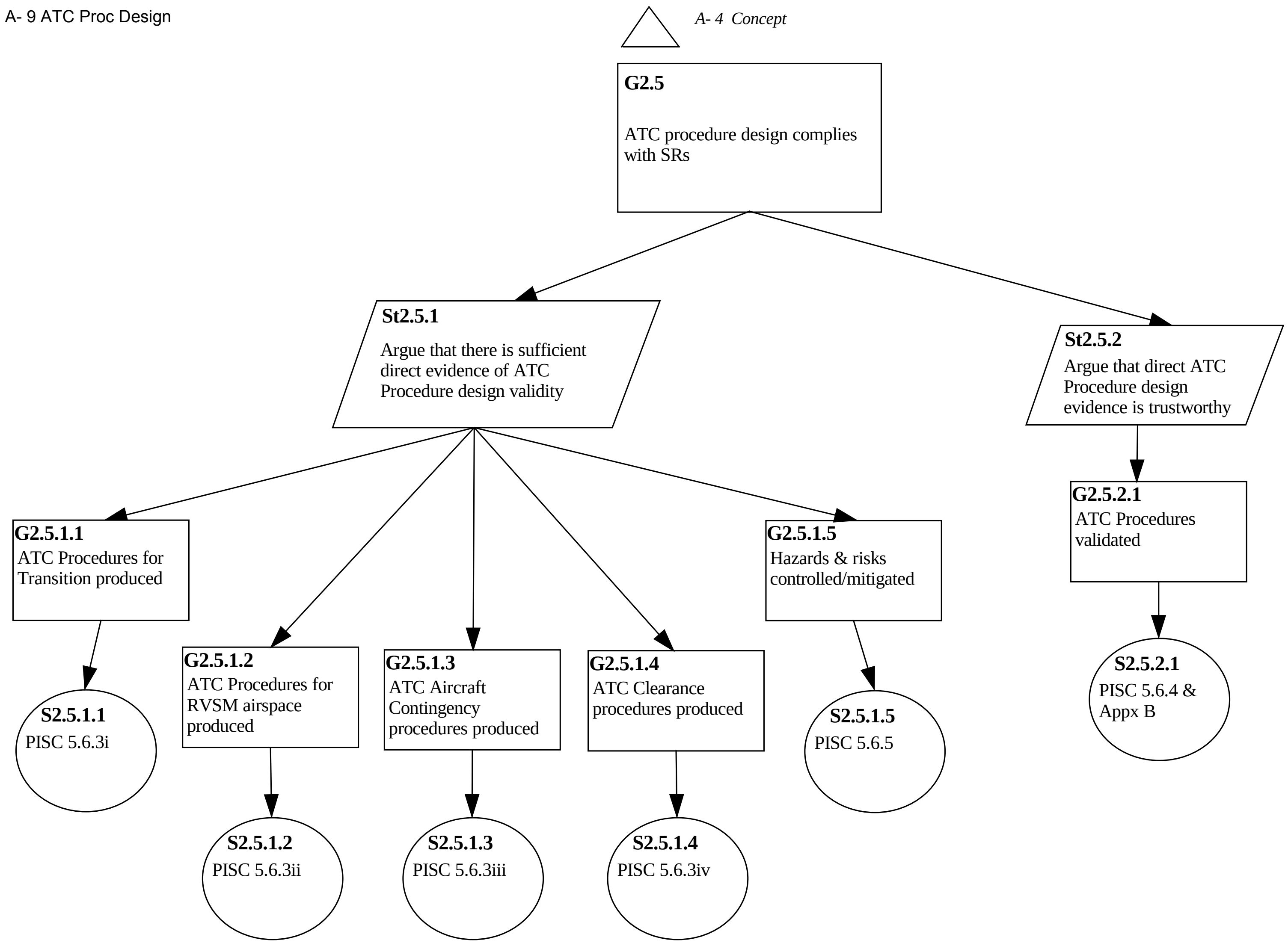


Figure 9: FIGURE A-9 / ATC Procedure Design

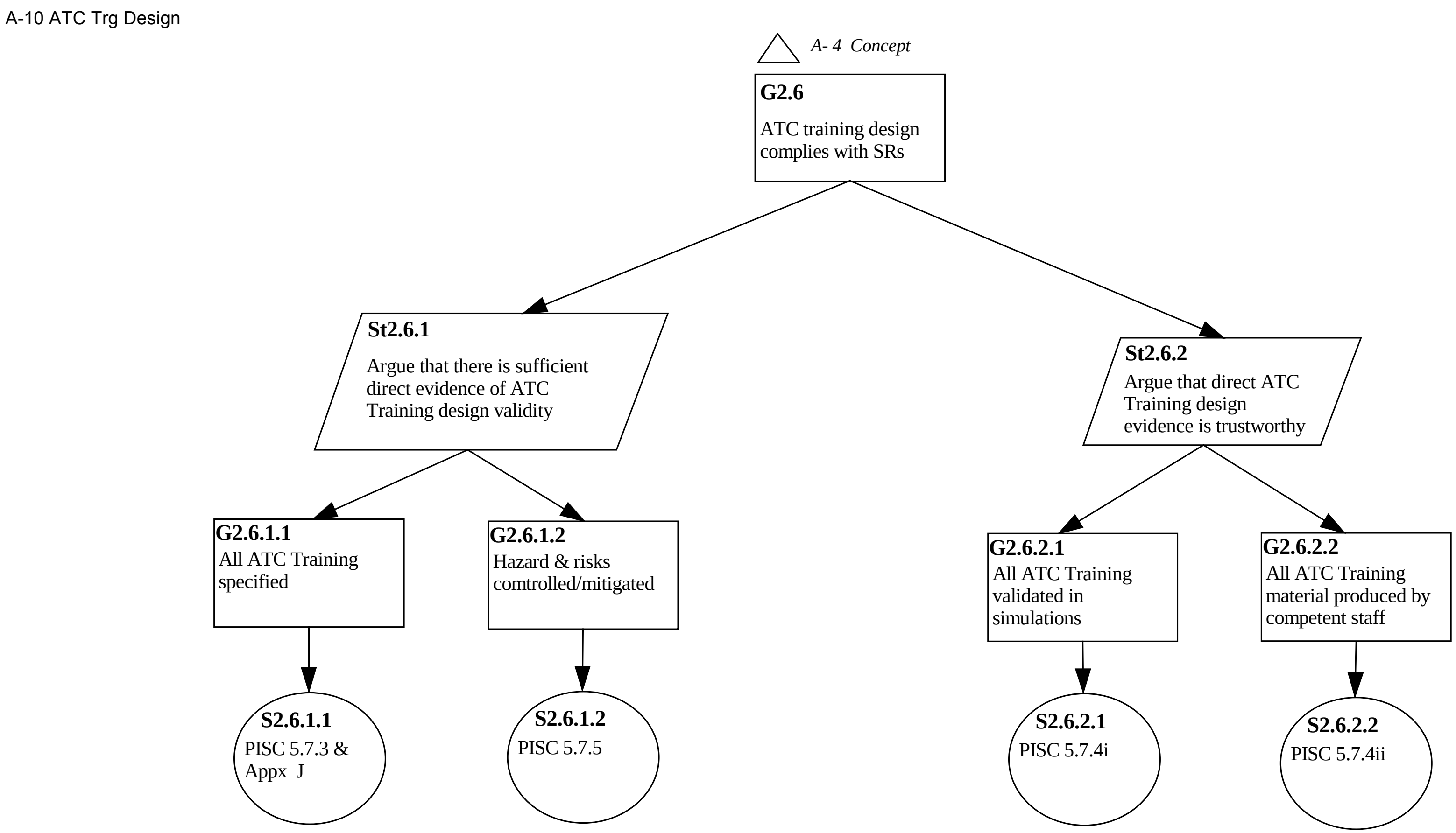


Figure 10: FIGURE A-10 / ATC Training Design

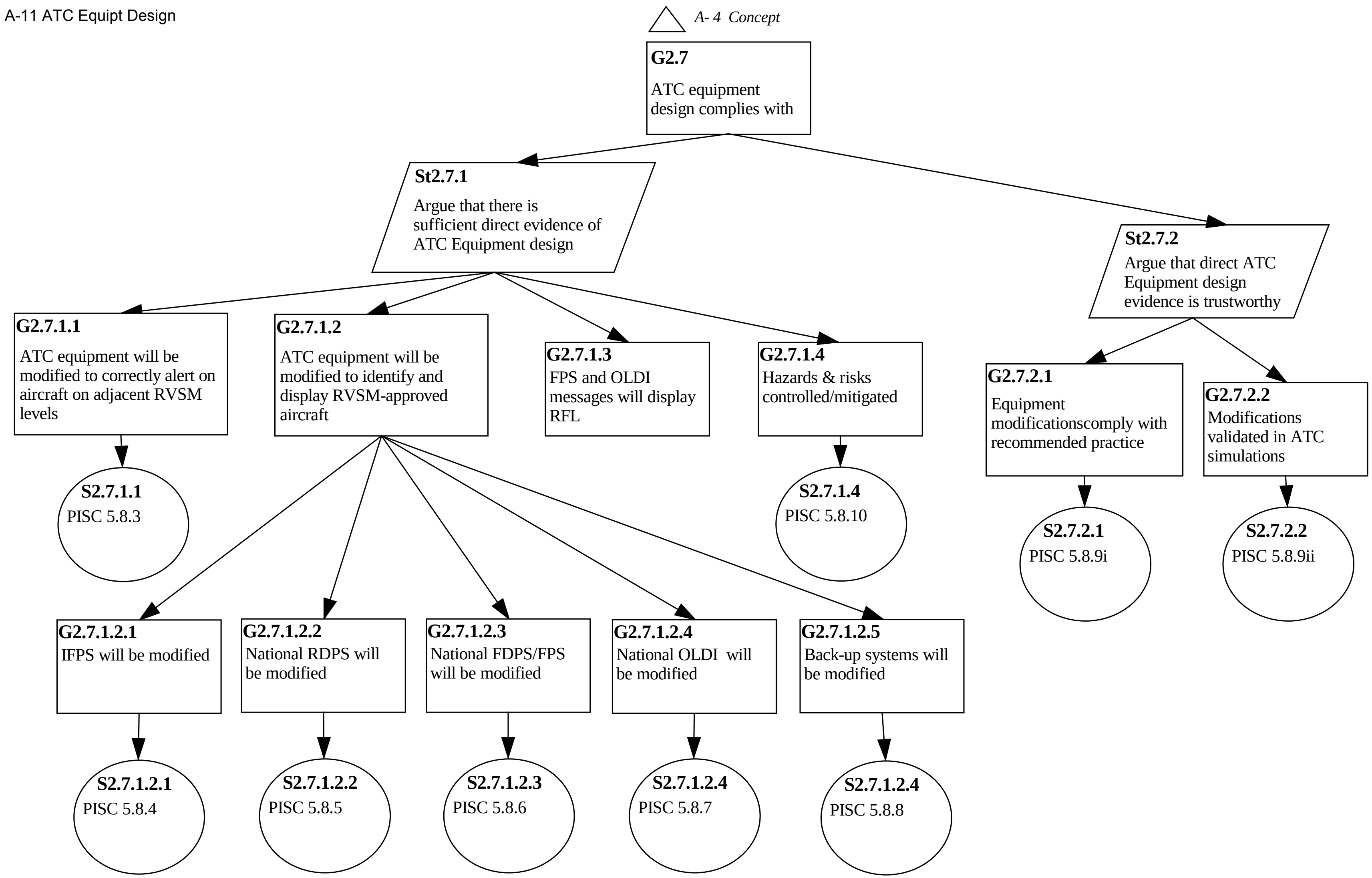


Figure 11: FIGURE A-11 / ATC Equipment Design

A-12 System Monitoring

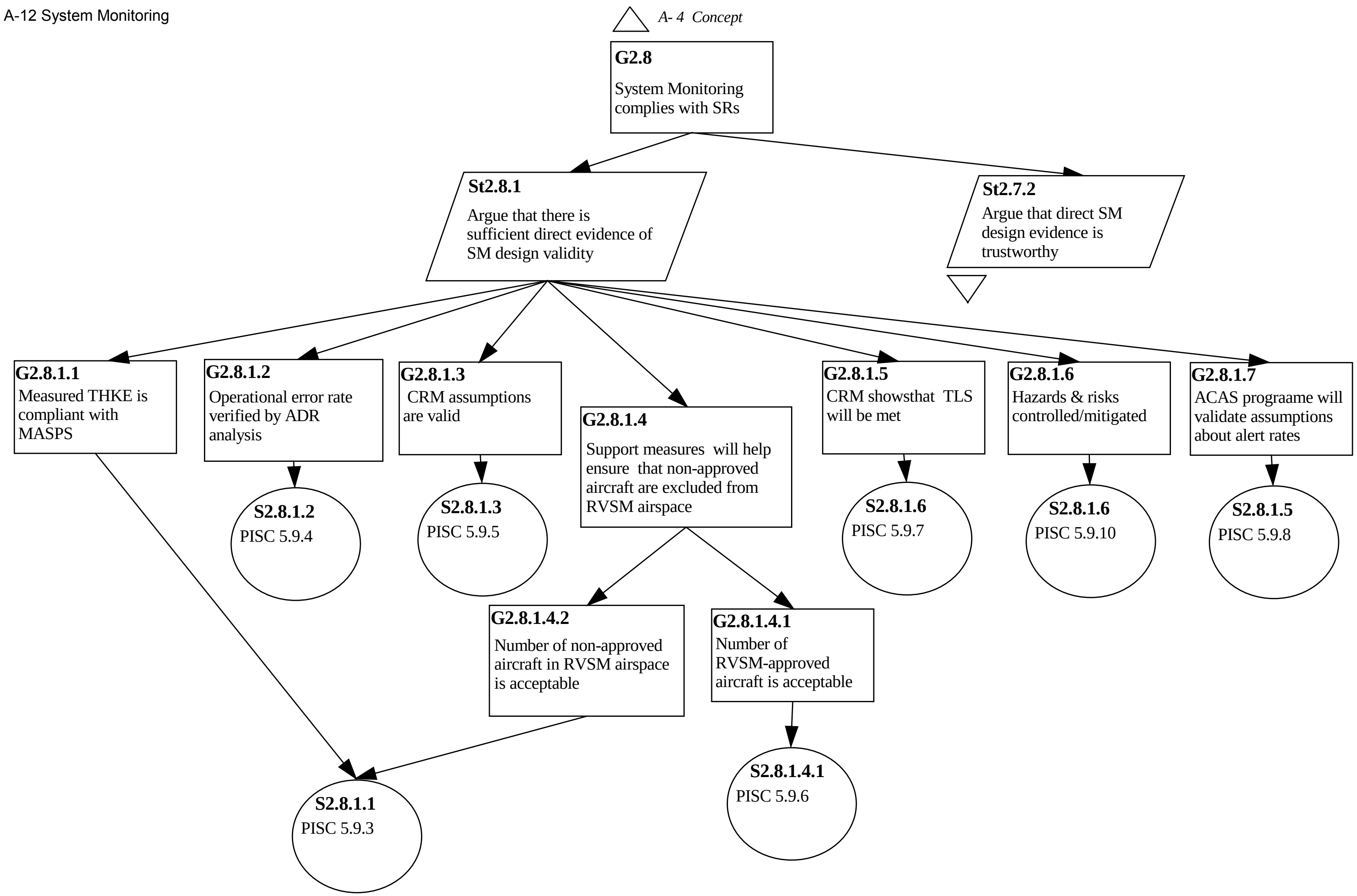


Figure 12: FIGURE A-12 / System Monitoring

A-13 SM Backing

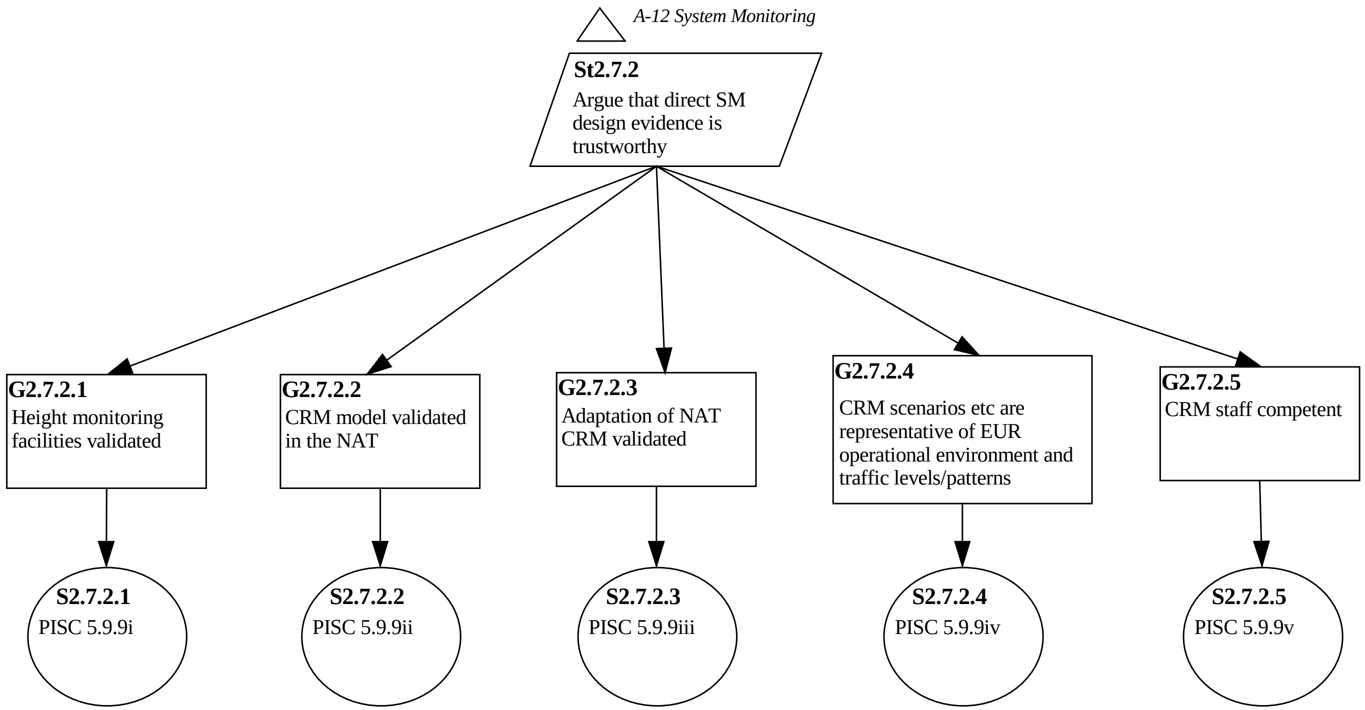


Figure 13: FIGURE A-13 / SM Backing

A-14 Safety Constraints

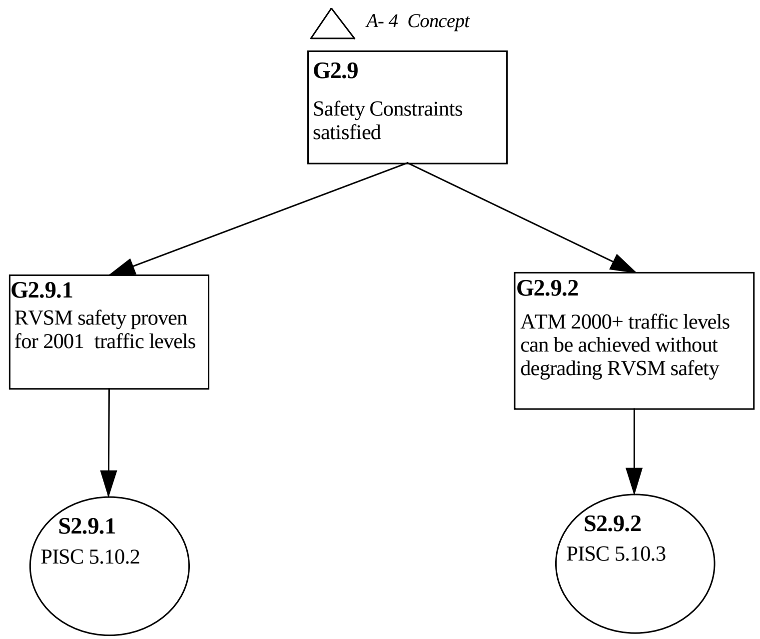


Figure 14: FIGURE A-14 / Safety Constraints

A-15 Implementation

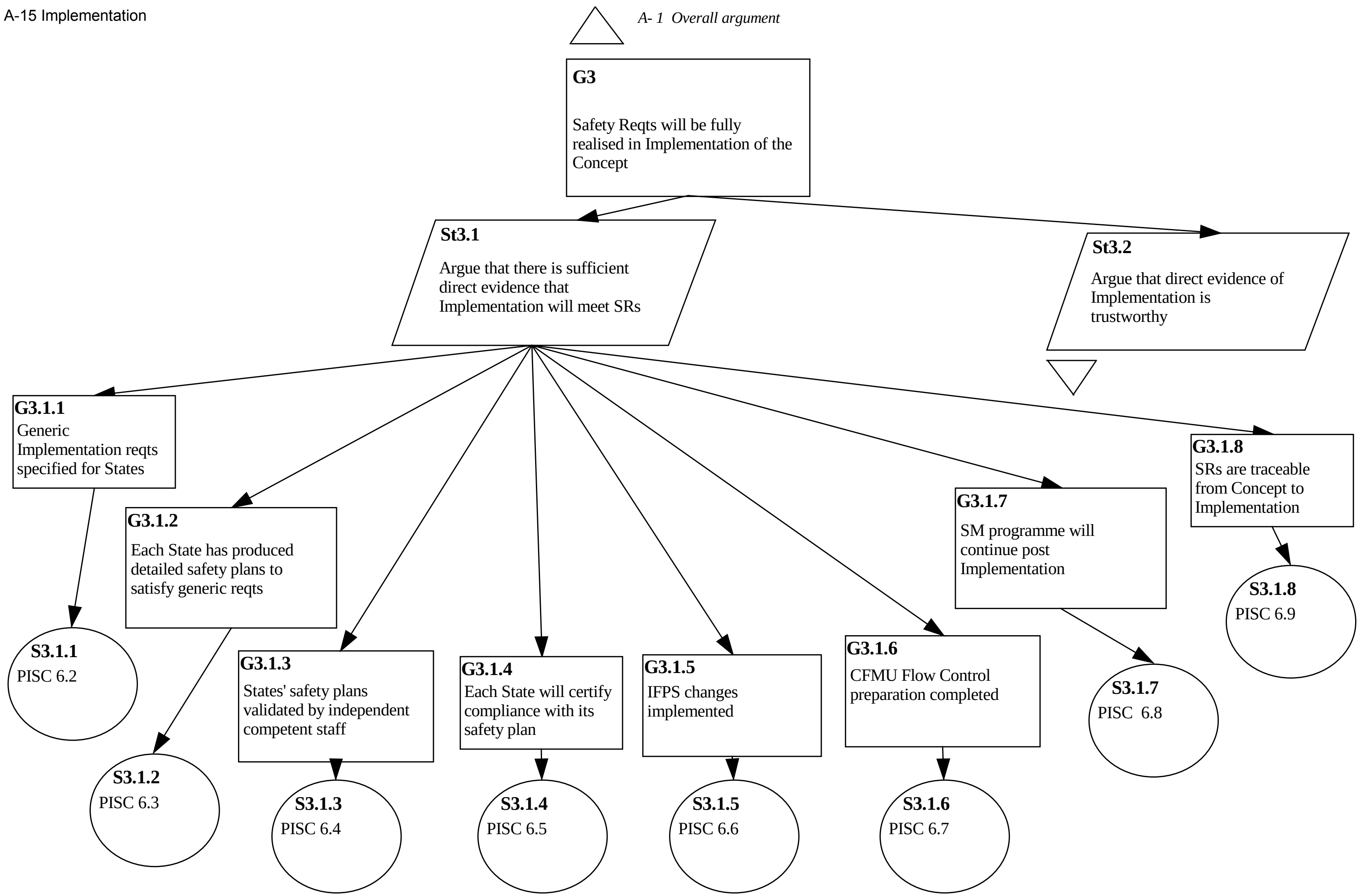


Figure 15: FIGURE A-15 / Safety Requirements Realisation in Implementation

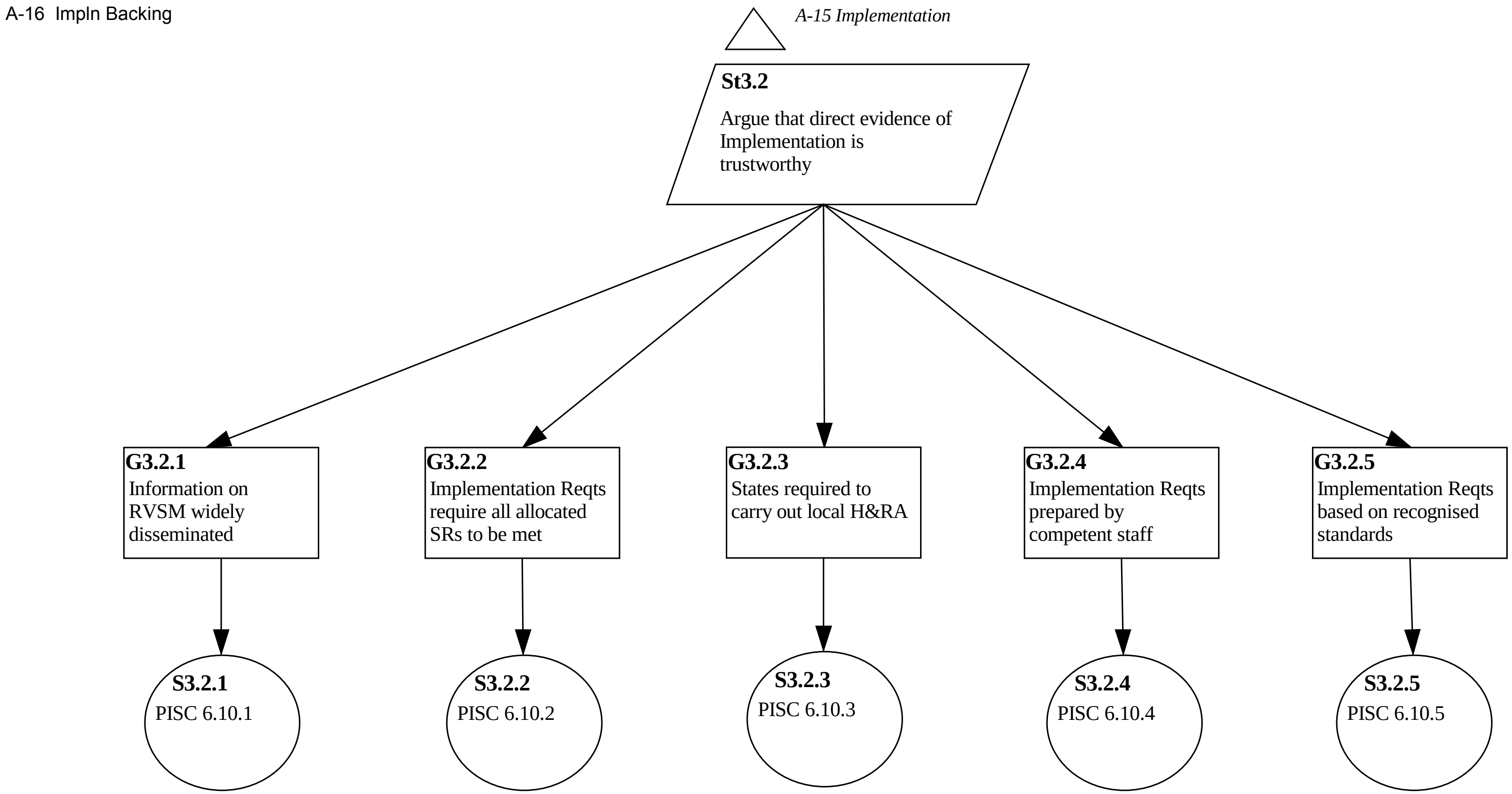


Figure 16: FIGURE A-16 / Safety Requirements Backing for Implementation

A-17 Switchover

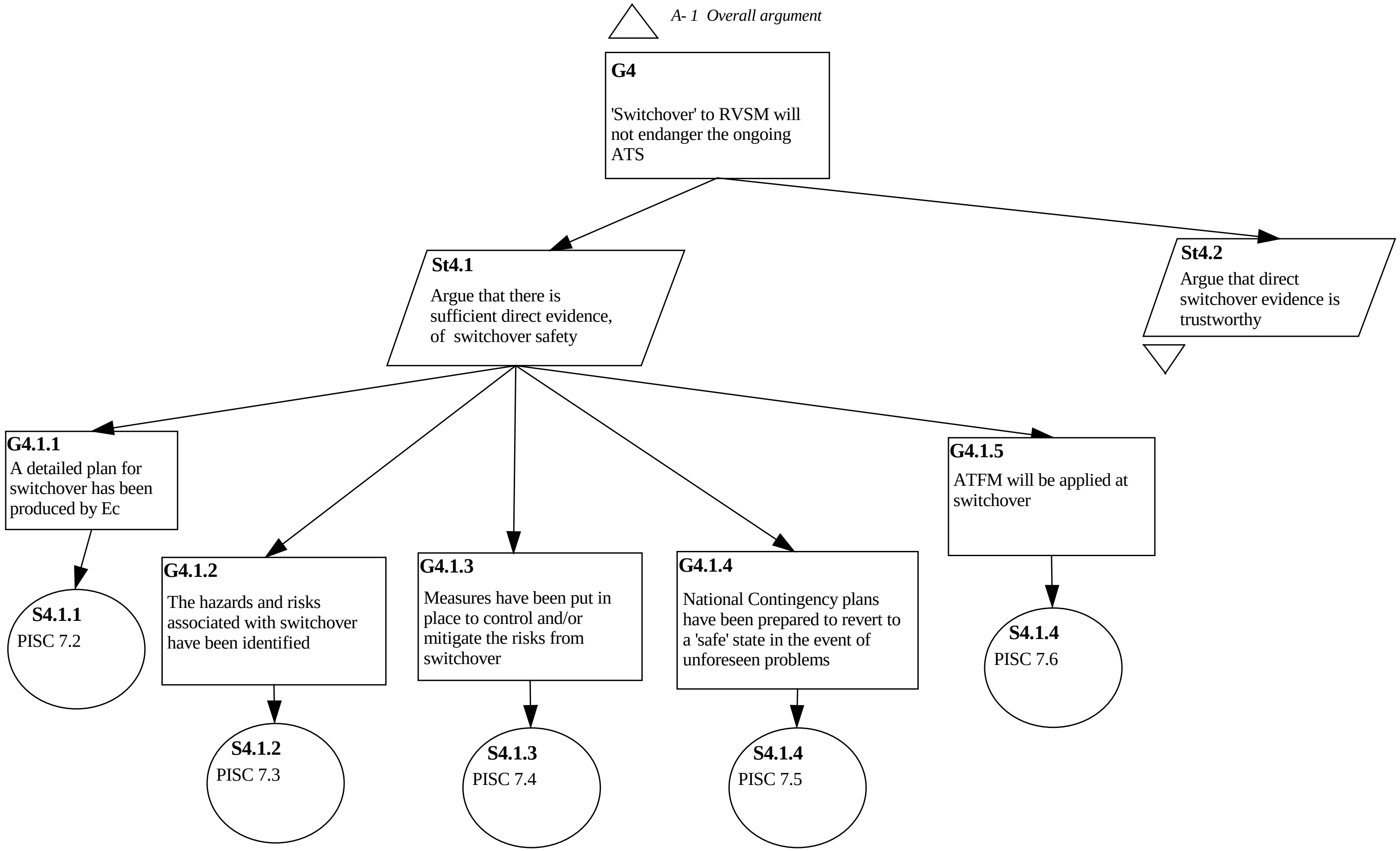


Figure 17: FIGURE A-17 / Switch-Over

A-18 Switchover Backing

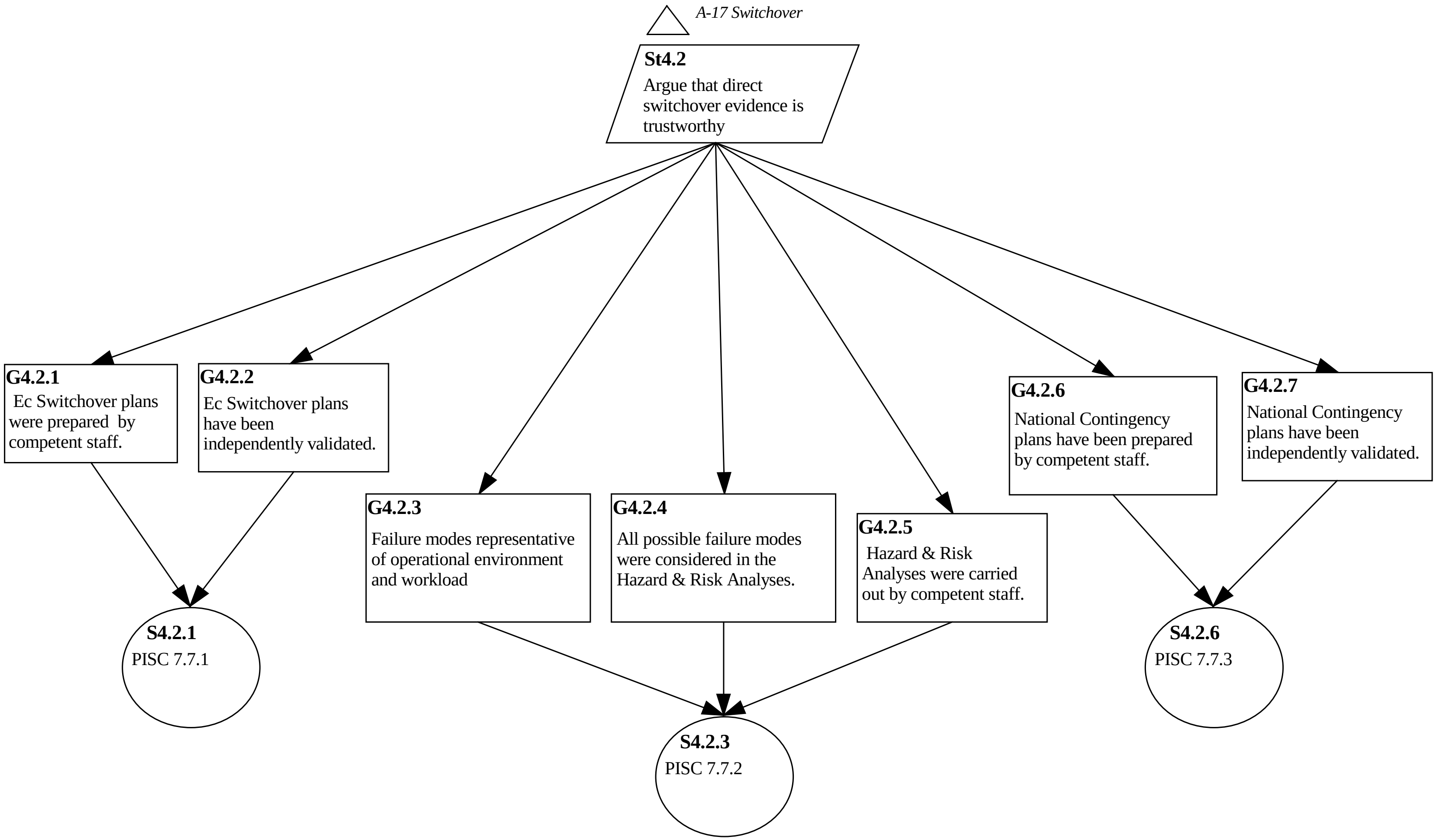


Figure 18: FIGURE A-18 / Switch-Over Backing

APPENDIX B - ATC SIMULATIONS

Introduction

The most effective means of assessing the operational impact, and of determining the implications and consequences, of the implementation of RVSM on ATC and Airspace Issues, is through the use of ATC Simulations. Two types of simulation studies were used in the examination of RVSM - Fast Time and Real Time.

Fast Time Simulations

Fast Time simulations involve the use of computer-generated aircraft following computer-generated routes and behaving in accordance with pre programmed characteristics. ATC responses are also generated by the computer in accordance with pre programmed situation resolutions that have been determined by examining actual controllers reactions and preferences to any given situation. Recorded aircraft data is obtained from the appropriate ATC centre or centres. Different scenarios applicable to the particular study are then determined. Each scenario can include up to 6 hours of recorded traffic data.

As the simulation of the agreed scenarios is progressing, the actions of the aircraft and the simulated controller inputs are recorded for subsequent analysis. ATC workload has proved to be a sensitive indicator of the viability of particular scenarios, or of the concept as a whole, and also to show which aspects of the scenario warrant further study in Real Time Simulations. A series of Fast Time Simulations have been completed to-date.

Real Time Simulations

Real Time Simulations also involve the use of computer-generated aircraft and routes but air traffic controllers are used to give the responses to situations in actual (real) time. The traffic and scenario preparations are much the same as those of Fast Time simulations.

The results of the simulations are again analysed through the detailed examination of the recorded output. The considerable advantage of Real Time Simulations is the subjective feedback from the controllers involved in the conduct of the simulation.

The first Real Time RVSM Simulation Study was undertaken for the North Atlantic (NAT) area in May 1994. The first Continental European RVSM Simulation was carried out in May 1995. A further ten Real Time Simulations have been conducted since then. Six of the eleven simulations were commissioned through the EUROCONTROL Experimental Centre (EEC) at Bretigny, and either took place there or were subcontracted (see RVSM 4 below) to other simulation facilities. These are identified below as Simulations RVSM 1 to RVSM 6. The RVSM Programme sponsored and/or assisted in a further four simulations and one study was undertaken by Sweden. A brief summary of the objectives, conclusions and recommendations of these real time simulations is provided below, in chronological order.

a) First Continental RVSM Simulation (RVSM 1): AS 16 - REIMS, ZURICH, and KARLSRUHE – May 1995 [14]

This simulation was the 'first look' at the implications of RVSM in Continental Europe. It examined Parts of Reims and Zurich airspace together with a Military Sector. It was concluded that significant benefits could accrue from the use of RVSM; and that every effort should be made to introduce RVSM in the widest area possible at the earliest time.
The report recommended that consideration should be given to the problems that may arise if civil MASPS and non-MASPS are expected to fly in the same airspace as Military non-MASPS aircraft would suffer a penalty compared with MASPS equipped aircraft.
It was also recommended tha, wherever possible, consideration should be given to making military aircraft MASPS compliant.

b) Second Continental RVSM Simulation (RVSM 2): SA 4 – HUNGARY. May – June 1996 [15]

The airspace of Hungary, with the addition of a North/South route, was used to emulate the core area of Europe. The simulation studied the two possible Flight Level Orientation Schemes (FLOS) that had been identified by an earlier Fast Time Simulation. It also considered how the 6 extra flight levels, that RVSM would provide, could be used and it examined the implications of non-RVSM approved traffic operating in RVSM airspace.
As a secondary objective the simulation evaluated the difficulty of restoring standard separation in the case of turbulence for the chosen FLOS.
In all there were seven Civil sectors and two Military sectors involved in this simulation.

The simulation concluded that future studies should concentrate on the following:

- Confirmation of the benefits of the Double Alternate FLOS. The Double Alternate scheme has real merit and should be tested further in other environments.
- Confirmation of the benefits for the military in other environments. The benefits for military non-MASPS traffic with Double Alternate should be confirmed in an another environment.
- Investigation of procedures for contingency situations. The turbulence scenario highlighted the fact that contingency situations must be addressed and procedures drawn up prior to RVSM introduction.

c) Simulation of Amsterdam airspace (APDSG/RVSM Programme sponsored) conducted at Dutch Military (Nieuw Milligen) in Oct 1996 [16]

The purpose of this simulation was to carry out an initial validation of ATC RVSM Procedures relating to:

A. Non-MASPS compliant Aircraft operating as GAT on ATS Routes, and as OAT crossing ATS Routes.
B. Contingencies when aircraft are unexpectedly unable to meet the MASPS requirements.
C. Contingencies should it be necessary to revert to a 2000ft VSM.
D. Co-ordination between Sectors/Centres for handling non-MASPS compliant aircraft and contingencies.
E. RTF Procedures.

The report concluded that:

A. The Double FLOS was deemed suitable for accommodating both State aircraft non-MASPS compliant and in handling contingency situations

B. Route Structure (i.e.: uni-directional vs. bi-directional) is considered an extremely important element in the total RVSM concept

C. Regardless of the FLOS or Route Structure implemented, there will be a requirement for a well coordinated FLAS to facilitate the handling of traffic over major crossing points.

D. The requirement to adapt FDPSs and automated flight data exchange systems to support the implementation of RVSM is paramount.

E. Controller training in the form of initial instruction on the procedures to be used in the RVSM airspace and as regular part of a refresher training package will be a requirement.

d) Third Continental RVSM Simulation (RVSM 3): SO 8 - REIMS, GENEVA, ZURICH, and RHINE, Jan – Feb 1997 [17]

This simulation examined the core area of European airspace and involved four ATC centres from France, Germany and Switzerland. A total of nine Civil sectors and one Military sector were simulated

The results from the first two simulations (RVSM 1 and RVSM 2) showed that the six extra flight levels available with RVSM offered many operational benefits. The aim of the third simulation was to determine the optimum application of the initial implementation of RVSM and to quantify the benefits of RVSM in the core area of Europe.

