

AFI RVSM

POST-IMPLEMENTATION SAFETY CASE



alTran
SUD-OUEST

**Immeuble SYNAPSE
Parc Centreda
4, Avenue Didier Daurat
31700 Blagnac, France
Tél. : 05 34 610 400
Télécopie : 05 34 610 410**

Document à l'attention de :

International Air Transport Association

Mr Gaoussou KONATE
Regional Director, Africa - Indian Ocean
Safety, Operations & Infrastructure,
Sandown Mews, East Block, Ground Floor
88, Stella Street, SANDOWN 2196
PostNet Suite 167, Pvt Bag X9916, SANDTON, 2146
SOUTH AFRICA

Manager ALTRAN SUD-OUEST : Sémou DIOUF, +33 666356505, semou.diouf@altran.com

Page intentionally left blank.

AFI RVSM POST-IMPLEMENTATION SAFETY CASE

MARCH 2010



Page intentionally left blank.

READERS NOTES

Page intentionally left blank.

DOCUMENT RELEASE APPROVAL

< To be completed by ICAO/ARMA >

Page intentionally left blank.

DOCUMENT CHANGE RECORD

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

| Version | Issue Date | Author | Change description |
|---------|------------|------------------|--|
| 0.1 | 30/11/2009 | Altran Sud-Ouest | Initial outline only |
| 0.2 | 19/02/2010 | Altran Sud-Ouest | Draft report for IATA and ARMA review |
| 0.3 | 24/02/2010 | Altran Sud-Ouest | Complete report for IATA and ARMA review |
| 0.4 | 01/03/2010 | Altran Sud-Ouest | Update following IATA and ARMA review |
| 1.0 | 04/03/2010 | Altran Sud-Ouest | Released issue |

Page intentionally left blank.

SUMMARY

A Reduced Vertical Separation Minima (RVSM) of 300 m (1000 ft) between FL 290 and 410 inclusive was safely and successfully implemented in the AFI (Africa and Indian Ocean) airspace on 25 September 2008.

This document constitutes the AFI RVSM Post-Implementation Safety Case (POSC), as a major deliverable required by the AFI RVSM Safety Policy, and follows on from the AFI RVSM Pre-Implementation Safety Case (PISC), accepted by APIRG/16 and forwarded to the ICAO Air Navigation Commission for consideration.

It aimed to show by means argument and supporting evidence that the on-going application of the ICAO RVSM concept in the AFI Region satisfies the key AFI RVSM Safety Objectives set out in the AFI RVSM Safety Policy. It did not attempt to address the safety of particular implementations of this concept, which remains under the full responsibility of the States. The safety of the AFI RVSM concept was addressed, for the time period 25 September 2008 - 30 September 2009.

The strategy to demonstrate the aim achievement was underpinned by three principal safety arguments:

- That AFI RVSM continues to be safe “in principle” (i.e. subject to subsequent and correct realisation of the necessary safety requirements), by means of a review in light of the operational experience of the set of safety requirements developed in the PISC;
- That the AFI RVSM concept is safe by means of the on-going safety requirements realisation (by the AFI RVSM Concept) which is measured on the basis of the available data over the time period 25 September 2008 - 30 September 2009; and,
- That the issues that were active in the PISC, and the assumptions made therein, have been addressed satisfactorily.

Each of the above principal arguments is developed in the relevant section of the POSC. The detailed conclusions can be summarised as follows:

- It was concluded that AFI RVSM continues to be safe “in principle”. The review of the safety requirements confirmed those developed in the PISC and also developed new requirements related to the integrity of the AFI RVSM System. The last ones address a number of hazard causes and mitigations that were not explicitly revealed in the previous FHA. No specific requirement addressing the new issues that has risen since the implementation was found necessary;
- It was not concluded that the AFI RVSM Concept is safe. Some safety requirements were not shown to be achieved. In particular, on the basis of the available data, the total vertical TLS of 5×10^{-9} fatal accidents per flight hour has been shown to be exceeded by a factor of approximately 6 and the risks rising from an aircraft being assigned a wrong (i.e. potentially conflicting) flight level and from an aircraft deviating from cleared flight level (situation unknown by flight crew) have been assessed as not acceptable. In addition, although the ARMA monitoring arrangements have been shown to be effective, application thereof have been shown to be affected as some States/CAAs have chosen to ignore the requirements in the areas of RVSM approvals, traffic flow data and operational errors reporting, and height monitoring.
- It was not be concluded that the issues that were outstanding at the time the PISC was issued, have been addressed satisfactorily, as levels busts and AFI RVSM airspace classification A issues continue to be outstanding.

As an overall conclusion, it was NOT concluded that AFI RVSM is safe in operational service in the time period 25 September 2008 - 30 September 2009.

A set of safety recommendations has been provided to the attention of ICAO, States, ANSPs and Aircraft Operators. These recommendations are issued to improve the safety of AFI RVSM in operational service as well as the reliability of the next POSCs.

Page intentionally left blank.