The following conclusions were made:

A. The Single and Double FLOS offered operational advantages compared to CVSM with the only disadvantages being lack of familiarity, the presence of non-MASPS certified aircraft and the need for some revised procedures. The main advantage to the controller was gaining the use of six extra flight levels. All the controllers were in favour of RVSM, and when asked at the end of the simulation to indicate a preference towards a FLOS (Single or Double) many were hesitant as they felt they could operate in either situation given adequate training and procedures. The final result showed no clear preference to either FLOS.

B. The Military controllers also showed no preference for either FLOS. They considered that to safely operate OAT within an RVSM environment it would be essential to be able to co-ordinate directly with the civil controllers and to have a radar system which was able to give information on the flight level intentions of the civil traffic.

C. There was no significant difference in controller workload between the Single and the Double FLOS regardless of the traffic level. The presence of non-MASPS aircraft increased controller workload when compared to a totally MASPS environment. There was little difference in controller workload figures when CVSM was compared to RVSM with 3% non-MASPS traffic using the same traffic load.

D. There was a decrease in controller workload in RVSM exercises when all traffic was MASPS certified compared to the same traffic using CVSM.

E. RVSM at +55% traffic (0% non-MASPS) showed a similar average controller workload level to CVSM at +35% traffic. Further study is recommended to validate the results.

F. After using the proposed general ATC procedures as developed by the ATM Procedures Development Sub-Group (including ATC procedures to accommodate Non-MASPS State Aircraft) the Controllers agreed that:

- The integration of non-MASPS certified traffic within RVSM airspace caused many problems.
- **Radar label** - All the controllers used a Sony screen with colour display. The green radar label used to highlight the non-MASPS traffic was very effective and all controllers considered it necessary.
- **Flight Strip** - The controllers considered the printing of the words ‘ Non-RVSM’ on the flight strip necessary, and many used a different colour strip holder as an additional reminder.
- **Phraseology** - The controllers considered that the proposed R/T phraseology was excessive and took up too much R/T time. It was agreed to modify the procedures for the simulation and all the controllers considered that the phrase “Non-RVSM” was sufficient

G. The ATC Contingency Procedures for the change from RVSM to CVSM to RVSM (in the event of pre-described ATC contingency situations) were handled with few comments, however the controllers felt that there should be the capability to change the colour of the radar label to indicate the non-MASPS status of the aircraft following an equipment failure.

The Report recommended that:

A. • The decision on which FLOS to use within ECAC airspace is made as soon as possible to allow RVSM implementation to commence and at the same time a FLAS should be considered to enable a more orderly flow of traffic across Europe, especially at major cross over points.

B. • The simulation identified that non-MASPS GAT traffic increased controller workload appreciably. It is therefore recommended that the number of non-MASPS GAT aircraft within RVSM airspace be kept to a minimum. Further study should be carried out using a smaller number of non-MASPS GAT (1% or 2%) to confirm the effects on controller workload and safety.

C. The effect of Vortex Wake turbulence within an RVSM environment is investigated.

D. The simulation proved that some new R/T phraseology, coloured radar labels and specific flight strip marking all helped to highlight to the controller the non-MASPS traffic. Therefore in the interests of safety, it is recommended that these procedures are introduced for non-MASPS traffic operating within RVSM airspace.

E. Procedures for contingency situations should be simulated when a FLOS has been chosen using scenarios based upon real life occurrences.

e) Simulation of Romanian airspace at Constanta ACC (APDSG/RVSM Programme sponsored), June 1998 [18]

Simulation Objectives

A. Initial Validation of transition procedures and airspace design criteria relevant to RVSM transition.

B. Further validation of RVSM ATC Procedures

C. Further validation of ATC Systems adaptations supporting RVSM.

D. Investigate the operational impact of accommodating civil aircraft, non-RVSM approved, in RVSM transition airspace, climbing/descending to levels appropriate to adjacent airspace, as a function of the RFLs.

E. Further investigation of the operational impact of accommodating, non-RVSM transition airspace.
F. Investigate optimal operating practices in regards to feet/metric transition in the RVSM/non-RVSM transition airspace.

Conclusions/Recommendations:

The Report of the Simulation:

A. Provided further validation of those RVSM ATC procedures which were submitted for validation. Controllers confirmed the applicability and relevance of the existing procedures. The requirement to develop additional RTF phraseology based on the comments received of controllers will be studied within the terms of reference of the APDSG.
B. Provided further validation of the ATS systems adaptations prescribed for RVSM implementation.
C. Confirmed that transition tasks can be accomplished provided that all conditions and requirements regarding equipment (radar displays, flight strips, etc.), co-ordination, as stipulated in the procedures, are met.
D. Confirmed that training in advance of RVSM implementation is critical
E. Confirmed that local assessments as to the required scope of adaptations to airspace (e.g.: uni-directional flows, parallel ATS routes, etc.) and sectorisation associated with RVSM implementation should be undertaken early to ensure a comprehensive operational evaluation of the best solutions that could facilitate transition.
F. Confirmed the original assessment that the application of a FLAS which precluded the use of FLs 310, 350 and 390 in the eastbound sense within transition airspace, was an effective solution to resolving conflicts associated with the dissimilarities between the RVSM and CVSM systems of cruising levels.
G. Clarified that a strategy of incorporating a parallel ATS system to facilitate transition is one which needs to be evaluated on an individual basis..
H. Confirmed that the specific issue of feet/metric transition would require a separate evaluation based on airspace and operating practices which are already existing in the context of CVSM/metric transition.
I. Confirmed that a specific small-scale, real-time simulation regarding communication failure and contingency procedures would be required.
J. Confirmed that training issues will be of significant importance in permitting operational staff to acquire the required level of familiarity and proficiency with the application of the RVSM levels and 1 000 ft VSM.

f) Fourth Continental RVSM (Transition) Simulation (RVSM 4): TURKEY, Jan 1999. (EEC Report No. 341 – October) [19]

This simulation was held at ENAC Toulouse and was the first Real Time Simulation to examine an area in which the transition to and from CVSM/RVSM levels would take place. Turkish airspace was used as the model (Ankara FIR). The simulation studied the implications of the transition to/from a non-RVSM, non-radar environment to a radar RVSM environment. Various methods of effecting the transition to and from RVSM were tested including dualised routes, additional routes and a buffer zone.

With reference to the specific objectives the following conclusions were reached from the simulation.

1. **To investigate ATC techniques for handling traffic making the transition from an RVSM environment to a non-RVSM procedural environment and vice-versa.**
   It can be concluded that transition was achieved in all of the Scenarios, that is, aircraft were always established at their CVSM flight levels before entering the Tehran FIR. This was true for all exercises.
   The controllers felt that their workload in the sectors not affected by transition, was lower when using RVSM. In the transition sectors, the workload was similar to CVSM as they had to do the additional tasks of transition and transfer to Tehran FIR. There was no significant difference between the workload in the three RVSM scenarios.

2. **Examine the following airspace structure issues**
   - testing a revised route structure to handle transition
   - assess the impact of a defined Buffer Zone for handling transition

   A clear preference was expressed for the ROUTE scenario.

3. **Further validate the RVSM ATC Procedures developed by the ATM Procedures Development Sub Group (APDSG) of the ANT. This will include:**
   - **RT Phraseology**.

   The RT phraseology and the information displayed on the flight strips were considered appropriate by all the controllers. Some confusion did occur between
   the display of non-RVSM and non-RVSM State aircraft due to the fact that the Radar Position Symbol was the same for both aircraft and identification rested upon
   the pilot or the planning controller to notify the executive controller.
   - **RVSM Procedures - including the handling of non-RVSM approved traffic entering RVSM airspace which are required to descend below FL290 (orclimb above FL410), and non-RVSM approved State aircraft which have to be incorporated in the RVSM area.**

   All of the controllers felt that the non-RVSM traffic did increase their workload, however, no major problems were experienced with descending the non-RVSM (non-State) traffic below FL290. The controllers also managed to climb non-RVSM traffic (which was below FL290 and exiting RVSM airspace to CVSM airspace) to their RFL whilst still within the transition area.

g) Simulation of Latvian Airspace, Riga ACC, Sept. 1999 [20]
Objective: transition between RVSM FLs and metric levels at the EUR/Russian Federation boundary.(Ref.20).

h) Fifth Continental RVSM Simulation (RVSM 5) – European Core Area, October – November 1999. (EEC Report No. 349).[21]

This was the largest and longest simulation of all. It involved 8 ACCs from 5 States and took 7 weeks to complete. 70 controllers participated and 30 sectors were measured. The primary objectives were to test the possible advantages of using Flight Level Allocation Schemes (FLAS) in heavily congested sectors and to assess the impact of RVSM on sectorisation.

The study recommended that when preparing the airspace for RVSM implementation:

A. States avoid establishing Flight Level Allocation Schemes wherever possible. However, if circumstances dictate that a FLAS is necessary, this should be carefully co-ordinated with neighbouring ACCs and built on a temporary (not H24) or flexible basis.

B. The vertical DFLs between sectors are closely examined and an assessment is made of new DFLs, best suited to the expected redistribution of traffic.

C. Further Study of the inversion of UN852/3 is required. This should include adjacent ACCs in order to resolve the problems with arrival and departure routeings, within Reims airspace. Reims ACC considered that the inversion was under no circumstances a precondition for RVSM implementation.

i) Sixth Continental RVSM Simulation (RVSM 6) Cyprus and Greece (Sep – Oct 2000) [22]

This was the most recent Continental RVSM simulation and took place at the EUROCONTROL Experimental Centre (EEC) Bretigny between the 25th September 2000 and the 13th October 2000. The simulation studied the introduction of RVSM in the Cypriot and Southern Greek airspace and involved the participation of the neighbouring countries Egypt, Lebanon and Syria.
Controllers from the Area Control Centres at Nicosia and Athens demonstrated that they could successfully handle up to a 20% increase in traffic and perform the transition task from RVSM to non-RVSM airspace and vice-versa using a modified route structure involving uni-directional routes.
The controllers felt confident and positive using RVSM and continued the validation of RVSM ATC procedures. Changes to current ATC systems and ATC procedures were identified as requirements for successful RVSM implementation.

Conclusions and Recommendations

A. The use of uni-directional routes was considered to be the most appropriate method to handle the transition within the simulated airspace.
Short term – In view of the time constraint for RVSM implementation (24 January 2002), Nicosia and Athens should use the existing route network to create uni-directional routeings to handle the transition task required between their FIRs and adjacent non-RVSM FIRs.
Long term – In order for the Nicosia ACC to manage future traffic levels (equivalent to 30% increase on 2000 capacity) a re-organistion of the current sectorisation, route network and ATC procedures is required

B. The controllers were seen to successfully handle the transition task with a traffic increase of 20%. However, the workload figures for the 30% traffic were unacceptably high in some cases, and show that in the future, changes are required to ATC procedures, airspace design and the Nicosia ATC system in order to handle increased levels of traffic.

C. Non-RVSM approved aircraft created additional workload, especially STATE flights operating within the 3 sectors handling the transition task. The addition of the RFL on the Cyprus paper strips was required to reduce the R/T, and allow the controller to plan ahead.

D. The majority of the controllers felt positive and confident using RVSM

E. The changeover of flight levels from non-RVSM to RVSM planned for 24 tJanuary 2002 should not be difficult provided that the correct pre-implementation preparation has been carried out by the ACCs. It will be important that the controllers have received sufficient RVSM training and there are enough controllers available at the time of changeover to handle the forecast

j) Simulation of Moroccan airspace, Casablanca ACC, Oct 2000 (RVSM Programme assistance) [23]

Objective: to determine the best airspace organisation for Morocco and to examine transition procedures. Report not yet available.

k) Swedish RVSM simulation [24]

In the context of National activities undertaken as a part of the EUR RVSM Programme, Sweden has performed a real-time simulation to study the operation of RVSM within Swedish airspace and to define the Division Flight Level (DFL).

General Conclusions from the Simulations

The early simulations showed that the use of RVSM could reduce Controller workload. On the assumption of identical sectorisation and traffic flows, it was found that Controller workload in an RVSM environment would reach today's workload levels when an increase in traffic growth of around 20% had been experienced. In addition the availability of the six extra flight levels would increase the flexibility of the Controllers and enable them to :

(a) Handle current and future levels of traffic more efficiently.

(b) De-conflict traffic at European ATS crossing points more easily

(c) Accommodate pilot requests for optimal cruising levels more easily.

The availability of the additional Flight Levels in the busiest height band (FL 290 to FL 410 inclusive) would also allow Operators to plan for, and operate at or closer to, the optimum vertical route profile for the particular aircraft type and operating weight. This would provide fuel economies in terms of both the fuel carried, and the fuel used, for the flight. The economies were estimated at between 0.5% and 1% of the total fuel burn.

The specialised ATC conclusions that were drawn from the simulations have been instrumental in the development of the material addressed in Section 5 relating to:

- Airspace Design.
- Flight Crew Procedures
- Flight Crew Training.
- Aircraft Equipment
- ATC Procedures
- ATC Training.
- ATC Equipment

APPENDIX C - AIRSPACE DESIGN

Proposed Area of Applicability (See footnote)

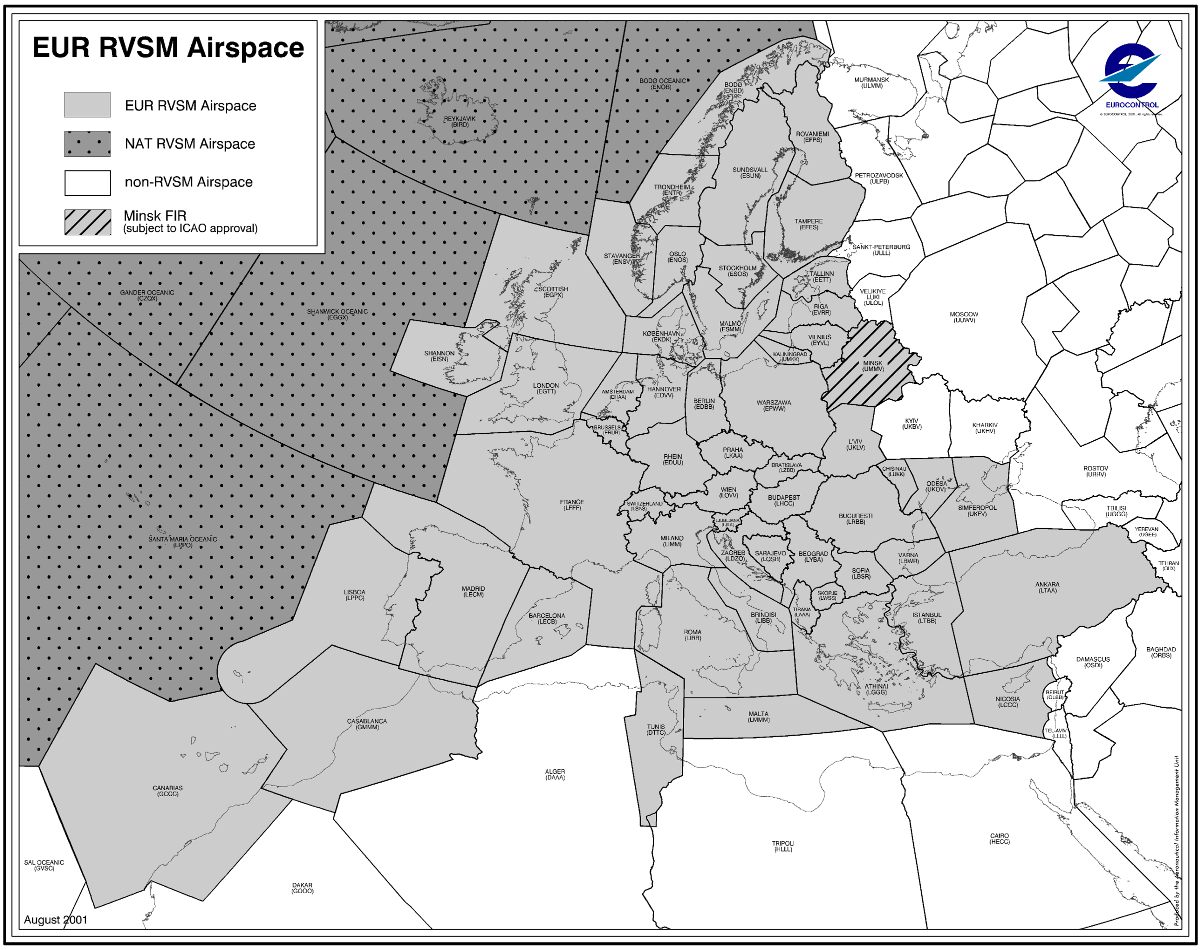


Figure 19: European RVSM Area

Footnote: The PISC document applies only to the above RVSM Area which is based on the 40 States participating in the RVSM Programme. The Programme exercises no influence over the airspace immediately adjacent to this area, in terms of whether or not that airspace becomes RVSM (as in the case of Belarus) or whether other changes occur. From the RVSM Programme perspective the affected States have to complete an LOA which takes account of any changes and provides an effective and safe transfer to/from the RVSM Area.

For Belarus, the affected neighbouring States have concluded LOAs which take into account that RVSM Operations start in Minsk. In addition , the RVSM Programme is providing co-ordination and support where necessary to facilitate the LOA and to influence and manage the change in environment.

Airspace Changes

The ATC Simulations described in Appendix B confirmed that the implementation of RVSM in the European Airspace would require major changes to the existing system for the Flight Level Orientation Scheme (FLOS) from FL 290 to FL 410 inclusive. The present and future system for the allocation of Flight Levels, are prescribed in ICAO Annex 2 – Rules of the Air, Appendix 3 **[27].** The existing system is shown in Table 3: Orientation of Flight Levels in existing 2000ft Vertical Separation, and the RVSM FLOS is shown in Table 4: The Orientation of RVSM Flight Levels with 1000ft Vertical Separation and in Annex 1 to this Appendix. In both schemes the usable Flight Levels are determined by the direction of flight. Aircraft on a track of between 000 to 179 degrees (or 090 to 269 in the FIRs/UIRs of Italy, France, Portugal, and Spain) are termed EASTBOUND, Aircraft on a track of 180 to 359 degrees (or 270 to 089 in the aforementioned FIRs/UIRs) are termed WESTBOUND.

Westbound Flights (180 -359°M)	Eastbound Flights (000 - 179°M)	Remarks
FL 430		Non RVSM Level
		FL 420 not used
	FL 410	
		*FL 400 not used
FL 390		
		*FL 380 not used
	FL 370	
		*FL 360 not used
FL 350		
		*FL 340 not used
	FL 330	
		*FL 320 not used
FL 310		
		*FL 300 not used
	FL 290	
FL 280		Non RVSM Level

Table 3: **Orientation of Flight Levels in existing 2000ft Vertical Separation**

Note: The Flight Levels marked with an * will become usable levels in RVSM airspace.

Westbound Flights (180 -359°M)	Eastbound Flights (000 - 179°M)	Remarks
FL 430		Non RVSM Level
		FL 420 not used
	FL 410	
FL 400		
	FL 390	
FL 380		
	FL 370	
FL 360		
	FL 350	
FL 340		
	FL 330	
FL 320		
	FL 310	
FL 300		
	FL 290	
FL 280		Non RVSM Level

Table 4: **The Orientation of RVSM Flight Levels with 1000ft Vertical Separation**

Note: The change with the greatest significance for RVSM operations is that, in a 1,000ft separation environment, the orientation and use of FLs 310, 350, and 390 is reversed.

The allocation of Flight Levels for the transition of aircraft to/from RVSM/non-RVSM airspace, and from Feet/Metric Levels, are shown in Annexes 2 and 3 (respectively) to this appendix.

Adaptation of the Airspace for RVSM Operations

The proposals for the necessary changes to the affected EUR Airspace in order to handle RVSM operations are set out in the document “Guidance Material – Adaptation of ECAC Airspace for EUR RVSM Implementation”. [26]. These proposals were developed after a detailed evaluation of the RVSM Simulations described in Appendix “B”; the analysis of traffic patterns at the proposed RVSM/non RVSM interface (using the System for Analysis and Assignment at the Macroscopic Level (SAAM) tool (SAAM Report No. 27, December 1998); and the Fast-Time Simulation into the impact of RVSM on part of the core area of Europe using the Total Airspace and Airport Modeller (TAAM) (Report in preparation). The Guidance Material [26] addresses the following issues:

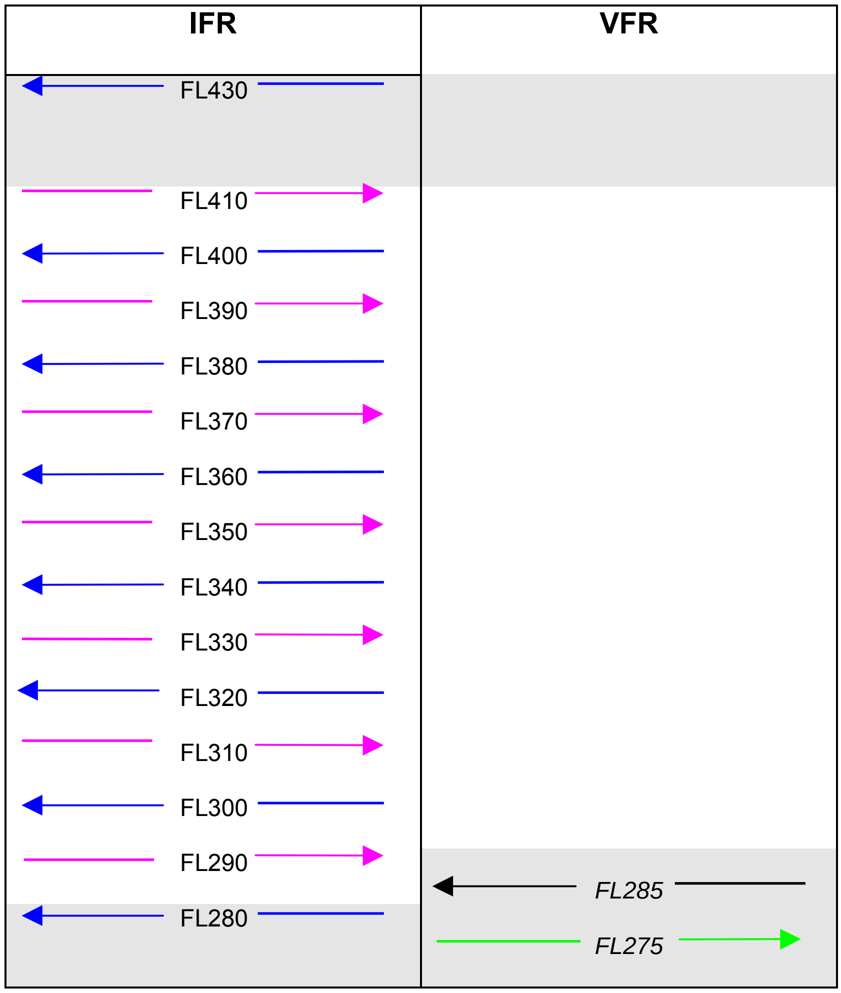
a) Transition Area Issues.
   i. Location
   ii. Transition Tasks,
   iii. RVSM/non RVSM Airspace,
   iv. Metric/Feet transition.
   v. Route Structure Solutions – Dualised Routes
   vi. Flight Level Allocation Scheme (FLAS)
   vii. Solution of Sectorisation Issues
b) Impact on EUR (non Transition) Airspace of RVSM.
   i. Climbing and Descending

ii. Routes Internal to EUR RVSM Area
iii. FLAS
iv. Sectorisation Issues
v. Selection of the Division Flight Level (DFL) for vertical sectorisation

c) Inter Sector Co-ordination to handle non RVSM approved aircraft.

Annex 1 to Appendix C

RVSM Table of Cruising Levels
(Reference: ICAO Annex 2, Appendix 3, Paragraph a))



IFR Cruising Level for Tracks 000° - 179° (or 090° - 269°in the FIRs/UIRs of Italy, France, Portugal and Spain)

IFR Cruising Level for Tracks 180° - 359° (or 270° - 089° in the FIRs/UIRs of Italy, France, Portugal and Spain)

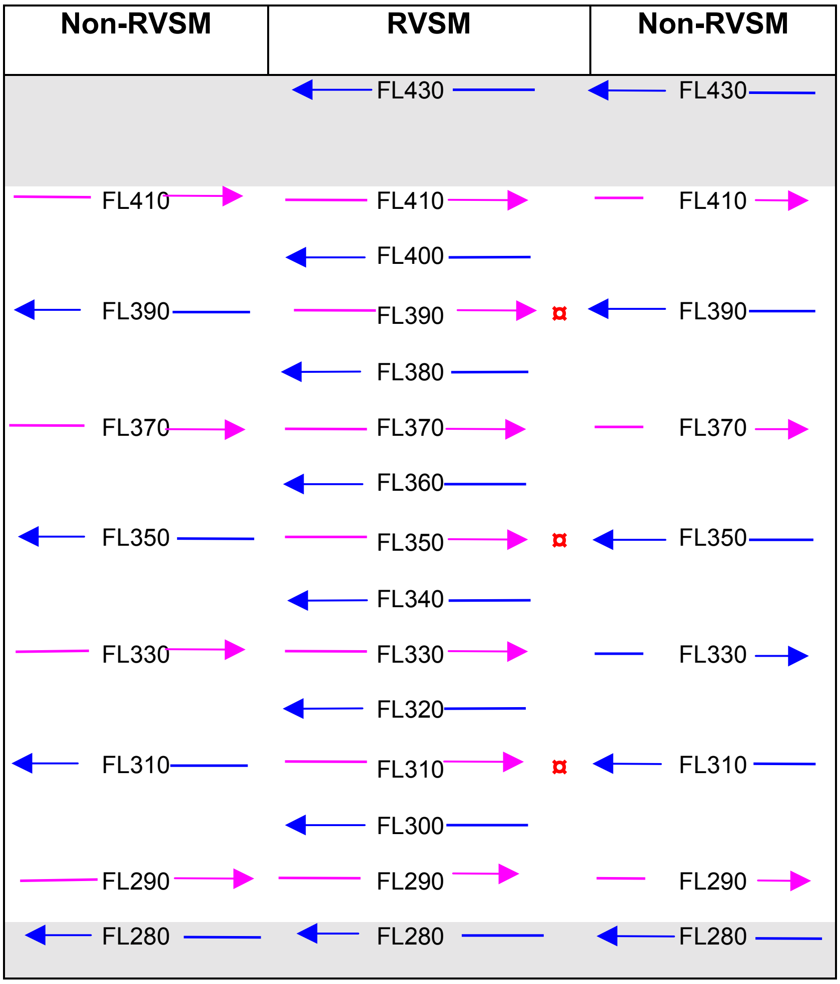
VFR Cruising Level for Tracks 000° - 179° (or 090° - 269° in the FIRs/UIRs of Italy, France, Portugal and Spain)

VFR Cruising Level for Tracks 180° - 359° (or 270° - 089° in the FIRs/UIRs of Italy, France, Portugal and Spain)

Note: The provisions of ICAO Annex 2 preclude VFR flight above FL 290. Accordingly, attention is drawn to the absence of VFR cruising levels above FL410, where the VSM reverts to 2 000 ft

Annex 2 to Appendix C

RVSM/Non-RVSM Transition



¤ conflict to be resolved during transition

Tracks 000° - 179° (or 090° - 269° in the FIRs/UIRs of Italy, France, Portugal and Spain)

Tracks 180° - 359° (or 270° - 089° in the FIRs/UIRs of Italy, France, Portugal and Spain)

Annex 3 to Appendix C

Feet - Metric Transition

Metric* Area	RVSM Area	Metric* Area
← 13,100 m (42,978 ft)	← FL430	← 13,100 m (42,978 ft)
	FL410 →	
12,100 m (39,698 ft) →	← FL400	12,100 m (39,698 ft) →
	FL390 →	
← 11,600 m (38,057 ft)	← FL380	← 11,600 m (38,057 ft)
	FL370 →	
11,100 m (36,417 ft) →		11,100 m (36,417 ft) →
	← FL360	
← 10,600 m (34,776 ft)	FL350 →	← 10,600 m (34,776 ft)
	← FL340	
10,100 m (33,136 ft) →	FL330 →	10,100 m (33,136 ft) →
	← FL320	
← 9,600 m (31,496 ft)	FL310 →	← 9,600 m (31,496 ft)
9,100 m (29,855 ft) →	← FL300	9,100 m (29,855 ft) →
	FL290 →	
← 8,600 m (28,214 ft)	← FL280	← 8,600 m (28,214 ft)

* system of metric cruising levels as applied, for instance, in the Russian Federation

→ Tracks 000° - 179° (or 090° - 269° in the FIRs/UIRs of Italy, France, Portugal and Spain)

← Tracks 180° - 359° (or 270° - 089° in the FIRs/UIRs of Italy, France, Portugal and Spain)

Airspace where Transition Tasks are carried out

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APPENDIX D – FUNCTIONAL HAZARD ASSESSMENT

INTRODUCTION

This Section, apart from minor editorial changes, has been copied from the Executive Summary of the draft Report of the RVSM Functional Hazard Assessment (FHA). It provides a summary of the FHA process that was conducted for the European RVSM Programme and includes a brief explanation of the objectives, principles, conduct and results of the FHA activities.

PURPOSE

The overall objective of an FHA is to determine how safe the system shall be by specifying the *safety integrity requirements* of the system related to the identified hazards. That is, specifying the minimum requirements to be achieved by the system. In this context, a "system" is considered to consist of three elements: people, equipment and procedures.

This RVSM FHA has been conducted in order to demonstrate compliance with the EATMP Safety Policy and to provide assurance that all hazards and risks associated with EUR RVSM have been identified and classified.

The RVSM FHA constitutes an essential part of the basis for the Go/Delay decision for EUR RVSM. Furthermore, the results of the RVSM FHA will be used as input to the Collision Risk Assessment and the National Safety Cases, where appropriate.

METHODOLOGY

The RVSM FHA is based upon the Safety Assessment Methodology developed by the EUROCONTROL Safety & Quality Management and Standardisation Unit (SQS). The methodology is laid down in the "EATMP Air Navigation System Safety Assessment Methodology" - SAF.ET1.ST03.1000-MAN-01-00 [ref. 2].

The Methodology consists of two main fundamentals which together constitute the foundation for deriving the safety objectives:

SEVERITY CLASSIFICATION

The severity classifications are derived from the EUROCONTROL Safety Regulatory Requirement (ESARR) 4; Risk Assessment and mitigation in ATM [ref. 4]. The severity classification determines the severity of the hazard. Five classes are used ranging from 1 (most severe) to 5 (least severe).

PROBABILITY CLASSIFICATION

The probability of occurrence is determined for each hazard. This determination of probabilities is a subjective process and is based on the participants at the FHA sessions. To guide the participants in determining the probability, a probability table (Figure 20) was developed and approved by SQS.

Probability class	Per flight hour/ per plane (P)	RVSM airspace (P)
Probable	$10^{-5} < P$	$1/\text{day} < P$
Remote	$10^{-7} < P \leq 10^{-5}$	$1/\text{year} < P \leq 1/\text{day}$
Extremely Remote	$10^{-9} < P \leq 10^{-7}$	$1/100 \text{ years} < P \leq 1/\text{year}$
Extremely Improbable	$P \leq 10^{-9}$	$P \leq 1/100 \text{ years}$

Figure 20: Probability Scheme

As mentioned above, the overall objective of an FHA is to determine safety integrity requirements of the system related to the identified hazards. The figure below presents the risk classification scheme providing the coherence between the severity classification and the probability classification. From Figure 21, the tolerable/not tolerable levels can be derived.

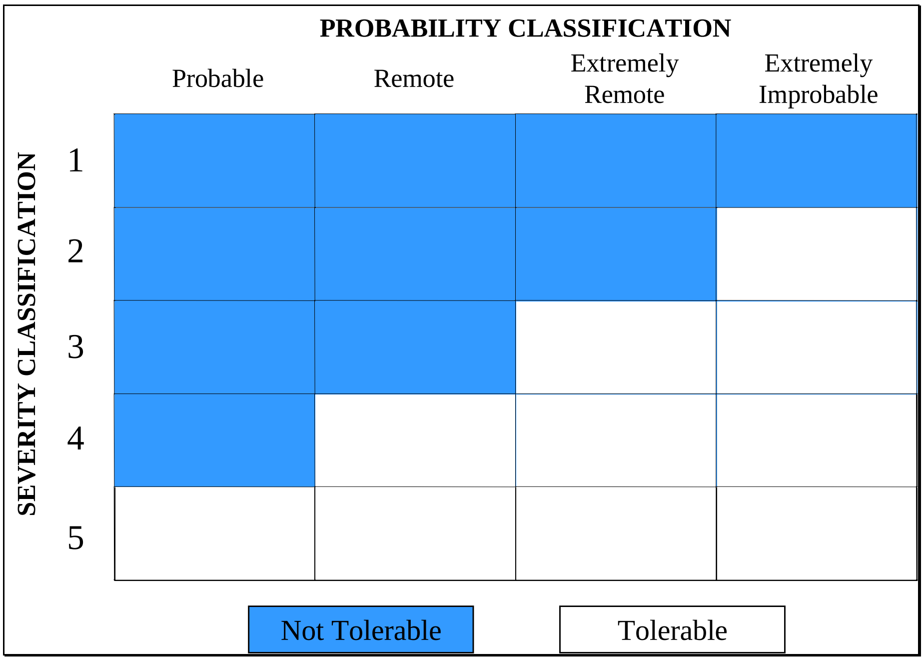

Figure 21: Risk Classification Scheme

Finally, the safety integrity requirement related to a hazard can be derived as shown in the following example:

If the severity classification is determined as 3 (by the operational experts, see below), the safety integrity requirement would be: “the probability of ‘a hazard’ occurring shall not be greater than extremely remote”.

The probability will be determined to “not greater than extremely remote” in order to stay in the TOLERABLE area as shown in Figure 21.

In the conduct of the RVSM FHA, it was necessary to introduce a number of variations from the FHA procedure described in the EATMP Methodology [ref. 2] were introduced.

Some variations were caused by the timing of the conduct the RVSM FHA. An FHA is normally conducted during the design phase of the proposed system. The RVSM FHA, however, was performed at a much later stage and the RVSM Programme was so advanced that it would be difficult to change operational procedures and system requirements. However, it was accepted that if the FHA identified any problem areas, they would be subsequently addressed by the RVSM Programme.

Hence, the RVSM FHA is not solely an FHA according to the methodology focusing on identifying the safety integrity requirements related to the identified hazards. The RVSM FHA can be considered to be a combination of the FHA, the PSSA, and the SSA as well.

During the hazard analysis, already developed RVSM mitigation means were identified and taken into consideration when risk assessing the hazard. Each hazard was, in fact, risk assessed before implementation of any RVSM mitigation means (i.e. taking the Conventional Vertical Separation Minimum (CVSM) environment and implementing RVSM into it) and after (i.e. allowing for any RVSM mitigation means that has been developed by the RVSM Programme Team). A ‘normal’ FHA would terminate the analysis following the first risk assessment.

SCENARIOS

The RVSM FHA was conducted in three separate sessions to address the areas identified in the initial Functional Hazard Assessment [ref. 9] :

1) Core EUR RVSM area ;
2) Transition Airspace ;
3) Switch-Over (+/- 24 hours of time of Switch-Over).

The output from the sessions was the identification of a number of hazards. For the analysis, these hazards have been grouped in two categories as follows:

a) Safety critical hazards.

   Hazards falling into this category are hazards that do not achieve the safety integrity requirement according to the Risk Classification Scheme (Figure 21). Thus, the hazard is considered to be NOT TOLERABLE. Any risks that fall into this category after RVSM mitigation will require the attention of the RVSM Programme.

b) Not safety critical hazards.

If hazards are achieving their safety integrity requirement they do not constitute a safety issue and therefore it is assumed that the identified RVSM mitigation is sufficient.

PROCESS

As described above, three FHA sessions were carried out. They were prepared in co-operation between Integra Consult and the RVSM Programme.

Before each session, each participant received a briefing pack including a Briefing Paper for the particular FHA session and other relevant RVSM material. The objective of the Briefing Paper was to allow the participants to familiarise themselves with some of the most important definitions and the FHA methodology. The Briefing Paper did also introduce the different scenarios related to that specific session.

The sessions themselves were conducted as “brainstorm” sessions with various flight crew members and air traffic controllers participating as operational experts.

A great deal of importance was attached to selecting these operational experts, as their knowledge and experience was required to fulfil the overall objective. The final result of the FHA sessions was very dependent on the involvement from the attendees, and the expertise of the selected participants was related to the area in focus for the particular FHA session. The RVSM programme group performed the selection of the participants.

In addition to the operational experts, representatives from the RVSM Programme were present at the sessions. Their roles were to assist the operational experts in any technical RVSM related issue and to introduce to the operational experts any RVSM mitigation, i.e. any specific RVSM operational procedures to be introduced when RVSM becomes operational.

For each session, specific scenarios were developed. The aim of these scenarios was to ensure that all aspects of flying and air traffic control operations were critically examined at some point during the session. Prior to each session, the scenarios were assessed for suitability and totality and amended in necessary.

In addition, the framework for the particular session was developed and referred to as the operational environment. The aim of the operational environment was to ensure that all participants had a common perception of the conditions under which the FHA was carried out.

Several assumptions were made in the development of the various aspects of the likely operational environment. These assumptions had to be assessed to make sure that they were realistic for the participants, i.e. they are not overly pessimistic or optimistic.

As with the scenarios, the operational environment was discussed and, if necessary, modified before the FHA brainstorm. Once the operational environment was agreed, it was used consistently throughout the particular session.

Once the scenarios and the operational environment were agreed upon, the FHA session itself commenced. The brainstorming sessions were completed in order to identify all potential hazards and this process had the advantage of providing a free-flowing diversity of thoughts whilst ensuring that all aspects were covered. The brainstorm sessions were facilitated by a moderator.

An FHA secretary, using a database specifically tailored to this FHA RVSM assessment, undertook the recording of the results of the assessment. This was done on-line during the brainstorm – and projected to a white screen for the approval of the participants.

Once the hazards associated with a particular operational scenario were identified, the study team discussed each hazard in turn to determine whether they were credible; i.e. did they affect the safe operation of the system?, was there an identifiable cause or failure mode?, and was there a measurable probability of occurrence?.

For those hazards which were considered credible, the operational experts then determined the precise description of the hazard.

After the FHA session, the process was completed as follows:

a) the recorded information was structured ;
b) safety integrity requirements for the hazards (before any RVSM mitigation means is implemented) were derived ;
c) assessment (after RVSM mitigation) of whether the hazards were tolerable or not tolerable was performed;
d) all hazards, where further actions by EUROCONTROL are needed, were highlighted ;
e) recommendations for not tolerable hazards (if any) were developed.

HAZARD ASSESSMENT

The hazards documented in this FHA are all a result of a “brainstorm” session and they are all subjective statements from operational experts attending those sessions.
In this connection it can be stated that most of the hazards identified with an operational/safety consequence settled as ‘increased workload’ do not necessarily belong to the mature situation, which is an assumption for the first two sessions (mature situation, one year after implementation with all teething problems solved). Problems with increased workload may be adjusted through capacity regulations.

THE POSITIVE AND NEGATIVE ASPECTS OF THE FHA

FHA is a process which focuses on issues that can go wrong. In that sense, an FHA will on the surface appear as a negative process. This can be combined with the fact that the operational experts are asked to identify each and every potential failure and to assess the worst case consequences. This approach can lead to a relatively negative view on RVSM.

It should be recognised that RVSM will also have many positive aspects. It will undoubtedly provide much extra, urgently needed, capacity to the European ATM system by introducing six new flight levels. General handling of air traffic will also be easier to accomplish for the controllers. Where de-confliction today may require time and effort consuming radar vectoring, this can, in an RVSM environment, be resolved more easily and swiftly by a temporary level change of only 1000 ft. Finally, it will be possible for aircraft to operate at, or closer to, their optimum flight levels in RVSM airspace.

Table D-1 – Safety Integrity requirements Derived from FHA

FHA Ref	Safety Integrity requirement	Hazard severity category	Allocated to :	Reference	Comments
$H_M1.1$	The probability that an intolerable situation occurs because of nuisance TAs and RAs for aircraft with MTOW < 15.000 kg or < 30 pax not carrying ACAS 7.00 shall not be greater than **remote**	4	System Monitoring	SM5	Monitor TAs and RAs Increased risk cf CVSM for TCAS 6.04a aircraft. Mitigate probability by strongly recommending TCAS V7.0,
$H_M1.2$	The probability that an intolerable situation occurs due to nuisance TAs and RAs shall not be greater than **remote**	4	N/a	N/a	Probability of occurrence is reduced by TCASV7.0. Upgrade of TCAS to V7.0 is not a specific safety requirement for EUR RVSM but is being done by most operators.
$H_M1.8$	The probability that an intolerable situation occurs because a pilot deviates from a clearance shall not be greater than **extremely remote**	3	Flight Crew Procedures Flight Crew Training	FC3 FC6	No mitigation available. No increase in risk cf CVSM
$H_M1.3$	The probability that an intolerable situation occurs due to an altitude deviation generated by a system error shall not be greater than **extremely remote**	3	Aircraft Equipment System Monitoring	AC1	Mitigation of probability covered by basic reqt for MASPS.
$H_M1.6$	The probability that an intolerable situation occurs because a pilot deviates from the cleared level/track due to lack of visual perspective shall not be greater than **extremely remote**	3	Flight Crew Training	FC6	Mitigation possible through pilot awareness training
$H_M1.9$	The probability that an intolerable situation occurs because an aircraft unexpectedly encounters turbulence shall not be greater than **extremely remote**	3	ATC Procedures ATC Training	ATC5 ATC7	Mitigation possible through temporary suspension of RVSM
$H_M1.10$	The probability that RVSM operations have to be suspended, due to sever turbulence, shall not be greater than **remote**	5	ATC Procedures ATC Training	ATC5 ATC7	Mitigation to severity 5 through ATC procedures and training, to handle such situations
$H_M1.11$	The probability that an intolerable situation occurs due to a sudden deviation from cleared FL and/or route caused by wake vortex shall not be greater than **remote**	4	Airspace Design	AD2	No mitigation available.
$H_M1.13$	The probability that an aircraft's status has to be down-graded to non-RVSM, due to aircraft equipment failure or adverse weather, shall not be greater than **remote**	4	ATC Procedures ATC Training	ATC5 ATC7	Mitigation possible through ATC procedures and training, to handle such situations

FHA Ref	Safety Integrity requirement	Hazard severity category	Allocated to :	Reference	Comments
H_M1.14	The probability that an intolerable situation occurs because of approval status (downgraded due to equipment failure), and that the pilots are not initially able to control the level, shall not be greater than **extremely improbable**	2	Aircraft Equipment	AC1	No mitigation available
H_M1.15	The probability that an intolerable situation occurs due to an unserviceable RX/TX shall not be greater than **remote**	4	Flight Crew Procedures Flight Crew Training ATC Procedures ATC Training	FC7 FC8 ATC5 ATC7	Procedural mitigation can reduce to SC4
H_M2.1	The probability that an aircraft with degraded RVSM status has to be accepted into RVSM airspace shall not be greater than **remote**	4	ATC Procedures ATC Training	ATC5 ATC7	Mitigation possible through ATC procedures and training, to handle such situations
H_M2.2	The probability that an intolerable situation occurs because a 'W' is indicated in the FPL or the pilot claims aircraft for RVSM approved despite this is not the case shall not be greater than **remote**	4	Flight Crew Procedures Flight Crew Training System Monitoring	FC4 FC5 SM4	Mitigation of probability through flight crew awareness and in-service height monitoring.
H_M2.4	The probability that an intolerable situation occurs due to a missing flight plan shall not be greater than **remote**	4	ATC Procedures ATC Training	ATC3 ATC6	No mitigation available
H_M2.5	The probability that an intolerable situation occurs due to application of two different separation standards (RVSM approved/non-RVSM approved state a/c) within the EUR RVSM airspace shall not be greater than **remote**	4	ATC Equipment ATC Procedures ATC Training	ATC10 ATC3 ATC6	Mitigation of probability through ATC displays, procedures and training
H_M2.6	The probability that an intolerable situation occurs due to STCA functionality shall not be greater than **remote**	4	ATC Equipment	ATC4	Mitigation of probability through modification to STCA
H_M2.7	The probability that an intolerable situation occurs because the RVSM status of aircraft operating immediately above and below RVSM airspace is not known to ATCO shall not be greater than **remote**	4	ATC Equipment ATC Procedures ATC Training	ATC10 ATC8 ATC9	Mitigation of probability through ATC radar displays, and through development of special co-ordination procedures (for DFLs at 295)
H_M2.8	The probability that an intolerable situation occurs due to missing IFPS check of FPLs coming from states inside RVSM area shall not be greater than **extremely remote**	4	ATC Equipment	ATC10	Mitigation of probability through IFPS check of FPLs

FHA Ref	Safety Integrity requirement	Hazard severity category	Allocated to :	Reference	Comments
H_M2.9	The probability that an intolerable situation occurs due to manual insertion of changes or missing RVSM approval status shall not be greater than **remote**	4	ATC Procedures ATC Training	ATC8 ATC9	No mitigation available
H_M2.10	The probability that an intolerable situation occurs because of lack of adequate system support to the external exchange of RVSM related flight data and co-ordination data (OLDI messages) shall not be greater than **remote**	4	ATC Equipment	ATC10	Mitigation of probability through modification of OLDI-based systems (or limitations on sector capacity)
H_M2.11	The probability that an intolerable situation occurs due to lack of adequate system support to the internal exchange of RVSM related flight data and co-ordination data (posting, printing of flight strips, etc.) shall not be greater than **remote**	4	ATC Equipment	ATC10	Mitigation of probability through modification of flight strip systems (or limitations on sector capacity)
H_M2.13	The probability that the manual co-ordination obligation of RVSM approval status in case of missing information on flight plans will lead to an intolerable situation, shall not be greater than **remote**	4	ATC Equipment	ATC10	Some mitigation of probability through IFPS rejection of illegitimate FPLs. State aircraft and non-IFPS FPLs handled manually – may limit sector capacity
H_M2.17	The probability that an intolerable situation occurs because of issue of an incorrect clearance to a <u>non</u>-RVSM approved aircraft (applying a wrong separation standard) by a controller shall not be greater than **remote**	4	ATC Equipment ATC Procedures ATC Training	ATC10 ATC8 ATC9	Mitigation of probability through modification of radar display and flight strip systems, and special R/T phraseology / co-ordination procedures
H_M2.27	The probability that a computer failure will lead to an intolerable situation shall not be greater than **probable**	5	ATC Equipment	ATC10	Mitigation of effect (to SC 5) through modification of Back-up systems to achieve RVSM compatibility.
H_T1.1	The probability that an intolerable situation occurs due to adjustment to CVSM FL too early of a non-RVSM approved aircraft shall not be greater than **remote**	4	ATC Procedures ATC Training	ATC1 ATC2	Mitigation of probability through ATC procedures and training
H_T1.2	The probability that an intolerable situation occurs because a non-RVSM approved aircraft is given RVSM separation in transition airspace shall not be greater than **extremely remote**	3	ATC Equipment ATC Procedures ATC Training	ATC10 ATC1 ATC2	Mitigation of probability through modification of radar display and flight strip systems, and ATC procedures and training
H_T1.5	The probability that an intolerable situation occurs due to inability to provide longitudinal separation for RVSM	4	ATC Procedures ATC Training	ATC1 ATC2	Mitigation of probability through flow-control procedures for affected areas.

FHA Ref	Safety Integrity requirement	Hazard severity category	Allocated to :	Reference	Comments
	approved aircraft entering CVSM (congestion) shall not be greater than **remote**				
$H_T1.8$	The probability that two aircraft appear at the same level in opposite directions, at the same time, shall not be greater than **extremely remote**	3	Airspace Design ATC Procedures ATC Training	AD1 ATC1 ATC2	Mitigation of probability / effect through use (where possible) of unidirectional routes, freezing of FLs 310,350 and 390 for specified distance in Transition areas and use (where possible) of offsets
$H_T1.9$	The probability that an intolerable situation occurs due to an aircraft exiting at a non-existing CVSM level shall not be greater than **extremely remote**	3	Flight Crew Training ATC Equipment ATC Procedures ATC Training	FC2 ATC11 ATC1 ATC2	Mitigation of probability through pilot awareness training. Also, RFL to be shown on FPS and OLDI messages Also, improved co-ordination between States
$H_T1.10$	The probability that an intolerable situation occurs because the length of the buffer area is too short shall not be greater than **extremely remote**	3	Airspace Design	AD1	Mitigation of effect (to SC5) through design of buffer areas and use (where possible) of unidirectional routes
$H_T2.2$	The probability that an intolerable situation occurs because the ATCO fails to perform conversion to the metric CIS system shall not be greater than **extremely remote**	3	ATC Procedures ATC Training Airspace Design	ATC1 ATC2 AD1	Mitigation of probability through ATC procedures and training. Mitigation of effect (to SC5) through use (where possible) of unidirectional routes
$H_T3.5$	The probability that an intolerable situation occurs due to a late hand-over of an aircraft from a non-RVSM airspace shall not be greater than **remote**	4	Flight Crew Procedures Flight Crew Training ATC Procedures ATC Training	FC1 FC2 ATC1 ATC2	Mitigation of probability through Flight Crew and ATC procedures / training, including use of compulsory reporting points
$H_T3.6$	The probability that an intolerable situation occurs due to congestion at FL280 and below occurs shall not be greater than **remote**	4	ATC Procedures ATC Training Airspace Design	ATC1 ATC2 AD1	Mitigation of probability through flow-control procedures and/or sectorisation.
$H_S1.1$	The probability that an aircraft fuel shortage occurs due to an ATC-enforced level change at Switchover shall not be greater than **extremely remote**	3	Flight Crew and ATC awareness and training	SP10	Mitigation of probability through issue of an AIC regarding level changes at Switchover.
$H_S1.2$	The probability that an intolerable situation occurs due to an incorrect and unsafe command issued by an ATCO due to the inability of ATCO to adjust to RVSM procedures shall not be greater than **extremely**	2	ATC Training ATC Procedures	SP1 SP2	Mitigation of probability through ATC training to be completed before Switch-Over. Also additional special procedure for ATCO to obtain verbally RVSM status of each aircraft

	improbable				under control, in period before Switch-Over
H_S1.3	The probability that an intolerable situation occurs because of an incorrect and unsafe command issued by an ATCO due to high ATCO workload due to simultaneous implementation of new ATC procedures/new ATS systems shall not be greater than **extremely improbable**	2	Airspace Design ATC Equipment	SP3 SP4 SP5	Mitigation of probability through completion of route structure/sectorisation in the EUR RVSM airspace by October 2001; Also, required that new/modified ATS systems be in place and checked by 24 January 2002, or acceptable Contingency Plan shall be available. Also, CFMU shall have a capacity policy in place
H_S1.4	The probability that an intolerable situation occurs due to an incorrect and unsafe command issued by an ATCO due to misuse of the Flight Level Allocation Scheme shall not be greater than **extremely improbable**	2	ATC Training ATC Procedures	SP1 SP6	Mitigation of probability through ATC training to be completed before Switch-Over Also, additional special handover procedure for each sector/centre to independently verify the level of inbound aircraft
H_S1.5	The probability that an incorrect and unsafe command is issued by an ATCO due to ATC equipment or OLDI failure at Switchover shall not be greater than **remote.**	4	Contingency Planning ATC Equipment	SP11 SP4	Mitigation of probability through Contingency planning Also, required that new/modified ATS systems be in place and checked by 24 January 2002, or acceptable Contingency Plan shall be available.
H_S1.9	The probability that excessive workload on ATCOs occurs at Switchover due to traffic congestion below FL290 shall not be greater than **remote.**	4	ATC Procedures	SP7	Mitigation of probability through additional flow restrictions at Switchover and timing of Switchover to coincide with period of low traffic demand.
H_S1.12	The probability that loss of separation occurs as a result of not being able to get aircraft to climb/descend due to high traffic density shall not be greater than **remote**	4	ATC Procedures	SP7	Mitigation of probability through additional flow restrictions at Switchover and timing of Switchover to coincide with period of low traffic demand.
H_S1.13	The probability that loss of separation occurs as a result of re-routing/diverting due to in-flight contingency or bad weather shall not be greater than **remote**	4	Flight Crew and ATC awareness and training	SP1 SP12	Mitigation of probability through completion of Flight Crew and ATC RVSM training before Switchover.
H_S1.16	The probability that loss of separation occurs as a result of aircraft not changing level when required to do so due to pilot unpreparedness or bad weather shall not be greater than **remote**	4	Flight Crew and ATC awareness and training	SP1 SP12	Mitigation of probability through completion of Flight Crew and ATC RVSM training before Switchover.
H_S1.17	The probability that an intolerable situation occurs due to ATC system not being able to detect RVSM Status shall not be greater than **extremely improbable**	2	ATC Equipment ATC Procedures	SP4 SP2	Mitigation of probability through SPs4 and 2, as above
H_S1.18	The probability that an intolerable situation occurs due to an intolerable situation caused by wrong RVSM	2	ATC Equipment	SP4	Mitigation of probability through SPs4 and 2, as

	status indication on flight plan shall not be greater than **extremely improbable**		ATC Procedures	SP2	above
H_S2.1	The probability that loss of separation occurs due to incorrect use of the FLAS shall not be greater than **extremely remote**	3	ATC Procedures ATC Training	SP13 SP9 SP1	Covered in part by H_T1.8. Specific requirement for Switchover is for LoAs to address issues related to FL310, 350 and 390, ensuring that LoAs are in place, and ATC training is completed, on time.
H_S2.2	The probability that an intolerable situation occurs due to a FPL indicating a wrong RVSM status shall not be greater than **remote**	4	ATC Equipment ATC Procedures	SP4 SP2	Mitigation of probability through SP4 (specifically for IFPS) and SP2, as above
H_S3.2	The probability that an aircraft fuel shortage occurs due to an non-RVSM aircraft, departing from outside IFPS area and planning to fly in RVSM airspace shall not be greater than **remote**	4	Flight Crew and ATC awareness and training	SP1 SP12	Mitigation of probability through completion of Flight Crew and ATC RVSM training before Switchover.
H_S5.1	The probability that an intolerable situation occurs due to unsafe and incorrect commands issued by ATCO during high traffic density shall not be greater than **extremely remote**	3	ATC Procedures	SP7 SP5 SP8 AD1.3	Mitigation of probability through additional flow restrictions, Mitigation of probability through SP5, as above Mitigation of probability through special briefings / extended handover for on-coming watches, for the period immediately before, during and following Switch-Over Mitigation of probability through introduction of uni-directional routes
H_S5.2	The probability that an excessive level of R/T traffic occurs due to a greater number of level changes at Switchover shall not be greater than **remote**	4	ATC Procedures Flight Crew and ATC awareness and training	SP7 SP14	Mitigation of probability through additional flow restrictions and last-minute briefings on R/T procedures before Switchover.
H_S5.9	*The probability that an intolerable situation occurs due to pilot deviating from the cleared level/track because of lack of visual perspective shall not be greater than **extremely remote***				*Not a specific Switch-Over hazard - already covered by H_M1.6.*
H_S5.10	The probability that an intolerable situation occurs due to inadequate procedures shall not be greater than **remote**	4	ATC Procedures	SP7 SP9	Mitigation of probability through additional flow restrictions. Also ensure that LoAs are in place before Switch-Over
H_S6.1	The probability that an intolerable situation occurs due to ATCO applying wrong separation standards shall not be greater than **extremely improbable**	2	ATC Equipment ATC Procedures	SP4 SP2	Mitigation of probability through SPs4 and 2, as above

$H_S6.5$	The probability that an intolerable situation occurs due to an FPL indicating that a State aircraft is RVSM approved, however, being non-RVSM approved shall not be greater than **extremely improbable**	2	ATC Procedures	SP2	Mitigation of probability through SP 2, as above
$H_S6.7$	The probability that loss of separation occurs as a result of failure to identify formation flights due to ATCO error or wrong FPL shall not be greater than **extremely improbable**	2	ATC Procedures	SP2	Mitigation of probability through SP 2, as above

FHA REFERENCES

Ref.	Document	Edition	Author
1.	ATC Manual for a Reduced Vertical Separation Minimum (RVSM) in Europe	1.0	EUROCONTROL
2	EATMP Air Navigation System Safety Assessment Methodology, SAF.ET1.ST03.1000-MAN-01-00	1.0	EUROCONTROL
3.	En-route encounters with Wake Vortices, and the implications of the Reduced Vertical Separation Minima (RVSM)		EUROCONTROL
4.	Risk Assessment and Mitigation in ATM	0.2	ESARR 4
5	ICAO Doc 7030/4 EUR SUPPS Amendments		ICAO
6.	ICAO Definition: Airborne Collision Avoidance System. Annex 2 – Rules of the Air		ICAO
7.	RVSM Safety Policy Document	1.0	EUROCONTROL
8.	DOC 8168 – Procedure for Air Navigation Services		ICAO
9.	Initial Functional Hazard Assessment for the RVSM Programme	1.0	IABG mbH
10.	Flight Planning Requirements. Article from the EUROCONTROL RVSM website.		EUROCONTROL

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APPENDIX E - HEIGHT MONITORING

E.1 Height Monitoring Requirement

ICAO Doc 9574 **[6]** specifies that "system performance monitoring is necessary to ensure that the implementation and continued operation of RVSM meet the safety objectives".

In Doc 9574, the objectives of the height monitoring are to:

i) provide 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) provide guidance on the efficacy of the MASPS and on the effectiveness of altimetry system modifications; and
iii) provide evidence of ASE stability.

In JAA TGL6 Rev1 **[11]** Objective i) is reinforced by the statement "For airspace where a numerical Target Level of Safety is prescribed, monitoring of aircraft height keeping performance in the airspace by an independent height monitoring system is necessary to verify that the prescribed level of safety is being achieved".

To meet these requirements and objectives, the EUR RVSM Programme has established a height monitoring infrastructure, based on ICAO requirements **[2]** and NAT RVSM experience. Policy and requirements for the European RVSM Monitoring Programme can be found in the European RVSM Monitoring Policy **[1]**.

E.2 Height Monitoring Infrastructure

The preparation for the implementation of RVSM in the NAT Region resulted in the development of two systems, either of which would be technically capable of meeting the monitoring requirements. These are the ground based Height Monitoring Units (HMUs) and the portable GPS Monitoring Units (GMUs).

The HMU and GMU were each seen to have advantages and disadvantages in providing a means of measuring Altimetry System Error (ASE) for the European RVSM Programme; these are summarised below:

- The HMU is a fixed ground based system. Its main advantage is the ability to capture a large amount of data which can be made available for analysis rapidly without manual intervention. The main disadvantage is that it requires a flight within range of the HMU during the pre-RVSM implementation monitoring period and at appropriate intervals thereafter

- The GMU is a carry-on system. It requires co-operation from the target aircraft and significant manual intervention in its operation and data extraction.

The NAT RVSM Programme made use of 40 GMUs and initially a single HMU although, for long term monitoring, two HMUs will be available.

The NAT environment has gateway locations ensuring a large proportion of the aircraft will fly over the HMU during the monitoring period. No such gateway locations exist for European operations which would could allow such a high coverage from a single HMU. However studies have shown that the incremental value of additional HMUs reduces rapidly after the second unit. For this reason and following a detailed study of traffic flows it was proposed that three units be employed. These were originally proposed as being sited at:

- Germany/Luxembourg - Nattenheim (NTM)
- France/Switzerland - Geneva (GEN)
- Austria - Sollenau (SNU)

These would be additional to the Strumble HMU which would provide a coverage of approximately 5% of the European traffic.

A review of the revised ARN route structure and the expected traffic flows has shown that the HMU in Austria should be sited at LINZ (LNZ) rather than SOLLENAU.

A detailed review was undertaken into the number of aircraft that will need to be monitored during the initial validation period. This was taken from data that was not as complete as it is now but, from CFMU and the CRCO data it was possible to estimate that up to 5,000 aircraft would need RVSM approval for the first time as a result of the European RVSM programme (nearly twice that of the NAT RVSM programme at that time).

This study also confirmed that a significant proportion of these aircraft could not, without significant diversions, overfly the proposed HMUs. At the time the decision in respect to monitoring configuration was made. 40 GMUs were being employed in the NAT RVSM programme, and these had accounted for approximately 23% of the total monitored aircraft.

A detailed study of aircraft operations in ECAC was carried out and, and taking into account the experience of the NAT RVSM programme it was concluded that the monitoring requirements could be satisfied in a one year monitoring programme if an infrastructure of three HMU and 25 GMUs were provided. However, the experience to date for the GMU operation is that operators have been willing to make significant detours and, exceptionally, special flights to use the HMU so the use of the GMUs has been significantly lower than expected.

All GMU and HMU height monitoring data is correlated to additional information about individual aircraft such as operator, type, and RVSM approval status and stored in a central database.

In addition to the data collected by the European RVSM program, height measurement and approval data collected by the CMA (Central Monitoring Agency) and APARMO (Asia Pacific Regional Monitoring Office) are stored in the same central database. The CMA receives height keeping monitoring data from two HMUs and 46 GMUs and the APARMO uses a portion of the same GMUs. The HMUs are located in Strumble in Wales and Gander in Canada.

E.3 Quality and Reliability of Monitoring Infrastructure

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.

Both HMU and GMU have been specified to measure the absolute height of an aircraft in WGS 84. From this absolute (geometric) height the ASE needs to be derived. The GMU and HMU differ in the methods by which the ASE is derived but both use meteorological data to establish the true height of the flight levels thus the performance of the met forecasting is an important part of the validation.

The concept applied in the validation of the monitoring system has been:

1 to confirm the absolute accuracy of the height estimation capability of both GMU and HMU against accurate external sources
2 To confirm the coherence of measurement between each of the measurement means for the European RVSM
3 To confirm that the measurement performance is in agreement with the NAT RVSM measurement systems

To confirm the accuracy of the Meteorological data, studies were undertaken by the UK Meteorological Office and are reported below.

GMU Performance

The GMU validation was central to the monitoring validation as it is portable and can be carried to each of the HMUs to confirm internal coherence of measurements.

The GMU was flight tested on a calibration aircraft of Flight Precision Ltd. This aircraft was equipped with a local area differential GPS system which was adopted as the main reference source. The results of these tests are reported in the FPL Report dated May 2000 **[51]**

An important part of the test was to ensure coherence with the NAT measurement systems and also to ensure that the GMU analysis software gave ASE results which agreed with those systems. As part of the flight test the GMU was flown over the Strumble HMU. In addition the ARINC GMU as used for the North Atlantic RVSM Monitoring was carried and the data analysed by ARINC and the FAA to provide their estimation of the height of the aircraft and the ASE. The execution of these trials identified initial problems in the Aerodata software which were corrected and the validation of the resultant performance of GMU is reported in Aerodata Report BG-447-014.

HMU Performance

The Linz HMU was the first to be commissioned and it was tested by flight tests with the Flight Precision aircraft carrying the GMU and their own precision GPS system. This is reported in the FPL report **[51]**. This flight test identified errors in the Linz system which resulted in modifications to the calibration of the timing systems. The Linz HMU was further validated in September 2000 using a calibrated flight test aircraft of STNA again using both the GMU and a local area differential GPS calibration system.

Due consideration of the accuracy and noise of the height data derived from the Linz HMU has resulted in the decision that the performance requirements of 29ft 1SD for tracks of p to 20 N mile can be met by the Linz HMU for distances up to 30 N miles from its central site. Multipath induced errors prevent the use of data outside of this region and all data has been restricted to the region of acceptable accuracy. Work continues to develop means to extend the area of coverage to meet the full specification.

Flight Tests to calibrate the **Nattenheim and Geneva HMUs** were undertaken by the STNA using their calibration aircraft fitted with differential GPS. Again the GMU was carried as a further reference. For **Nattenheim** two flights were made. The first identifying the need for a modified time delay maps in the HMU which were confirmed by the second flight to meet the accuracy requirements. This is reported in: STNA report **[41]** and RMR Report **[42]**. The accuracy of the Nattenheim system has enables data to be used over the full 90*90 n Mile square as specified.

For **Geneva** three flights in total were made, the additional flight being necessitated by a failure of the Geneva system during the flight test due to water ingress during a storm. The Geneva system has proved more difficult to calibrate. The process used by RMR has been to use the flight test aircraft to derive the corrections to the timing delays and then confirm the consistency of the results using aircraft of opportunity – this method allows confirmation that the corrections are also working in areas which the flight test aircraft did not pass. This method is describing in RMR report **[43]**. Whilst this worked well at Nattenheim there is a problem which at this stage appears to be generated by the much smaller granularity of meteorological conditions in the Geneva area than at Nattenheim. It is considered likely at this stage that this results from the impact of the mountains on the FL height but it is not yet confirmed. Whilst this met effect produces a relatively small impact on height of the FL and the geographical scale is such that it does not affect aircraft height performance, it does impact on the area in which the Geneva HMU can be guaranteed to meet the 29 ft accuracy. There is a high degree of confidence in data from a more restricted area around the HMU. Following a review of RMR report **[44]** the data from Geneva is restricted to a range of 30 Nmile from the central station.

The **TMU** is common to all HMUs and uses logic common to the NAT HMU. The validation of this has been carried out by comparison with data recorded at Strumble. This is recorded in RTEL report **[45]**.

E.4 Data Used for Assessments

<u>Criteria for Data Usability</u>

For a measurement to have been used in the assessments it must:

a) be positively identified and linked to an individual airframe that has either been confirmed as participating in the part of the RVSM-EUR programme or its status is still unknown,
b) have been taken on or after the aircraft MASPS approval date, and
c) have been recorded correctly and passed through quality control checks.

These three requirements are further described below.

Linking Measurement and Aircraft

An attempt is made to link every height measurement to an aircraft. In simple terms, this is done by matching the ModeS code and/or registration number stored in the measurement data to the ModeS code and/or registration number stored in the aircraft data. In addition the date of the measurement is compared to the date of the aircraft registration. If the ModeS and/or registration numbers match and the date of measure is on or after the date of registration then the measurement and aircraft are linked. Only measures that are positively linked to an aircraft are considered in the analysis.

To track the aircraft that are important to the program, each aircraft is marked as yes, no, or unknown as to whether it is intended that this aircraft will fly in the European RVSM airspace. This information is gathered from the Operators themselves or State Authorities. Only those aircraft that are specifically marked as “no” they will not fly in the RVSM airspace once RVSM is introduced are excluded from the analysis.

Identify Status of Aircraft at Time of Measure

Once a measure has been linked to an aircraft as described in the previous section, it is then determined if the measurement was taken before or after the aircraft was MASPS approved. The date of measure is compared to the date of MASPS approval. If the date of measure is on or after the date of MASPS compliance the measure is marked as an “approved” measure (i.e., taken after the aircraft has been made MASPS compliant). It should be noted that a measure can only be marked as approved when it is positively linked to an aircraft. Only “approved” measures are considered in the analysis.

Quality Control Checks

Any “approved” (i.e., linked to an aircraft and taken on or after the date the aircraft received MASPS approval) European measure that is aberrant or non-compliant must pass through a quality control check. These checks include:

a. Verify if track has enough points (i.e., >200) if the measure is inconsistent with other measures for the aircraft.
b. Verify no site serviceability problems occurred at time measurement was recorded.
c. Verify measure did not have an SSR code swap
d. Verify measure was not processed during problems with software.
e. Verify that track was not at the edge of the coverage area.

It was assumed that data received from another CMA had already passed quality control checks so no additional checking was completed.

E.5 Available Data

All European height measurement data recorded on or before 7 July 2001 with the exception of Geneva which was on or before 03 May 2001 and all NAT CMA/APARMO height measurement data recorded on or before 06 July 2001 have been considered in this analysis. Aircraft details such as MASPS approval status or operator are reported as they were known on 17 July 2001. In addition, all the data must pass the usability criteria as described in the previous section.

Currently, the information from the 3 monitoring regions comprises 12389 aircraft from 3117 Operators and 146 States. Of these 9046 aircraft have been confirmed as participating in the EUR RVSM program and 3339 have been confirmed not to operate in EUR RVSM airspace from 24 January 2002 whilst 4 have not been confirmed either way. This results in a potential total of 9050 aircraft from 2171[1] operators and 118 States. Of these 8081 aircraft have been recorded as MASPS approved. Of the MASPS approved aircraft, 6912 have been included in this assessment which accounts for 1682 operators.

The total number of measurements used in this assessment can be broken down as displayed in the following table:

	CMA & APARMO	EUR
Number of measurements	116406	245360

E.6 Monitoring Targets

Introduction

This section describes the initial monitoring targets and aircraft groupings at the start of the European RVSM monitoring programme. These initial targets and groupings will be assessed throughout the pre-implementation phase of the European RVSM programme and adjusted accordingly.

Initial Targets

The European Reduced Vertical Separation Minimum (EUR RVSM) Monitoring Policy defines the group[2] and non-group aircraft monitoring targets for the performance verification (pre-implementation) phase of the European RVSM programme as follows:

<u>Monitoring targets for aircraft falling into groups</u>

An initial minimum target of 60% of the RVSM approved airframes of each aircraft group from each operator is required in order to generate sufficient monitoring data to confirm (with a high level of confidence) whether a particular group is compliant with the MASPS.

Based upon the analysis undertaken by the NAT RVSM Programme, this percentage may be reduced (to a minimum of 10% or 2 aircraft whichever is greater) once a sufficient number of aircraft have been monitored. The lower limit can be applied once sufficient data has been acquired to demonstrate that the group as a whole can meet the MASPS with a high level of confidence.

<u>Monitoring targets for aircraft not falling into groups</u>

All non-group RVSM approved aircraft need to be monitored on an individual basis unless flight test evidence can be provided to show that each airframe is compliant with the MASPS.

[1] The operator is unknown for some aircraft.
[2] 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.

Target of Monitoring Prior to RVSM Implementation

Subject to a satisfactory collision risk assessment and other operational considerations, the performance verification phase could be terminated, provided that 90% of the flights in European RVSM airspace would be made by operator-aircraft group pairings, or non-group aircraft, that have satisfied the monitoring requirements during the performance verification (pre-implementation) phase.

Use of data from other RVSM Monitoring Programmes (NAT & PAC RVSM)

On the assumption that ASE is demonstrated to be stable, the data from other existing (NAT & PAC RVSM) monitoring programmes is used as follows:

- If an operator is, or has been, participating in another Region's RVSM monitoring programme, the number of aircraft of that operator monitored in that programme will be used in determining how many aircraft of that operator should be monitored in the European RVSM monitoring programme.
- In principle, any operator-group pairings, or non-group aircraft already satisfying the European RVSM monitoring requirements through the RVSM Programme of another region would not require any further monitoring.

E.7 Applied Monitoring Targets and Aircraft Groupings

In addition to being a group or non-group aircraft, an aircraft also belongs to a Monitoring Classification. Aircraft that nominally have the same build standard and/or nominally have the same MASPS compliance method have been put into the same Monitoring Classification. All data has been examined by Monitoring Classification.

Monitoring classifications that have ASE data which indicates good MASPS performance were analysed to determine if the monitoring target could be reduced. The following factors where considered when determining if a target could be reduced.

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

   TGL 6 paragraph 7.2.3 states that the ASE for an aircraft group when the aircraft are operating in the basic flight envelope should meet the criteria of |mean| + 3stdev $\leq$ 200 ft. This performance standard is more strict than that set for aircraft in the total flight envelope (|mean| + 3stdev $\leq$ 245 ft.).

   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 classification is meeting the standard for the basic flight envelope then they are likely to satisfy |mean| + 3stdev $\leq$ 245 ft. when operating in the total flight envelope. As such, when deciding as to whether 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 would be necessary for at least 75% of the total operators to have had at least one of their aircraft monitored to provide a good representation of the entire operator population. In addition, this operator population must contain operators that are from the European monitoring program.

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

   For each monitoring classification, the individual aircraft means are compared to the monitoring classification mean +/- the between airframe standard deviation with a correction factor. The correction factor is dependent on the number of repeated samples and corrects for any bias in the estimation of standard deviation. The individual aircraft means should fall within these upper and lower bounds.

   Addition examination was made of plots of individual aircrat standard deivation against the pooled estimate of the within airframe standard deviation with a 97.5% confidence interval based on the assumption that the within airframe variation of ASE is the same for all the aircraft of a monitoring classification. These plots are not provided in this report however, can be made available upon request.

4. European performance is comparable to non-European performance.

   Another consideration when reducing a monitoring target is to determine if the performance of an operator/monitoring classification in the European region is similar to that already seen in other regions. If no significant difference is observed between the monitoring classification means and standard deviation then it was concluded that the European data was comparable to the non-European data.

   It is unknown exactly which aircraft and measures where used by other monitoring agencies to make their monitoring assessments. As such, the assumption was made that measures recorded via the European monitoring program form the sample for the European operator/monitoring classification and that all measures recorded other than by the European monitoring program form for the sample for what has already been seen by other regions.

5. 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 160ft 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 classification 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 however if this grew to greater than 10% of the fleet it is considered that it is not appropriate to reduce the monitoring requirement to as low at 10%. To cater for small fleets the individual operator requirement is that there must be at least 2 aircraft showing performance worse than 190 ft and that these must constitute at least 10% of the Operators measured fleet.

The following two tables list the currently applied monitoring classifications and targets for group and non-group aircraft. Changes from initial targets and classifications are highlighted. Some monitoring classifications as presented in the previous assessment have been removed as no MASPS aircraft were known for this classification or no MASPS solution was available at the time this report was written. It is assumed that such aircraft would not operate in RVSM airspace. 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 E-1: Applied Monitoring Classification for Group Aircraft

Monitoring Classification	Target	A/C ICAO	A/C Type	A/C Series
A306	30%/2	A306	A300	600, 600F, 600R, 620, 620R, 620RF
A30B	60%	A30B	A300	B2-100, B2-200, B4-100, B4-100F, B4-120, B4-200, B4-200F, B4-220, C4-200
A312-GE	10%/2	A310	A310	200, 200F
A312-PW	60%	A310	A310	220, 220F
A313-GE	60%	A310	A310	300, 300F
A313-PW	30%/2	A310	A310	320
A319	10%/2	A319	A319	CJ , 110, 130
A320	30%/2	A320	A320	110, 210, 230
A321	60%	A321	A321	110, 130, 210, 230
A330	60%	A332 A333	A330	200, 220, 240, 300, 320, 340
A340	60%	A342 A343 A345 A346	A340	210, 310, 540, 640
B712	60%	B712	B717	200
B733	10%/2	B733	B737	300
B734	10%/2	B734	B737	400
B735	30%/2	B735	B737	500
B736	30%/2	B736	B737	600
B737	10%/2	B737	B737	700, 700BBJ
B738	10%/2	B738	B737	800
B739	60%	B739	B737	900
B741	60%	B741	B747	100, 100B, 100F, SR
B742	60%	B742	B747	200B, 200C, 200F, 200SF
B743	60%	B743	B747	300
B744	60%	B744	B747	400, 400D, 400F
B74S	60%	B74S	B747	SP
B752	10%/2	B752	B757	200, 200PF
B753	60%	B753	B757	300
B762	60%	B762	B767	200, 200EM, 200ER, 200ERM
B763	60%	B763	B767	300, 300ER, 300ERF
B764	60%	B764	B767	400ER
B772	30%/2	B772	B777	200, 200ER
B773	60%	B773	B777	300, 300ER
CARJ	10%/2	CRJ1,	REGIONALJET	100, 200, 200ER, 200LR

Monitoring Classification	Target	A/C ICAO	A/C Type	A/C Series
		CRJ2		
CL60-600	30%/2	CL60	CL-600	CL-600-1A11
CL60-601	10%/2	CL60	CL-601	CL-600-2A12, CL-600-2B16
CL60-604	60%	CL60	CL-604	CL-600-2B16
DC10	60%	DC10	DC-10	10, 10F, 15, 30, 30F, 40, 40F
F2TH	60%	F2TH	FALCON 2000	ALL SERIES
F900	60%	F900	FALCON 900	ALL SERIES
GLEX	60%	GLEX	BD-700 GLOBAL EXPRESS	ALL SERIES
GLF4	60%	GLF4	GULFSTREAM IV (G-1159C)	ALL SERIES
GLF5	60%	GLF5	GULFSTREAM V (G-1159D)	ALL SERIES
H25C*	60%	H25C	BAE 125 / HAWKER 1000	A , B
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)
LJ60	60%	LJ60	LEARJET 60	ALL SERIES
MD11	60%	MD11	MD-11	COMBI, ER, FREIGHTER, PASSENGER
MD80	30%/2	MD81, MD82, MD83, MD87, MD88	MD-80	81, 82, 83, 87, 88
MD90	60%	MD90	MD-90	30, 30ER

*Except where classified as a non-group aircraft on a serial number basis. This is determined by compliance service and is on a serial number basis.

Table E-2: Applied Monitoring Classification for Non-Group Aircraft

Monitoring Classification	Target	A/C ICAO	A/C Type	A/C Series
A124	100%	A124	AN-124 RUSLAN	ALL SERIES
A3ST	100%	A3ST	A300	600R ST BELUGA
AN72	100%	AN72	AN-74, AN-72	ALL SERIES
ASTR	100%	ASTR	1125 ASTRA	ALL SERIES
ASTR-SPX	100%	ASTR	ASTR SPX	ALL SERIES
B703	100%	B703	B707	320, 320B, 320C
B721	100%	B721	B727	100, 100C, 100F, 100QF
B722	100%	B722	B727	200, 200F
B732	100%	B732	B737	200, 200C
BA46-AVRO	100%	RJ1H, RJ70, RJ85	AVRO	RJ70, RJ85, RJ100
BE40	100%	BE40	BEECHJET 400A	ALL SERIES
C500	100%	C500	500 CITATION, 500 CITATION I, 501 CITATION I SINGLE PILOT	ALL SERIES
C525	100%	C525	525 CITATIONJET, 525 CITATIONJET I	ALL SERIES
C525-II	100%	C25A	525A CITATIONJET II	ALL SERIES

Monitoring Classification	Target	A/C ICAO	A/C Type	A/C Series
C550-B	100%	C550	550 CITATION BRAVO	ALL SERIES
C550-II	100%	C550	550 CITATION II, 551 CITATION II SINGLE PILOT	ALL SERIES
C560	100%	C560	560 CITATION V, 560 CITATION V ULTRA, 560 CITATION V ULTRA ENCORE	ALL SERIES
C56X	100%	C56X	560 CITATION EXCEL	ALL SERIES
C650	100%	C650	650 CITATION III , 650 CITATION VI , 650 CITATION VII	ALL SERIES
C750	100%	C750	750 CITATION X	ALL SERIES
DC8	100%	DC85, DC86, DC87	DC-8	50, 50F, 60, 60F, 70, 70F
DC9	100%	DC91, DC92, DC93, DC94, DC95	DC-9	10, 21, 30, 30F, 41, 51
E135	100%	E135	EMB-135	ALL SERIES
E145	100%	E145	EMB-145	ALL SERIES
F100	60%	F100	F-100	ALL SERIES
F200	100%	FA20	FALCON 200	ALL SERIES
F70	60%	F70	F-70	ALL SERIES
FA10	100%	FA10	FALCON 10	ALL SERIES
FA20	100%	FA20	FALCON 20	ALL SERIES
FA50	100%	FA50	FALCON 50, FALCON 50EX	ALL SERIES
GALX	100%	GALX	1126 GALAXY	ALL SERIES
GLF2	100%	GLF2	GULFSTREAM II (G-1159), GULFSTREAM IIB (G-1159B)	ALL SERIES
GLF3	100%	GLF3	GULFSTREAM III (G-1159A)	ALL SERIES
H25B-700	100%	H25B	BAE 125 / HS125	700
H25B-800**	100%	H25B	BAE 125 / HAWKER 800XP, BAE 125 / HAWKER 800, BAE 125 / HS125	ALL SERIES/A, B/800
H25B-800-1**	100%	H25B	BAE 125 / HAWKER 800XP, BAE 125 / HAWKER 800, BAE 125 / HS125	ALL SERIES/A, B/800
H25C-1*	100%	H25C	BAE 125 / HAWKER 1000	A , B
IL62	100%	IL62	IL-62	NO SERIES , M
IL76	100%	IL76	IL-76	M, T
IL86	100%	IL86	IL-86	NO SERIES
IL96	100%	IL96	IL-96	M , T, 300
L29B-2	100%	L29B	L-1329 JETSTAR 2	ALL SERIES
LJ45	100%	LJ45	LEARJET 45	ALL SERIES
SBR1-65	100%	SBR1	NA-265 SABRELINER 65	ALL SERIES
T134	100%	T134	TU-134	A, B
T154	100%	T154	TU-154	A , B, M, S
T204	100%	T204	TU-204	100, 100C, 120RR, 200, C
YK42	100%	YK42	YAK-42	ALL SERIES

*Except where classified as a group aircraft. This is determined by compliance service and is on a serial number basis.
** This is determined by compliance service and is on a serial number basis.

E.8 Achievement of Monitoring Targets

On the assumption that the RVSM population would be comprised of all aircraft currently known to be MASPS compliant, as of 26 July 2001 there were 2679 possible Operator/monitoring classification combinations. Of these:

- 2164 Operator/monitoring classification combinations have been fully satisfied,
- 124 Operator/monitoring classification combinations have not been fully satisfied but have some aircraft monitored, and
- for 391 Operator/monitoring classification combinations no monitoring data was available.

Current percentage of flights made by operator/types which meet targets

Flight plan data covering 2,124,916 flights made above FL280 between 01/01/2001 to 30/06/2001 was obtained from the CFMU. 96% of these flights were operated by 3,215 operator/aircraft type combinations where the operator entered their ICAO code in the flight plan. The remaining 4% of flights were operated by 9,871 International General Aviation (IGA) Operator/type combinations who do not have an ICAO code.

Due to the fact that:

- information contained in the flight plan differed in its content and level of detail, depending on the operator and type of aircraft flown
- it is only possible to link back to specific monitoring target data using either an operator ICAO code or an aircraft registration
- some operators used (ICAO) code sharing, flew under franchise arrangements or charter operations, where the ICAO code in the flight plan did not reconcile with the operator ICAO code in the monitoring target data

a 2 stage approach was used to calculate the percentage of flights made by operators that had met their monitoring target:

Stage 1.
Of the 3,215 operator/aircraft types accounting for 96% of the flights who entered an ICAO code in the flight plan:

- 939 (1,696,498 flights) had sufficient information to be able to link to the 2679 Operator/monitoring classification combinations:
    - 716 had met their monitoring target, this accounted for 1,571,988 flights
    - 223 had not met their monitoring target, this accounted for 124,510 flights

    - Of the remaining 2,276 Operator/Aircraft types that did not match (346,205 flights), the % of operators meeting their monitoring target ***for that aircraft type*** was calculated and applied to the number of flights ***made by that type*** e.g. 3 Operators with A124 type aircraft were left unmatched from above and none had met their monitoring target, therefore all remaining unmatched A124 flights for these operators were counted as ‘not meeting target’. Using this assumption:
    - 183,732 flights had met their monitoring target
    - 120,356 flights had not met their monitoring target
    - 42,117 flights disregarded due to the aircraft type not having an RVSM solution, or none of that type are yet confirmed MASPS

Stage 2.
From the remaining 4% (82,213) of flights undertaken by the 9,871 IGA Operator/types:

- 44,961 flights (by 2,207 operator/aircraft type combinations) contained a registration in the flight plan that matched to an aircraft that was part of the 2679 Operator/monitoring classification combinations:
  - 23,877 flights met their monitoring target
  - 4,425 flights did not meet their monitoring target
  - 16,659 flights disregarded, due to no RVSM solution or aircraft not MASPS

- From the 37,252 remaining flights that did not match the same approach followed in stage 1. was adopted to determine the number, by aircraft type, that had met their monitoring target:
  - 12,328 flights met their monitoring target
  - 15,867 flights had not met their monitoring target
  - 9,057 flights disregarded, no RVSM solution or aircraft type not MASPS

A final check of aircraft types with no available RVSM solution, or where no aircraft of a specific type are confirmed MASPS compliant, was undertaken. This identified a further 48,279 flights to be disregarded from this sample. This final step ensured consistency of approach with that adopted for the Technical Risk Assessment calculation. It is assumed these aircraft types will not fly in RVSM airspace after January 2002.