Table of contents

| | |
|---|-----------|
| 1. INTRODUCTION | 19 |
| 1.1 BACKGROUND..... | 19 |
| 1.2 PURPOSE | 19 |
| 1.3 AIM..... | 20 |
| 1.4 SCOPE | 20 |
| 1.5 USE OF THE POSC BY THE STATES..... | 21 |
| 1.6 STRUCTURE OF THE DOCUMENT..... | 21 |
| 2. AFI RVSM SAFETY MANAGEMENT | 23 |
| 2.1 AFI RVSM SAFETY OBJECTIVES | 23 |
| 2.2 AFI RVSM SAFETY DELIVERABLES..... | 24 |
| 2.2.1 AFI RVSM FHA..... | 24 |
| 2.2.2 AFI RVSM CRA | 24 |
| 2.3 AFI RVSM SAFETY RESPONSIBILITIES | 25 |
| 2.3.1 On-going safety of the AFI RVSM concept | 25 |
| 2.3.2 On-going safety of the AFI RVSM operations at State level | 26 |
| 3. OVERALL STRATEGY AND SAFETY ARGUMENT..... | 27 |
| 3.1 OVERALL CLAIM | 27 |
| 3.2 CONTEXT | 27 |
| 3.3 SAFETY CRITERIA..... | 27 |
| 3.4 STRATEGY..... | 28 |
| 3.5 PRINCIPAL SAFETY ARGUMENTS | 28 |
| 3.6 CONCLUSION | 29 |
| 4. ARGUMENT 1: AFI RVSM SAFETY REQUIREMENTS..... | 31 |
| 4.1 STRATEGY..... | 31 |
| 4.2 DIRECT EVIDENCE | 32 |
| 4.2.1 Review of system integrity SER..... | 32 |
| 4.2.2 Review of system monitoring SER..... | 33 |
| 4.2.3 Completeness and correctness of reviewed SER..... | 34 |
| 4.3 BACKING EVIDENCE | 35 |
| 4.3.1 SER reviewed by competent staff | 35 |
| 4.3.2 Validation of FHA review process | 35 |
| 4.4 CONCLUSION | 36 |
| 5. ARGUMENT 2: SAFETY OF THE AFI RVSM CONCEPT | 37 |
| 5.1 STRATEGY..... | 37 |
| 5.2 NEW INTEGRITY REQUIREMENTS..... | 39 |
| 5.2.1 Strategy | 39 |
| 5.2.2 Direct evidence | 40 |
| 5.2.3 Backing evidence..... | 40 |
| 5.2.4 Conclusion | 40 |
| 5.3 AIRCRAFT HEIGHT-KEEPING PERFORMANCE..... | 41 |
| 5.3.1 Strategy | 41 |
| 5.3.2 Direct evidence | 42 |
| 5.3.3 Backing evidence..... | 42 |
| 5.3.4 Conclusion | 43 |
| 5.4 TOTAL VERTICAL COLLISION RISK..... | 44 |

| | | |
|-------------------|---|------------|
| 5.4.1 | <i>Strategy</i> | 44 |
| 5.4.2 | <i>Direct evidence</i> | 45 |
| 5.4.3 | <i>Backing evidence</i> | 46 |
| 5.4.4 | <i>Conclusion</i> | 47 |
| 5.5 | ATM-INDUCED ACCIDENTS AND SERIOUS INCIDENTS | 48 |
| 5.5.1 | <i>Strategy</i> | 48 |
| 5.5.2 | <i>Direct evidence</i> | 49 |
| 5.5.3 | <i>Backing evidence</i> | 50 |
| 5.5.4 | <i>Conclusion</i> | 50 |
| 5.6 | AFI RVSM SYSTEM MONITORING | 51 |
| 5.6.1 | <i>Strategy</i> | 51 |
| 5.6.2 | <i>Measures to monitor exclusion of non-RVSM approved non-State aircraft from AFI RVSM airspace</i> | 52 |
| 5.6.3 | <i>Measures to monitor aircraft height-keeping performance</i> | 53 |
| 5.6.4 | <i>Measures to collect data on operational errors</i> | 53 |
| 5.6.5 | <i>Measures to collect data on risk exposure</i> | 54 |
| 5.6.6 | <i>Measures to collect data on ACAS/TCAS events</i> | 54 |
| 5.6.7 | <i>Backing evidence</i> | 54 |
| 5.6.8 | <i>Conclusion</i> | 55 |
| 5.7 | CONCLUSION | 55 |
| 6. | ARGUMENT 3: VALIDITY OF PISC | 57 |
| 6.1 | STRATEGY..... | 57 |
| 6.2 | SWITCHOVER..... | 58 |
| 6.3 | LEVEL BUSTS..... | 59 |
| 6.4 | PISC ASSUMPTIONS..... | 59 |
| 6.5 | PISC ACTIONS..... | 60 |
| 6.6 | AIRSPACE CLASSIFICATION | 60 |
| 6.7 | CONCLUSION | 60 |
| 7. | ASSUMPTIONS | 61 |
| 7.1 | ASSUMPTIONS MADE IN THE POSC | 61 |
| 7.2 | ASSUMPTIONS MADE IN THE CRA | 61 |
| 7.3 | ASSUMPTIONS MADE IN THE FHA REVIEW | 61 |
| 8. | OUTSTANDING SAFETY ISSUES | 63 |
| 9. | RECOMMENDATIONS | 65 |
| 10. | CONCLUSIONS | 70 |
| APPENDIX A | POSC SAFETY ARGUMENT AND EVIDENCE STRUCTURE | 72 |
| APPENDIX B | AFI RVSM SYSTEM | 79 |
| APPENDIX C | FHA REVIEW | 82 |
| APPENDIX D | AFI RVSM SYSTEM ELEMENT REQUIREMENTS | 88 |
| APPENDIX E | HEIGHT MONITORING REQUIREMENTS | 102 |
| ANNEX 1 | DEFINITIONS AND ACRONYMS | 105 |

ANNEX 2 APPLICABLE AND REFERENCE DOCUMENTS 111

Table of figures

| | | |
|------------|---|----|
| Figure 1: | Overall strategy and argument | 29 |
| Figure 2: | Argument A1 - Argument and evidence structure | 32 |
| Figure 3: | Argument A2 – Argument and evidence structure | 38 |
| Figure 4: | Argument A2.1 - Argument and evidence structure | 39 |
| Figure 5: | Argument A2.2 - Argument and evidence structure | 41 |
| Figure 6: | Argument A2.3 - Argument and evidence structure | 44 |
| Figure 7: | Argument A2.4 - Argument and evidence structure | 48 |
| Figure 8: | Argument A2.5 - Argument and evidence structure | 51 |
| Figure 9: | Argument A3 - Argument and evidence structure | 57 |
| Figure 10: | GSN Symbology | 72 |
| Figure 11: | Overall strategy and argument | 74 |
| Figure 12: | Argument A1 - Argument and evidence structure | 75 |
| Figure 13: | Argument A2 – Argument and evidence structure | 75 |
| Figure 14: | Argument A2.1 - Argument and evidence structure | 76 |
| Figure 15: | Argument A2.2 - Argument and evidence structure | 76 |
| Figure 16: | Argument A2.3 - Argument and evidence structure | 77 |
| Figure 17: | Argument A2.4 - Argument and evidence structure | 77 |
| Figure 18: | Argument A2.5 - Argument and evidence structure | 78 |
| Figure 19: | Argument A3 - Argument and evidence structure | 78 |
| Figure 20: | AFI RVSM hazard model | 84 |

Table of tables

| | | |
|-----------|---|-----|
| Table 2: | States which participated in the AFI RVSM programme | 19 |
| Table 3: | RVSM airspace as addressed by POSC | 20 |
| Table 4: | Assumptions made in the POSC | 61 |
| Table 5: | Assumptions made in the CRA | 61 |
| Table 6: | POSC outstanding safety issues | 63 |
| Table 7: | Safety recommendations | 68 |
| Table 8: | AFI RVSM area of applicability | 79 |
| Table 9: | FHA review meetings work plan | 83 |
| Table 10: | Safety objectives (FHA review) | 85 |
| Table 11: | Assessment of the risks arising from the AFI RVSM hazards (1/2) | 86 |
| Table 12: | Assessment of the risks arising from the AFI RVSM hazards (1/2) | 86 |
| Table 13: | AFI RVSM System Element Requirements | 99 |
| Table 14: | 'New' System Element Requirements | 100 |
| Table 15: | Approach for realising 'new' SERs in concept | 101 |
| Table 16: | AFI RVSM Height Monitoring Requirements | 104 |

Page intentionally left blank.

1. Introduction

1.1 Background

A Reduced Vertical Separation Minimum (RVSM) of 300 m (1000 ft), between RVSM-approved aircraft operating at/between FL 290 and 410 inclusive [8], was safely and successfully introduced into the AFI (Africa and Indian Ocean) airspace on 25 September 2008.

The implementation of this major change to the AFI air navigation system was managed through the AFI RVSM programme run by the AFI RVSM Task Force (ARTF) according to its mandate as assigned by APIRG/14 [15].

The 51¹ ICAO contracting States which participated in the AFI RVSM Programme are listed in the following table:

| | | | |
|----------------------|------------|----------------------|-------------------------|
| Algeria ² | Angola | Benin | Botswana |
| Burkina Faso | Burundi | Cameroon | Cape Verde ³ |
| Central African Rep. | Chad | Comoros | Congo |
| Côte d'Ivoire | Djibouti | DR Congo | Equatorial Guinea |
| Eritrea | Ethiopia | Gabon | Ghana |
| Guinea Bissau | Guinea | Kenya | Lesotho |
| Liberia | Libya | Madagascar | Malawi |
| Mali | Mauritania | Mauritius | Mozambique |
| Namibia | Niger | Nigeria | Reunion |
| Rwanda | Sao Tome | Senegal ³ | Seychelles |
| Sierra Leone | Somalia | South Africa | Sudan |
| Swaziland | Tanzania | The Gambia | Togo |
| Uganda | Zambia | Zimbabwe | |

Table 2: States which participated in the AFI RVSM programme

The AFI Regional Monitoring Agency (ARMA) is the designated RMA for these States [9].

1.2 Purpose

This document constitutes the AFI RVSM Post-Implementation Safety Case (POSC), as a major deliverable required by the AFI RVSM Safety Policy [1] to demonstrate that the safety of the on-going AFI RVSM operations is continuously ensured. It follows on from the AFI RVSM Pre-Implementation Safety Case (PISC) [22], accepted by APIRG/16 and forwarded to the ICAO Air Navigation Commission for consideration.

In application of the APIRG ATS/AIS/SAR Sub-Group Decision 10/01 [2], this document has been developed under the responsibility of the ARMA and is intended to be presented to the APIRG/17 meeting for appropriate actions.

¹ Although Egypt was included in the PISC scope, it had implemented along with the MID Region in November 2003, and is affiliated to the MIDRMA.

² Algeria introduced RVSM - into the northern part of the Algiers FIR - ahead of the other countries

³ Capo Verde and Senegal introduced RVSM into a portion of the airspace for which they have jurisdiction as part of RVSM implementation in the EUR-SAM corridor, in January 2002.

1.3 Aim

The aim of this document is to show by means argument and supporting evidence that AFI RVSM is safe in operational service, i.e. to provide documented assurance that the on-going application of the ICAO RVSM concept in the AFI Region satisfies the key AFI RVSM Safety Objectives set out in the AFI RVSM Safety Policy [1].

The POSC aims therefore to address the on-going safety of the AFI RVSM concept. It does not attempt to address the safety of particular implementations of this concept, which remains under the full responsibility of the States. This differs from the PISC which addressed the safety of RVSM implementation as a principal safety argument.

1.4 Scope

The scope of the POSC is limited to presenting arguments and supporting evidence, obtained from the on-going service monitoring and general experience of AFI RVSM operations, against the AFI RVSM Safety Objectives, and to addressing any matters that were outstanding at the time the PISC was issued.