Final results (July 2001):

1.	Flights to be disregarded from sample due to no available RVSM solution, or no aircraft of type being confirmed RVSM compliant	**116,112**
2.	Flights made by Operator/monitoring classifications that met their monitoring target	**1,791,925**
3.	Flights made by Operator/monitoring classifications that have not met their monitoring target	**216,879**

Therefore **89.06%** of the applicable flights from January 2001 to June 2001 were undertaken by operator/monitoring classification combinations that have met their monitoring targets.

E.9 Verification of the MASPS

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.

Methodology

The verification of the MASPS was carried out on the basis of the graphical tool set which is described in European Mathematical Supplement [34].

Performance against Global Height-Keeping Performance

In ICAO Document 9574, Section 2.1.1.3 states that the aggregate of TVE[3] performance in the airspace simultaneously satisfies the following four requirements, constituting the Global Height-Keeping Performance Specifications:

(a) the proportion of TVE beyond 90 m (300 ft) in magnitude is less than 2.0×10^{-3};
(b) the proportion of TVE beyond 150 m (500 ft) in magnitude is less than 3.5×10^{-6};
(c) the proportion of TVE beyond 200 m (650 ft) in magnitude is less than 1.6×10^{-7}; and
(d) the proportion of TVE between 290 and 320 m (950 and 1050 ft) in magnitude is less than 1.7×10^{-8}.

A TVE distribution was fit based on a convolution of the ASE and core AAD distributions (refer to Appendix F). Predicted proportions of TVE with a magnitude as specified in (a) – (d) were calculated based on this distribution. Results are presented in Table E-3.

Table E-3: Predicted TVE Proportions

Magnitude of TVE (feet)	Requirement	Predicted Proportion	Meets Requirement
> 300	2.0×10^{-3}	6.72×10^{-4}	✔
> 500	3.5×10^{-6}	5.86×10^{-6}	No
> 650	1.6×10^{-7}	7.40×10^{-7}	No
>= 950 & <= 1050	1.7×10^{-8}	2.39×10^{-8}	No

ASE Performance Regarding Aircraft Types

The following characteristics were developed in accordance with the conclusions of the RGCSP/6 Meeting (ICAO Doc 9536), and are also reflected in JAA TGL6 **[11]**. They describe the performance which aircraft types need to be capable of achieving in service, exclusive of human factors 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.

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

[3] A detailed explanation of TVE can be found in Appendix F and **[34]**

(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.

Although it is shown that the Global Height-Keeping Performance Specifications have been met, for EUR RVSM the ASE performance has also been monitored to assess how the aircraft monitoring classifications behave against the above capability requirements, which were set as basis for the MASPS.

ASE by Aircraft Type

In support of (a) and (b) listed in the above section the mean and standard deviation of each monitoring classification was examined. Results are presented in Table E-4 and summarised in the following paragraphs.

The following monitoring classifications have enough data to assess their ASE performance and it has been shown that they are successful in meeting the specified capability requirements or the current amount of data suggests the classification is likely to meet the capability requirements;

A306, A30B, A312-GE, A312-PW, A313-GE, A313-PW, A319, A320, A321, A330, A340, A3ST, ASTR-SPX, B703, B712, B721, B722, B732, B733, B734, B735, B736, B737, B738, B741, B742, B743, B744, B74S, B752, B753, B762, B763, B764, B772, B773, C525, C550-B, C56X, C650, C750, CARJ, CL60-600, CL60-601, CL60-604, DC10, F100, F2TH, F70, F900, FA10, FA20, GALX, GLEX, GLF2, GLF3, GLF4, GLF5, H25B-800, H25C, IL62, IL96, L101, LJ45, LJ60, MD11, MD80, MD90, SBR1-65, T154

The aircraft monitoring classifications currently not meeting the MASPS or are likely not to meet the MASPS according to current data are;

A124, BA46-AVRO, C560, DC8, E135, E145, F200, FA50, H25B-800-1, H25C-1, IL76, IL86

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

ASTR, BE40, B739, DC9, C500, AN72

The following monitoring classifications do not have monitoring data available to make any conclusions at this time;

C525-II, C550-SII, H25B-700, L29B-2, T134, T204, YK42

Table E-4: Mean and Standard Deviation per Monitoring Classification

Monitoring Classification	Group Mean[a]	Overall Std. Dev.[b]	Group Mean + 3 Overall Std. Dev.
H25B-800-1	5.2	119.9	364.9
H25C-1	2	116.3	350.9
E135	77.9	85.6	334.7

Monitoring Classification	Group Mean[a]	Overall Std. Dev. [b]	Group Mean + 3 Overall Std. Dev.
A124	97.1	77.1	328.4
C560	38.4	91.5	312.9
F200	-45.6	86.5	305.1
IL76	66.5	78.2	301.1
IL86	30.3	86.6	290.1
BA46-AVRO	78	65.3	273.9
DC8	57	71.2	270.6
FA50	75.9	61.1	259.2
E145	87.2	55.7	254.3
FA10	34.7	66.2	233.3
T154	6.2	75	231.2
IL62	60.6	56.5	230.1
H25C	70.2	52.8	228.6
B721	61.6	55.6	228.4
F2TH	-65	53.5	225.5
C750	-17.6	67.5	220.1
F900	31.5	59.9	211.2
H25B-800	3.6	68.3	208.5
DC10	7.4	66	205.4
B742	-18.8	61.8	204.2
GLF2	-0.4	66.9	201.1
B741	-34.3	55.2	199.9
GALX	70.5	42.7	198.6
A3ST	31.1	53.9	192.8
A320	56.8	45	191.8
L101	16	58.4	191.2
GLF5	14.6	58.3	189.5
ASTR-SPX	41.6	48.1	185.9
B703	57.7	42.7	185.8
B743	-9.3	58.6	185.1
A321	43	47	184
FA20	-23.6	53	182.6
IL96	53.5	43	182.5
F70	-77.5	34.6	181.3
A306	18.7	54.1	181
C650	17	54.6	180.8
C550-B	44.2	45.3	180.1
A330	52.3	42.2	178.9
A313-GE	-42.7	45.3	178.6
B744	-37.6	46.9	178.3
LJ60	28.2	49.7	177.3
B732	6.9	56.5	176.4
GLF3	-27	49.6	175.8
A313-PW	28.5	49	175.5
CL60-604	3.4	56.8	173.8
CARJ	-17.2	51.8	172.6
B763	-39	44.4	172.2
B736	38.2	44.4	171.4
B74S	-7.2	54.3	170.1
B734	-46.3	41.1	169.6

Monitoring Classification	Group Mean[a]	Overall Std. Dev.[b]	Group Mean + 3 Overall Std. Dev.
CL60-600	25.9	47.6	168.7
LJ45	54.8	37.1	166.1
GLF4	-12.2	50.9	164.9
SBR1-65	-53	36.9	163.7
B772	40.2	40.8	162.6
MD11	-1.6	53.6	162.4
A319	41.5	40.3	162.4
B722	52.3	35.9	160
B762	-11.6	48.9	158.3
F100	-2.4	51.7	157.5
B733	-22.2	44.9	156.9
A30B	5.2	50.4	156.4
MD90	37.7	39.3	155.6
CL60-601	5	48.8	151.4
B735	-12.6	45.7	149.7
B737	17.2	43	146.2
C525	25.6	39.8	145
B712	26.2	39.4	144.4
A340	9.3	44.7	143.4
GLEX	60	26.9	140.7
A312-GE	-21.6	39.3	139.5
MD80	12.3	39.1	129.6
B764	6.4	40.9	129.1
B738	19.3	36.4	128.5
C56X	-5.4	38.9	122.1
A312-PW	52.8	21.8	118.2
B752	2.3	37.8	115.7
B753	23.8	30.5	115.3
B773	25	19.2	82.6

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

[b] The overall ASE standard deviation is a combination of the within airframe and between aircraft standard deviation. When no within aircraft standard deviation is available for a particular airframe then a default value of 36.6 was used.

Overall ASE

Criteria (c) listed in the section ASE Performance Regarding Aircraft Types discusses the overall ASE. Figure E-1 shows one minus cumulative curves based on empirical ASE data, a double exponential distribution with specified standard deviation of 43 feet, and a Gaussian Double Exponential Distribution based on a fit to the data. Current data suggests that the rate of decrease of error frequency is worse than the specification. Moreover, the mean of all approved ASE values equals -.38 (near zero), however the standard deviation equals 56.65.

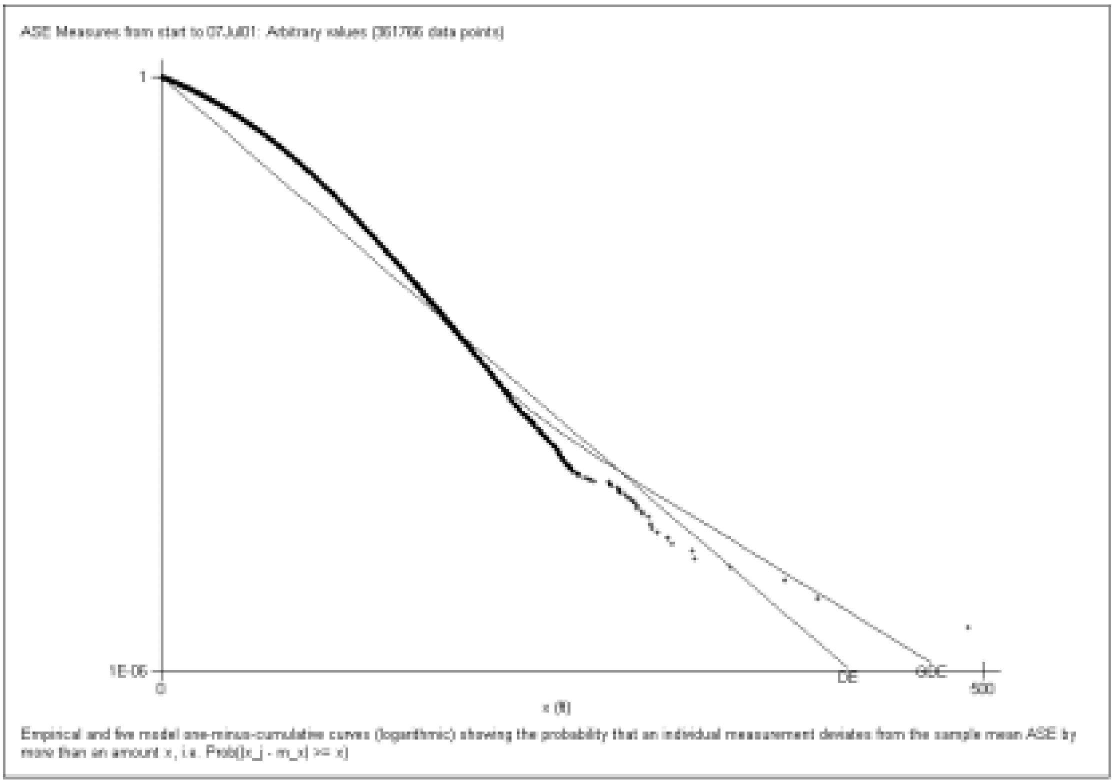


Figure E-1: ASE Error Rate

E.10 Follow-Up Activities

Height keeping measurements are continually scrutinised to reveal any poor height keeping performance for MASPS complaint aircraft, in order to ascertain and remedy the causes. The follow-up actions discussed below are in place to help ensure that the overall height keeping performance of aircraft expected to operate in EUR RVSM airspace is in line with the MASPS, thus helping ensure safety requirements are met. The process in place includes contacting operators, state authorities and aircraft manufacturers, and is done in consultation with other regions where RVSM is in operation.

Overall Performance

Consultation with manufacturers is initiated when the overall performance of a group monitoring classification does not comply with the MASPS (refer to E.7 for monitoring class definitions for group aircraft).

Individual Aircraft Performance

When a measured height deviation is excessive, indicating an aircraft to be out of the MASPS tolerances, immediate action is taken towards the relevant operator and State Authority in order to correct the situation as soon as practicable.

Of the total 6912 monitored airframes, official notifications for 2 aircraft exhibiting non-complaint ASE performance have been sent to operators and State Authorities. Issues related to both aircraft have since been resolved. Consultation with operators is ongoing regarding aircraft which have been measured to perform within MASPS compliance limits, but exhibit aberrant performance.

APPENDIX F - COLLISION RISK ASSESSMENT-

F.1 Introduction

As outlined in the main text, the level of collision risk within European RVSM airspace shall satisfy the following quantitative safety objectives:

- In accordance with ICAO Guidance Material, the risk of mid-air collision in the vertical dimension within RVSM airspace, due to some failure or error in technical height keeping performance shall meet a Target Level of Safety of $2.5x10^{-9}$ fatal accidents per flight hour.

- In accordance with ICAO Guidance Material, the management of the overall vertical collision risk within RVSM airspace shall meet the Target Level of Safety of $5.0x10^{-9}$ fatal accidents per flight hour;

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

The collision risk methodology used in the estimation process is detailed fully in the European Mathematical Supplement **[34]**. It has been developed by the Mathematics Drafting Group (MDG), a group which reports through its parent body the Navigation Sub-Group to the EUROCONTROL Airspace and Navigation Team. The MDG is chaired and minuted by EUROCONTROL staff, and its membership comprises EUROCONTROL and certain member states (France, Germany, Netherlands, Spain and UK). Attendance from some of those states is funded by EUROCONTROL. All of the MDG members have a extensive background in mathematics and aviation risk assessment.

In addition to the development of the methodology, the MDG has acted as a peer review for the results coming from the application of the methodology. The data analysis itself has been performed within the RVSM programme, but the steps taken during the analysis process, together with the results, have been presented and reviewed by the MDG.

F.2 Vertical Collision Risk – General Concept

The mathematical model described in **[34]** has essentially two components. 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.

All of the data used in the estimation of the parameters described below is presented in Tables F1 to F9.

F.3 Assessment of the technical vertical risk against the TLS of 2.5x10^{-9} fatal accidents per flight hour

The TLS of 2.5x10^{-9} fatal accidents per flight hour applies to the vertical collision risk due to technical height keeping error. The model described in **[34]** has been used to assess the collision risk due to this type of error, as now outlined. The two components of the risk are discussed separately.

F.3.1 Frequency of horizontal overlap

The frequency of horizontal overlap has been derived from data pertaining to FL290 to FL410, collected from the HMUs situated at Geneva, Linz and Nattenheim during the period 13th April 2001 to 18th July 2001 . The estimate has been based on the number of proximity events observed in the data. A proximity event occurs between two aircraft when they pass 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.

Because the relative velocity is a factor in the horizontal overlap frequency, the overlap frequency must be calculated twice – once for the case when both aircraft in the proximate event are in level flight, and once for the case where at least one aircraft is in climb or descent. Data pertaining to the aircraft dimensions and relative velocities are presented in Table F1. The classification used for the different proximity event geometries is shown in Table F2.

Theoretically, 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 quite rare, it would be necessary to sample date over a very long period of time to be sure of a stable estimate. For this reason, a value of R larger than the average aircraft size is used. Whilst this results in more data, it necessitates the derivation of weighting factors to account for the fact that the distribution of the proximity events is not uniform, particularly for same direction traffic. This effect is due to the navigation capability of the aircraft population and can be seen from Table F3 and Figures F1 to F3. The non-uniformity means that estimating the overlap frequency from data collected over a value of R that is greater than the size of the average aircraft would result in an underestimate of the true frequency, unless a weighting factor is introduced.

To ensure sufficient data, R is taken to be 0.5 Nm. From Table F3, it can be seen that the appropriate weighting factor for same direction traffic over this range is estimated as 3.13 and for opposite direction traffic is estimated as 1.1. The distribution of proximity events for crossing direction traffic is approximately uniform over this range and therefore no weighting factor is necessary.

In order to estimate the frequency of horizontal overlap that would pertain to a 1000ft RVSM environment immediately following implementation, some consideration must be given to the likely redistribution of traffic. If traffic were to redistribute evenly over the additional flight levels, then the frequency of horizontal overlap could be expected to decrease by up to 50%. However, it may be more likely that traffic would instead 'bunch' around the optimum flight levels, in which case the frequency could be expected to remain roughly the same. It may even be the case that the additional system capacity would allow a higher density of traffic within the same time interval, in which case the frequency of horizontal overlap could be expected to increase. In the absence of further data, it will be assumed that the horizontal overlap frequency will not change following the introduction of RVSM. This assumption will be verified during the post-implementation safety assessment.

Based on the data from 13th April 2001 to 18th July 2001 , the frequency of horizontal overlap within a 2000ft environment is estimated to be 9.01x10-3 for level flight aircraft and 1.14x10-2 for climbing/descending aircraft. Based on the assumption that the horizontal overlap frequency will not immediately change following the introduction of RVSM, the same values will be taken for a 1000ft environment.

The exact method of calculating the horizontal overlap frequency is detailed in Reference **[34]**. Further relevant data is shown in Table F4 of this Appendix.

F.3.2 Probability of vertical overlap

The probability of vertical overlap has been derived from data collected by all available HMU sites and GMUs during the period as detailed in Appendix E and which has satisfied the criteria for useability as outlined in Appendix E. This period matches that used for the assessment of the height monitoring targets as outlined in Appendix E.

The height monitoring systems measures the Total Vertical Error (TVE) for each aircraft observed in straight and level flight. As shown in Figure F4, the TVE is made up of the altimetry system error (ASE) and flight technical error (FTE). In practice the recorded assigned altitude deviation (AAD) is used to approximate the FTE, since the correspondence error is assumed to be small.

To estimate the probability of vertical overlap, ASE height keeping measurements are averaged over each aircraft group, to produce an average performance for that group. Based on the spread of the data, a Gaussian (G), Double Exponential (DE) or Mixture (Gaussian-Double Exponential - GDE) distribution is fitted to the data seen for each group. The overall ASE distribution is then derived from the combination of distributions for each aircraft group, weighted by the proportion of flights made by that group. The ASE fits for each aircraft group that have been derived for the current collision risk analysis are shown in Table F5. Where no measurements were available for an aircraft group, a default GDE distribution based on the total set of measurements was assumed.

To determine whether the best fit would be G, DE or GDE, the within group and between group variation in measurements were considered. In most cases the performance appears to fit a Mixture distribution curve. Those groups whose performance currently appears to follow a Gaussian or Double Exponential distribution typically have less data. Therefore, as more data is collected it may be that these types will need to be remodelled with a GDE fit. It is possible that this may lead to an increase in the value of P_z, since a Mixture distribution tends to model the tails of the distribution more conservatively.

The overall ASE distribution is then convoluted with the distribution derived from the typical AAD performance, which is again obtained from the height monitoring systems. In this analysis, ‘typical’ AAD performance has been taken to be that which is not greater than 300ft in magnitude. Any AAD greater than this value would be considered atypical, and thus would be modelled following the approach detailed for other atypical AADs and assessed for its contribution towards the TLS of $5x10^{-9}$. Table F6 presents the currently observed proportions of typical AAD. The distribution chosen to model the typical AAD is a DE, with mean zero and lambda value 31.82. The closeness of the fit is shown in Figure F5.

The value of $P_z(1000)$ based on the currently observed ASE and typical AAD data is estimated to be 2.22x10-8 .

The value of $P_z(1000)$ based on the currently observed ASE and typical AAD data does not satisfy the Global System Performance Specification that the probability that two aircraft will lose procedural vertical separation of 1000ft should be not greater than $1.7x10^{-8}$. It was this probability value that was used as a basis for the derivation of the MASPS. An examination of individual group types shows that not all are performing at a level which would meet the MASPS. This is shown in Figure F6. It should be noted that for a number of these aircraft the available data is limited to only a few measurements.

F.3.3 Results

Combining the probability of vertical overlap with the horizontal overlap frequency, the vertical risk due to technical height-keeping performance for European RVSM airspace is thus estimated to be 2.00x10-10 , compared with the TLS of $2.5x10^{-9}$. 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.

It must be noted that a small number of aircraft are demonstrating Altimetry System Errors close to limits set in the MASPS. At present the number of measurements involved are not sufficient to come to final conclusions, but from the data presently available it seems that whilst the individual measurements show compliance with the MASPS, the ensemble of nominally identical aircraft to which these aircraft belong are not going to meet the ‘aircraft group’ requirements.

F.4 Assessment of the total vertical risk against the TLS of $5.0x10^{-9}$ fatal accidents per flight hour

The model described in **[34]** has also been used to assess the total vertical collision risk due all causes. The TLS that this risk must satisfy is $5.0x10^{-9}$ fatal accidents per flight hour. 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, as collected by the RVSM Programme. These deviations are referred to as atypical. The way in which this is done is now discussed for each type of atypical altitude deviation.

F.4.1 The type of data collected by the European RVSM Programme

There are 40 States participating in the European RVSM Programme. Because of agreements relating to ATS provision, these 40 States combine to form 37 reporting regions. Of these reporting regions, 2 are currently unable to report due to, for example, limited surveillance capability. This leaves 35 reporting regions that are in a position to provide reports to the RVSM Programme.

From April 2000, the RVSM Programme has collated information supplied by these 35 regions. The data falls into 3 basic error categories, which are depicted in Figure F7, which depicts a scenario where aircraft 1 should climb to a certain flight level. The correct path of the aircraft is shown by the solid line. The three possible types of deviation which aircraft 1 might make are depicted by the dotted line paths A, B and C.

F.4.1.1 Deviations not of a whole number of flight levels:

In scenario A, aircraft 1 fails to capture its correct flight level, and performs a height bust. This manoeuvre could result in a loss of separation with aircraft 2 on the adjacent level. In addition, although aircraft 1 does not reach the flight level of aircraft 2, there is still a small chance of collision due to the possible errors in the technical height keeping performance of the two aircraft. For example, if the height bust resulted in a nominal Mode C vertical separation of 500ft between the two aircraft, the actual vertical separation could be less (or greater) depending upon the technical height keeping error of the two aircraft.

F.4.1.2 Joining an incorrect level:

In scenario B, aircraft 1 climbs to and joins an incorrect level. This results in a possibility of collision with aircraft 2, the risk being dependent on the relative horizontal velocity of the two aircraft (ie whether they are same or opposite direction traffic) and the length of time the aircraft spends on the incorrect level without the deviation being corrected in some way, either by a reclearance or return to the correct flight level.

F.4.1.3 Crossing an incorrect flight level:

In scenario C, aircraft 1 climbs through an incorrect level. This again results in a possibility of collision with aircraft 2, the risk again being dependent on the relative horizontal velocity of the two aircraft, but also on the climb rate of aircraft 1, since this is directly proportional to the length of time it takes aircraft 1 to pass through the level of aircraft 2.

From consideration of Figure F7, it can be seen that an individual deviation could contribute to more than one category of error. For example, once an aircraft has crossed an incorrect level, and is at scenario C, there are a number of different outcomes that could follow:

i. Aircraft 1 is given a new clearance to join the level of aircraft 3 or return to its own level. In this case aircraft 1 has only being involved in one crossing-level type risk.

ii. Aircraft 1 is continues without clearance to join the level of aircraft 3. In this case aircraft 1 is involved in a further joining-level event with aircraft 3.

iii. Aircraft 1 descends without clearance to join the level of aircraft 2. In this case, aircraft 1 is involved in a height-bust type event with aircraft 3, and joining-level event with aircraft 2.

iv. Aircraft 1 descends without clearance to its correct flight level. In this case aircraft 1 is involved in the height-bust type event with aircraft 3, and another crossing-level event with aircraft 2.

v. Aircraft 1 continues to climb without clearance. In this case aircraft 1 is involved in another crossing-level event, this time with aircraft 3, and is in the position of needing a new clearance (outcome i) or being involved in further height-bust, joining-level or crossing-level events (outcomes ii to v).

It should be noted that deviations falling into these categories can have any one of a number of causes, such as human error on the part of ATC and/or aircrew, or environmental factors such as turbulence or wake vortex. In all cases, these deviations have been considered for their contribution to the total risk, which is assessed against the TLS of $5x10^{-9}$. They are not part of the assessment against the TLS of $2.5x10^{-9}$, which is taken to relate only to the risk due to the performance of technical height-keeping equipment.

F.4.2 A review of the quantity of data collected by the RVSM Programme

As stated previously, the RVSM Programme has from April 2000 collated information supplied by the 35 regions that are in a position to provide reports. During the period April 2000 to October 2000 , 230 reports have been provided.

It is important that the data set used for risk estimation is reliable and representative. In order to be representative of an RVSM environment, it is proposed to use data from the 23 core regions only, in the assessment of the quantitative TLS objectives.

Consideration of the 23 core regions indicates that there are 5 core regions that show about the same reporting rate, that is, to within half an order of magnitude (ie the largest rate is no more than 5 times greater than the smallest rate) when flight hours have been taken into account. These 5 regions have contributed 158 of the 197 reports received from core regions for the period April 2000 to October 2000 .

There are a further small number of regions that may also fit the same pattern, but due to the small number of flight hours covered so far, it is not yet possible to determine whether this is the case or not. Thus, there are a significant number of regions where it would appear that the reporting rates are a significant underestimate of the true rate of error occurrence.

Until it appears that the reporting rates are consistent and reliable, it is proposed to base the quantitative risk estimation only on the data from the subset of 5 core regions, with the proviso that this proposal will be reviewed as more data becomes available.

F.4.3 Analysis of the data collected by the RVSM Programme

The information collected by the RVSM Programme is analysed for its contribution towards the assessment of the TLS of 5×10^{-9} differently, depending upon the different error categories.

Of the 158 reports received from the core regions, 94 are relevant for the RVSM risk analysis. This is because they occurred either at an RVSM flight level, or at FL280, but with the deviation being in direction of RVSM airspace. Table F7 gives the breakdown of these 94 reports, by error type.

Of the reports summarised in Table F7, it is proposed to use only those relating to the last three type of events – real TCAS collision avoidance events, altitude deviations due to equipment failure, and altitude deviations due to human error. It is proposed not to use the reports relating to the first four types of events for the following reasons.

<u>Horizontal errors</u>: These are not included because the target levels of safety apply to risk in the vertical dimension only. However, it is noted that there are difficulties in identifying an event as ‘vertical’ or ‘horizontal’ because the assumption of the independence of the dimensions does not always clearly apply in reality. Certain events are more ‘3-dimensional’ in nature, with both horizontal and vertical components. Nevertheless, the current approach in collision risk estimation is to separate the dimensions, and for this reason, those errors where the root cause is a horizontal deviation of some kind have not been included in the RVSM risk estimation.

<u>Errors not greater than 300ft</u>: These are not included because a deviation of up to 300ft is currently considered tolerably within the bounds of level occupancy.

<u>Errors in transponded altitude</u>: These events relate to where the Mode C output does not match the altitude that the aircraft is maintaining. For example, the Mode C may be transponding FL344, but when queried, the pilot confirms that the aircraft is at FL340. Therefore, no deviation is actually occurring, and these events are therefore not included in the RVSM risk estimation.

TCAS nuisance or false alerts: An ACAS 'nuisance' (or operationally unnecessary) advisory is defined as "an advisory in accordance with the ACAS technical specifications in a situation where there was not, or would not, have been a risk of collision between the aircraft" *(ICAO SICASP 7 Report, 22 Sep 2000)*. A TCAS false alert refers to an event where the aircraft receives (and follows) an RA even though there are no other aircraft in its vicinity which should have triggered an RA.

It is proposed not to include TCAS events of these types in the collision risk assessment for the following reasons:

i. False alerts are clearly of negligible collision risk, since by definition, there is no other aircraft present. Nuisance alerts should also result in no risk to other aircraft since the logic employed by the TCAS equipment takes into account all aircraft in the vicinity, and the RA given should therefore not result in a collision.

ii. TCAS is designed to be a safety improvement measure. That is, its net result should be an overall decrease in risk, not an increase. It is argued that it is therefore sufficient for the risk assessment of RVSM to show that without TCAS, RVSM would meet its safety objectives. Then, since TCAS is an additional safety layer, RVSM with TCAS should also meet the same safety objectives. This approach is in line with current EATMP guidelines which say that safety nets should not be relied up to demonstrate acceptable safety. This aspect is dealt with in more detail in section 5.12.2 of the PISC, and further information is provided in Appendix L.

It should be noted that this approach means that the assessment of events where TCAS played an actual collision avoidance role is aimed at determining what would have occurred if TCAS had not been present.

In summary, from Table F7, there are 22 events remaining which are included in the risk estimation for RVSM. These pertain to TCAS real events and atypical altitude deviations due to equipment failure or human error. The details for these events are given in Table F8.

F.4.4 Frequency of horizontal overlap

The frequency of horizontal overlap used to estimate the risk from the atypical altitude deviations listed in Table F8 are the same as those values used to estimate the risk from technical height keeping errors, namely 9.01x10-3 for aircraft in level flight, and 1.14x10-2 for aircraft in climb/descent.

F.4.5 Probability of vertical overlap

Table F8 summarises the atypical deviations, based on data from April 2000 to October 2000 . In a few cases, the report specified the length of time taken to reach the maximum deviation, and the length of time spent at that maximum. Where this duration was not specified, it was calculated based on an assumed climb/descent rate of 1500 ft/min.

Table F8 assesses each error for its actual effect in the 2000ft environment, and for its assumed effect in the RVSM environment. In each case, the aim is to determine the proportion of time spent at a given magnitude of deviation. For example, a height bust of 500ft has also contributed to the proportion of time spent in deviation by 100ft, 200ft, 300ft and 400ft. For deviations in excess of 1000ft, the impact would be different between a 1000ft and 2000ft environment. For example, a 1500ft error in a 1000ft environment would have a potential to affect aircraft on two flight levels, whereas in a 2000ft environment only one flight level would be potentially affected. Table F9 shows the proportion of time spent in climb or descent through given deviations, taking into account the different contexts of the 1000ft and

2000ft environment. The information is also shown pictorially in Figure F8. Table F9 also shows the proportion of time spent in level flight at a given deviation, again taking into account the different contexts of the 1000ft and 2000ft environment. Table F9 is based solely on the errors reported to the RVSM Programme, as listed in Table F8 – no atypical AAD data is recorded by the HMU systems.

Of the atypical altitude deviation reports received by the RVSM Programme during the period April 2000 to October 2000 , two involve aircraft in level flight at exactly the wrong flight level, and one other involves an aircraft in level flight at 400ft deviation from flight level. The reports do not indicate how long the aircraft spent at exactly the wrong level and so a default value of 100 seconds will be used. The report related to the aircraft in level flight at 400ft deviation states the duration as 90 seconds.

The value of Pz(1000) is calculated separately for the climbing/descending deviations and the level flight deviations, using the methodology for atypical deviations described in **[34]**. Based on the data in Table F9, the value of Pz(1000) for climbing/descending deviations is 3.92x10-8 and the value for level flight deviations is 4.13x10-8 .

F4.6 Results

Combined with the appropriate values of horizontal overlap frequency, this gives collision risk estimates, based only on atypical data, of 4.47x10-10 and 3.72x10-10 for climbing/descending and level flight deviations respectively. The total vertical risk is the sum of these risks due to atypical performance and the risk due to technical vertical height-keeping performance (2.00x10-10 from section F3). It is estimated to be 1.02x10-9 , compared with the TLS of $5x10^{-9}$ fatal accidents per flight hour.

F5. Assessment of the Effect of RVSM on the Overall Risk of En-Route Mid-Air Collision

As outlined in the RVSM Safety Policy, the RVSM Programme shall, as its principal safety objective, minimise the programme's contribution to the risk of an aircraft accident. The RVSM Programme recognises the Safety Objectives of the ATM 2000+ Strategy, in particular the general objective to 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, it is the policy that the implementation of RVSM shall not adversely affect the risk of en-route mid-air collision.

To assess this objective quantitatively, it would be necessary to have both a collision risk methodology that could be applied to the risk of collision across the 3 dimensions – vertical, lateral and longitudinal – and the necessary data pertaining to the total en-route environment. Currently, neither of these requirements is available. The assessment of this objective has therefore being done qualitatively, in line with EATMP Safety Assessment Methodology, through the performance of the FHA and through the identification of all necessary mitigation factors. In addition, the organisation and management of the RVSM Programme has been such that all possible changes in risk due to RVSM have been addressed.

Nevertheless, it is possible to provide some quantitative information relating to this overall objective by examining the change in vertical risk which the implementation of RVSM may bring about. This can be done by re-assessing the vertical collision risk, based on a 2000ft separation, bearing in mind that the vertical collision risk is only one factor in the overall collision risk.

Thus, the total vertical risk estimated for current operations between FL290 and FL410 is estimated to be 5.45x10-10 . This compares with the estimate of 1.02x10-9 that is predicted to pertain in RVSM airspace. Thus, it is predicted that RVSM implementation will increase the total vertical risk between FL290 to FL410 by a factor of 87% .

However, this is not to say that the overall effect of RVSM on the total vertical risk of en-route mid-air collision will be an 87% , as this quantitative estimate relates to only part of the risk. In addition, the risk for 2000ft separation has been based on the MASPS performance. The risk that would have pertained in a 2000ft environment without the implementation of the MASPS could be expected to be greater in value, and thus the apparent increase in vertical risk due to RVSM would not be as great as 87% .

F.6 The effect of future traffic growth

As traffic increases, the frequency of horizontal overlap also increases. The relationship is linear in nature. That is, if traffic were to double, so would the frequency of overlap. Although there is considerable spread in the data, the general linearity of the relationship can be observed in Figure F9, which presents graphs of overlap frequency against flight hours observed at each HMU site during the period 13th April 2001 to 18th July 2001 .

The effect of traffic growth on risk is illustrated in Figure F10. The heavy solid line denotes the increase in technical vertical risk over the coming years, assuming an annual traffic growth of 6%. Assuming technical height-keeping performance remains constant (that is, no change in the probability of vertical overlap occurs during the period) the technical vertical risk will remain below the TLS of 2.5×10^{-9} until about the year 2045. The heavy dotted line denotes the increase in total risk over future years. Based on the previous assumption about technical performance and on the further assumptions that there is no under-reporting of errors, and that RVSM does not affect either the rate of occurrence or magnitude of operational errors, the total risk will remain below the TLS of 5×10^{-9} until about the year 2028.

However, such predictions about future risk may be optimistic. First, because the stability of the linear relationship between traffic growth and overlap frequency may not be maintained for large increases in traffic, and second, because of the likelihood of under-reporting.

F.7 Comparison of results with previous version of PISC

The following table compares the risk estimates presented in this appendix, with those presented in the previous version of the PISC[4].

	Technical vertical risk in RVSM	Number of operational errors	Number of Flight Hours	Total Risk in RVSM	Total Risk in current system	Change in vertical risk with RVSM
PISC V1.0[1]	7.84×10^{-12}	16	2.95×10^{5}	1.15×10^{-9}	9.44×10^{-10}	22%
Current	2.00x10-10	22	5.32×10^{5}	1.02x10-9	5.45x10-10	87%
Change in parameter value	≈ 25 times greater	≈ 40% greater	≈ 80% greater	≈ 10% less	≈ 40% less	

[4] As presented in RVSM/WP3.3/A778: Update to Appendix F of RVSM Safety Case V1.0 – 02 May 2001

At first glance it seems strange that whilst the total risk estimate has decreased since the previous version of the PISC, the change in vertical risk associated with RVSM has increased, from 22% to 87%. A review of the data shows that this apparent paradox is due to 2 main reasons. First, there has been only a small number of additional operational errors seen during the extra data period analysed in the present review. Second, the estimate of technical vertical risk in the present review is now no longer negligible in comparison with the risk due to operational error.

The estimates from the previous PISC were based on 4 months data, during which $2.95x10^5$ flight hours were recorded. The present estimates were based on 7 months data. This increased the number of flight hours recorded by 80%. However the number of risk-bearing operational errors recorded showed an increased of only 40%. Therefore the estimate for the total risk in the <u>current</u> system actually <u>decreased</u> by a similar amount of 40%. The total risk in a 2000ft system is almost entirely due to operational error: the technical vertical risk associated with 2000ft separation is negligible in comparison.

The technical vertical risk estimate in the previous version of the PISC was based on the assumption that the set of aircraft not meeting the MASPS would be subject to remedial action enabling them to do so. This resulted in the technical vertical risk associated with 1000ft separation being negligible in comparison with the operational risk associated with 1000ft separation. In the present review, this assumption of completely effective remedial action has not yet been fully borne out, and the technical vertical risk associated with 1000ft separation is now non-negligible in comparison with the risk due to operational error. Thus, compared with the previous PISC, the total risk in RVSM has changed by only 10% compared with the 40% change in estimates for the total risk associated with 2000ft separation.

These two factors combined result in the increased estimate of the change in risk between 2000ft and 1000ft separations.

F.8 Summary

This Appendix 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 does <u>not</u> satisfy the Global System Performance Specification that the probability of two aircraft losing procedural vertical separation of 1000ft should be not greater than $1.7x10^{-8}$. It was this probability value that was used as a basis for the derivation of the MASPS. An examination of individual group types shows that not all are performing at a level which would meet the MASPS. If the observed performance for these aircraft types is effectively resolved then the Global System Performance Specification requirement will be met.

Nevertheless, when the observed frequency of horizontal overlap is taken into account, it is estimated that both the TLS of $2.5x10^{-9}$ and the TLS of $5x10^{-9}$ would be satisfied within European RVSM airspace. However, it must be noted that the risk assessment has been based on a number of assumptions, as follows:

i. The risk of collision in an RVSM environment with TCAS will be lower than the risk of collision without TCAS.

ii. The frequency and magnitude of operational errors will not be affected by RVSM implementation.

iii. The frequency and magnitude of operational errors is independent of the proximity of other aircraft.

iv. The type of operational errors observed in the set of 5 States used for the present analysis is representative of Europe as a whole.

v. The set of reports for the 5 States used in the present analysis is complete. That is, there is no under-reporting. Based on the current risk estimates, it would appear that if the level of under-reporting is greater than 80% (ie only 1 out of every 5 atypical altitude deviations is reported) then the current level of risk may be in excess of the overall TLS of $5x10^{-9}$ fatal accidents per flight hour.

vi. That the implementation of RVSM will not affect the frequency of horizontal overlap.

vii. The lack of data on atypical (greater than 300ft) deviations from the HMU system is not sufficient to invalidate the current risk estimates.