The safety of the AFI RVSM concept is addressed, for the time period 25 September 2008 - 30 September 2009, as applied in the following FIRs:

| | | | |
|-----------|---------------|------------------|--------------|
| Accra | Addis Ababa | Algiers | Antananarivo |
| Asmara | Beira | Brazzaville | Cape Town |
| Dakar | Dar es Salaam | Entebbe | Gaborone |
| Harare | Johannesburg | Johannesburg Oc. | Kano |
| Khartoum | Kinshasa | Lilongwe | Luanda |
| Lusaka | Mauritius | Mogadishu | Nairobi |
| N'Djamena | Niamey | Roberts | Seychelles |
| Tripoli | Windhoek | | |

Table 3: RVSM airspace as addressed by POSC

The ARMA is the designated RMA for the provision of monitoring and safety assessment activities in these FIRs [9].

Canarias, Sal Oceanic and Dakar Oceanic FIRs have not been included in the scope, as RVSM was implemented in this airspace ahead from rest of the AFI Region, under the scope of South Atlantic Monitoring Agency (SATMA) which is responsible for providing post-implementation safety assessment in that area. In order to ensure in the future a seamless assessment of the on-going RVSM safety for the entire AFI RVSM area of applicability (as designated in the AFI Regional Supps - ICAO Doc. 7030 [11]), the question is raised as to whether all AFI FIRs can report to the ARMA.

1.5 Use of the POSC by the States

States can use the POSC to support their own safety assessment and safety cases. However, each State must ensure, before subsequent use, that the data and results presented herein are applicable to its particular operational environment and to its area of responsibility.

In this context, this document is intended to be sent to the RVSM National Program Managers (NPM) through an ICAO State Letter whose acknowledge receipt can be used as evidence of States' commitments to make endeavours to review and implement the AFI RVSM safety requirements. Indeed, as set out in the Section 3 of the AFI RVSM Safety Policy [1], the RVSM NPMs are responsible for ensuring the compliance of the State RVSM activities with the AFI RVSM Safety Policy and appropriate international standards and requirements.

1.6 Structure of the Document

The remainder of this document is structured as follows:

- Section 2 provides important background information on the safety management of AFI RVSM: it describes the AFI RVSM Safety Objectives, as set out in the AFI RVSM Safety Policy, the safety deliverables and the safety responsibilities which directly relate to the on-going safety of AFI RVSM.
- Section 3 explains how the POSC is constructed using Goal-Structuring Notation (GSN) in the same way as the PISC was constructed, and explains how the POSC safety claim is broken down into three principal safety arguments, which represent a necessary and sufficient condition for the safety claim to be true.
- Sections 4 - 6 address each of the three principal safety arguments in turn by further decomposition into lower-arguments, and the provision of supporting evidence as a text within the relevant Section, or as an appendix to the POSC or by a reference to external published documents when the evidence is bulky.
- Section 7 lists the assumptions on which the POSC is based.
- Section 8 provides the outstanding safety issues to be resolved for the POSC claim to be true, provided that the assumptions made are valid.
- Section 9 provides recommendations concerning the on-going safety of AFI RVSM including proposals, to the attention of ICAO, States and other responsible agencies, for further monitoring and the resolution of the outstanding safety issues.
- Section 10 brings together the conclusions from the individual Sections 4 to 6 and provides the POSC conclusion in relation to its aim.
- Appendix A sets out how the GSN methodology was applied to AFI RVSM, and contains the relevant diagrams which illustrate the POSC argument and evidence structure.
- Appendix B provides an overview of the AFI RVSM System
- Appendix C presents a summary of the FHA review
- Appendix D provides the set of AFI RVSM System Elements Requirements, as reviewed as part of the argument A1 (Section 4) and addressed in the design of the AFI RVSM System as part of the Argument A2 (Section 5).
- Appendix E briefly presents the minimum height monitoring requirements.
- Annex 1 provides a list of abbreviations and explanation of terms.
- Annex 2 presents the applicable and reference documents.

Page intentionally left blank.

2. AFI RVSM Safety Management

- ☞ This Section provides important background information on the safety management of AFI RVSM: it describes the AFI RVSM Safety Objectives, as set out in the AFI RVSM Safety Policy [1], the safety deliverables and the safety responsibilities which directly relate to the on-going safety of AFI RVSM.

2.1 AFI RVSM Safety Objectives

Section 2.2 of the PISC [22] described how the AFI RVSM Safety Policy was developed by the AFI RVSM Task Force to meet the ICAO Standards and Recommended Practices (SARPs) and guidance material on managing collision risk related to the implementation of RVSM; and presented its key elements, namely the AFI RVSM Safety Statements, the AFI RVSM Safety Objectives, and the AFI RVSM Safety Deliverables.

The AFI RVSM Safety Objectives have been established to meet the Safety Statements and defines the tolerable level of risk for AFI. The following four of which remain directly relevant to the on-going safety of AFI RVSM:

- (i)⁴ The RVSM Programme shall conduct a full Functional Hazard Analysis (FHA) 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 program's contribution to the risk of an aircraft accident. The RVSM Programme recognises the AFI safety objectives and 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, the implementation of RVSM shall not adversely affect the risk of en-route mid-air collision;
- (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;

These Safety Objectives form the basis for demonstrating the on-going safety of the AFI RVSM Concept.

⁴ The numbering used for the PISC is maintained to facilitate traceability. The safety objectives related to the AFI RVSM Safety sub-programme (iii) and to the guidance provided to States for the implementation (vi) are considered as not relevant from a post-implementation perspective.

2.2 AFI RVSM Safety Deliverables

The AFI RVSM Safety Policy has defined five deliverables in support of the assurance of the achievement of the Safety Objectives:

- AFI RVSM Functional Hazard Analysis (FHA)
- AFI RVSM Collision Risk Assessment (CRA)
- AFI RVSM National Safety Plans (NSPs)
- AFI RVSM Pre-Implementation Safety Case (PISC)
- AFI RVSM Post-Implementation Safety Case (POSC)

The FHA and CRA constitute major inputs to the PISC (with the NSPs) and to the POSC. They are briefly discussed below.

2.2.1 AFI RVSM FHA

As an important part of the PISC, a FHA [23] was conducted between November 2005 and April 2006 with the objective to identify and mitigate hazards associated with RVSM operations, and to determine a set of integrity safety requirements, whose realisation, by the AFI RVSM concept and its implementation, was addressed in the subsequent parts of the PISC. This FHA also included activities of a typical Preliminary Safety Assessment (PSSA), referring to the EUROCONTROL Safety Assessment Methodology [34]. The process used was fully successful in supporting the related PISC safety arguments.

As a major input to the present POSC, a review of the FHA [18] was conducted between November 2009 and February 2010 with the objective to update, in light of the operational experience, the safety requirements related to the integrity of the AFI RVSM System (cf. Section 4.1) and to assess the on-going AFI RVSM risks for the time period 25 September 2008 - 30 September 2009 (cf. Section 5.5). Although the methodology used for the previous FHA was fully successful, its application for the POSC would present some limitations and a new methodology framework has been set up to support the assessment of the risks arising from the on-going AFI RVSM hazards. The objective of the FHA review was thereby not to challenge the previous FHA results, but to model them differently for the purpose of the POSC, taking also account of the return on experience. The FHA review is therefore to be considered from a post-implementation perspective only. A summary is provided in Appendix C.

2.2.2 AFI RVSM CRA

As an important part of the PISC, three CRAs were conducted in 2005, 2007 and 2008 with the objective of assessing the technical and total vertical collision risks against the technical and total vertical TLSs of $2.5 \cdot 10^{-9}$ and $5 \cdot 10^{-9}$ fatal accidents per flight hour respectively. These CRAs are documented in [24], [25] and [26].

As a major input to the present POSC, a post-implementation CRA [17] was conducted between November 2009 and February 2010 with the objective to assess the above technical and total vertical collision risks over the time period 25 September 2008 - 30 September 2009 (cf. Sections 5.3 and 5.4). It was carried out on the basis of the data and piece of information available for this time period and the collision risk models developed as a part of the pre-implementation assessments with updated parameter values.

2.3 AFI RVSM Safety Responsibilities

From a post-implementation perspective, a distinction is made between the responsibilities for the management of the on-going safety of the AFI RVSM concept and of the AFI RVSM operations at States level.

2.3.1 On-going safety of the AFI RVSM concept

The management of the on-going safety of the AFI RVSM concept consists in establishing explicit processes and arrangements to continuously achieve the AFI RVSM safety objectives, to provide assurance thereof, and to continuously improve safety.

As set out in Section 2.2.5 of the PISC [22], the AFI RVSM Programme Office was, among others, responsible for developing the AFI RVSM concept, as well as the PISC together with ARMA.

Following the dismantlement of the AFI RVSM Programme⁵, the on-going safety of the AFI RVSM concept is managed through the following mechanisms:

- ICAO/ARMA has the responsibilities [9], among others, to monitor aircraft height-keeping performance and the occurrence of large height deviations, and to conduct safety assessments for its affiliated ICAO contracting States and FIRs (cf. Section 1). ARMA is hosted by Air Traffic Navigation Services Company of South Africa (ATNS) and is managed on behalf of ICAO. ARMA interacts with the ICAO ESAF office for all ICAO type administration and produces RVSM outputs to satisfy ICAO for AFI. ARMA reports certain activities to ICAO Montreal and belongs to the Global RMA committee which meets on an annual basis to harmonise the working principles of the global RMAs.

In this context, the development of the AFI RVSM POSC was placed under the ARMA responsibility by the ICAO Special AFI RAN 2008 Recommendation 6/6 [12] and APIRG ATS/AIS/SAR Sub-Group [2].

- The AFI POSC Management Team was established under the authority of the APIRG ATS/AIS/SAR Sub-Group with the aim, as was the PISC, to provide a broad spectrum of input from a representative cross section of AFI. The membership included ICAO ESAF & WACAF, ARMA, ASECNA, ATNS, IATA and the consultants from Altran and NLR when required.
- The AFI Tactical Action Group (TAG) [16] is a multidisciplinary group established under the authority of the ICAO Special AFI RAN 2008 [12] and aiming to carry out on-going safety assessment of operations in the AFI airspace above FL290 by addressing the identified problems in the air navigation system on a tactical, short-term basis. This includes the collection, compilation, discussion, classification, and directed action in relation to Unsatisfactory Condition Reports (UCR)⁶ that are received from system users, ANSPs, pilots, air traffic controllers and/or the public.

The AFI TAG works in close coordination with the ARMA in the discharge of its duties. It contributed, from the provision of the data on reported safety occurrences (UCRs) and the unique and representative field of expertise of its members (ICAO Montreal, WACAF & ESAF, ARMA, IATA, ASECNA, ATNS, Kenya, IFALPA and IFATCA), to the POSC modelling and assessment of the on-going risks associated with the FHA hazards, under the guidance of ARMA and the consultants of Altran.

- The ARMA Scrutiny Group was recommended by the ICAO Special AFI RAN 2008 under its Recommendation 6/6 [12], in order to monitor and analyse operational errors and deviations and propose mitigation measures to control them. These include all RVSM incidents in the vertical plan and large height deviations data for incorporation into the various CRAs. It will be managed and chaired by the ARMA and will form a small group representative of AFI.