Figure F1

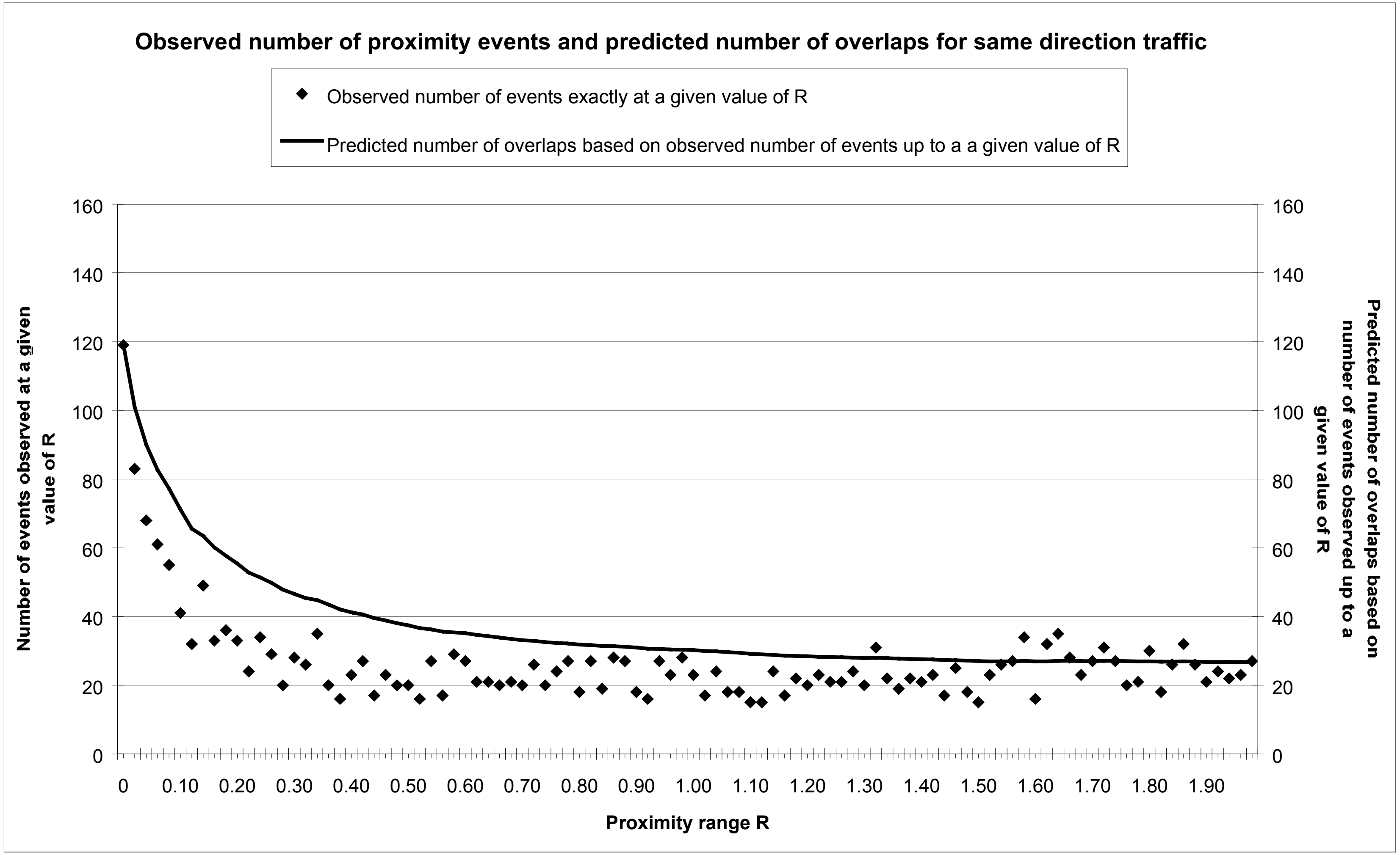

Observed number of proximity events and predicted number of overlaps for same direction traffic
Observed number of events exactly at a given value of R
Predicted number of overlaps based on observed number of events up to a a given value of R
Number of events observed at a given value of R
Predicted number of overlaps based on number of events observed up to a given value of R
Proximity range R
0
20
40
60
80
100
120
140
160
0
0.10
0.20
0.30
0.40
0.50
0.60
0.70
0.80
0.90
1.00
1.10
1.20
1.30
1.40
1.50
1.60
1.70
1.80
1.90

Figure F2

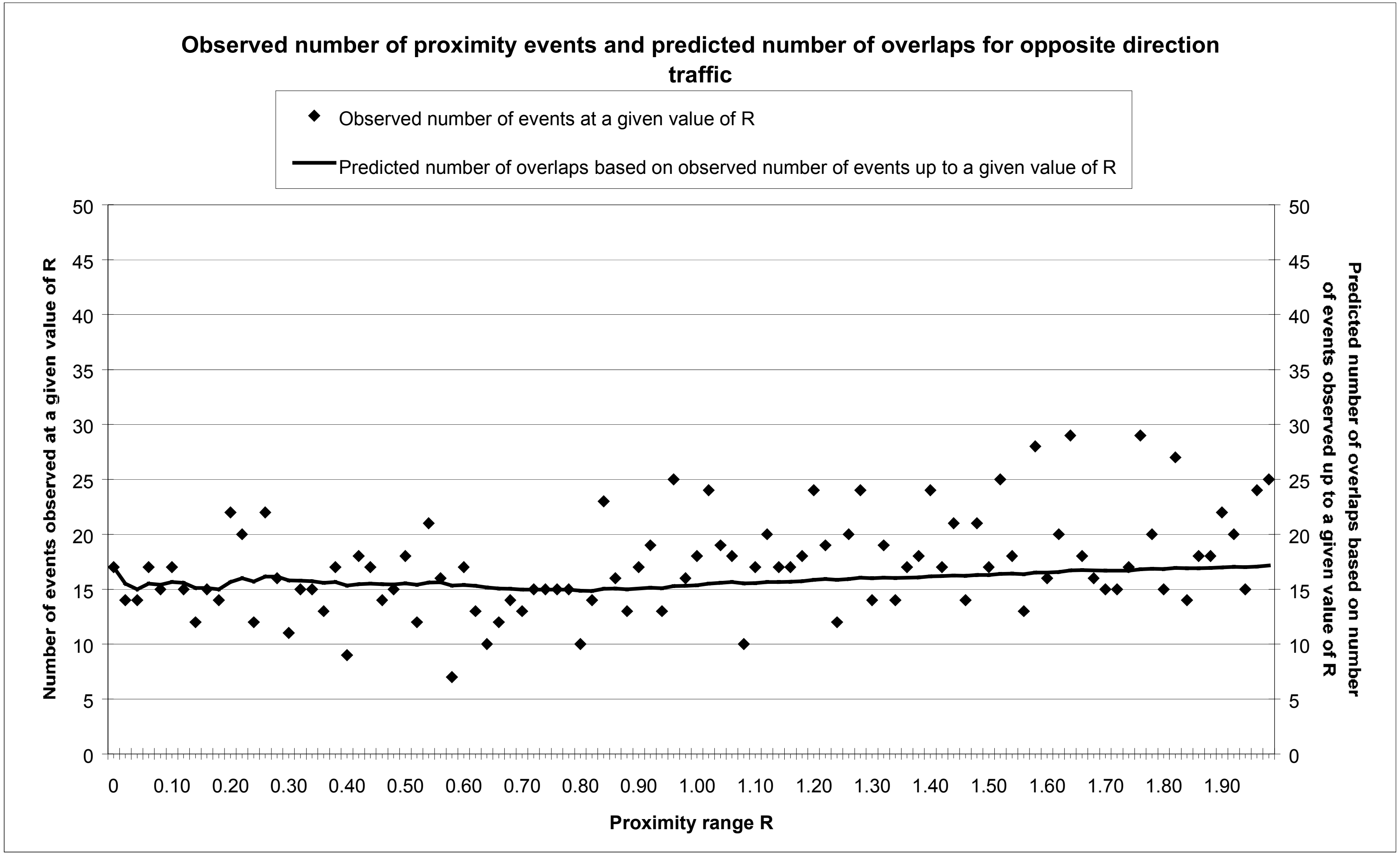

Observed number of proximity events and predicted number of overlaps for opposite direction traffic
Observed number of events at a given value of R
Predicted number of overlaps based on observed number of events up to a given value of R
Number of events observed at a given value of R
Predicted number of overlaps based on number of events observed up to a given value of R
Proximity range R
0 5 10 15 20 25 30 35 40 45 50
0 0.10 0.20 0.30 0.40 0.50 0.60 0.70 0.80 0.90 1.00 1.10 1.20 1.30 1.40 1.50 1.60 1.70 1.80 1.90

Figure F3

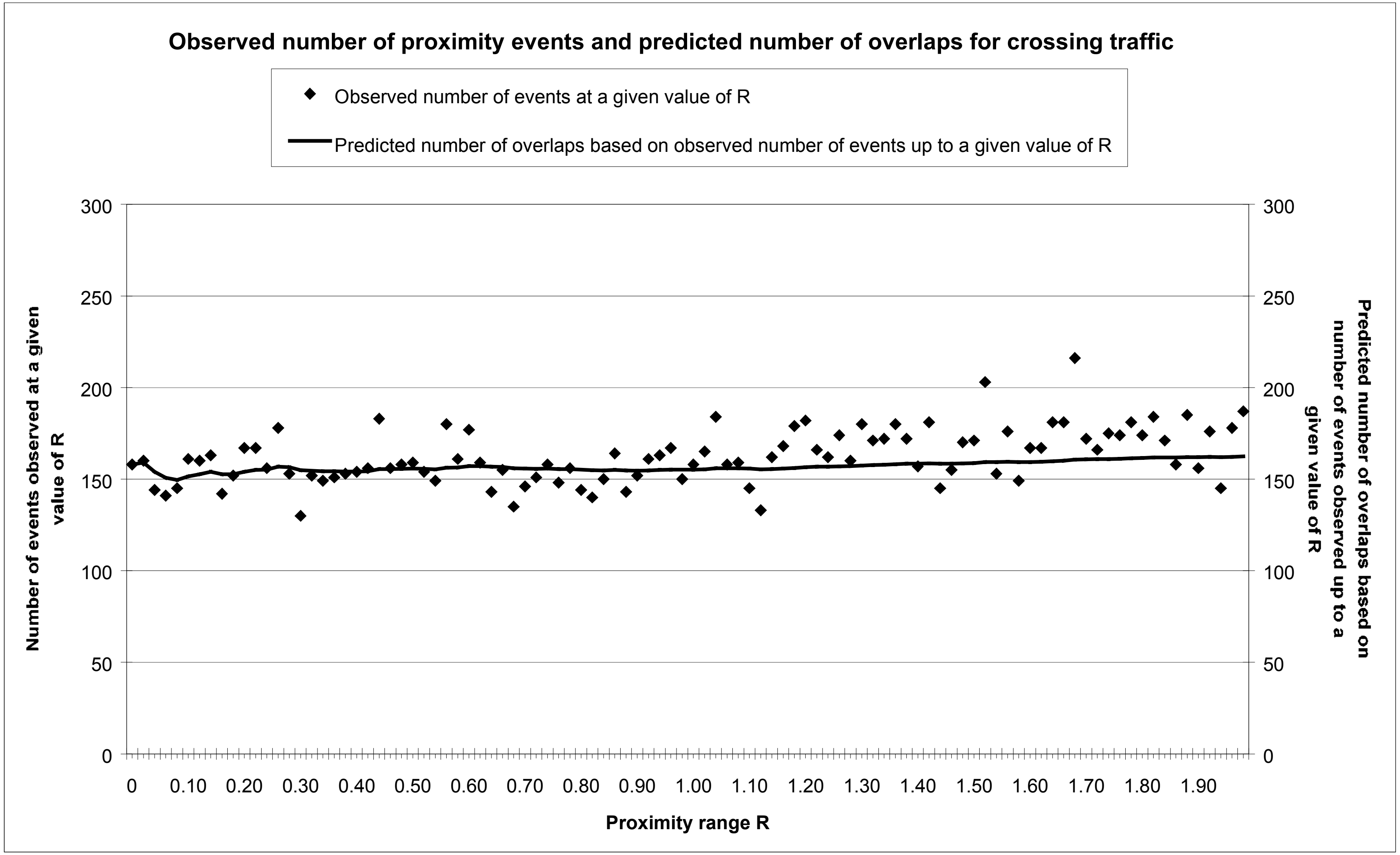

Observed number of proximity events and predicted number of overlaps for crossing traffic
Observed number of events at a given value of R
Predicted number of overlaps based on observed number of events up to a given value of R
Number of events observed at a given value of R
Predicted number of overlaps based on number of events observed up to a given value of R
0
50
100
150
200
250
300
0 0.10 0.20 0.30 0.40 0.50 0.60 0.70 0.80 0.90 1.00 1.10 1.20 1.30 1.40 1.50 1.60 1.70 1.80 1.90
Proximity range R

Figure F4

Components which combine to form the Total Vertical Error (TVE)

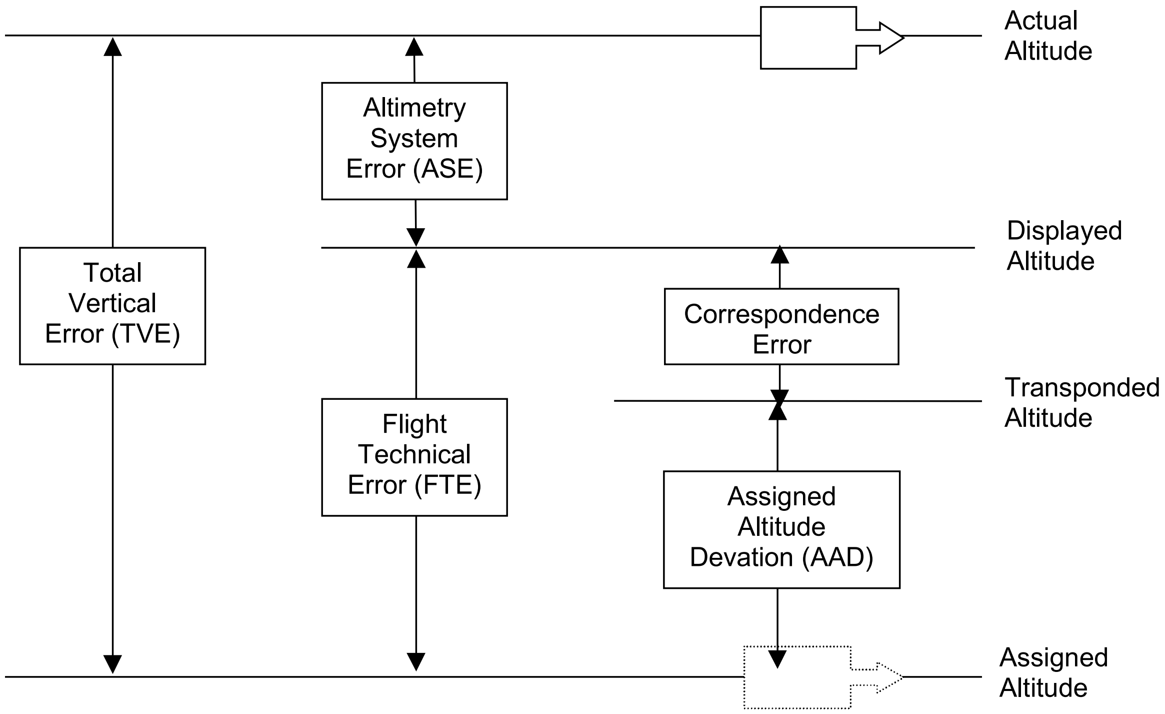
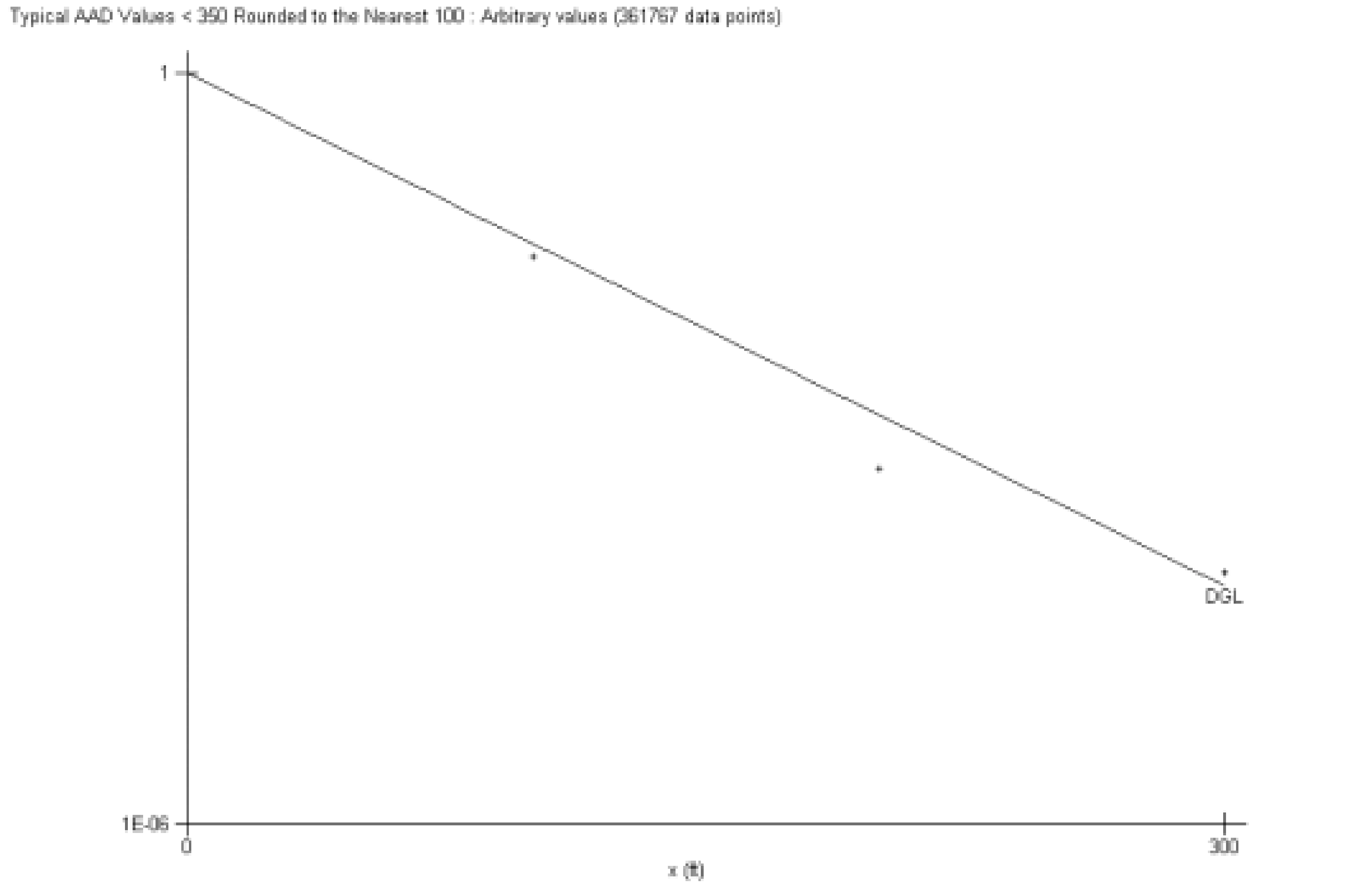


Figure F5

Fit to Rounded AAD Values not greater than 300ft inMagnitude



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 F6

ASE mean and standard deviation for aircraft currently not meeting the MASPS

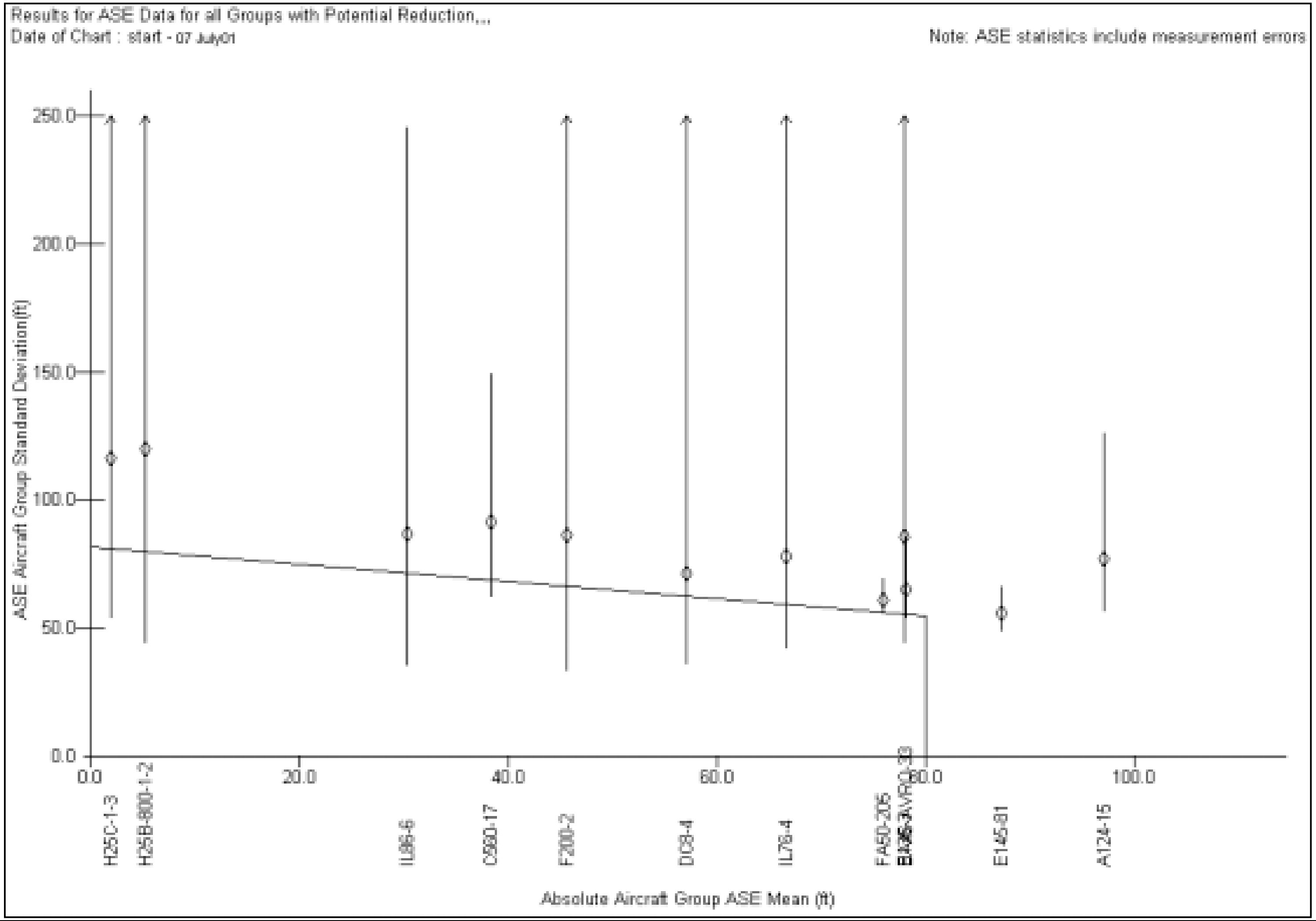


Figure F7

Illustration of the three basic error categories

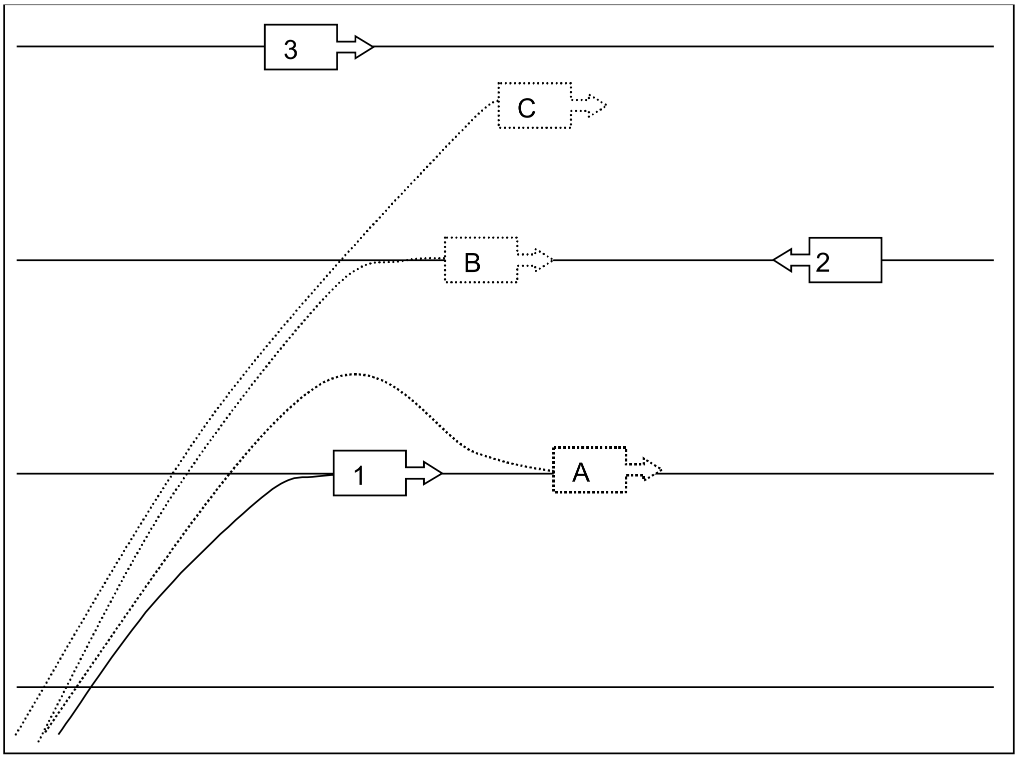


Figure F8

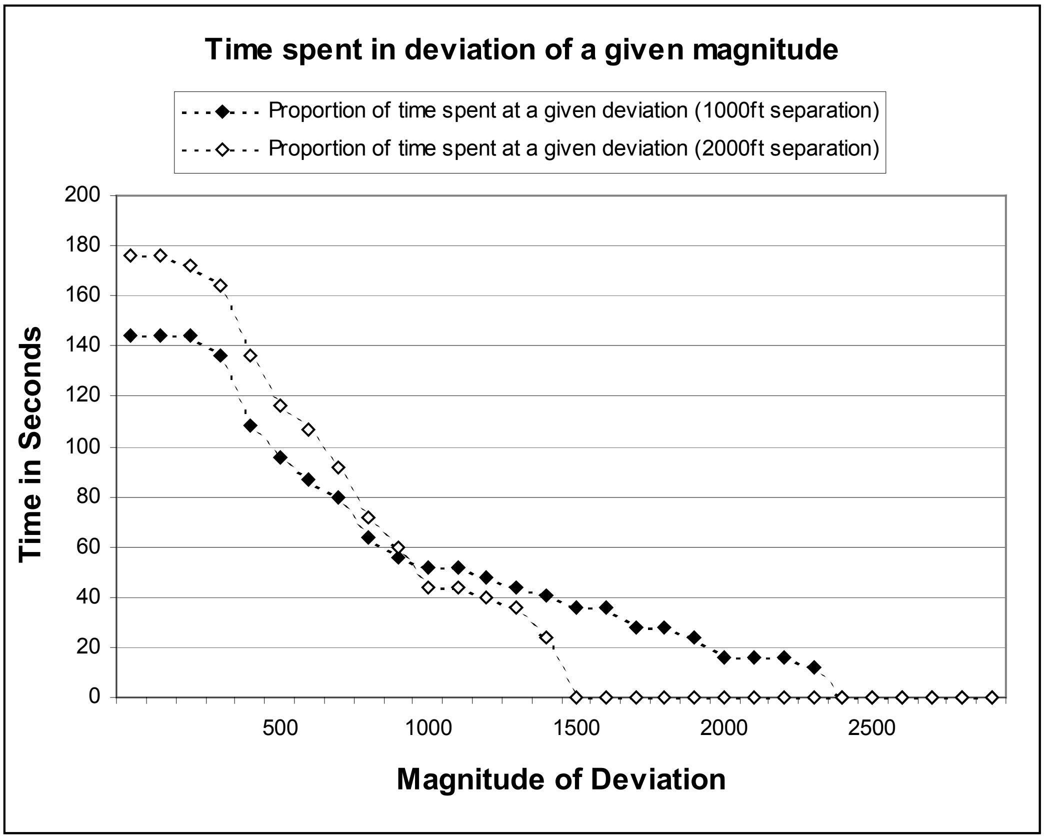

Time spent in deviation of a given magnitude
Proportion of time spent at a given deviation (1000ft separation)
Proportion of time spent at a given deviation (2000ft separation)
200
180
160
140
120
100
80
60
40
20
0
Time in Seconds
500
1000
1500
2000
2500
Magnitude of Deviation

Figure F9

Graphs of proximity frequency against flights hours

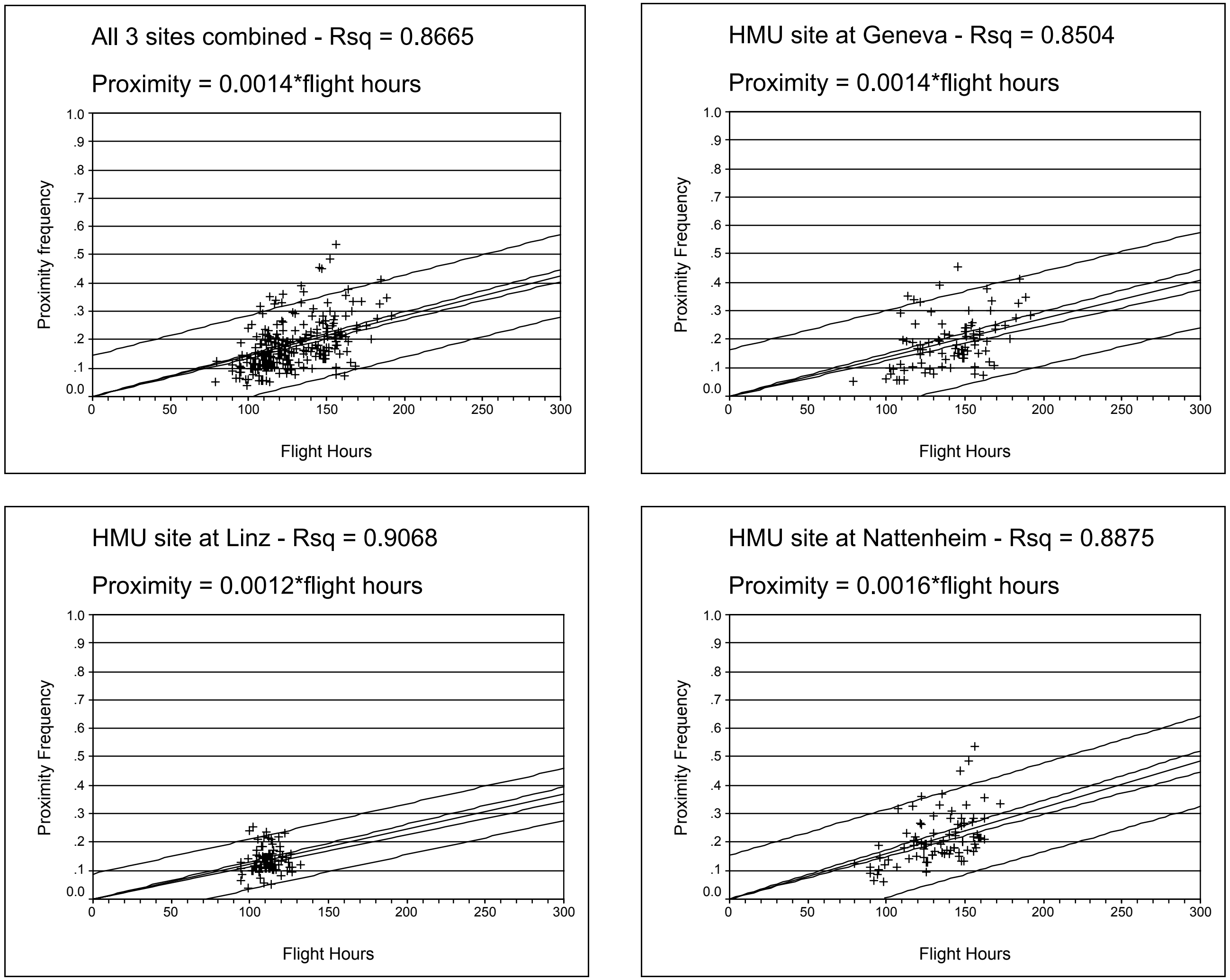


Figure F 10

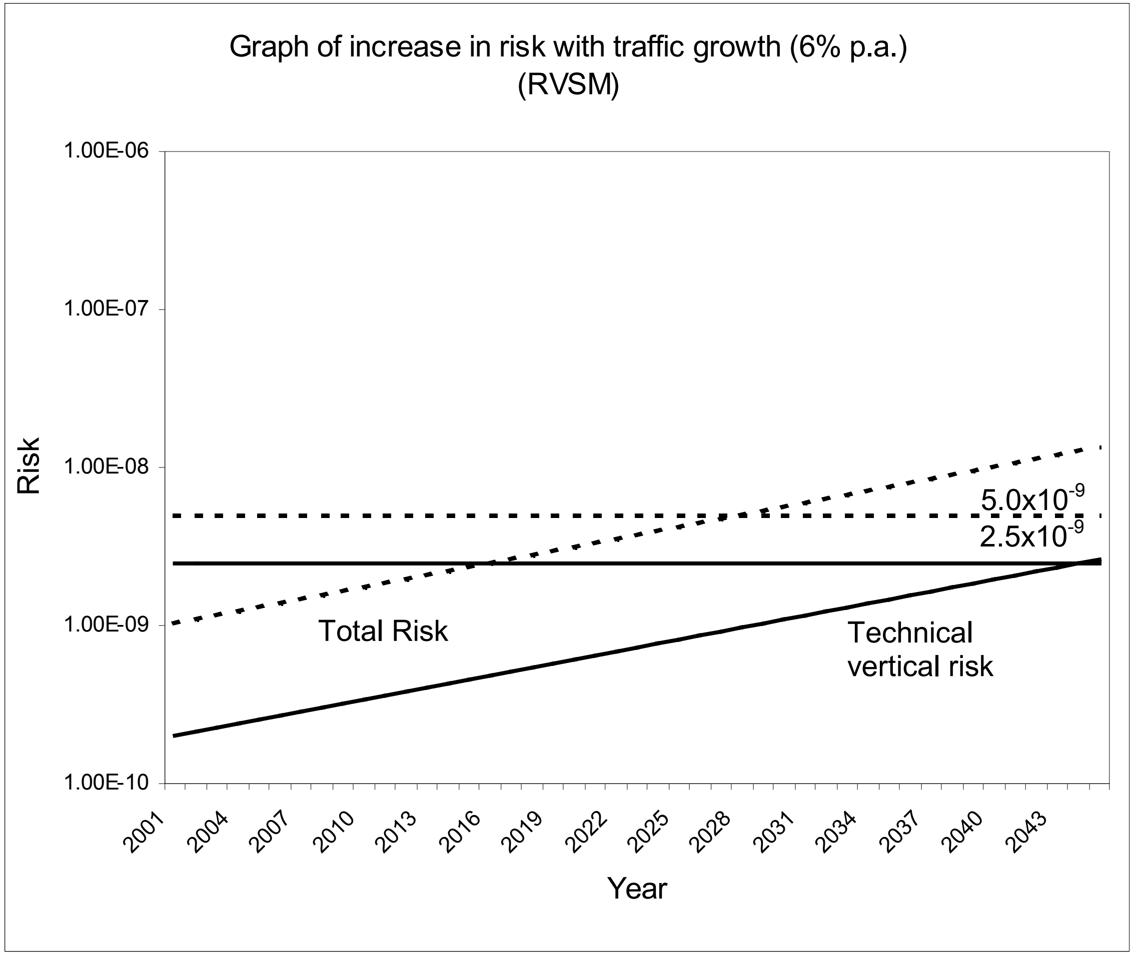

Graph of increase in risk with traffic growth (6% p.a.)
(RVSM)
1.00E-06
1.00E-07
1.00E-08
1.00E-09
1.00E-10
Risk
5.0x10-9
2.5x10-9
Total Risk
Technical
vertical risk
2001
2004
2007
2010
2013
2016
2019
2022
2025
2028
2031
2034
2037
2040
2043
Year

Table F1

Average aircraft dimensions and kinetic data

Average aircraft vertical size	39.22 ft	0.0065 Nm
Average aircraft horizontal size	132.94 ft	0.0219 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 F2

Classification 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 F3

Derivation of Weighting Factors[5] associated with estimation of Horizontal Overlap Frequency

	Same Direction Traffic			Opposite Direction Traffic			Crossing Traffic		
R	Observed number of events	Predicted number of overlaps	Weighting Factor	Observed number of events	Predicted number of overlaps	Weighting Factor	Observed number of events	Predicted number of overlaps	Weighting Factor
0.02	119	119.00	1.00	17	17.00	1.00	158	158.00	1.00
0.04	83	101.00	1.18	14	15.50	1.10	160	159.00	0.99
0.06	68	90.00	1.32	14	15.00	1.13	144	154.00	1.03
0.08	61	82.75	1.44	17	15.50	1.10	141	150.75	1.05
0.10	55	77.20	1.54	15	15.40	1.10	145	149.60	1.06
0.12	41	71.17	1.67	17	15.67	1.09	161	151.50	1.04
0.14	32	65.57	1.81	15	15.57	1.09	160	152.71	1.03
0.16	49	63.50	1.87	12	15.13	1.12	163	154.00	1.03
0.18	33	60.11	1.98	15	15.11	1.13	142	152.67	1.03
0.20	36	57.70	2.06	14	15.00	1.13	152	152.60	1.04
0.22	33	55.45	2.15	22	15.64	1.09	167	153.91	1.03
0.24	24	52.83	2.25	20	16.00	1.06	167	155.00	1.02
0.26	34	51.38	2.32	12	15.69	1.08	156	155.08	1.02
0.28	29	49.79	2.39	22	16.14	1.05	178	156.71	1.01
0.30	20	47.80	2.49	16	16.13	1.05	153	156.47	1.01
0.32	28	46.56	2.56	11	15.81	1.08	130	154.81	1.02
0.34	26	45.35	2.62	15	15.76	1.08	152	154.65	1.02
0.36	35	44.78	2.66	15	15.72	1.08	149	154.33	1.02
0.38	20	43.47	2.74	13	15.58	1.09	151	154.16	1.02
0.40	16	42.10	2.83	17	15.65	1.09	153	154.10	1.03
0.42	23	41.19	2.89	9	15.33	1.11	154	154.10	1.03
0.44	27	40.55	2.93	18	15.45	1.10	156	154.18	1.02
0.46	17	39.52	3.01	17	15.52	1.10	183	155.43	1.02
0.48	23	38.83	3.06	14	15.46	1.10	156	155.46	1.02
0.50	20	38.08	3.13	15	15.44	1.10	158	155.56	1.02

[5] The data in this table relate to proximate events at adjacent and non-adjacent flight level in order to maximise the number of observations.

Table F4

Details of horizontal proximity events recorded at the 3 HMU sites

			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	86	12138	15	17	1169	1201	0.198	0.046	0.055	9.10E-03	1.09E-02
Linz	81	9023	45	20	554	619	0.137	0.054	0.085	7.42E-03	1.16E-02
Nattenheim	86	11403	12	305	931	1248	0.219	0.047	0.054	1.02E-02	1.18E-02
Combined	253	32564	72	342	2654	3068	0.188	0.048	0.060	9.01E-03	1.14E-02

Table F5

Observed ASE performance for aircraft groups

Monitoring Classification[6]	Proportion FT[7]	Density[8]	Group Mean (ft)	Overall standard deviation (s.d.)	s.d. 1 (GDE only)	s.d. 2 (GDE only)	Alpha (GDE only)
A124	2.15E-04	DE	97.1	77.1			
A306	7.14E-03	GDE	18.7		41.67	96.12	0.0035
A30B	7.98E-03	GDE	5.2		50.78	46.18	0.0931
A312-GE	2.65E-03	GDE	-21.6		38.57	42.33	0.1131
A312-PW	3.31E-04	GDE	52.8		18.81	18.36	0.1194
A313-GE	9.39E-03	GDE	-42.7		43.19	46.33	0.3166
A313-PW	3.98E-03	GDE	28.5		48.36	105.34	0.0045
A319	4.04E-02	GDE	41.5		43.77	78.02	0.0081
A320	1.06E-01	GDE	56.8		48.49	44.04	0.1546
A321	4.62E-02	GDE	43		42.92	47.90	0.1371
A330	1.60E-02	GDE	52.3		41.88	44.66	0.0267
A340	1.73E-02	GDE	9.3		48.64	37.92	0.2983
A3ST	4.50E-04	G	31.1	53.9			
AN72	3.15E-05	GDE	4.5		56.40	60.43	0.0708
ASTR	9.63E-06	GDE	4.5		56.40	60.43	0.0708
ASTR-SPX	2.60E-04	GDE	41.6		51.53	35.62	0.0114
B703	6.12E-05	DE	57.7	42.7			
B712	1.85E-03	DE	26.2	39.4			
B721	1.22E-03	G	61.6	55.6			
B722	1.68E-04	G	52.3	35.9			
B732	1.36E-02	DE	6.9	56.5			
B733	8.85E-02	GDE	-22.2		40.74	50.93	0.2518
B734	5.24E-02	GDE	-46.3		37.59	41.63	0.2259
B735	5.09E-02	GDE	-12.6		38.41	63.31	0.1020
B736	1.50E-02	G	38.2	44.4			
B737	1.92E-02	GDE	17.2		42.56	79.13	0.0058
B738	6.03E-02	GDE	19.3		33.30	38.56	0.3591
B739	1.08E-06	GDE	4.5		56.40	60.43	0.0708
B741	3.74E-04	GDE	-34.3		60.70	39.74	0.1018
B742	1.50E-02	GDE	-18.8		58.02	82.49	0.0025
B743	4.57E-03	GDE	-9.3		57.82	93.89	0.0218
B744	3.02E-02	GDE	-37.6		43.52	51.41	0.1684
B74S	5.08E-04	G	-7.2	54.3			
B752	5.90E-02	GDE	2.3		32.70	43.71	0.2972
B753	3.76E-03	GDE	23.8		27.89	60.32	0.0427
B762	8.31E-03	GDE	-11.6		48.06	46.08	0.1184

[6] Refer to Appendix E for Definitions of Monitoring Groups.

[7] Flight proportions are based on observed flight proportions from January 2001 – June 2001. These observations were then adjusted according to the number of MASPS approved aircraft as of July 2001. Flights currently made by aircraft monitoring groups for which no MASPS approved aircraft existed were removed from the sample on the assumption that these flights will not be able to fly in RVSM airspace.

[8] G- Gaussian, DE – Double Exponential, GDE – Gaussian Double Exponential. Where no data is available for a monitoring classifcation, a default GDE distribution of mean 4.5, sd1 56.40, sd2 60.43 and alpha 0.0708 has been assumed. This has been derived from the total set of observed measurements.

Monitoring Classification[6]	Proportion FT[7]	Density[8]	Group Mean (ft)	Overall standard deviation (s.d.)	s.d. 1 (GDE only)	s.d. 2 (GDE only)	Alpha (GDE only)
B763	3.83E-02	GDE	-39		43.12	49.99	0.1514
B764	3.54E-04	DE	6.4	40.9			
B772	1.82E-02	GDE	40.2		38.73	54.88	0.0489
B773	2.69E-04	GDE	25		14.10	26.24	0.1260
BA46-AVRO	1.14E-02	GDE	78		65.10	168.11	0.0070
BE40	1.14E-04	GDE	4.5		56.40	60.43	0.0708
C500	6.83E-06	GDE	4.5		56.40	60.43	0.0708
C525	1.25E-03	DE	25.6	39.8			
C525-II	3.11E-06	GDE	4.5		56.40	60.43	0.0708
C550-B	8.90E-04	DE	44.2	45.3			
C550-II	7.12E-05	GDE	4.5		56.40	60.43	0.0708
C560	6.02E-04	DE	38.4	91.5			
C56X	7.04E-04	GDE	-5.4		33.41	59.67	0.1593
C650	7.80E-04	DE	17	54.6			
C750	2.54E-04	DE	-17.6	67.5			
CARJ	4.15E-02	DE	-17.2	51.8			
CL60-600	2.92E-04	G	25.9	47.6			
CL60-601	1.87E-03	GDE	5		45.44	129.18	0.0263
CL60-604	9.06E-04	DE	3.4	56.8			
DC10	7.34E-03	GDE	7.4		58.78	65.82	0.0557
DC8	1.21E-04	DE	57	71.2			
DC9	3.84E-05	GDE	4.5		56.40	60.43	0.0708
E135	8.03E-04	DE	77.9	85.6			
E145	2.70E-02	GDE	87.2		59.37	39.16	0.1334
F100	1.37E-02	DE	-2.4	51.7			
F200	4.43E-05	G	-45.6	86.5			
F2TH	1.56E-03	GDE	-65		55.22	111.49	0.0294
F70	1.36E-02	GDE	-77.5		30.87	49.86	0.0541
F900	3.07E-03	G	31.5	59.9			
FA10	1.48E-04	DE	34.7	66.2			
FA20	7.53E-04	G	-23.6	53			
FA50	2.09E-03	GDE	75.9		65.64	51.74	0.0693
GALX	9.31E-05	G	70.5	42.7			
GLEX	7.68E-05	DE	60	26.9			
GLF2	1.31E-04	DE	-0.4	66.9			
GLF3	4.73E-04	GDE	-27		47.48	61.99	0.2097
GLF4	3.00E-03	GDE	-12.2		51.15	55.27	0.2106
GLF5	7.46E-04	GDE	14.6		55.23	92.42	0.1416
H25B-700	1.64E-05	GDE	4.5		56.40	60.43	0.0708
H25B-800	2.84E-03	GDE	3.6		69.89	46.26	0.2778
H25B-800-1	4.93E-05	DE	5.2	119.9			
H25C	2.04E-04	G	70.2	52.8			
H25C-1	3.61E-05	DE	2	116.3			
IL62	2.24E-05	DE	60.6	56.5			
IL76	2.54E-05	G	66.5	78.2			
IL86	8.31E-04	DE	30.3	86.6			
IL96	2.13E-04	G	53.5	43			
L101	1.35E-03	DE	16	58.4			

Monitoring Classification[6]	Proportion FT[7]	Density[8]	Group Mean (ft)	Overall standard deviation (s.d.)	s.d. 1 (GDE only)	s.d. 2 (GDE only)	Alpha (GDE only)
L29B-2	1.39E-05	GDE	4.5		56.40	60.43	0.0708
LJ45	8.84E-04	G	54.8	37.1			
LJ60	1.47E-03	DE	28.2	49.7			
MD11	1.19E-02	G	-1.6	53.6			
MD80	1.00E-01	GDE	12.3		37.65	59.30	0.0401
MD90	3.33E-03	G	37.7	39.3			
SBR1-65	4.78E-05	DE	-53	36.9			
T134	7.20E-05	GDE	4.5		56.40	60.43	0.0708
T154	5.14E-04	DE	6.2	75			
T204	1.22E-04	GDE	4.5		56.40	60.43	0.0708
YK42	2.21E-04	GDE	4.5		56.40	60.43	0.0708

Table F6

Observed typical[9] performance for MASPS Approved Aircraft, as recorded by the height monitoring systems

Magnitude of Deviation	Observed number of deviations	Observed Proportion
-300	30	8.29E-05
-200	151	4.17E-04
-100	6002	1.66E-02
0	349258	9.65E-01
100	6253	1.73E-02
200	66	1.82E-04
300	7	1.93E-05

Table F7

Summary of atypical altitude deviations by error type

Type of Event	Number of Occurrences
Deviation caused by error in horizontal plane	7
Errors not greater than 300ft	17
Errors in transponded altitude	8
TCAS nuisance or false events	40
TCAS real, ie actual collision avoidance, event	5
Altitude deviations due to other technical error, eg autopilot failure	2
Altitude deviations due to other operational error, eg pilot error	15
Total number of errors	**94**

[9] 'Typical' AAD performance is defined to be not greater than 300ft in magnitude

Table F8

Description of the atypical altitude deviations used for assessment of the TLS of $5x10^{-9}$

Ref#	Date of Event	Type of Error	Description	Remarks	Assumed effect in 2000ft environment	Assumed effect in 1000ft environment
SG/015/2000	13-Apr-00	Height bust due to autopilot problem	a/c cleared to FL330, reached FL337 before descending	Time at FL337 reported to be 3 seconds	700 ft deviation then return to cleared level	700 ft deviation then return to cleared level
SG/034/2000	12-Apr-00	Pilot acted on clearance for another aircraft	a/c1 cleared to descend to FL350 above a/c2 at FL330. a/c2 was then cleared to FL270. a/c1 followed clearance for a/c2 and was noticed by ATC at FL331. Avoiding action given.	a/c1 assumed to continue further 400 ft before avoidance manoeuvre initiated.	2300ft deviation and 300ft deviation then continuing on new clearance	1500ft deviation and 1300ft deviation and 300ft deviation then continuing on new clearance
SG/037/2000	17-Apr-00	Pilot acted on clearance for another aircraft	a/c1 cleared to descend to FL200. a/c2 also followed instruction. Error eventually picked up by ATC.	Maximum deviation assumed to be 800ft	800ft deviation then continuing on new clearance	800ft deviation then continuing on new clearance

Ref#	Date of Event	Type of Error	Description	Remarks	Assumed effect in 2000ft environment	Assumed effect in 1000ft environment
SG/041/2000	29-Apr-00	Lack of co-ordination between sectors	a/c1 cleared to climb from FL370 to FL390. a/c2 cleared to climb from FL350 to FL390, through level of a/c1. Avoiding action given at FL355 to a/c2.		500ft deviation then continuing on new clearance	500ft deviation then continuing on new clearance
SG/049/2000	21-May-00	Pilot acted on clearance for another aircraft	a/c1 cleared from FL290 to FL310. ATC then noticed a/c2 climbing without clearance through FL298 in conflict with a/c3 at FL310. ATC provided avoidance manoeuvre.	a/c1 assumed to continue further 400 ft before avoidance manoeuvre initiated.	1200 ft deviation then continuing on new clearance	1200ft deviation and 200ft deviation then continuing on new clearance
SG/051/2000	03-May-00	Autopilot did not capture level	a/c cleared to FL330, observed at FL334 Assumed height bust.	Time at FL334 stated to be 4 seconds.	400ft deviation then return to cleared level	400ft deviation then return to cleared level
SG/087/2000	22-Jun-00	Unknown: Stated as pilot error.	a/c cleared to FL290 observed at FL299	Time at FL299 stated to be ‘a few seconds’ – assumed to be 4 seconds.	900ft deviation then return to cleared level	900ft deviation then return to cleared level

Ref#	Date of Event	Type of Error	Description	Remarks	Assumed effect in 2000ft environment	Assumed effect in 1000ft environment
SG/094/2000	06-Jun-00	ATC error	a/c1 cleared to descend through from FL370 to FL350 when FL350 occupied by a/c2. ATC noticed error and gave avoiding action, which was followed at FL357	Clearance assumed to be 1 separation standard for 2000ft and 1000ft	1300ft deviation then continuing on new clearance	1000ft deviation Joining incorrect level (Assumed that in RVSM, a/c would have reached level by time ATC noticed error)
SG/095/2000	03-Jun-00	ATC error	a/c1 cleared to level of other aircraft	Time at level assumed to be 100 seconds Clearance assumed to be 1 separation standard	2000ft deviation then Joining incorrect level	1000ft deviation then Joining incorrect level
SG/097/2000	10-Jul-00	Pilot error	a/c1 at FL280 actually at FL284	Time at FL284 stated as 1' 30''	400ft deviation then return to cleared level Level flight at 1600ft separation	400ft deviation then return to cleared level Level flight at 600ft separation
SG/104/2000	20-Jun-00	Pilot error	a/c1 cleared to FL290, queried by ATC at FL294, maximum deviation FL296	Time at FL296 assumed to be 4 seconds	600ft deviation then return to cleared level	600ft deviation then return to cleared level

Ref#	Date of Event	Type of Error	Description	Remarks	Assumed effect in 2000ft environment	Assumed effect in 1000ft environment
SG/105/2000	08-Jun-00	ATC error	a/c1 received real TCAS alert from military a/c2 cleared to climb through its level.	Assessment ignores TCAS and assumed deviation applies to 1 separation standard a/c2 assumed to continue further 400 ft before avoidance manoeuvre initiated.	2400ft deviation 400ft deviation	1400ft deviation 400 ft deviation
SG/106/2000	14-Jun-00	Unknown	a/c1 received real TCAS alert from a/c2 climbing through its level	Assessment ignores TCAS and assumed deviation applies to 1 separation standard a/c2 assumed to continue further 400 ft before avoidance manoeuvre initiated.	2400ft deviation 400 ft deviation	1400ft deviation 400 ft deviation
SG/120/2000	06-Jul-00	Pilot error	a/c performed height bust of unknown deviation	Maximum deviation assumed to be 500ft for 4 seconds	500ft deviation then return to cleared level	500ft deviation then return to cleared level
SG/123/2000	02-Jul-00	ATC loop error	a/c cleared to climb to FL270, understood climb to FL370 Noted by ATC at FL285 - maximum deviation FL299.		1900ft deviation then continue on new clearance	1500ft deviation 900ft deviation then continue on new clearance

Ref#	Date of Event	Type of Error	Description	Remarks	Assumed effect in 2000ft environment	Assumed effect in 1000ft environment
SG/130/2000	12-Jul-00	Unknown	a/c with high climb rate appeared to perform height bust	Seen to climb to 'FL295 or higher' – assumed 800ft	800ft deviation then return to cleared level	800ft deviation then return to cleared level
SG/188/2000	16-Sep-00	Assumed ATC error	Indication that a/c was inappropriately cleared to descend	Assessment ignores TCAS and assumed deviation applies to 1 separation standard Assumed a/c would travel 400ft through wrong level before receiving new ATC clearance	2400ft deviation 400ft deviation	1400ft deviation 400 ft deviation
SG/215/2000	01-Aug-00	Assumed pilot error	a/c1 received real TCAS alert from military a/c performing height bust.	Assessment ignores TCAS	1700ft deviation then return to level	1500ft deviation 700 ft deviation then return to level
SG/239/2000	11-Oct-00	ATC error	a/c spotted in climb at 900ft off level	Assumed a/c would travel further 400ft before receiving new ATC clearance	1300ft deviation then continuing on new clearance	1300ft deviation 300ft deviation then continuing on new clearance
SG/241/2000	14-Oct-00	ATC error	a/c1 cleared to descend through FL330 when FL330 occupied by a/c2. ATC noticed error and gave avoiding action	Maximum deviation assumed to be 1000 ft	1000ft deviation then continuing on new clearance	1000ft deviation then continuing on new clearance

Ref#	Date of Event	Type of Error	Description	Remarks	Assumed effect in 2000ft environment	Assumed effect in 1000ft environment
SG/242/2000	27-Oct-00	Pilot error	Military a/c performed height bust of 1500ft	Maximum deviation assumed to be 1500ft for 4 seconds	1500ft deviation then return to cleared level	1500ft deviation 500ft deviation then return to cleared level
SG/243/2000	31-Oct-00	ATC loop error	a/c performed height bust of 800ft		800ft deviation then continuing on new clearance	800ft deviation then continuing on new clearance

Table F9

Proportions of A-Typical AAD of given magnitude

	Climbing/Descending Traffic		Level Traffic	
Deviation	1000ft separation	2000ft separation	1000ft separation	2000ft separation
100	9.19E-08	7.52E-08		
200	9.19E-08	7.52E-08		
300	8.98E-08	7.52E-08		
400	8.57E-08	7.10E-08	4.70E-08	4.70E-08
500	7.10E-08	5.64E-08		
600	6.06E-08	5.01E-08		
700	5.59E-08	4.54E-08		
800	4.81E-08	4.18E-08		
900	3.76E-08	3.34E-08		
1000	3.13E-08	2.93E-08	1.04E-07	
1100	2.30E-08	2.72E-08		
1200	2.30E-08	2.72E-08		
1300	2.09E-08	2.51E-08		
1400	1.88E-08	2.30E-08		
1500	1.25E-08	2.14E-08		
1600		1.88E-08		
1700		1.88E-08		
1800		1.46E-08		
1900		1.46E-08		
2000		1.25E-08		1.04E-07
2100		8.36E-09		
2200		8.36E-09		
2300		8.36E-09		
2400		6.27E-09		
2500				
2600				
2700				
2800				
2900				
3000				

Table of Bookmarks

Numberbodiesabletoreport	35
Numberbodiesnotresponding	4
Numberbodiesresponding	29
Numberbodiesunabletoreport	2
Numbercorebodies	23
Numbercorebodiesgoodrate	5
Numberparticipatingbodies	37
Numberparticipatingstates	40
Numberrelevantreports	94
NumberRiskReports	22
Numberreportscorebodies	197
Numberreportsgoodcorebodies	158
NumberTotalReports	230
Numbertransitionbodies	12
PeriodEMAdata	April 2000 to October 2000
periodusedforN(R)K(R)	13th April 2001 to 18th July 2001
periodusedforPz(1000)	as detailed in Appendix E
setHMUsusedforN(R)K(R)	the HMUs situated at Geneva, Linz and Nattenheim
setHMUsusedPz(1000)	all available HMU sites and GMUs
ValueChangeInRisk	87%
ValueeffectofRVSM	increase
ValueLevelRisk	$3.72x10^{-10}$
valueN(R)K(R)climbdescent	$1.14x10^{-2}$
valueN(R)K(R)levelflight	$9.01x10^{-3}$
ValueNonLevelRisk	$4.47x10^{-10}$
valuePz(1000)technical	$2.22x10^{-8}$
ValuePz(1000)OperationalLevel	$4.13x10^{-8}$
ValuePz(1000)OperationalClimb	$3.92x10^{-8}$
ValueRiskAfterRVSM	$1.02x10^{-9}$
ValueRiskBeforeRVSM	$5.45x10^{-10}$
valuetechnicalrisk	$2.00x10^{-10}$
ValueTotalRisk	$1.02x10^{-9}$

APPENDIX G – NATIONAL SAFETY PLANS AND STATES SAFETY AWARENESS

G.1 Introduction

The general approach that has been used in this review of States' safety preparedness is as follows:

a) The aspects, on which the review is based, derive from established ICAO documents.

b) That review and approval of national safety documentation is a State activity. The role of the RVSM programme is therefore:

- to provide guidance on the structure and content of this national documentation, and

- to report in the PISC the necessary evidence to show that individual States are identifying and meeting minimum safety standards.

c) The purpose of the RVSM Programme's review of the National Safety Plans is to establish compliance with the guidelines on safety documentation that has been provided to the States. It is not intended to form an approval of the received safety documentation

d) In a few States there are existing Safety Management Systems that may require a different form of safety documentation. In such circumstances the review will recognise that compliance with the guidelines is not practical and will, on a case-by-case basis establish other means of reviewing that State's safety preparedness.

e) The National Programme Mangers have agreed to provide National Safety Plans. Every effort will be made by the National Programme Managers and EUROCONTROL RVSM Programme to ensure that National Safety Plans are developed and approved by State authorities and that these plans are fully compatible with the guidance provided by the EUROCONTROL RVSM Programme. However if, despite best efforts, it is not possible to achieve this, then the review will examine other sources for evidence of State safety preparedness. In particular an essential item in the Go/Delay decision process is the requirement that all Director Generals of the National CAAs will be asked to confirm the readiness of the State to safely implement RVSM on 24 Jan 2002.

G.2 Guidance Provided on National Safety Planning

Principles

The guidance provided focuses on documenting the State compliance with existing obligations within ICAO Annexes. In particular Annex 11 requires that "the State is responsible for the provision of an appropriate ATS". The review will focus on five important activities associated with ATS that are required for the implementation of RVSM in a State:

a) Changes to ATS Equipment;

b) Changes to Procedures;

c) Additional Controller training;

d) Switch-Over to RVSM;

e) Monitoring of safety performance after implementation of RVSM.

Review Criteria

For each of these important activities, the review will seek to establish that:

1. **An appropriate ATS is provided for RVSM.** A description of the activities to be undertaken by the State to ensure that an appropriate ATS is provided for the Implementation of RVSM. This is a summary of the activities shown in the National RVSM Master Plans.

2. **There are approval or regulatory processes that show that the State accepts responsibility for the provided ATS**. In practical terms, the information required is the staff position and name of Organisation of the person with the responsibility for approval.

3. **There are activities to provide assurance that each of the above five important activities will meet the requirements of the relevant ICAO documents**. This was termed quality achievement in the guideline material provided to the States. States have been asked to provide those activities that they have undertaken or are prepared to make a commitment to undertake. The review covered here will not comment on the appropriateness, or completeness of these quality achievement activities.

4. **There are activities to manage identified risks to safety of aircraft that arise out of the Implementation of RVSM.** That hazards have been identified, associated risk assessed and that any additional activities to develop additional mitigation, required to ensure the risks are tolerably low, are planned and monitored through to successful completion. The Programme has supplied each State's RVSM Programme Manager with the reports and results of the EUROCONTROL FHA for RVSM, so that States can adapt it for their own safety plan.

In addition, the review will seek to establish that each State has;

a) an overall approval/ regulatory process for the Implementation of RVSM and the State acceptance of the National Safety Plan, and

b) an effective regulatory process for approval of Operators and aircraft for RVSM operations.

G.3 Review of States Safety Preparedness

Preamble

The development and national approval of State safety plans is ongoing and final information is not available for this edition of the PISC. The current status (10 August 2001) of both the

States in their development of National Safety Plans and the RVSM Programme's review of their preparedness is provided below.

Status of National Safety Plans

The status of the National Safety Plans is shown in **Table G-1** and is summarised below.

Four States have been exempted from the production of National Safety Plans. Luxembourg, Monaco, and Bosnia & Herzegovina are exempted because the responsibility for the upper airspace has been delegated to other Authorities. Ireland is also exempted as it is currently a NAT RVSM transition region and has little additional changes to make for the EUR implementation of RVSM.

All States have provided second editions (June updates) of their Safety Plans, except five States – Estonia, FYROM, Greece, Moldova and Morocco – who have not yet provided updated and approved second editions of their Safety Plans. However, these States are in the process of approving their Safety Plans and copies of these approved plans will be sent to the RVSM Programme Office as soon as they are available.

The remaining States (and Maastricht UAC) have supplied updated National Safety Plans that have been approved. Approval has been taken as:

- either a dated signature by all the identified signatories to the Safety Plan;
- or, for those plans where only an electronic version has been sent, approval signatures have been assumed provided dates have been typed against all the identified signatories.

RVSM Programme Review of the Received Safety Plans

With the exception of Morocco all the safety plans received show a high degree of conformance with the guidance material provided by EUROCONTROL. Morocco has produced a high level plan and have been asked to provide more detail to show conformance with the guidance material.

Details of the review are as follows:

- All National safety plans received have provided a summary of the activities that are required to implement RVSM (changes to equipment, procedures etc as indicated in the guidance material). In some instances further clarification has been sought from the States. This clarification would enhance the information in the safety plan on specific national issues (e.g. some states have indicated that the required changes to the ATS equipment will either not be ready in time or will only just be ready in time. For many of these States further clarification has been sought concerning the interim arrangements or contingency arrangements.). Clarification was sought from Estonia, Moldova, Greece, Latvia, Lithuania, Morocco and Poland, as indicated in RVSM Go Decision Recommendation Paper. All these States have provided appropriate clarification and have either updated their National safety plans or have committed to include this clarification in the next update to their safety plans.

- All the States that have submitted a safety plan have documented their approval processes, as recommended in the guidance material. The following exceptions were noted:

  - A few States were only able to provide the name of the Organisation (Dept) that is responsible for the approval in question. The guidance material asked for staff position in addition. The RVSM Programme accepts that some States have a pool of competent approval staff and do not normally allocate named staff this early in the process.

  - Many States were not able to provide documented criteria used to grant approval. The guidance material asked for this information if it were readily available. The RVSM Programme accepts that where States have not provided this information the only inference that can be drawn is that it would take additional national effort to officially document these criteria. In such circumstances the RVSM Programme asked States to prepare and submit Safety Plans without these criteria. Approval criteria would supply additional assurance that there is a clear objective basis for approval. However such States must be assumed to be properly discharging their ICAO obligations (which for example require that the State is responsible for the provision of an appropriate ATS) and so information on criteria for approval, whilst it would be desirable, is not essential.

- Many States have documented quality achievement activities. There was considerable and intelligent use of the supplied example text in the guidance material. States tailored this text as appropriate to their circumstances. The RVSM Programme considered that the States conformed in these aspects provided for each of the main RVSM activities (equipment changes, airspace structure changes, ATS procedure changes, ATS training) there were one or more quality achievement activities committed to in the National Safety Plan.

  - States have adapted the Eurocontrol FHA and documented this adaptation in their June-update safety plans. However this adaptation is being reported in the June update to the safety plans. There are however eight States (Bulgaria, Estonia, France, Greece, Moldova, Morocco, Slovenia and The FYROM) that have not yet provided this update. It is anticipated that these States will provide this information in their updated safety plans. It is anticipated that these States will provide this information in their updated safety plans. National Programme Managers have been asked to provide information on the status of their hazard and risk analysis.

- In conclusion all States have prepared Safety Plans that broadly conform to the guidance that was provided by the RVSM Programme.

Overall Assessment of States' Safety Preparedness

In addition to the above review of the submitted safety plans there are two additional factors that need to be considered:

- The first is that, through the national master programme plans and the ongoing dialogue with States, there were several States additional issues that needed to be addressed. These issues have either been resolved or an activity has been identified with their national safety plan to achieve resolution of the issue. Some of these updated safety plans have not yet been received by RVSM Programme Manager. He will continue to press these States for the updated safety plan. Thus at present these issues have not proved to be a significant factor in this review of States safety preparedness.

- The second factor concerns the general arrangements within a State for the safety regulation and safety management of the ATS. If the Safety Plan provided sufficient information concerning the regulation and safety management of the RVSM implementation then this is taken as sufficient safety preparedness. However, if the submitted Safety Plan does not provide sufficient information then the assessment of States safety preparedness will take into account the information available on the general arrangements. However as there has been an excellent response from Sates on their National Safety Plans, this second factor has not been required for use.

G.4 Conclusions

The RVSM Programme has received the required National safety plans and considers that they provide good evidence of the safety preparedness for RVSM from all States.

State	Safety Plan developed for PISC 1.0	Safety Plan updated for PISC 2.0[10]	State Hazard Log included in safety plan[11]	Safety Plan Approved[12]	Good conformance with guidance material	DG CA Confirmation letter received	Comments
Albania	x	✓	✓		✓	✓	Safety Plan should be available by end-August 2001
Austria	✓	✓	✓	✓	✓		
Belgium	✓	✓	See Maastricht Safety Plan	×	✓	✓	Approval of plan in progress
Bosnia & Herz	See Croatian plan						
Bulgaria	✓	✓	×	✓	✓	✓	
Croatia	✓	✓	✓	✓	✓	✓	
Cyprus	✓	✓	✓	✓	✓	✓	
Czech Rep	✓	✓	✓	✓	✓	✓	
Denmark	✓	✓	✓	✓	✓	✓	
Estonia	✓	x	×	×	✓	✓	

[10] This is either an updated plan if a version had previously been sent and reviewed in PISC 1.0 or a plan provided in time for review in PISC 2.0
[11] Either included in the text or as an annex to the safety plan or as a referenced document in the safety plan
[12] Approval of at least one edition – not necessarily the latest

State	Safety Plan developed for PISC 1.0	Safety Plan updated for PISC 2.0[10]	State Hazard Log included in safety plan[11]	Safety Plan Approved[12]	Good conformance with guidance material	DG CA Confirmation letter received	Comments
Fed Rep Yugo	✓	✓	✓	✓	✓	✓	
Finland	✓	✓	✓	✓	✓	✓	
France	✓	✓	×	✓	✓	✓	
Germany	✓	✓	✓	✓	✓	x	
Greece	✓	x	×	✓	✓	✓	
Hungary	✓	✓	✓	✓	✓	✓	
Ireland	No plan required					✓	
Italy	✓	✓	✓	✓	✓	✓	
Latvia	✓	✓	✓	✓	✓	✓	
Lithuania	✓	✓	✓	✓	✓	✓	
Luxembourg	No plan required					✓	
Malta	✓	✓	✓	✓	✓	✓	
Moldova	✓	✓	×	×	✓	x	
Monaco	No plan required					Not Applicable	

State	Safety Plan developed for PISC 1.0	Safety Plan updated for PISC 2.0[10]	State Hazard Log included in safety plan[11]	Safety Plan Approved[12]	Good conformance with guidance material	DG CA Confirmation letter received	Comments
Morocco	×	✓	×	×	×	x	Plan is at a high level and gives a description of the activities necessary to implement RVSM.
Netherlands	✓	✓	See Maastricht Safety Plan	✓	✓	✓	
Norway	✓	✓	✓	✓	✓	✓	
Poland	✓	✓	✓	✓	✓	✓	
Portugal	✓	✓	✓	✓	✓	✓	
Romania	✓	✓	✓	✓	✓	✓	
Slov Rep	✓	✓	✓	✓	✓	✓	
Slovenia	✓	x	×	✓	✓	✓	
Spain	✓	✓	✓	✓	✓	x	
Sweden	✓	✓	✓	✓	✓	✓	
Switzerland	✓	✓	✓	✓	✓	✓	
The FYROM	✓	x	×	✓	✓	✓	
Turkey	✓	✓	✓	✓	✓	✓	

State	Safety Plan developed for PISC 1.0	Safety Plan updated for PISC 2.0[10]	State Hazard Log included in safety plan[11]	Safety Plan Approved[12]	Good conformance with guidance material	DG CA Confirmation letter received	Comments
Tunisia	✓	✓	✓	✓	✓	✓	
Ukraine	✓	✓	✓	✓	✓	✓	
UK	✓	x	✓	✓	✓	✓	Verbal assurance has been provided that plan has been approved
Maastricht	✓	✓	✓	✓	✓	Not Applicable	

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APPENDIX H - RVSM SAFETY REQUIREMENTS

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Table H-1 – Overall RVSM Safety Requirements

Attribute	Safety Requirement	Source
Function	RVSM1 Provide safe vertical separation of aircraft by assigning aircraft to different flight levels (as in RVSM4 below) RVSM2 Provide safe transition to and from CVSM (feet and metric systems)/RVSM flight levels within the defined transition airspace. RVSM3 Prevent non-approved aircraft from entering RVSM airspace.	Changes to existing separation minimum Need to interface with non-RVSM airspace Fundamental requirement of RVSM
Accuracy	RVSM4 Nominal separation of flight levels to be : (i) 300m (1000 ft) between RVSM approved aircraft. (ii) 600m (2000 ft) between: • non RVSM approved State aircraft and any other aircraft operating within the EUR RVSM airspace. • all formation flights of State aircraft and any other aircraft operating within the EUR RVSM airspace. • non RVSM approved aircraft and any other aircraft operating within the defined RVSM transition airspace RVSM5 The accuracy of the Aircraft (technical) height keeping performance (i.e. the performance bounded by the requirements of the MASPS) shall be sufficient to ensure that the risk of mid-air collision in the vertical dimension, in RVSM airspace, shall meet a Target Level of Safety of 2.5×10^{-9} fatal accidents per flight hour	Fundamental requirement of RVSM Safety Objective for RVSM – see PISC section 2, sub-paragraph 2.4v
Capacity	No specific safety requirements but see note 1	N/a
Overload tolerance	No specific safety requirements but see note 1	N/a
Robustness	RVSM6 Provide facilities for safe operation under abnormal conditions – eg aircraft on-board emergencies and loss of R/T.	Aircraft emergency and contingency procedures required for all existing operations
Reliability	RVSM7 Probability of any system failure leading to a mid-air collision shall be sufficiently low to ensure that the total vertical risk of mid-air collision due to the loss of vertical separation, from all causes, is within the TLS of 5×10^{-9} fatal accidents per flight hour.	Safety Objective for RVSM – see PISC section 2, sub-paragraph 2.4v

Attribute	**Safety Requirement**	**Source**
	RVSM8 System shall be sufficiently reliable to ensure that the number of ATM-induced accidents and serious or risk-bearing incidents, under RVSM, shall not increase from current (pre-RVSM) levels and shall, where possible, decrease.	Safety Objective for RVSM – see PISC section 2, sub-paragraph 2.4v
Maintainability	RVSM9 Prevent deterioration of system performance (parameters 1-5) and reliability in service	Implicit in above requirements

Note:
1 Safety constraints relating to traffic capacity are described in Section 4, para 4.2 of this PISC.

Table H-2 – Overall RVSM Safety Requirements Mapping

Safety Requirement	Allocated to :	Reference	Comments
RVSM1 Provide vertical separation of aircraft by assigning aircraft to different flight levels	(No new safety requirements)	N/a	As for current operations
RVSM2 Provide transition to and from RVSM Flight Levels within the designated Transition Areas.	Airspace Design Flight Crew Procedures Flight Crew Training ATC Procedures ATC Training	AD1 FC1 FC2 ATC1 ATC2	New Transition areas New Transition procedures Training in new Transition procedures New Transition procedures Training in new Transition procedures
RVSM3 Prevent non-approved aircraft from entering RVSM airspace	Flight Crew Procedures Flight Crew Training ATC Procedures ATC Training ATC Equipment System Monitoring	FC4 FC5 ATC8 ATC9 ATC10 SM4	Revised flight planning procedures Training in revised flight planning procedures New clearance procedures Training in new clearance procedures Provision for identification of RVSM-approved aircraft Support measures to exclude non-RVSM aircraft from RVSM airspace
RVSM4 Nominal Separation of Flight Levels as specified in Table H1, RVSM4 above	Airspace Design Flight Crew Procedures Flight Crew Training ATC Procedures ATC Training ATC Equipment	AD2 FC3 FC6 ATC3 ATC6 ATC4	New Flight Level Orientation Scheme Use of new levels and revised flows Training in new procedures Use of new levels and revised flows Training in new procedures 'Conflict' parameter changes
RVSM5 Aircraft (technical) height keeping accuracy to be sufficient to ensure that the risk of mid-air collision in the vertical dimension, under failure-free conditions, is not greater than 2.5E-9 fatal accidents per flight hour	Aircraft Equipment	AC1	Entire safety requirement apportioned to aircraft altimetry and autopilot systems
RVSM6 Provide facilities for safe operation under abnormal conditions – eg aircraft on-board emergencies	Airspace Design Flight Crew Procedures Flight Crew Training ATC Procedures ATC Training	AD3 FC7 FC8 ATC5 ATC7	Provision of emergency levels New contingency procedures Training in new procedures New contingency procedures Training in new contingency procedures

Safety Requirement	Allocated to :	Reference	Comments
RVSM7 Probability of any system failure leading to a mid-air collision shall be sufficiently low to ensure that the total vertical risk of mid-air collision in the vertical dimension from all causes is within the TLS of 5E-9 fatal accidents per flight hour.	(Not allocated to specific system elements)	RVSM7	This requirement covers that portion of the TLS which is not taken up by technical height-keeping error (ie RVSM5). As it relates to the aggregate risk arising from failures anywhere in the system (after mitigation is taken into account), it cannot therefore be allocated to specific system elements. Therefore, it is carried forward unchanged – ie as system-level safety requirement RVSM7.
RVSM8 System shall be sufficiently reliable to ensure that the implementation of RVSM does not increase the number of ATM-induced fatal accidents or serious risk-bearing incidents.	(Not allocated to specific system elements)	RVSM8	This requirement relates to the total risk arising from RVSM (after mitigation is taken into account). It cannot therefore be allocated to specific system elements and is carried forward unchanged – ie as system-level safety requirement RVSM8.
RVSM9 Ensure achievement and maintenance of system performance (parameters 1-5) and reliability in service	Aircraft Equipment	AC2	Provision of ongoing Maintenance Programmes for MASPS approved Aircraft
	System Monitoring	SM1	Monitor effectiveness of ongoing Maintenance Programmes in MASPS
	System Monitoring	SM2	Data collection and analysis to determine Collision Risk due to Operational Errors
	System Monitoring	SM3	Monitor Horizontal Overlap Frequency to validate CRM input values
	System Monitoring	SM5	Monitor rates of ACAS/TCAS TAs and RAs

Table H-3 – Safety Requirements for System Elements

System Element / Ref	**Source**	**Safety Requirement**	**Realised by:**	**Actions**
Overall System				
RVSM7	RVSM7	Probability of any system failure leading to a mid-air collision shall be sufficiently low to ensure that the total vertical risk of mid-air collision in the vertical dimension from all causes is within the ICAO TLS of 5E-9 fatal accidents per flight hour.	This Safety Requirement is shown to have been realised through the evidence provided in Sub –Paragraph **5.9.11,** and amplified by Appendices **E and F**, that the ICAO Overall TLS has been met.	**Note:** Except for the Hazards H_M1.3 and H_M1.4 which relate to Aircraft Equipment (System Elements AC1 and AC2) and are bounded by the Technical TLS (2.5 x 10^{-9} fatal accidents per flight hour.); the consequences of all of the hazards, identified by the FHA and included in this Table (H3), will be evidenced as Operational Errors and should be reported by States as Altitude Deviation Reports. As such they will be analysed and the quantified risk will be set against the overall TLS of 5 x 10^{-9} fatal accidents per flight hour.
RVSM8	RVSM8	System shall be sufficiently reliable to ensure that the implementation of RVSM does not increase the number of ATM-induced fatal accidents or serious risk-bearing incidents	This Safety Requirement is realised through: • The measures, described in this Table (H3), to mitigate all identified hazards and to reduce the consequent risk toa level that is as low as reasonably practical, and: • The on-going studies of Operational Errors (See **Note** at RVSM7 above) to establish the level of operational risk in the RVSM airspace both pre and post implementation. The detailed analysis of these errors will further indicate the causes of operational errors and the measures necessary to eliminate these causes.	Mitigations are summarised in Sub-Paragraph **4.8.3,** with details of the various measures shown in Table H3 and referenced to the appropriate paragraphs of Section 5. The methodology for the conduct of the studies of Operational Errors is described in Appendix M. The pre-implementation results are set out in Sub-Paragraph **5.9.11**
aAirspace Design				

System Element / Ref	Source	Safety Requirement	Realised by:	Actions
AD1	RVSM2, $H_T1.10$, $H_T1.8$, $H_T2.2$, $H_S5.1$, $H_T3.6$	**AD1.1** - Make provision in airspace design for safe transition to and from CVSM (feet and metric systems)/RVSM flight levels within the defined transition airspace. **AD1.2** - Buffer areas of length sufficient to mitigate hazard $H_T1.10$ shall be provided at the boundaries of RVSM airspace. **AD1.3** - Establish uni-directional routes in Transition areas (including at the boundaries of RVSM and CVSM metric level airspace) sufficient to partially mitigate hazards $H_T1.8$, $H_T2.2$ and $H_S5.1$, **AD1.4** - Re-sectorise as required to avoid congestion at flight levels immediately below RVSM airspace, sufficient to mitigate hazard $H_T3.6$.	The realisation of Safety Requirement AD1 is addressed: • As part of the application of the concept in Sub-Paragraph **5.2.3**. This includes the provision of Guidance Material to, and consultation with, States. • Through the Implementation of the concept by States. Commitment to this implementation is contained within the National Safety Plans. These plans are reviewed and reported in Appendix G. In particular the plans show that the safety aspects of changes to airspace design are being addressed by States. The specific mitigation of the identified hazards is provided in Sub-Paragraph **5.2.7** and may be supplemented by individual States in their National Safety Plans and hazard logs. Note that the safety requirements AD1.2 and AD1.3 may be realised in different ways as local circumstances permit. Where there are local (national) differences there will, where appropriate, be supplementary analysis by the State in question to show that the hazards has been appropriately mitigated.	**Action 1.** The RVSM Programme has provided Guidance Material (Sub-Paragraph 6.2 and Appendix M refer) to each Transition State [47] regarding possible airspace design changes to handle transition. It is the responsibility of Individual States introduce the necessary measures and to confirm their readinees for the implementation of RVSM (Sub-Paragraph 6.5.) **Action 2.** Cyprus and Greece to consider the use of unidirectional routes to mitigate the hazard. (Reference[22]). **Action 3.** RVSM Programme has completed a study [35]. on possible congestion below FL290 following the implementation of RVSM based on worst case scenarios of aircraft equipage. **Action 4.** As part of the RVSM Approval process, States will require Operators to notify ATC of changes to RVSM status via a change(CHG) message. Flight Crew Sub-Paragraph (5.3) and ATC RVSM Procedures Sub-Paragraph (5.6) refer.. This requirement is referenced in the Guidance Material provided to States by the RVSM Programme **[47]** and in the ATC RVSM Manual [25].
AD2	RVSM1, $H_M1.11$	**AD2.1** - Provide new RVSM Flight Levels and Flight-level Orientation scheme, within the designated EUR RVSM airspace. **AD2.2** - The probability of occurrence of a sudden deviation of greater than 300 ft from cleared FL and/or route caused by wake vortex shall not be greater than	The realisation of Safety Requirement AD2 is addressed: • As part of the application of the concept in Sub-Paragraph 5.2.4. This includes the agreement of the FLOS through the RNDSG of the ANT and the involvement of the National Programme Managers. • Through the implementation of this concept by States. Commitment to this implementation is contained within the	The mitigation of the hazard created by Wake Vortices is provided in the Conclusions of the study that was conducted by Woodfield Aviation Research (Sub-paragraph **5.12.3** and Appendix M) **Action 5.** The RVSM Programme is in the process of issuing Training and Awareness Material to make Pilots and Air Traffic Service Providers (Appendix J) aware of the possibility that nuisance encounters of wake vortex effects may

System Element / Ref	Source	Safety Requirement	Realised by:	Actions
		remote	national safety plans. These plans are reviewed and reported in Appendix G. In particular the plans show that the safety aspects of changes to airspace design are being addressed by States. The specific mitigation of the hazard created by Wake Vortices is provided in Sub-paragraph **5.12.3** and through adherence Flight Crew (**5.3)** and ATC RVSM Procedures **(5.6)**.	increase due to the application of RVSM
AD3	RVSM6	Make provision in airspace design for safe operation under abnormal conditions – eg aircraft on-board emergencies	The realisation of Safety Requirement AD3 is addressed as part of the application of the concept in Sub-Paragraph **5.2.5**. This shows that there are no specific changes required to handle abnormal or contingency procedures. Hence there are no implementation issues for States to consider.	No Actions required
Flight Crew Procedures & Training				
FC1	RVSM2, $H_T3.5$	**FC1.1** – Develop new Flight Crew Procedures for operating in RVSM Transition Areas FC1.2 - New Flight Crew Transition Procedures shall include measures (including compulsory reporting points) to prevent late hand-over of an aircraft from a non-RVSM airspace, sufficient to mitigate hazard $H_T3.5$	Specialised flight crew procedures for operations in EUR RVSM airspace are provided in ICAO Doc 7030/4 **[7]** (see Sub-Paragraph (**5.3.3**). ICAO Document 7030/4 also addresses the granting of Approvals to operate in RVSM airspace. This responsibility lies with the Aviation Authority of the State in which the Operator is based and is addressed in the Guidance Material provided to States (Sub-Paragraph **6.2** refers).. EUR RVSM Transition States will also publish AICs, NOTAMs etc, which give further more detailed information on operations within that State's airspace. (this will include new compulsory reporting points where appropriate).	**Action 6.** EUR RVSM Transition States will publish AICs, NOTAMs etc, which give more detailed information on operations within that State's airspace (this will include compulsory reporting points, where considered necessary).
FC2	RVSM2,	**FC2.1** – Provide training for Flight Crews for operating in RVSM	Specialised flight crew procedures for Operations in EUR RVSM airspace are provided in ICAO Doc 7030/4 [7] (see	**Action 7.** The State Authority responsible for issuing RVSM Approvals must ensure that

System Element / Ref	Source	Safety Requirement	Realised by:	Actions
	H_T1.9, H_T3.5	Transition areas **FC2.2** – Flight Crew Transition Training shall include awareness of need to prevent aircraft exiting RVSM airspace at a non-existing CVSM flight level due to pilot error, sufficient to partially mitigate hazard H_T1.9 **FC2.3** – Flight Crew Transition Training shall include measures (including use of compulsory reporting points) to prevent late hand-over of an aircraft from a non-RVSM airspace, sufficient to mitigate hazard H_T3.5	Sub-Paragraph **5.3.3**). Approval to operate in RVSM airspace is provided by Authorities of the State in which the Operator is based. Details on the implementation of this by States are found in Sub-Paragraph 6.1.2 The mitigation of the two identified hazards is set out at Sub-Paragraph **5.4.4**.	Operators have received the appropriate training in RVSM Procedures before granting such an Approval - ICAO Doc 7030/4 [7]. The procedures include those required for EUR RVSM transition airspace (including compulsory reporting points if adopted by States -. See Action 6 above) This requirement is included in the the Guidance Material provided to States by the RVSM Programme **[47]** States should be satisfied that these actions have been completed before granting an RVSM approval.
FC3	RVSM1, H_M1.8	**FC3.1** – Develop new Flight Crew Procedures for operating in RVSM airspace **FC3.2** – Flight Crew RVSM Procedures shall ensure that the probability that an intolerable situation occurs because a pilot deviates from a clearance shall not be greater than **extremely remote**	Specialised flight crew procedures for Operations in EUR RVSM airspace are provided in ICAO Doc 7030/4 (see Sub-Paragraph **5.3**). Approval to operate in RVSM airspace is provided by Authorities of the State in which the Operator is based. Details on the implementation of this by States are found in Sub-Paragraph **6.1.2.** EUR RVSM States will also publish AICs, NOTAMs etc, which give further more detailed information on operations within that State's airspace. The mitigation of the identified hazard is at Sub-Paragraph **5.3.5** Strict adherence to Flight Crew Procedures supported by the training, guidance and awareness material provided by States and by the RVSM Programme are expected to provide an overall reduction of this hazard such that the frequency of occurrence of height busts are at least as manageable as in the current 1000 ft environment below FL 290. (Sub –Paras **5.3.7** and **5.12.1 refer)**	**Action 8.** Operators must receive appropriate training in the flight crew procedures for operating in RVSM airspace **Action 9.** States are to ensure that RVSM approved operators have appropriate procedures for operating within the EUR RVSM airspace **Action 10.** RVSM Programme and National Programme Managers are to ensure that Operators are fully aware of the RVSM requirements for new procedures and flight crew training These requirements are included in the Guidance Material provided to States by the RVSM Programme **[47]** and **[50]**. States should be satisfied that these actions have been completed before granting an RVSM approval.