⁵ Following ARTF/15 meeting in April 2009 [14]. This explains why the AFI RVSM Safety Objective (iii) is not considered for the post-implementation phase.

⁶ UCR: TAG concept that encompasses all safety risk bearing events.

2.3.2 On-going safety of the AFI RVSM operations at State level

States are sovereign and responsible for meeting their obligations in terms of the Convention on International Civil Aviation (Doc 7300) and in Annexes establishing international Standards and Recommended Practices (SARPs). In the RVSM context, such obligations include the operation of aircraft and operator approval processes, as per ICAO Annexes 2 [3] and 6 [4], and the provision of appropriate air traffic services in the airspace under their jurisdiction, together with the implementation and operation of State Safety Programme (SSP) and Safety Management System (SMS), as per ICAO Annex 11 [5].

Therefore, States are ultimately responsible for managing the safety of the on-going RVSM operations in their airspace. This includes the production of State-level post-implementation safety cases, as part of the ATS performance safety monitoring, and the reporting of operational errors and traffic data to ARMA. Where the responsibility for upper airspace have been delegated to Air Navigation Services Providers (ANSPs), the latter are responsible for carrying out their own RVSM post-implementation safety assessment as part of their SMS activity. States are responsible for overseeing this assessment in the framework of their State Safety Programmes (SSPs) activities.

States' commitments to conduct these activities are contained in the National Safety Plans (NSP), which were promulgated prior to RVSM implementation, in relation to the ICAO Annexes 2 and 11 (cf. [22], Section 5).

3. Overall strategy and safety argument

- ☞ This Section explains, using Goal-Structuring Notation, how the POSC aim is addressed by three principal safety arguments and how these principal arguments are developed and supported by evidence in the subsequent Sections of the POSC.

3.1 Overall claim

As set out in Section 1.3, the aim of the POSC is to show by means of argument and supporting evidence (assurance) that AFI RVSM is safe in operational service, i.e. that the on-going application of the ICAO RVSM concept in the AFI Region satisfies the key AFI RVSM Safety Objectives set out in the AFI RVSM Safety Policy [1] in the time period 25 September 2008 - 30 September 2009.

This aim is considered to be achieved by demonstrating the overall **Safety Claim A0**:

A0: “AFI RVSM is ‘safe’ in operational service”

3.2 Context

An overview of the AFI RVSM System is provided in Appendix B, in the same way as it was considered in the PISC [22] as a result of the application of the ICAO RVSM Concept in the AFI air navigation system.

3.3 Safety criteria

In the context of the overall claim **A0**, what is safe is defined by the safety criteria **Cr01**.

As set out in Section 2.1, the AFI RVSM Safety Objectives (i), (ii), (iv) and (v) form the basis for demonstrating the on-going safety of AFI RVSM. As the Safety Objectives (iii) and (vi) which are not addressed as part of the POSC do not explicitly refer to safety levels, **Cr01** is developed in the same way as it was in the PISC (cf. [22], §2.3.4):

Cr01 encloses sub-criteria defining absolute safety levels as follows:

- (a) TLS of 5.10⁻⁹ fatal accidents per flight hour for total vertical collision risk
- (b) TLS of 2,5.10⁻⁹ fatal accidents per flight hour for technical vertical collision risk
- (c) AFI RVSM Risk Classification Scheme (RCS) for the risks arising from the FHA hazards

Sub-criteria (a) and (b) are directly derived from the Safety Objectives (v) and (iv) respectively. Sub-criterion (c) relates to the Safety Objective (i) and was developed by the AFI RVSM programme in the form of a Risk Classification Scheme which was approved by the AFI RVSM Task Force.

Cr01 is completed by the Safety Objective (ii), which refers to a relative safety criterion in relation to the number of ATM-induced accidents and serious or risk-bearing incidents in the AFI RVSM airspace.

3.4 Strategy

The strategy (**St00**) for demonstrating that the safety claim **A0** is true is based on the following twofold approach:

- (**St001**) Use measurement of achievement of the safety criteria Cr01 as the evidence of the on-going safety of the AFI RVSM concept; and,
- (**St002**) Confirm the validity of the PISC by reporting all issues in it that were ongoing at the time the final version was issued.

The rationale for this two-fold approach is as follows:

- The most direct way to demonstrate validity of A0 is to actually measure⁷ whether the AFI RVSM AFI RVSM Safety Objectives are being achieved in operational service.
- The AFI RVSM concept was shown to be safe in the PISC, but subject to assumptions and resolution of certain issues: the POSC is to provide an update on those matters concerning AFI RVSM that were active at the time when the PISC was issued, accepted by APIRG and forwarded to the ICAO ANC for consideration.

3.5 Principal safety arguments

According to the above strategy, the safety claim **A0** is broken down into three principal safety arguments, which represent a necessary and sufficient condition for that safety claim to be true.

The strategy (**St00.1**) of using measurement of the achievement of **Cr01** is underpinned by two principal safety arguments:

- **Argument A1** asserting that AFI RVSM continues to be safe “in principle”, i.e. subject to subsequent and correct realisation of the necessary safety requirements which fully address all the functionality, capacity, performances and integrity of the AFI RVSM system. Necessary in this context means necessary to achieve **Cr01**. The strategy to show that **A1** is valid consists in reviewing in light of the operational experience the set of AFI RVSM safety requirements developed in the PISC.
- **Argument A2** asserting that the AFI RVSM concept is safe through the on-going realisation, in the design of the constituent elements of the AFI RVSM System, of the safety requirements and therefore of **Cr01**. The strategy to show that **A2** is valid consists in measuring if the AFI RVSM safety requirements continue to be achieved at concept level, on the basis of the available data over the time period 25 September 2008 - 30 September 2009.

The strategy (**St00.2**) of validating the PISC is addressed by the following third principal safety argument:

- **Argument A3** asserting the issues that were active in the PISC, and the assumptions made therein, have been addressed satisfactorily.

⁷ It is recognised that in practice these measurements inevitably involve some degree of statistical uncertainty, especially if the amount of available data is limited.

3.6 Conclusion

The overall strategy and argument, which is considered to be sufficient to show that AFI RVSM is safe in operational service, is illustrated as follows using an adaptation of GSN:

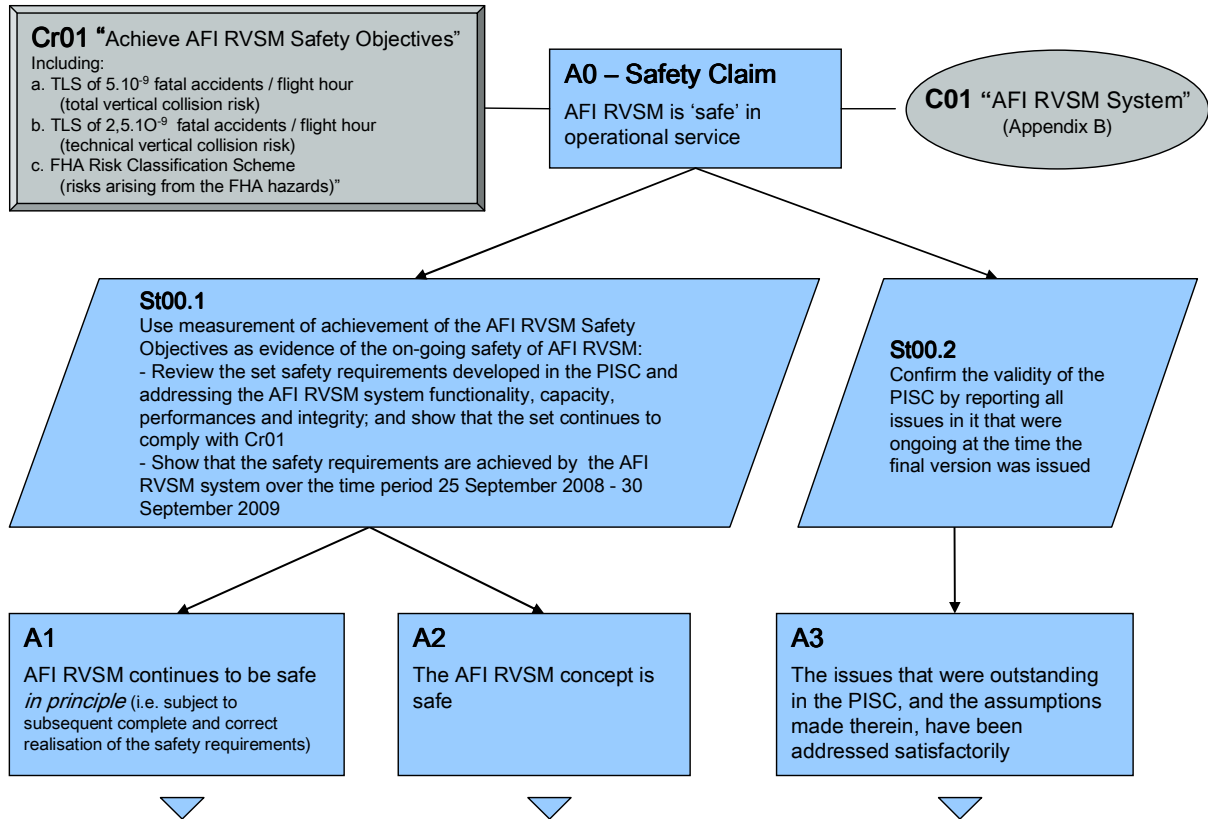


Figure 1: Overall strategy and argument

Further decomposition of the three principal safety arguments, together with the associated supporting evidence, are provided in the relevant Section of this document (Sections 4, 5 and 6 respectively).

A synthesis of the overall argument and evidence structure is provided in Appendix A.

Page intentionally left blank.

4. Argument 1: AFI RVSM Safety Requirements

- ☞ This objective of this Section is to set out the detailed arguments, strategies and evidence that the principal safety argument A1 is valid.

4.1 Strategy

A1: “AFI RVSM continues to be safe ‘in principle’”

A1 asserts the continuing ‘in principle’ safety of AFI RVSM. It addresses, following the strategy **St00.1**, the completeness and correctness of the AFI RVSM safety requirements which realisation are necessary to achieve the safety criteria **Cr01**.

The strategy **St01** to show that Argument **A1** is valid consists primarily in:

- Reviewing in light of the operational experience the set of AFI RVSM safety requirements developed in the PISC [22]
- Showing that this set continues to be, within reason, complete and correct

In this context, completeness means that all aspects of AFI RVSM safety are addressed, and correctness means that these have been addressed in a manner that complies with the AFI RVSM Safety Objectives (**Cr01**).

The safety of the AFI RVSM System does not only relate on its integrity, but also on its desired functionality, performance and capacity. Either reduction in the System functionality, performance and capacity, or failure within the System, can cause risk to increase and to exceed the safety targets contained in **Cr01**. This explains why the set of safety requirements developed in the PISC comprised initially two types of requirements, namely:

- the High-Level Safety Requirements (HLSRs) directly resulting from the AFI RVSM Safety Objectives, and specifying the desired functional, performance and capacity properties of the AFI RVSM system; and,
- the Integrity Safety Requirements (FHASRs) indirectly resulting from the AFI RVSM Safety Objective (i) through the FHA process, and specifying the necessary risk mitigations identified during the hazard and risk analysis.