System Element / Ref	**Source**	**Safety Requirement**	**Realised by:**	**Actions**
FC4	RVSM3, H_M2.2	**FC4.1** – Develop new Flight Crew Procedures for flight planning **FC4.2** – Flight Crew Flight-planning Procedures shall ensure that the RVSM status of all aircraft is correctly indicated on the flight plan for that aircraft or correctly stated by the pilot if no flight plan exists, sufficient to mitigate hazard H_M2.2	Specialised flight crew procedures for Operations in EUR RVSM airspace are provided in ICAO Doc 7030/4 (see Sub-Paragraph **5.3**). Approval to operate in RVSM airspace is provided by Authorities of the State in which the Operator is based. Details on the implementation of this by States are found in Sub-Paragraph **6.1.2**. EUR RVSM States will also publish AICs, NOTAMs etc, which give further more detailed information on operations within that State's airspace. The mitigation of the identified hazard is at Sub-Paragraph **5.3.5**	**Action 11.** Operators are to develop new flight crew procedures for flight planning, which is to include detailed procedures for the correct notification of RVSM status in the submitted plans **Action 12.** Operators are to ensure that their air-crew awareness training for RVSM includes the importance of correct height keeping in a RVSM environment These requirements are included in the Guidance Material provided to States by the RVSM Programme **[47]**. States should be satisfied that these actions have been completed before granting an RVSM approval.
FC5	RVSM3, H_M2.2	**FC5.1** – Provide training for Flight Crews in new Flight-planning procedures **FC4.2** – Flight Crew Flight-planning Training shall ensure that the RVSM status of all aircraft is correctly indicated on the flight plan for that aircraft or correctly stated by the pilot if no flight plan exists, sufficient to mitigate hazard H_M2.2	Specialised flight crew procedures for Operations in EUR RVSM airspace are provided in ICAO Doc 7030/4 **[7]**. Approval to operate in RVSM airspace is provided by the Aviation Authorities of the State in which the Operator is based. Details on the implementation of this by States are found in Sub-Paragraph **6.1.2** EUR RVSM States will also publish AICs, NOTAMs etc, which give further more detailed information on operations within that State's airspace. The majority of States in the EUR region that are participants in the RVSM Programme are also part of IFPS. CFMU has issued detailed flight planning requirements for flights within the IFPS area (more details are provided in Sub-Paragraph **5.8.4**). The mitigation of the two identified hazards is set out at Sub-Paragraph **5.4.4**.	**Action 13.** Operators are to ensure that their air-crew awareness training for RVSM includes the importance of the correct notification of RVSM-approval status This requirement is included in the Guidance Material provided to States by the RVSM Programme **[47]** States should be satisfied that this action has been completed before granting an RVSM approval.
FC6	RVSM1, H_M1.6,	**FC6.1** – Provide training for Flight Crews for operating in RVSM airspace	Specialised flight crew procedures for Operations in EUR RVSM airspace are provided in ICAO Doc 7030/4 **[7]**. Approval to operate in RVSM airspace is provided by	**Action 14.** Operators are to provide flight crew training for operations in RVSM airspace, which will include awareness training in the possibility of loss

System Element / Ref	Source	Safety Requirement	Realised by:	Actions
	$H_M1.8$	**FC6.2** – Flight Crew RVSM Training shall ensure that pilots using RVSM airspace are made aware of the possibility of visual perspective loss leading to unnecessary avoiding action for oncoming aircraft 1000 feet above, sufficient to mitigate hazard $H_M1.6$ **FC6.3** – Flight Crew RVSM Training shall ensure that the probability that an intolerable situation occurs because a pilot deviates from a clearance shall not be greater than **extremely remote**	Authorities of the State in which the Operator is based. Details on the implementation of this by States are found in Sub-Paragraph **6.1.2** The mitigation of the two identified hazards is set out at Sub-Paragraph **5.4.4**.	of visual perspective This requirement is included in the Guidance Material provided to States by the RVSM Programme **[47]** States should be satisfied that this action has been completed before granting an RVSM approval.
FC7	RVSM6 $H_M1.15$	**FC7.1** - Develop new Flight Crew Procedures for handling aircraft emergencies in RVSM airspace and transition areas **FC7.2** - New Flight Crew Contingency Procedures shall include procedures for handling loss of R/T communications, sufficient to mitigate hazard $H_M1.15$	Specialised flight crew procedures for Operations in EUR RVSM airspace are provided in ICAO Doc 7030/4 **[7]**. Approval to operate in RVSM airspace is provided by Authorities of the State in which the Operator is based. Details on the implementation of this by States are found in Sub-Paragraph **6.1.2** The mitigation of the identified hazard is at Sub-Paragraph **5.3.5**	**Action 15.** Operators are to provide flight crew training for operations in RVSM airspace, which will include awareness training in the possibility of loss of visual perspective This requirement is included in the Guidance Material provided to States by the RVSM Programme **[47]** States should be satisfied that this action has been completed before granting an RVSM approval.
FC8	RVSM3 $H_M1.15$	**FC8.1** - Provide Flight Crew Contingency Training for handling aircraft emergencies in RVSM airspace and transition areas **FC8.2** - Flight Crew Contingency Training shall include use of procedures for handling loss of R/T communications, sufficient to	Specialised flight crew procedures for Operations in EUR RVSM airspace are provided in ICAO Doc 7030/4 **[7]**. Approval to operate in RVSM airspace is provided by Authorities of the State in which the Operator is based. Details on the implementation of this by States are found in Sub-Paragraph **6.1.2** The mitigation of the identified hazard is set out at Sub-	**Action 16.** Operators will provide flight crew training in handing aircraft emergencies in RVSM airspace, which will include loss of R/T communication. This requirement is included in the Guidance Material provided to States by the RVSM Programme **[47]** States should be satisfied that this

System Element / Ref	Source	Safety Requirement	Realised by:	Actions
		mitigate hazard H_M1.15	Paragraph **5.4.4**.	action has been completed before granting an RVSM approval.
Aircraft Equipment				
AC1	RVSM5, and H_M1.3, H_M1.14	**AC1.1** - Aircraft Height Keeping Performance shall be sufficient to ensure that the risk of mid-air collision in the vertical dimension, due to technical causes, is not greater than 2.5 x 10^{-9} fatal accidents per flight hour. **AC1.2** - The probability of altitude deviation of >300m due to aircraft equipment failure shall be no greater than **extremely remote**	The realisation of Safety Requirement AC1.1 and 1.2 is addressed: • As part of the application of the RVSM Concept in Sub-Paragraph **5.5.3**. This details the derivation and validation of the MASPS, which was designed to provide the required height keeping performance (AC 1.2). The evidence that the TLS has ben satisfied (AC 1.1) is provided in Sub-Paragraph **5.9.11** and in Appendices E and F. • Through the requirement placed on States to ensure that Operators/Aircraft, for whom they have responsibility, obtain RVSM Approval before operating in RVSM airspace. Details on the implementation of this by States are found in Sub-Paragraph **6.1.1** The mitigation of these hazards is at Sub-Paragraph **5.5.6**	**Action 17.** It is the responsibility of the EUROCONTROL Agency to provide and maintain such means as necessary to demonstrate that the ICAO TLS is met. Evidence that this requirement is satisfied is provided at Sub-Paragraph **5.9.11** and in Appendices E and F. **Action 18.** States must ensure that those Operators/Aircraft, for whom they have responsibility, obtain RVSM Approval before operating in RVSM airspace. This requirement is included in the Guidance Material provided to States by the RVSM Programme **[47]**
AC2	RVSM9	Maintain aircraft technical height keeping performance within specification, throughout the life of the aircraft	The provision of on-going maintenance programmes is an important aspect of the MASPS, This issue is addressed at Sub-Paragraphs **5.5.3** to **5.5.5** inclusive.	See Action 17 above.
ATC Procedures & Training				
ATC1	RVSM2,	**ATC1.1** – Develop new ATC Procedures to provide safe transition to and from CVSM (feet and metric systems) / RVSM flight	The realisation of the detailed Safety Requirements ATC 1.1 to ATC 1.9 is addressed: • As part of the application of the RVSM Concept in Sub-	**Action 19.** Transition States assess feasibility of carrying out transition tasks. **Action 20.** Transition States will develop local

System Element / Ref	Source	Safety Requirement	Realised by:	Actions
	  $H_T1.1$, $H_T1.2$, $H_T1.5$, $H_T1.9$, $H_T2.2$, $H_T3.5$,	levels within the designated Transition Areas. **ATC1.2** – New ATC Transition Procedures shall ensure that aircraft do not move to CVSM levels too early in the transition area, sufficient to mitigate hazard $H_T1.1$ **ATC1.3** – New ATC Transition Procedures shall ensure that non-RVSM approved aircraft are not given RVSM separation in transition airspace, sufficient to mitigate hazard $H_T1.2$ **ATC1.4** – New ATC Transition Procedures shall ensure that flow control is applied to avoid congestion at the transition between RVSM and CVSM airspace in RVSM airspace and below RVSM airspace, sufficient to mitigate hazard $H_T1.5$ **ATC1.5** – New ATC Transition Procedures shall ensure that aircraft do not exit RVSM airspace at a non-existing CVSM flight level, sufficient to partially mitigate hazard $H_T1.9$ **ATC1.6** – New ATC Transition Procedures shall ensure that conversion to the metric CIS system aircraft is carried out at the appropriate boundaries, sufficient to partially mitigate hazard $H_T2.2$ **ATC1.7** – New ATC Transition Procedures shall include measures (including compulsory reporting points) to prevent late hand-over of an aircraft from a	Paragraph **5.6.3** . In particular, by means of the ATC Transition Procedures detailed in the Guidance provided to States in the ATC RVSM Manual.**[25]** • Through the Implementation of the concept by States within the EUR RVSM Transition area. Commitment to this implementation is contained within the National safety plans. These plans are reviewed and reported in Appendix G. In particular the plans show that the safety aspects of changes to ATC procedures are being addressed by States. The mitigation of each of the listed Hazards that were identified by the FHA, when considering ATC Transition Procedures, is described in Sub-Paragraph **5.6.5**.	instructions for its controllers for level changes to those transition aircraft that are not RVSM approved **Action 21.** The RVSM Programme, the CFMU and those Transition States that are not part of the IFPS region develop contingency plans to be introduced should the required longitudinal separation into non-RVSM airspace not be possible to be achieved efficiently. **Action 22.** Tunisia is to develop ATC procedures and agree improved LoAs with adjoining States to reduce the possibility of aircraft exiting at a non-existing CVSM level (this is a recognised issue for Eastbound traffic in the region). **Action 23.** Transition States that are required to handover to adjoining ACCs that use the metric CIS system are to have specific detailed procedures to ensure that the controller performs the correct conversion **Action 24.** Such States (that perform CIS metric conversion) are to consider the use of uni-directional routes to mitigate the hazard of incorrect conversion Transition Procedures are detailed in the ATC RVSM Manual **[25]** and are referenced in the Guidance Material provided to States by the RVSM Programme **[47]**

System Element / Ref	Source	Safety Requirement	Realised by:	Actions
	 $H_T3.6$ $H_T1.8$	non-RVSM airspace, sufficient to mitigate hazard $H_T3.5$ **ATC1.8** - New ATC Transition Procedures shall include flow control as required to avoid congestion at flight levels immediately below RVSM airspace, sufficient to mitigate hazard $H_T3.6$ **ATC1.9** - New ATC Transition Procedures shall include use of offsets (where possible), and freezing of FLs 310, 350 and 390 for a specified distance within the Transition areas, sufficient to partially mitigate hazard $H_T1.8$		
ATC2	RVSM2, $H_T1.1$, $H_T1.2$, $H_T1.5$,	**ATC2.1** - Provide Training for ATC staff in new ATC Transition Procedures **ATC2.2** – ATC Transition Training shall include awareness of need not to move aircraft to CVSM levels too early in the transition area, sufficient to mitigate hazard $H_T1.1$. **ATC2.3** – ATC Transition Training shall ensure that non-RVSM approved aircraft are not given RVSM separation in transition airspace, sufficient to mitigate hazard $H_T1.2$ **ATC2.4** – ATC Transition Training shall include use of flow control to avoid congestion at the transition between RVSM and CVSM airspace in RVSM airspace and below RVSM airspace, sufficient	The realisation of the detailed Safety Requirements ATC 2.1 to ATC 2.9 inclusive is addressed: • As part of the application of the concept in Sub-Paragraph **5.7**. In particular this sub-paragraph provides detailed information on the Guidance and Support provided to States and describes the training package developed and the training briefings provided by the RVSM Programme. • Through the Implementation of the RVSM Concept by States within the EUR RVSM Transition area. Commitment to this implementation is contained within the National Safety Plans. These plans are reviewed and reported in Appendix G. In particular the plans show that the ATC training is being addressed by States. The mitigation of the listed Hazards that were identified by the FHA , when considering ATC Transition Training, is described in Sub-Paragraph **5.7.5**.	**Action 25.** Transition States are to ensure appropriate ATC Training to cover the relevant aspects related to transition. Transition Procedures are detailed in the ATC RVSM Manual **[25]** and are referenced in the Guidance Material provided to States by the RVSM Programme **[47]**

System Element / Ref	Source	Safety Requirement	Realised by:	Actions
	$H_T1.9$, $H_T2.2$, $H_T3.5$, $H_T3.6$ $H_T1.8$	to mitigate hazard $H_T1.5$ **ATC2.5** – ATC Transition Training shall include awareness of need to prevent aircraft exiting RVSM airspace at a non-existing CVSM flight level, sufficient to partially mitigate hazard $H_T1.9$ **ATC2.6** – ATC Transition Training shall ensure that conversion to the metric CIS system aircraft is carried out at the appropriate boundaries, sufficient to partially mitigate hazard $H_T2.2$ **ATC2.7** – ATC Transition Training shall include measures (including use of compulsory reporting points) to prevent late hand-over of an aircraft from a non-RVSM airspace, sufficient to mitigate hazard $H_T3.5$ **ATC2.8** - ATC Transition Training shall include use of flow control as required to avoid congestion at flight levels immediately below RVSM airspace, sufficient to mitigate hazard $H_T3.6$ **ATC2.9** - ATC Transition Training shall include use of offsets (where possible), and freezing of FLs 310, 350 and 390 for a specified distance within the Transition areas, sufficient to partially mitigate hazard $H_T1.8$		
ATC3	RVSM4, $H_M2.4$	**ATC3.1** – Develop ATC RVSM procedures for providing vertical separation of aircraft by assignment of aircraft to different RVSM flight levels.	This is a specific aspect of the development of the ATC procedures and is covered by ATC1 and ATC2. The provision of ATC Procedures is detailed at Sub-Paragraph **5.6.3** and the validation of those procedures is at **5.6.4**.	RVSM States are to make provision for the following actions to be implemented: **Action 26.** In the event of air RX/TX unavailability Air Traffic Service Providers are to

System Element / Ref	Source	Safety Requirement	Realised by:	Actions
	$H_M2.5$ $H_M2.13$,	**ATC3.2** – Modify existing ATC Procedures for handling situations in which a flight plan is missing to cater for the absence of essential RVSM information, sufficient to mitigate hazard $H_M2.4$. **ATC3.3** – ATC RVSM procedures shall ensure the correct application of two different separation standards (for RVSM approved/non-RVSM approved state a/c) within the EUR RVSM airspace, sufficient to mitigate hazard $H_M2.5$ **ATC3.4** ATC RVSM procedures shall include manual co-ordination of State aircraft and those RVSM-approved aircraft with approval status missing from the FPL, sufficient to mitigate hazard $H_M2.13$.	The mitigation of the Hazards identified by the FHA, when considering the ATC RVSM Procedures, is described in Sub-Paragraph **5.6.5**	apply 2000 ft vertical separation with other aircraft **Action 27.** Air Traffic Service Providers in regions where a DFL of 295 is to be applied are to provide special co-ordination procedures to ensure that the RVSM Status of aircraft at FL280 is known to both ATC centres **Action 28.** ATC instructions are to include procedures for obtaining current flight plan information from Aircraft/Operators regarding RVSM status. **Action 29.** Air Traffic Service Providers are to apply the RVSM Procedures detailed in the ATC RVSMManual.**[25]** These requirements are included in the Guidance Material provided to States by the RVSM Programme **[47]**
ATC5	RVSM6 $H_M1.9$ $H_M1.15$	**ATC5.1** – Develop ATC Contingency procedures for safe operations under abnormal conditions (including aircraft emergencies) **ATC5.2** – New ATC Contingency Procedures shall include procedures for handling an aircraft that have unexpectedly encountered turbulence in Transition or RVSM airspace, sufficient to mitigate hazard $H_M1.9$ **ATC5.3** – New ATC Contingency Procedures shall include procedures for handling loss of R/T communications, sufficient to mitigate hazard $H_M1.15$. See also	The realisation of the detailed Safety Requirements ATC 5.1 to ATC 5.6 inclusive is a specific aspect of the development of the ATC procedures and is covered by ATC1 and ATC2. The provision of ATC Contingency Procedures is detailed at Sub-Paragraph **5.6.3** and the validation of those procedures is at **5.6.4** The mitigation of these Hazards identified by the FHA is described in Sub-Paragraph **5.6.5**	RVSM States are required to make provision for the following action to be implemented: **Action 30.** Air Traffic Service Providers are to apply the RVSM Contingency Procedures set out in the ATC RVSM Manual.**[25]** This requirement is included in the Guidance Material provided to States by the RVSM Programme **[47]**

System Element / Ref	Source	Safety Requirement	Realised by:	Actions
	H_M1.13 H_M2.1 H_M1.10	FC 8.2 above. **ATC5.4** – New ATC Contingency Procedures shall include procedures for handling downgrading of aircraft RVSM status , sufficient to mitigate hazard H_M1.13 **ATC5.5 –** New ATC Contingency Procedures shall include special co-ordination procedures for accepting aircraft with degraded RVSM status into RVSM airspace, sufficient to mitigate hazard H_M2.1 **ATC5.6** – New ATC Contingency Procedures shall include procedures for suspending RVSM operations in the event of severe turbulence, sufficient to mitigate hazard H_M1.10		
ATC6	RVSM4, H_M2.4 H_M2.5 H_M2.13	**ATC6.1** - Provide Training for ATC staff in new ATC RVSM Procedures **ATC6.2** – ATC RVSM Training shall include use of procedures for handling situations in which a flight plan is missing, sufficient to mitigate hazard H_M2.4. **ATC6.3** – ATC RVSM Training shall include use of procedures for ensuring the correct application of two different separation standards (for RVSM approved/non-RVSM approved state a/c) within the EUR RVSM airspace, sufficient to mitigate hazard H_M2.5 **ATC6.4** – ATC RVSM Training shall include use of procedures for manual co-ordination of State	The realisation of the specific Safety Requirements ATC 6.1 to ATC 6.4 inclusive, which together comprise the requirement for the Training of ATC Staff in RVSM Procedures is addressed: • As part of the application of the RVSM Concept as detailed in Sub-Paragraph **5.7.2** In particular this Sub-Paragraph provides detailed information on the Guidance and Support provided to States and describes the ATC Ttraining package developed and the training briefings provided. • Through the Implementation of the RVSM Concept by States within the EUR RVSM area. Commitment to this implementation is contained within the National Safety Plans. These plans are reviewed and reported in Appendix G. The plans show that the requirement for ATC Training is being addressed by States.	RVSM States are required to make provision for the following action to be implemented: **Action 31.** Air Traffic Service providers to provide training to ATC staff based on the ATC Manual. .**[25]** This requirement is included in the Guidance Material provided to States by the RVSM Programme **[47]**

System Element / Ref	Source	Safety Requirement	Realised by:	Actions
		aircraft and those RVSM-approved aircraft with approval status missing from the FPL, sufficient to mitigate hazard H_M2.	The mitigation of the listed Hazards that were identified by the FHA, when considering Training of ATC Staff in RVSM Procedures, is described in Sub-Paragraph 5.7.5.	
ATC7	RVSM6 $H_M1.9$ $H_M1.15$ $H_M1.13$ $H_M2.1$ $H_M1.10$	**ATC7.1** - Provide Training for ATC staff in new ATC Contingency Procedures **ATC7.2** – ATC Contingency Training shall include use of procedures for handling aircraft that have unexpectedly encountered turbulence in Transition or RVSM airspace, sufficient to mitigate hazard $H_M1.9$ **ATC7.3** – ATC Contingency Training shall include use of procedures for handling loss of R/T communications, sufficient to mitigate hazard $H_M1.15$ **ATC7.4** – ATC Contingency Training shall include use of procedures for handling downgrading of aircraft RVSM status , sufficient to mitigate hazard $H_M1.13$ **ATC7.5** - ATC Contingency Training shall include use of special co-ordination procedures for accepting aircraft with degraded RVSM status into RVSM airspace, sufficient to mitigate hazard $H_M2.1$ **ATC7.6** – ATC Contingency Training shall include use of procedures for suspending RVSM operations in the event of severe	The realisation of the specific Safety Requirements ATC 7.1 to 7.6 (inclusive), which relate to Training in ATC Contingency Procedures, addresses a specific aspect of the ATC Training covered by ATC6 above. The provision of a Training Package to support National ATC Trainers is described at Sub-Paragraph **5.7.2**. The content of the package and of training briefings is at Sub-Paragraph **5.7.3** The mitigation of the listed Hazards that were identified by the FHA, when considering Training of ATC Staff in RVSM Contingency Procedures, is described in Sub-Paragraph **5.7.5.**	RVSM States are required to make provision for the following action to be implemented: **Action 32.** Air Traffic Service providers are to provide training of Air Traffic Controllers in the new RVSM Contingency Procedures, which will include the handing of aircraft with missing flight plans, and loss of R/T This requirement is included in the Guidance Material provided to States by the RVSM Programme **[47] and is referenced to the ATC RVSM Manual** .**[25]**

System Element / Ref	Source	Safety Requirement	Realised by:	Actions
		turbulence, sufficient to mitigate hazard H_M1.10		
ATC8	RVSM3 & H_M2.17 H_M2.7, H_M2.9,	**ATC8.1** – Develop new ATC procedures for clearing aircraft into RVSM airspace **ATC8.2** – ATC Clearance procedures shall include the use of radar labels for ascertaining the RVSM status of aircraft operating immediately above and below RVSM airspace, sufficient to mitigate hazard H_M2.7 **ATC8.3** – ATC Clearance procedures shall include the manual insertion of changes or missing RVSM approval status into the system, sufficient to mitigate hazard H_M2.9	The realisation of the specific Safety Requirements ATC 8.1 to ATC 8.3 inclusive, which together comprise the requirement for new ATC Clearance Procedures for RVSM Airspace, is one aspect of the development of ATC RVSM Procedures and is covered by ATC1 and ATC2. The provision of ATC Clearance Procedures is detailed at Sub-Paragraph **5.6.3** and the validation of those procedures is at **5.6.4** The mitigation of the listed Hazards that were identified by the FHA, when considering ATC RVSM Clearance Procedures, is described in Sub-Paragraph **5.6.5**	RVSM States are required to make provision for the following action to be implemented: **Action 33.** Air Traffic Service Providers are to provide Clearance Procedures for RVSM Airspace, based on the ATC RVSM Manual.**[25]** This requirement is included in the Guidance Material provided to States by the RVSM Programme **[47] and is referenced to the ATC RVSM Manual .[25]**
ATC9	RVSM3 & H_M2.17 H_M2.7, H_M2.9,	**ATC9.1** - Provide Training for ATC staff in new ATC Clearance Procedures **ATC9.2** - ATC Clearance Training shall include the use of radar labels for ascertaining the RVSM status of aircraft operating immediately above and below RVSM airspace, sufficient to mitigate hazard H_M2.7 **ATC9.3** – ATC Clearance Training shall include the manual insertion of changes or missing RVSM approval status into the system, sufficient to mitigate hazard H_M2.9	The specific Safety Requirements ATC 9.1 to ATC 9.3 inclusive, which address the requirement for Training of ATC Staff in the new RVSM Clearance Procedures, are a specific aspect the ATC Training covered by ATC6. The provision of a Training Package to support National ATC Trainers is described at Sub-Paragraph **5.7.2** The content of the package and of training briefings is at Sub-Paragraph **5.7.3** The mitigation of these Hazards identified by the FHA is described in Sub-Paragraph **5.7.5**	RVSM States are required to make provision for the following action to be implemented: **Action 34.** Air Traffic Service providers will provide training of ATC Staff in the new ATC Clearance Procedures which will include co-ordination between controllers and the manual changes to the displayed RVSM status of aircraft This requirement is included in the Guidance Material provided to States by the RVSM Programme [47] **and is referenced to the ATC RVSM Manual .[25]**

System Element / Ref	Source	Safety Requirement	Realised by:	Actions
ATC Equipment				
ATC4	RVSM4, H_M2.6 & H_M 2.27	**ATC4.1** - Modify all ATC equipment (including back-up equipment and, where provided, STCA, and MTCD) to change vertical-separation parameters to 300m (1000ft) for RVSM airspace	The specific Safety Requirement ATC 4.1, which establishes the need to modify the vertical separation parameters of ATC Equipment for RVSM Operations, is addressed: • As part of the application of the RVSM Concept in Sub-Paragraph **5.8.3**. This sub-paragraph provides detailed information on the requirements for the changes to the ATC equipment that are necessary and desirable for the implementation of RVSM Additionally Sub-Paragraph 5.8.8 addresses the need to modify any back-up equipment, • Through the Implementation of the RVSM Concept by States within the EUR RVSM area. State commitment to this implementation is contained within the National Safety Plans. These plans are reviewed and reported in Appendix G. The plans show that the safety aspects of changes to equipment are being addressed by States. The mitigation of the hazard identified by the FHA, relating to ATC Equipment, is at Sub-Paragraph **5.8.10**	RVSM States are required to make provision for the following action to be implemented: **Action 35.** Air Traffic Service Providers are to modify ATC Equipment , as appropriate, to change vertical separation parameters, between FL 290 and FL 410 inclusive, to 1000 ft in the designated RVSM airspace This requirement is included in the Guidance Material provided to States by the RVSM Programme [47] **and is referenced to the ATC RVSM Manual .[25]**
ATC 10	RVSM3, H_M2.5, H_M2.17 & H_T1.2 H_M2.7, H_M2.8 & H_M2.13 H_M2.10,	**ATC10.1** - Modify all ATC equipment (including, but not limited to, radar displays, flight progress strips and OLDI –based systems) and back-up equipment, to enable RVSM and non-RVSM approved aircraft to be identified separately **ATC10.2** - RVSM status of aircraft operating immediately above and below RVSM airspace shall be correctly shown on radar situation displays, sufficient to mitigate	The realisation of the specific Safety Requirements ATC 10.1 to 10.4 inclusive, relating to the measures necessary for the identification of RVSM/non RVSM aircraft, is addressed: • As part of the application of the RVSM Concept in Sub-Paragraph **5.8.5** This sub-paragraph provides detailed information on the requirements for the changes to the ATC equipment that are necessary and desirable for the implementation of RVSM • Through the Implementation of the RVSM Concept by States within the EUR RVSM area. Commitment to this implementation is contained within the National Safety	RVSM States are required to make provision for the following actions to be implemented: **Action 36.** Air Traffic Service providers are to modify ATC Equipment, as appropriate, to enable RVSM approved and non-RVSM approved aircraft to be identified separately **Action 37.** Air Traffic Service providers are to modify ATC Equipment to allow the RVSM status of aircraft above and below RVSM airspace to be displayed

System Element / Ref	Source	Safety Requirement	Realised by:	Actions
	H_M2.11, H_M 2.27	hazard H_M2.7 **ATC10.3** - IFPS shall correctly check the RVSM status on flight plans which propose to use RVSM airspace and shall reject all incorrect plans, sufficient to mitigate hazards H_M2.8 and H_M2.13 **ATC10.4** - OLDI/SYSCO – based systems shall support the external exchange of RVSM related flight data and co-ordination data , sufficient to mitigate hazard H_M2.10. **ATC10.5** - ATC equipment shall support to the internal exchange of RVSM related flight data and co-ordination data (posting, printing of flight strips, etc.), sufficient to mitigate hazard H_M2.11.	Plans. These plans are reviewed and reported in Appendix G. The plans show that the safety aspects of changes to equipment are being addressed by States. • Additionally Sub-Paragraph 5.8.8 addresses the need to modify any back-up equipment, The mitigation of the nine hazards identified by the FHA, when considering the changes to ATC Equipment necessitated by the need to clearly indicate the RVSM Status of Aircraft, is at Sub-Paragraph **5.8.9.** The integrity of the display of the RVSM status is reinforced by the fact that if, for any reason, the RVSM status of an aircraft (excluding State Aircraft) cannot be confirmed then that aircraft will not be accepted for flight in the RVSM airspace .	**Action 38.** CFMU (IFPS) and States external to the IFPS zone shall check all flight plans to ensure compatibility between the RVSM status and requested flight level and reject incorrect flight plans. **Action 39.** Air Traffic Service providers are to modify OLDI/SYSCO based systems to allow the exchange of RVSM related data These requirements are detailed in the ATC RVSM Manual **[25]** and are referenced in the Guidance Material provided to States by the RVSM Programme **[47]**
ATC 11	H_T1.9	Modify ATC equipment, including back-up equipment, so that Flight progress strips and OLDI messages display RFL, sufficient to mitigate hazard H_T1.9	The realisation of this Safety Requirement ATC 11, relating to the ability to display RFL, is included in Sub-Paragraphs 5.8.6 and 5.8.7. Additionally Sub-Paragraph 5.8.8 addresses the need to modify any back-up equipment, The mitigation of the hazard, identified by the FHA, is at Sub-Paragraph **5.8.9**	RVSM States are required to make provision for the following action to be implemented: **Action 40.** Air Traffic Service providers are to modify ATC equipment so that OLDI messages and flight progress strips display the RFL This requirement is detailed in the ATC RVSM Manual **[25]** and is referenced in the Guidance Material provided to States by the RVSM Programme **[47]**
In-service Monitoring				

System Element / Ref	Source	Safety Requirement	Realised by:	Actions
SM1	RVSM5	Carry out measurement and analysis of aircraft technical height-keeping performance sufficient to demonstrate the effectiveness of the MASPS in meeting the portion of the TLS allowed fore technical height-keeping errors	The realisation of Safety Requirement SM2/RVSM 5, relating to the ability to measure and analyse aircraft height Keeping performance, is addressed in Sub-Paragraph **5.9.3.** This sub-paragraph describes the comprehensive Height Monitoring System iwhich is in place and is fully operational.	**Action 41.** RVSM Programme has provided a comprehensive system for the monitoring of aircraft height keeping performance. The system is capable of monitoring sufficient aircraft to show that MASPs fitted and approved aircraft meet the TLS allowed for technical height keeping errors
SM2	RVSM7	Carry out measurement and analysis of aircraft assigned-altitude-deviation (AAD) errors sufficient to demonstrate that the size and frequency of occurrence of Operational Errors is sufficiently low to enable the non technical portion of the TLS to be met	The realisation of this Safety Requirement SM2/RVSM7 is contained in the description of the study of Altitude Deviation Reports-(ADRs) – Data Collection and Analysis, provided in Sub-Paragraph **5.9.4** and in Appendix **M.**	**Action 42.** RVSM Programme has established a system for the collection and analysis of all reports of deviations from assigned altitude (Altitude Deviation Reports (ADRs)) regardless of the cause. Such deviations occur as a consequence of Operational Errors and are assessed against that portion of the ICAO TLS which determines the tolerable level of risk allowed for such errors
SM3	RVSM5	Carry out measurement and analysis of aircraft Passing Frequency & Lateral Navigation Accuracy, sufficient to demonstrate that the values for those parameters use in the CRM are fully representative of RVSM operational conditions	The realisation of Safety Requirement SM3/RVSM5 is an integral part of the Height Monitoring System described at Sub-Paragraph **5.9.3**	**Action 43.** RVSM Programme has established the methodology and means for the measurement and analysis of aircraft passing frequency and lateral navigation accuracy in support of the collision risk modelling process.
SM4	RVSM3, & H_M2.2	Provide support measures to assist in the exclusion of non-RVSM approved aircraft from RVSM airspace.	The realisation of Safety Requirement SM4/RVSM3 is achieved through the establishment and maintainance of an RVSM Database which, amongt other capabilities, records the RVSM Status of all aircraft capable of operations in the EUR RVSM Airspace. The Database is described in Sub – Paragraph 5.9.6 The mitigation of the hazard identified by the FHA, relating to RVSM status of Aircraft, is at Sub-Paragraph **5.9.10**	**Action 44.** The RVSM Programme ihas developed, and is maintaining, a database of the RVSM approval status of all aircraft that are capable of operations in the EUR RVSM airspace

System Element / Ref	Source	Safety Requirement	Realised by:	Actions
SM5	H_M1.1	Carry out measurement and analysis of the rate of aircraft ACAS/TCAS TAs and RAs, sufficient to demonstrate that hazard H_M1.1 has been adequately mitigated	The realisation of Safety Requirement SM5, relating to ACAS/TCAS TAs and RAs generated by aircraft in the EUR RVSM airspace is outlined in Sub-Paragraph **5.12.2** and detailed in Appendix **L.** The mitigation of the hazards, identified by the FHA relating to TCAS/ACAS, is provided in Appendix **L** . The methodology for the assessment of any collision risk arising from TCAS/ACAS based ADRs is at Appendix **M**.	**Action 45.** EUROCONTROL is to ensure that the rate of ACAS TAs and RAs is monitored and assessed to show that the risk associated with such events is tolerable

System Element / Ref	Source	Safety Requirement	Realised by:	Actions
Switchover-specific Safety Requirements				
SP1	H_S1.2, H_S1.4, H_S1.13, H_S1.16, H_S2.1, H_S3.2	ATC training to be completed before Switchover	The realisation of this Safety Requirement is addressed: • As part of the application of the concept. EUROCONTROL has providing a switchover plan, which will provide detailed guidance on the planning requirements for switchover This plan provides mitigation for these switchover hazards. • Through the Implementation of the concept by States within the EUR RVSM area. Commitment to this implementation is contained within the National safety plans and will be further amplified through national switchover plans. The safety plans are reviewed and reported in Appendix G.	**Action 46.** Air Traffic Service providers are to complete their ATC training before Switchover This requirement is referenced in the Guidance Material provided to States by the RVSM Programme **[47] and in the RVSM Countdown and Switchover Plan [49]**
SP2	H_S1.2, H_S1.17, H_S1.18, H_S2.2, H_S6.1, H_S6.5, H_S6.7	Additional special procedure for ATCO to obtain verbally RVSM status of each aircraft under control, in period before Switchover	The realisation of this Safety Requirement is addressed: • As part of the application of the concept. EUROCONTROL has providing a switchover plan, which will provide detailed guidance on the planning requirements for switchover. This plan provides mitigation for these switchover hazards. • Through the Implementation of the concept by States within the EUR RVSM area. Commitment to this implementation is contained within the National safety plans and will be further amplified through national switchover plans. The safety plans are reviewed and reported in Appendix G.	**Action 47.** Air Traffic Service providers are to develop special procedures for the Switchover period to verbally obtain/confirm the RVSM status of all aircraft under control at the time of switchover This requirement is referenced in the Guidance Material provided to States by the RVSM Programme **[47] and in the RVSM Countdown and Switchover Plan [49]**

System Element / Ref	Source	Safety Requirement	Realised by:	Actions
SP3	H_S1.3	Route structure/sectorisation in the EUR RVSM airspace shall be completed by October 2001	The realisation of this Safety Requirement is addressed: • As part of the application of the concept. EUROCONTROL has providing a switchover plan, which will provide detailed guidance on the planning requirements for switchover This plan provides mitigation for these switchover hazards. • Through the Implementation of the concept by States within the EUR RVSM area. Commitment to this implementation is contained within the National safety plans and will be further amplified through national switchover plans. The safety plans are reviewed and reported in Appendix G.	**Action 48.** Air Traffic Service providers are to complete changes to EUR RVSM route structure and sectorisation and to notify ICAO by Oct 2001 This requirement is referenced in the Guidance Material provided to States by the RVSM Programme **[47] and in the RVSM Countdown and Switchover Plan [49]**
SP4	H_S1.3, H_S1.5, H_S1.17, H_S1.18, H_S2.2, H_S6.1	New/modified ATS systems shall be in place and checked by 24 January 2002, or acceptable Contingency Plan shall be available.	The realisation of this Safety Requirement is addressed: • As part of the application of the concept. EUROCONTROL has providing a switchover plan, which will provide detailed guidance on the planning requirements for switchover This plan provides mitigation for these switchover hazards. • Through the Implementation of the concept by States within the EUR RVSM area. Commitment to this implementation is contained within the National safety plans and will be further amplified through national switchover plans. The safety plans are reviewed and reported in Appendix G.	**Action 49.** Air Traffic Service providers are to complete the implementation of new/modified systems before switchover **Action 50.** Air Traffic Service providers shall develop contingency plans in case of slippage in the schedule for the equipment changes. Where the risk of slippage is judged to be low then only high level plans are required These requirements are referenced in the Guidance Material provided to States by the RVSM Programme **[47] and in the RVSM Countdown and Switchover Plan [49]**
SP5	H_S1.3 H_S5.1	CFMU shall have a capacity policy in place before Switchover	The realisation of this Safety Requirement is addressed: • As part of the application of the concept. EUROCONTROL has providing a switchover plan, which will provide detailed guidance on the planning requirements for switchover This plan provides mitigation	**Action 51.** RVSM Programme, the CFMU and the States are to develop and implement a suitable capacity planning to cover the Switchover period. EUROCONTROL has issued the RVSM Countdown and Switchover Schedule **[49]**

System Element / Ref	Source	Safety Requirement	Realised by:	Actions
			for these switchover hazards. • Through the Implementation of the concept by States within the EUR RVSM area. Commitment to this implementation is contained within the National safety plans and will be further amplified through national switchover plans. The safety plans are reviewed and reported in Appendix G.	This requirement on States is referenced in the Guidance Material provided to States by the RVSM Programme **[47] and in the RVSM countdown and Switchover Plan [49]**
SP6	$H_S1.4$	Special handover procedure to be implemented for each sector/centre to independently verify the level of inbound aircraft	The realisation of this Safety Requirement is addressed: • As part of the application of the concept. EUROCONTROL has providing a switchover plan, which will provide detailed guidance on the planning requirements for switchover This plan provides mitigation for these switchover hazards. • Through the Implementation of the concept by States within the EUR RVSM area. Commitment to this implementation is contained within the National safety plans and will be further amplified through national switchover plans. The safety plans are reviewed and reported in Appendix G.	**Action 52.** Each ACC within the EUR RVSM region will develop and implement special handover procedures for the switchover period to confirm the flight level of aircraft entering their sectors This requirement is referenced in the Guidance Material provided to States by the RVSM Programme **[47] and in the RVSM Countdown and Switchover Plan [49]**
SP7	$H_S1.9$, $H_S1.12$, $H_S5.1$, $H_S5.2$, $H_S5.10$	Additional flow restrictions to be imposed on day of Switchover	The realisation of this Safety Requirement is addressed: • As part of the application of the concept. EUROCONTROL has providing a switchover plan, which will provide detailed guidance on the planning requirements for switchover This plan provides mitigation for these switchover hazards. • Through the Implementation of the concept by States within the EUR RVSM area. Commitment to this implementation is contained within the National safety plans and will be further amplified through national switchover plans. The safety plans are reviewed and	**Action 53.** RVSM Programme, the CFMU and the States are to develop and implement a suitable capacity planning to cover the Switchover period. **Action 54.** States are to ensure that traffic levels at the point of switchover can be safely and efficiently handled These requirements are referenced in the Guidance Material provided to States by the RVSM Programme **[47] and in the RVSM Countdown and Switchover Plan [49]**

System Element / Ref	Source	Safety Requirement	Realised by:	Actions
			reported in Appendix G.	
SP8	H_S5.1	Special briefings / extended handover to be provided for on-coming ATC watches, for the period immediately before, during and following Switchover	The realisation of this Safety Requirement is addressed: • As part of the application of the concept. EUROCONTROL has providing a switchover plan, which will provide detailed guidance on the planning requirements for switchover. (ref to be provided) This plan provides mitigation for these switchover hazards. • Through the Implementation of the concept by States within the EUR RVSM area. Commitment to this implementation is contained within the National safety plans and will be further amplified through national switchover plans. The safety plans are reviewed and reported in Appendix G.	**Action 55.** All ACCs within States that are implementing RVSM are to provide special briefings and other arrangements to cover the switchover period This requirement is referenced in the Guidance Material provided to States by the RVSM Programme **[47] and in the RVSM Countdown and Switchover Plan [49]**
SP9	H_S.2.1, H_S5.10	LoAs to be in place before Switchover	The realisation of this Safety Requirement is addressed: • As part of the application of the concept. EUROCONTROL has providing a switchover plan, which will provide detailed guidance on the planning requirements for switchover. This plan provides mitigation for these switchover hazards. • Through the Implementation of the concept by States within the EUR RVSM area. Commitment to this implementation is contained within the National Safety Plans and will be further amplified through National Switchover Plans. The safety plans are reviewed and reported in Appendix G.	**Action 56.** All ACCs within the EUR RVSM airspace are to have modified and agreed LoAs with all their adjoining and sub-joining ACCs This requirement is referenced in the Guidance Material provided to States by the RVSM Programme **[47] and in the RVSM Countdown and Switchover Plan [49]**
SP10	H_S.1.1	An AIC shall be issued concerning level changes at Switchover	The realisation of this Safety Requirement is addressed: • As part of the application of the concept. EUROCONTROL has providing a switchover plan, which will provide detailed guidance on the planning	**Action 57.** The RVSM Programme will issue a draft AIC/4 confirming RVSM Implementation and flight planning arrangements. This requirement is referenced activities detailed in

System Element / Ref	Source	Safety Requirement	Realised by:	Actions
			requirements for switchover. This plan provides mitigation for these switchover hazards. • Through the Implementation of the concept by States within the EUR RVSM area. Commitment to this implementation is contained within the National Safety Plans and will be further amplified through National Switchover Plans. The safety plans are reviewed and reported in Appendix G.	**the RVSM Countdown and Switchover Plan [49]**
SP11	H_S.1.5	Contingency Plans shall be in place to cover the eventuality that ATC Equipment fails at Switchover	The realisation of this Safety Requirement is addressed: • As part of the application of the concept. EUROCONTROL has providing a switchover plan, which will provide detailed guidance on the planning requirements for switchover. This plan provides mitigation for these switchover hazards. • Through the Implementation of the concept by States within the EUR RVSM area. Commitment to this implementation is contained within the National Safety Plans and will be further amplified through National Switchover Plans. The safety plans are reviewed and reported in Appendix G.	**Action 58.** States are to ensure that Contingency plans are in place to cover the failure of ATC Equipment during the Switchover period. This requirement is referenced in the Guidance Material provided to States by the RVSM Programme **[47] and in Sub – Paragraph 4 of the RVSM Countdown and Switchover Plan [49]**
SP12	H_S.1.13, H_S.1.16, H_S.3.2	All Flight Crew training for RVSM shall be completed before Switchover	The realisation of this Safety Requirement is addressed: • As part of the application of the concept. EUROCONTROL has providing a switchover plan, which will provide detailed guidance on the planning requirements for switchover. This plan provides mitigation for these switchover hazards. • Through the Implementation of the concept by States within the EUR RVSM area. Commitment to this implementation is contained within the National Safety Plans and will be further amplified through National Switchover Plans. The safety plans are reviewed and	**Action 59.** States are to ensure that training of Flight Crew in RVSM Procedures is completed before Switchover. This requirement is referenced in the Guidance Material provided to States by the RVSM Programme [47] and in the RVSM Countdown and Switchover Plan [49]. Flight Crew training must be completed before an approval for operations in RVSM airspace can be issued by States.

System Element / Ref	**Source**	**Safety Requirement**	**Realised by:**	**Actions**
			reported in Appendix G.	
SP13	H_S.2.1	LoAs shall address issue related to FL310, FL350 and FL390 (address additional controls and/or use of those flight levels).	The realisation of this Safety Requirement is addressed: • As part of the application of the concept. EUROCONTROL has providing a switchover plan, which will provide detailed guidance on the planning requirements for switchover. This plan provides mitigation for these switchover hazards. • Through the Implementation of the concept by States within the EUR RVSM area. Commitment to this implementation is contained within the National Safety Plans and will be further amplified through National Switchover Plans. The safety plans are reviewed and reported in Appendix G.	**Action 60.** This safety requirement should be completed as part of Action 56 above. This requirement is referenced in the Guidance Material provided to States by the RVSM Programme **[47] and in the RVSM Countdown and Switchover Plan [49]**
SP14	H_S.5.2	Last minute briefing on RVSM R/T procedures shall be given to Flight Crews and ATCOs	The realisation of this Safety Requirement is addressed: • As part of the application of the concept. EUROCONTROL has providing a switchover plan, which will provide detailed guidance on the planning requirements for switchover. This plan provides mitigation for these switchover hazards. • Through the Implementation of the concept by States within the EUR RVSM area. Commitment to this implementation is contained within the National Safety Plans and will be further amplified through National Switchover Plans. The safety plans are reviewed and reported in Appendix G.	**Action 61.** States are to ensure that Operators and Flight Crews are reminded of the revised procedures and requirements relating to operations in RVSM airspace This requirement is referenced in the Guidance Material provided to States by the RVSM Programme **[47] and in the RVSM Countdown and Switchover Plan [49]**

APPENDIX J – TRAINING SYLLABUS

The EUROCONTROL ATC Training Package for the introduction of RVSM within the European RVSM Area was designed to support national air traffic control trainers in the design and conduct of national RVSM implementation training programmes.

The aim of the training package is to provide national trainers with sufficient information and knowledge to be able to develop theoretical and practical training for national air traffic controllers. The training package enables national trainers to set objectives for 5 simulation exercises and instruct sufficient theory on RVSM to prepare air traffic controllers for simulation exercises.

Ref: EUROCONTROL Air Traffic Control Training Package for the Introduction of Reduced Vertical Separation Minimum within the European RVSM Area. Edition 1.1 October 1999 **[36]**.

Training Syllabus

1. Historical Background
   - 1.1 The origins of 2000ft above FL 290
   - 1.2 RVSM in the NAT Region
   - 1.3 RVSM in Europe
2. Aircraft Certification
   - 2.1 Approval Procedure
   - 2.2 Certification Requirements
   - 2.3 ACAS
3. RVSM Programme
   - 3.1 RVSM Programme Overview
4. Safety & Monitoring
   - 4.1 Safety
   - 4.2 Monitoring
5. Flight Planning
   - 5.1 Flight Planning
6. Operational Procedures
   - 6.1 Overview
   - 6.2 General ProceduresTransition Procedures
   - 6.3 Communication Failure in Flight
7. Phraseology

7.1 Phraseology

8. Airspace Changes

8.1 Airspace Considerations

9. System Changes

9.1 Flight Data Processing Systems
9.2 Radar Display Systems
9.3 Flight Strips
9.4 OLDI
9.5 STCA/MTCD

10. National Training

10.1 Training Requirements
10.2 Skills Training Programme
10.3 Skills Training Syllabus

APPENDIX K – WAKE-VORTEX HAZARDS

Introduction

The experience gained from the implementation of RVSM in the NAT Region indicated that the turbulence created by the Wake Vortex of aircraft operating at the same Flight Level/Track could present operating difficulties. In order to evaluate the extent and possible consequences of these difficulties, in the EUR RVSM Airspace, an independent study was commissioned by the EUROCONTROL Agency. Woodfield Aviation Research undertook the study in March 1998. The following text is an extract from the report of the study [29].

Summary of the Woodfield Report [29].

Wake vortices are shed downstream by all aircraft and can be a potential hazard in en-route flight conditions as well as in the terminal area close to the ground. The introduction of Reduced Vertical Separation Minima(RVSM) will bring aircraft closer together and it is important to assess whether or not this will significantly increase the risk of a hazardous encounter with wake vortices. Operations under RVSM in Oceanic airspace provide some practical experience with which to make an initial assessment of the likely effects of introducing RVSM in the more complex environment of European airspace.

Particular relevant features in European airspace that do not occur in Oceanic airspace are a wider mix of aircraft sizes, a greater number of aircraft changing flight levels, the presence of traffic on reciprocal tracks in airways, the intersection of airways, and the presence of up and down draughts at high altitudes as a result of winds passing over mountain ranges. These effects have been considered and it is concluded that the presence of mountain ranges and the wider mix of aircraft sizes will increase the probability of encountering wake vortices with RVSM compared with Oceanic airspace, but the encounters should remain a nuisance rather than a hazard. When wake vortex encounters occur and persist then a change of flight level, heading, or a track offset of 1 n.m. will usually prevent further encounters.

Recommendations of the Woodfield Report [29]

- RVSM is not expected to increase the probability of a hazardous encounter with wake vortices, but pilots and air traffic should be informed that nuisance encounters would increase.

- A change of flight level, a tactical heading or a track offset of 1 n.m. should be made available on request from ATC as a contingency procedure to remove aircraft from persistent nuisance encounters with wake vortices when they occur.

- Before the introduction of RVSM, an effective system should be established for reporting, collecting and analysing reports from pilots and air traffic of significant wake vortex encounters.

- After the introduction of RVSM, a study should be made of the received wake vortex reports, together with details of any other major vortex encounters above 5000 ft. in recent years, and this should be included as part of the Monitoring Post Implementation Safety Case.

- Pilots and air traffic should be better informed of the character of wake vortices and typical encounters.
- Confirmation should be sought that recovery from unusual attitudes on instruments as a result of a major upset, such as a wake vortex encounter, is included in pilot simulator training schedules.

The RVSM Programme Response.

The RVSM Programme made the following response to the recommendations of the Woodfield Research Wake Vortex Report.

- Noted the content of the Report and its recommendations.
- Agreed that Doc 7030/4 allows a pilot to deviate if necessary from route/or flight level when encountering wake vortex.
- Agreed to include wake vortex awareness in local training briefings for controllers.
- Agreed to contact commercial flying schools with regard to wake vortex encounters.
- Agreed to initiate a Wake Vortex Turbulence Data Collection and that Wake Vortex Report Forms be prepared and circulated (as part of the RVSM Pre-Implementation Safety Case) – see below.

Action by the RVSM Programme

Wake Vortex Turbulence Data Collection

The collection of wake turbulence data above FL 245, from aircraft operators, commenced on the 1st Aug 2000 in order that sufficient data can be gathered as part of the Pre-Implementation Safety Case for the introduction of RVSM. Some 17 reports were received up to the end of March 2001.

Woodfield Aviation Research have evaluated these reports and have considered any safety impications that may affect the introduction of RVSM or other flight operations.

Some six of the 17 reports are in cruise flight and all were minor encounters. Four of these 6 are probably as a result of natural turbulence (CAT). The remaining 11 encounters all occurred when aircraft were climbing or descending, and these situations will not be affected by the introduction of RVSM.

In their later review, Woodfield Aviation Research concluded that the reports received in the period do not give any indication that the introduction of RVSM would increase the probability of a hazardous encounter with a wake vortex. The number of reports involving climbing and descending encounters, however, may indicate a problem that will become more significant as traffic volumes increase.

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APPENDIX L – ACAS/TCAS

L.1 INTRODUCTION

This Appendix sets out how the RVSM Programme takes into account ACAS related issues within the EUR RVSM Pre-Implementation Safety Case. **This approach has been co-ordinated and agreed with the EUR ACAS Programme.**

Following ICAO guidance, the 'total vertical ' risk includes the 'technical vertical' risk (associated with the technical height keeping of aircraft) as well as the risk due to operational errors and in-flight contingencies. When assessing first results of the collection of data on operational altitude deviations it was apparent that many of the reported deviation events were related to the operation of ACAS. While the risk-reducing effect of ACAS is not taken into account as a matter of principle (see L.3 below), it became clear that altitude deviations resulting from ACAS nuisance alerts would increase the 'overall' collision risk. It was questioned whether it was realistic to only take into account the negative aspects of ACAS in the risk assessment, thereby implying (and concluding) that in the context of RVSM the existence of Collision Avoidance System only increases collision risk.

This issue was discussed with the EUR ACAS Programme, and it became clear that safety assessments in the context of ACAS includes thorough consideration of both positive and negative effects of ACAS. The results of these assessments will be used as the basis to verify that ACAS meets its basic objective, i.e. reduce collision risk.

Since ATC workload as a result of ACAS/TCAS nuisance alerts was identified in the Function Hazard Analysis (FHA) as a potential hazard, this aspect is also taken into account regarding the interaction between RVSM and ACAS/TCAS.

L.2 GENERAL SAFETY RELATED ASPECTS OF ACAS

As referred to in L.1(above), the basic objective of ACAS is to reduce the risk of collision. The main assumption regarding the operation of ACAS in EUR RVSM airspace is therefore that ACAS actually reduces the risk of collision. While nuisance alerts may be an issue which calls for an operational consideration in terms of controller or flight deck workload this does not affect the effectiveness of ACAS in performing its main function, i.e. preventing collisions.

Taking into account data collections and assessments performed in the context of ongoing ACAS monitoring and EUR ACAS implementation activities, there is currently no reason to deviate from the point-of-view that "any ACAS is better than no ACAS ", i.e. also the availability of TCAS V6.04a in RVSM airspace results in a lower risk of collision than having no TCAS in RVSM airspace, despite the nuisance alerts that V6.04a may create.

Any manoeuvre based on ACAS Resolution Advisories (RAs), is based on the vicinity of any other (third party) aircraft and is co-ordinated accordingly. Therefore, when adhered to by the pilot, these manoeuvres do not induce a risk, but are actually taking place in the context of collision avoidance, reducing the potential for a collision. It is important to note that this is also the case when the manoeuvre is based on a 'nuisance' RA.

Although multiple encounters are very rare events, the available real-life data, involving TCAS II V6.04a, indicates satisfactory performance. The multi-threat logic in TCAS II V7.0 has been radically revised, improved and validated.

A high frequency of nuisance alerts may result in operational acceptability problems. For this issue and the forecast frequency of occurrence of nuisance alerts and expected numbers of V6.04a equipped flights in RVSM airspace, see L.4 of this Appendix.

L.3 APPROACH ON PROCESSING ACAS EVENTS FOR RVSM COLLISION RISK ASSESSMENT (CRA)

In the context of the collection of data on operational altitude deviations as the basis for the estimation of the risk due to these events, many reports have been received which describe altitude deviations caused by Airborne Collision Avoidance Systems (ACAS).

The majority of the reports involve pilot reactions to '*nuisance'* ACAS Resolution Advisories (RA's). An ACAS '*nuisance'* (or operationally unnecessary) advisory is defined as "an advisory in accordance with the ACAS technical specifications in a situation where there was not, or would not, have been a risk of collision between the aircraft." *(ICAO SICASP 7 Report, 22 Sep 2000)*

Some of the ACAS related altitude deviation reports however, concern the pilot follow-up after an ACAS RA which was truly operationally necessary to resolve a potential collision.

The EUROCONTROL ACAS Programme is responsible for the implementation of ACAS in European airspace. In this context the ACAS Programme also collects data on ACAS events, and performs safety studies to determine the effect of ACAS on the safety of European air traffic operations.

The ACAS safety studies include both conventional and RVSM environments, to ensure that ACAS meets its safety objectives. The ACAS safety studies encompass:

⇨ a risk ratio analysis

to assess the risk with and without ACAS, to identify the effect (positive and negative) of ACAS on the risk of collision.

⇨ a full system safety study

to assess, through fault-tree analysis, all areas where ACAS has a safety impact including those not addressed by the risk-ratio-analysis.

⇨ monitoring ACAS performance

to monitor the effectiveness of ACAS in European airspace, to identify safety, technical, and operational issues which need to be considered and/or resolved.

Given the above, the ACAS safety analysis related activities are specifically aimed at the effectiveness and safety implications of ACAS. These activities are not only RVSM related, but consider all environments, including the operation of ACAS in RVSM. The ACAS events, reported to the ACAS evaluation team at the EUROCONTROL Experimental Centre in Bretigny-sur-Orge (EEC, France), are used a basis for the ACAS analysis activities. These events are also available to the RVSM Programme in the context of the operational altitude deviation data collection exercise. In addition, specific highly focussed monitoring TCAS II Version 7.0 introduction, including Collision Avoidance System logic modifications, is undertaken in the ACAS EMOTION-7 Project.

It is a generally accepted ICAO principle that reduction of separation minima should be proven to be safe without taking into account the safety improving effect of ACAS. In other words, the application of separation minima should meet the agreed safety objectives and ACAS is to be considered as an additional ‘safety net’ to prevent actual collisions in case the ‘system’ fails.

Taking all the above into account, it is considered that if reported ACAS events are only related to the technical and operational aspects of ACAS, i.e. if the ACAS events are ‘nuisance’ events (see L.2), then these events should not be taken into account in the RVSM Programme safety assessment. They are, however, covered in the ACAS safety analysis activities to assess the effectiveness and safety implications of ACAS in European airspace.

Those ACAS related altitude deviation reports concerning an ACAS RA which was operationally necessary to resolve a potential collision are considered to result from an operational error and as such will be taken into account in RVSM safety assessments, disregarding any manoeuvre made on the basis of an ACAS RA.

This use of reported ACAS events complies with the approach in which the effect of ACAS should not be taken into account when determining whether the RVSM safety objectives are met. In this regard it is important to note that the effect of ACAS on the safety of air traffic operations in European airspace include the positive and negative effects of ACAS. The ACAS Programme performs assessments to ensure that ACAS meet its safety objectives when operated in EUR airspace, for both conventional and reduced Vertical Separation Minima.

After proving that RVSM can meet the EUR RVSM safety objectives, the actual safety levels will be further improved by the operation of ACAS. This resultant and improved effect on safety is however outside the context and responsibility of the RVSM Programme.

L.4 ACAS/TCAS ‘NUISANCE’ ALERTS AND ATC WORKLOAD

The RVSM FHA has identified ACAS/TCAS nuisance alerts to be a potential hazard for RVSM operations. Therefore this issue has been given due attention, without disregarding the safety aspects of ACAS as outlined in the previous sections.

ACAS study results

The EATMP ACAS Programme ACASA Project Work Package 3 (WP3) **[37]** studied the ACAS/RVSM interaction in European airspace. The purposes of the study were to ascertain:

- Whether there are any significant operational implications for ACAS II performance due to European RVSM implementation, and also:
- Whether the benefits expected from RVSM could be compromised due to the operation of ACAS II.

The study was based on different sources of data:

a) Modified radar data.,
b) Data extracted from real-time simulations,
c) Non-automatic artificial encounters,
d) Automatic artificial encounters (not conducted yet), and
e) Data extracted from fast-time simulations.

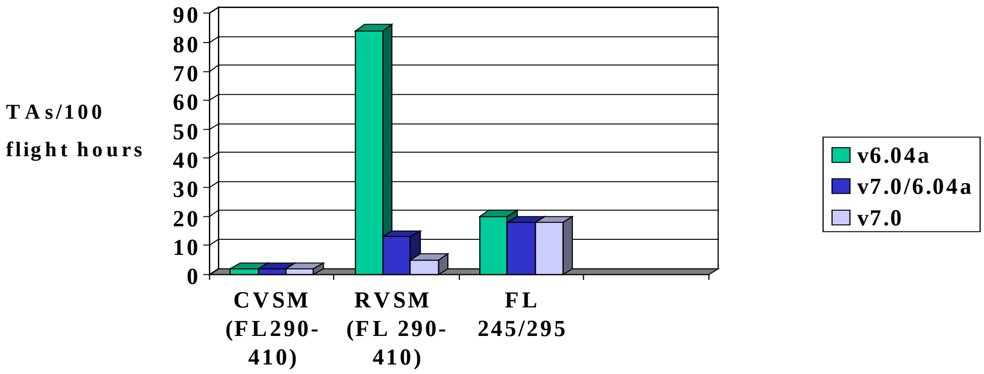
The main principle of the study was to perform, for each source of data, a pair-wise comparison of the ACAS performances within the future RVSM environment and the current CVSM environment, based on the same level of traffic. For each source of data, a large set of ACAS performance indicators were analysed in order to highlight potential improvements or drawbacks in terms of safety, pilot acceptance, and compatibility with ATC.

Additional to the results regarding RA and TA alert rates, taking into account TCAS V6.04a and TCAS V7.0, the study concluded that "*No safety issues, related to the introduction of an RVSM environment, have been discovered in studies comprising this interim report*".

Regarding RA and TA alert rates, the latest available conclusions are based on the results of both real-time simulation data and modified radar data. The ACAS simulation results show a comparison of TCAS II between the current situation in the FL 290-410 (CVSM) layer and the future situation in the FL 290-410 (RVSM) layer. The modified radar data makes a comparison between the future situation in the FL290-410 (RVSM) layer and the current situation in the FL245-295 layer. The study considered a full V7.0 environment, a mixed V7.0/V6.04a environment (90%/10%), and a full V6.04a environment.

The results (based on modified radar data) show that the estimated RA rates above FL 290, even in the RVSM environment, are lower than those computed for the FL 245-295 layer. For example for TCAS II V7.0 , the mean rate goes from 1 RA every 1000 flight hours in CVSM, to one RA per 400 flight hours in RVSM but 1 RA every 100 flight hours below FL 290.

Maximum Occurrences of TAs per Flight Hour (modified radar data).



Note: 2/3 times higher proportion of flight hours above FL 290

As illustrated, the number of TAs are much greater in RVSM than in the CVSM environment. With regard to rates per flight hours, V6.04a increases from 1 TA every 50 flight hours in CVSM to nearly one TA per flight hour in RVSM.

In a total V7.0 scenario (all aircraft equipped) with regard to the number of TAs per flight hour in RVSM, TCAS II V7.0 produces a significant improvement when compared with V6.04a. Even though the TA rate is expected to increase by some 3 times in RVSM when compared to CVSM, it is expected to be some 2 to 4 times **less** than the TA rate in the FL 245-295 layer. The mixed environment (with 10% TCAS II V6.04a) the overall results are similar except with a higher TA rate experienced by the V6.04a equipped aircraft whose TA alert rates increases by some 1.5 to 3 times in RVSM.

It should be noted that there is a greater proportion of flight hours above FL 290 (2-3 times than that below) which may suggest higher ACAS encounter rates in that band to the pilot. Nevertheless, in terms of flight hours, ACAS alert rates in future RVSM airspace are anticipated to be lower than those currently encountered in the FL 245-295 layer regardless of the TCAS II version.

Conclusions

The results produced thus far continue to be the best estimates of TCAS II V7.0 equipage rates and ACAS encounter rates in EUR RVSM airspace. The experience obtained with the early introduction of RVSM operations since 19 April 2001 in the United Kingdom, Germany and Austria, has not indicated the presence of any issue regarding V6.04a equipped in flights operating under RVSM conditions.

Excessive numbers of TCAS II V6.04a equipped aircraft represent a potential disruption to RVSM. The ACASA WP3 concluded that as the percentage figure rises above their 90%/10% scenario then the scenario portrayed in the total (100% fitted) V6.04a report will become increasingly representative and, therefore, unacceptable to both controllers and pilots. Research by the RVSM Programme of the total number of aircraft operating as GAT in RVSM airspace, thus far, concludes that the likely numbers of V6.04a fitted aircraft are likely to no more than 3% and as such, in accord with the findings of ACASA study on a mixed V7.0/V6.04a scenario, can be considered to be operationally acceptable.

Some concern has been expressed about the increase in ACAS alerts between CVSM and RVSM airspace. It was considered important to place the results in perspective and thus a comparison was first made with the results encountered in the layer FL 245-295. This most recent study is designed to express the encounter rates in terms of flight hours so that both pilots and controllers could envisage the operational implications of these alerts. It is evident from the latest findings that TCAS II alert rates in future RVSM airspace are anticipated to be lower in numbers and thus at greater intervals between alerts than those currently encountered in the FL 245-295 layer regardless of the TCAS II version.

Further, the above issue needs to seen in the light of the overall risk reducing effect of ACAS and the ATC workload reducing effect of RVSM implementation. Therefore, it is considered that the above approach provides a sufficient mitigation regarding safety implications of ACAS nuisance alerts in RVSM airspace. In case the amount of flights operating TCAS V6.04a in RVSM airspace is significantly higher than expected, the increased impact of nuisance alerts on ATC workload and safety may need to be re-assessed.

L.4 ONGOING ACTIVITIES

It is currently being assessed where and when (possible) TCAS V6.04a equipped aircraft may operate in RVSM airspace, in order to address their impact on ATC workload on sector level.

Because of the impact of a high rate of nuisance alerts (primarily TAs) by TCAS V6.04a in RVSM airspace on flight crew workload, operators are strongly advised that when they operate ACAS in RVSM airspace, the ACAS should be TCAS V7.0. This is expected to further reduce the number of flights operating TCAS V6.04a in RVSM airspace.

ACAS Workshops have been organised to take place in the period April 2001 - November 2001. This is expected to support the operational acceptability of ACAS aspects also in an RVSM environment and help to make ATC and flight crews aware of aspects associated with the operation of ACAS, including its operation in RVSM airspace. At the first Workshop (Brussels, 18-19 April 2001), one of the main conclusions was the need for more emphasis on the training of ATC and flights crews regarding ACAS/TCAS operations. This requirement, together with other conclusions from the Workshops, will be the basis for ongoing activities to improve the operational acceptability and effectiveness of ACAS/TCAS. A specific ACAS training package giving guidance for operation in EUR RVSM airspace is being developed by EUROCONTROL. The package will be delivered in the 3rd quarter of 2001.

ICAO and several States have initiated actions to reduce the occurrence of ACAS nuisance alerts, by addressing the main cause: high rates of climb and high rates of descent shortly before reaching the cleared flight level. Aircraft Operators and pilots are advised to reduce a high rate of climb/descent when approaching the cleared level. This advise is further emphasised through awareness activities by the RVSM and ACAS Programmes (including the above mentioned Workshops), and is expected to reduce the rate of nuisance alerts, both in RVSM and non-RVSM airspace.

In the context of the EUR ACAS Programme, the performance of ACAS II in EUR airspace will be monitored on an ongoing basis in order to confirm the outcome of above mentioned studies and identify any possible improvements, either technically or operationally.

APPENDIX M – SUMMARY OF THE STUDY OF OPERATIONAL ERRORS

Introduction

ICAO Doc 9574 “Manual on Implementation of a 300M (1000ft) Vertical Separation Minimum between FL 290 and FL 410 Inclusive” **[2]** requires an assessment and evaluation of the impact of the introduction of RVSM of the risk due to operational errors. The monitoring of operational errors is dependent upon the collection and submission of Assigned Altitude Deviation Reports (ADRs) when, for any reason, an aircraft deviates from its assigned altitude by 300 feet or more. Potential sources of ADRs include:

- Pilot Reports of errors
- ATC Reports of errors
- Deviations based on Mode C observations.

Requirement for Operational Error Data

The collection and analysis of Operational Error data is essential in order to satisfy two of the RVSM Objectives detailed in Sub-Paragraph **2.5** of this document, namely:

- The RVSM Programme shall, as its principal safety objective, minimise the programme’s contribution to the risk of an aircraft accident. The RVSM Programme recognises the Safety Objectives of the ATM 2000+ Strategy **[4]**, in particular the general objective to 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 implementation of RVSM shall not adversely affect the risk of en-route mid-air collision.

- In accordance with ICAO Guidance Material the management of vertical collision risk within RVSM airspace shall meet the Target Level of Safety of 5×10^{-9} fatal accidents per flight hour.

To achieve the first objective it is necessary to quantify the level of risk in the existing airspace, to institute any possible measures to reduce that risk, and then to quantify the level of risk after the implementation of RVSM. Should the Post Implementation Risk be shown to have increased, albeit whilst still satisfying the ICAO TLS, it will be necessary to determine the cause(s) of the increase and then to take remedial action. From this it can be seen that the collection of Operational Data will have to be maintained post-implementation so that any assumptions can be subsequently verified and that any differences can be further analysed.

To satisfy the second of these objectives, the overall ICAO TLS, it is necessary to quantify the level of Operational Risk in the system. This risk combined with the level of Technical vertical risk provides the Total vertical risk in the system and enables comparison with the TLS. This process is detailed in Appendix F – Collision Risk Assessment.

Collection and Categorisation of Data.

The Data Collection process consisted of the following stages:

- Operational Error Data Collection – accepted as part of the Work Breakdown Structure
- Develop ADR Form based on NAT format
- National Programme Managers briefed on conduct, purpose, and requirements for Data Collection.
- States set up their own Data Collection mechanisms
- Reporting commenced 1 April 2000.
- ADRs peaked over Summer 2000 Period (April to September inclusive). Some 275 reports were received up to March 01
- States required to provide Nil Returns where applicable.
- Scrutiny, Analysis and Categorisation of Reports.

The Categorisation of the data was based on the experience gained in the monitoring of Operational errors in the NAT.Region. The basic categories of error were:

- ATC/Pilot Communication Loop Errors and Errors resulting from incorrect ATC Clearances
- Level Busts (levelling after Climb or Descent)
- Aircraft Contingency Events (e.g.Emergency Descents)
- Deviations due to weather (e.g. Severe Turbulence)
- Deviations due to RAs from ACAS/TCAS

Role of the Scrutiny Group (SG):

The RVSM Programme received and collated the ADRS which were then reviewed by the Scrutiny Group (SG). The SG consisted of experienced ATCOs, Aircrew, and Mathematicians working on the CRM. All were members of the Eurocontrol Staff and three had previous experience of the analysis of Operational Errors with the NAT SPG in relation to the MNPS and RVSM operations.

The aims of the SG were to:

- Check the validity of each report (Accept or Reject) – see next bullet point.
- Determine the cause of the deviation and allocate appropriate deviation categories/types as basis for considering deviations as sources of risk.
- Determine extent and duration of the deviation

- Define data sample to obtain maximum representivity and integrity.
- Assess Flight Hours in airspace of selected sample.
- Assess total vertical risk resulting from Operational Errors (fatal accidents per Flight Hour)
- Consider whether remedial action is required.
- Review the effectiveness of the report forms.
- Make recommendations to the RVSM Programme.

The Scrutiny Group had 4 working sessions. The first meeting concentrated on the development of a methodology for handling the reports to ensure consistency throughout. A total of 250+ individual reports were scrutinised in accordance with the above aims and the analysis was then passed to the Mathematicians for the Risk Assessment process detailed in Appendix F.

The realisation of the aims of the Scrutiny Group relied heavily on the quality of the completed reports and on the operational expertise and judgement of the members of the Group. It was not considered practical, either in the initial development of the ADR Form or as a part of a follow up procedure of a report, to conduct any formal investigation of the details of a deviation. This was seen to be counter productive in that it could impose an additional workload, basically on ATC, and would act as a deterrent to the future completion and filing of reports.

Validity of the Sample

Initially the level and quality of the ADRs were satisfactory. However after the first few months of the Summer 2000 Period the reporting levels began to decline noticeably despite the continued and strenuous efforts of all concerned. The drive for additional reports has resulted in an extensive number of “Nil Returns” that supported the previously expressed view concerning the deterrent factor. This number of Nil Returns created some concern that the level of operational risk would be under estimated. Consequently 5 States were identified as having maintained a level of reporting throughout the period that was consistent with the number of flight hours observed in their Region. It was agreed that their combined data would provide the most representative and conservative sample possible. Of the 266 Reports summarised in the Table below, 110 were reported by the 5 selected States. These 110 deviations form the basis of the assesment of Operational Risk described in Appendix F Sub –Paragraph 4.2.

TCAS Reports:

A consistent level of the ADRs were as a result of TCAS RAs (some 60%). The following methodology was agreed at the outset as being the best method of handling these reports.

- If the TCAS RA was triggered as a result of an Operational Error by an aircraft, then the cause of that Operational Error, and hence the RA, was identified and assigned as appropriate i.e. if the cause was a level bust then that could be assigned as a pilot error or an equipment error depending on the circumstances.

- If the RA was triggered by a high vertical climb/descents with aircraft at adjacent flight levels. That is, if the alert was generated as a consequence of the TCAS software rather than any loss of separation, these reports were considered to be “Nuisance Alerts” and were not considered to be risk bearing.

As detailed in Appendices F and L, although the collection of ADRs as a result of ACAS/TCAS Resolution Advisories is continuing, it has been agreed not to include the ‘nuisance’ events in the CRA in order not to draw false conclusions on the effectiveness of ACAS/TCAS to reduce the risk of collision.

Documentation

Hard copies of all reports are held on file. Those reports forwarded by E-mail are also held on the Agency P Drive - P:/RVSM. All reports have been allocated a SG number which is retained regardless whether the report is subsequently considered accepted or rejected for inclusion in the sample.

The reports have been entered into a data base format which can be interrogated by the RVSM Programme. The findings of the SG are also entered into the data base. Each report, therefore, is referenced, together with the findings of the SG regarding validity, cause, size and duration of the deviation, and any recommendations of the Group. The findings are summarised below: The derivation of risk resulting from these deviations is addressed at Appendix F.

Summary of Reporting States

Altitude Deviation Reports	
AAD reports received	**275**
AAD reports reviewed by Scrutiny Group	**266**

Summary of AAD Reports

Category	Type of Errors		Total
ATC Errors	Poor techniques & procedures	2	**10**
	Faulty clearance	6	
	Lack of co-ordination	1	
	Communications loop error	1	
Pilot Errors	Climb descent without clearance	12	**25**
	Failure to follow ATC clearance	1	
	Level bust	6	
	Inaccurate flying	6	
TCAS Errors	Real alert (as a result of an Operational Error)	5	**40**
	Nuisance alert (not risk bearing)	26	
	Limited within protected volume	3	
	False alert	5	
	Outside protected volume	1	
Other errors	Faulty equipment	6	**9**
	To be determined	3	
Discard Errors	Not eligible for assessment against the overall TLS (e.g. below FL 280, Transponder errors, Deviation less than 300 feet)	182	**182**
		Grand Total	**266**

APPENDIX N – LIST OF ASSUMPTIONS MADE IN THE PISC AND THE FHA

The following assumptions have been made in the development of the PISC and in the FHA report.

1. Throughout the PISC document,

   That the level of collision risk due to a loss of vertical separation, throughout the current CVSM environment, is tolerably safe.

2. In Sub Paragraph 5.8 ATC Equipment

   Where modifications to ATC Equipment are necessary to accommodate RVSM Operations, it is assumed that existing system performance standards will be maintained.

3. In Sub-Paragraph 5.8.8 - Back-up Equipment:

   The safety requirements placed on many ATC systems assume the existence of a Back-up system to be used in the event of failure of the Primary system. Wherever a Primary system has been (or is to be) modified to accommodate RVSM it is assumed that the equivalent Back-up system is also modified in order to maintain its effectiveness.

4. In Section 6 - Implementation of the RVSM Concept and Appendix G – National Safety Plans and States Safety Awareness.

   i) That the National Safety Plans, and the letters from DGCAs of the participating States confirming their readiness of their State for RVSM, fully address all of the requirements detailed in the Guidance Material provided to States by EUROCONTROL and ICAO, the hazards identified by the FHA , and confirm the completion of the actions listed in Appendix H, Table H-3 of the PISC relating to:

   - Airspace Design
   - Flight Crew Procedures and Training
   - Aircraft Equipment (MASPS)
   - ATC Procedures and Training
   - ATC Equipment
   - Switchover –specific Safety requirements.

   ii) That States employ employ suitably qualified and competent staff in the planning, preparation, and implementation of all aspects of RVSM.Operations.

5. In Section 7 – Safety of Switchover from CVSM to RVSM.

   That Implementation of RVSM will be conditional upon the readiness of all States to implement – All Go/No Go.

6. In Appendix F - Collision Risk Assessment

The estimation of the risk of collision, based on the currently observed data, is dependant upon the following assumptions:

- The risk of collision in an RVSM environment with TCAS will be lower than the risk of collision without TCAS.
- The frequency and magnitude of operational errors will not be affected by RVSM implementation.
- The frequency and magnitude of operational errors is independent of the proximity of other aircraft.
- The type of operational errors observed in the set of 5 States used for the present analysis is representative of Europe as a whole.
- The set of reports for the 5 States used in the present analysis is complete. That is, there is no under-reporting. Based on the current risk estimates, it would appear that if the level of under-reporting is greater than 80% (ie only 1 out of every 5 atypical altitude deviations is reported) then the current level of risk may be in excess of the overall TLS of $5x10^{-9}$ fatal accidents per flight hour.
- That the implementation of RVSM will not affect the frequency of horizontal overlap.
- The lack of data on atypical (greater than 300ft) deviations from the HMU system is not sufficient to invalidate the current risk estimates.

7. In the FHA – Section 4.5.1 and in Appendix D

Overall Assumptions

For each FHA session, a number of assumptions were developed. However, instead of assumptions they were called ‘Operational Environment’ as they describe the environment the FHA has been conducted in.

Nevertheless, five main assumptions have been developed that are applicable to all three FHA sessions.These assumptions are related to the implementation of RVSM and are as follows:

- Aircraft certification process will continue to have the same high standard ;
- The introduction of RVSM will not lead to any additional intentionally violation of rules and procedures ;
- The same high standard of devotion to profession as of today is expected from both pilots and controllers ;
- Layout of sectors and determination of sector capacity is done by using the same philosophy, as under CVSM, i.e. the set sector capacity will ensure at least the same Target Level of Safety (TLS).
- Route Network is adapted to RVSM through the work undertaken by RNDSG, i.e. ARN ver. 4.

The detailed assumptions applicable to each of the three scenarios employed in the FHA are set out in Appendix J to the FHA Report.

APPENDIX 0 – TERMS OF REFERENCE OF THE RVSM VERIFICATION COMMITTEE (RVSM VC)

TERMS OF REFERENCE

1. MISSION

The RVSM Programme Verification Committee (VC) shall:

- Review the conditions placed on the RVSM Go Decision by the Provisional Council (PC)/Commission (CN) & the ICAO European Air Navigation Planning Group (EANPG) in July and verify that they have been met;
- If all conditions have been met confirm the Go Decision made by the PC/CN & EANPG;
- If any conditions have not been met or there is insufficient mitigation to enable RVSM to be implemented in a safe and effective manner, refer the Go Decision back to the PC/CN and EANPG;
- If the Go Decision is confirmed submit a report on their conclusions to the PC & EANPG;
- Keep the PC/CN and EANPG informed.

2. AUTHORITY

The RVSM VC was created by and reports to the PC/CN and the EANPG.

3. COMPOSITION

The RVSM VC members shall have the mandate to act on behalf of their State or International Organisation. Membership shall comprise:

- A chairman and a secretary (appointed by the Agency);
- Senior representatives with overall strategic responsibility for national RVSM programmes and, or, the Director of Air Navigation Services from the participating ECAC States, non-ECAC States and, if so required by their States, ANS providers;
- Senior representatives from relevant User and other International associations, including IATA, IACA, IAOPA, EBAA, AEA, IFALPA and IFATCA ;
- Senior representatives from relevant European and International Organisations, including the European Commission, JAA, ICAO and NATO;
- The RVSM PM, other relevant Agency staff.

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ANNEX 1 – 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
ANT	EUROCONTROL Airspace & Navigation Team
ASE	Altimetry System Error
ATC	Air Traffic Control
ATM	Air Traffic Management
ATS	Air Traffic Service
CAA	Civil Aviation Authority
CBA	Cost Benefit Analysis
CFMU	Central Flow Management Unit
CFL	Cleared Flight Level
COPS	Co-ordination Points
CRA	Collision Risk Assessment
CRM	Collision Risk Model
CVSM	Conventional Vertical Separation Minimum (2000ft at and above FL 290)
DGCA	Director General Civil Aviation
EAG	European ATFM Group
EANPG	European Air Navigation Planning Group
EATCHIP	European ATC Harmonisation and Implementation Programme.
EATMP	European Air Traffic Management Programme.
ECAC	European Civil Aviation Conference
EEC	EUROCONTROL Experimental Centre (Bretigny)
EOBT	Estimated Off Block Time
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
FMD	Flow Management Division
FPL	Flight Plan
FTE	Flight Technical Error
GMU	GPS Height Monitoring Unit
GPS	Global Positioning System
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
MNPS	Minimum Navigation Performance Specification
MTCD	Medium Term Conflict Detection
NAT	North Atlantic Region (of ICAO)
NATSPG	North Atlantic Systems Planning Group
OLDI	On-line Data Interchange
PC	Permanent Commission
PISC	Pre-implementation Safety Case
PSSA	Preliminary System Safety Assessment
RGCSP	Review of the General Concept of Separation Panel (of ICAO)
RVSM	Reduced Vertical Separation Minimum
ROADET	Review of Operational Altitude Deviations Evaluation Team
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
URB	User Relations Bureau (CFMU)
UIR	Upper Flight Information Region
USC	EUROCONTROL User Support Cell
VSM	Vertical Separation Mimimum

ANNEX 2 - DEFINITIONS/EXPLANATION OF TERMS

Note : The following definitions are taken from ICAO Document 9574 (2nd Edition) - Manual on Implementation of a 300M (1000 FT) Vertical Separation Minimum between FL290 and FL410 inclusive.

ASE

The difference between the altitude indicated by the altimeter display (assuming a correct altimeter barometric setting) and the pressure altitude corresponding to the undisturbed ambient pressure.

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.

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.

Target Level of Safety

A generic term representing the level of risk which is considered acceptable in particular circumstances (ICAO Doc. 9536 RGCSP/6 Vol. 1)

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.

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).

Vertical Collision Risk

That part of the overall Collision Risk (qv) which arises solely from two aircraft, which should be vertically separated, being at the same altitude.

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