These requirements were then in the PISC detailed and allocated to the various constituent elements of the AFI RVSM System (cf. Appendix B), in order to pave the way to a successful addressing and realisation in the design (concept) and implementation of the AFI RVSM System. The resulting requirements constituted the AFI RVSM System Element Requirements (SERs).

Since the implementation in September 2008, the AFI RVSM concept and its desired functional, performance and capacities have not changed. As part of strategy **St01**, the SER resulting from the HLSR are therefore considered to continue to be complete and correct, except those allocated to the System Monitoring (SM) element which by essence do not directly relate to the System properties. Consequently, only the SER related to the system integrity and monitoring have to be reviewed in light of the operational experience, in order to update the set of mitigations associated with the FHA hazards, and the system monitoring desired properties respectively.

Direct evidence of this is based on a review of the FHA conducted as part of the PISC and of a review of the system monitoring properties in light of the experience from the development of the present POSC and in conjunction with the ARMA.

Backing evidence is based on the competence of the staff who reviewed the requirements and on the validation, within reason, of the techniques used for the FHA review.

The figure below shows the argument and evidence structure supporting Argument A1:

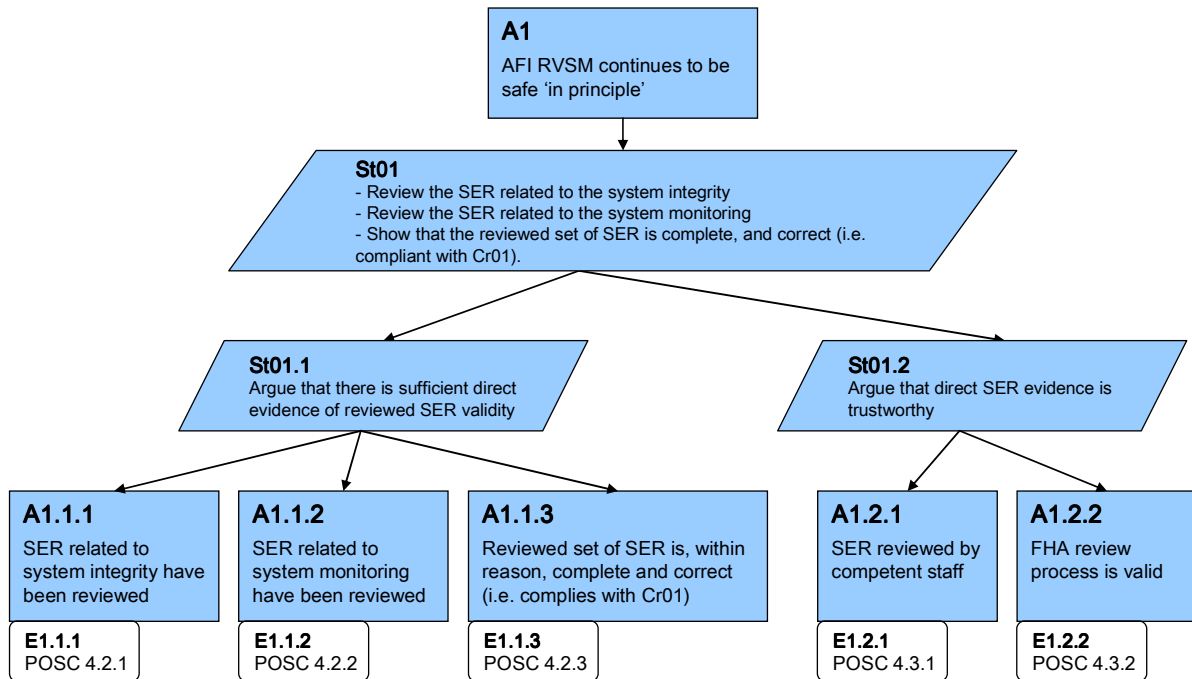


Figure 2: Argument A1 - Argument and evidence structure

4.2 Direct evidence

4.2.1 Review of system integrity SER

A1.1.1: “SER related to system integrity have been reviewed”

As set out in Section 2.2.1, a comprehensive FHA review was carried out between November 2009 and February 2010 to review, in light of the operational experience, the set of mitigations associated the AFI RVSM hazards, and to accordingly update the set of safety requirements related to the integrity of the AFI RVSM system. The risk mitigation strategy was derived on the basis of the modelling of the causes of the AFI RVSM hazards (see Appendix C).

As set out in Appendices C.5.1 and C.5.2, four individual hazards have been identified for AFI RVSM and their causes modelled using FTA technique. These hazards and associated causes are considered to be complete and correct, and to adequately cover the previous FHA results.

As set out in Appendix C.5.5, the AFI RVSM risk mitigation strategy has been derived in the form of integrity SER allocated to the elements of the AFI RVSM System and which reflects the mitigations which can be used to prevent the occurrence of the AFI RVSM hazards.

The derived set of integrity SER is provided in Appendix D. It confirms the previous FHA mitigations, with one exception which is relevant in light of the operational experience (cf. Appendix G.3 of reference [18]), and includes new requirements which adequately address a number of causes and mitigations that were not explicitly revealed in the previous FHA⁸. No

⁸ A number of causes and mitigations of individual hazards have emerged as a result of the FTA technique [18].

specific requirement addressing the new issues raised since the implementation was found necessary.

Further evidence can be found in the FHA review report [18].

Based on the above, **Argument A1.1.1 is valid.**

4.2.2 Review of system monitoring SER

A1.1.2: “SER related to system monitoring have been reviewed”

The SM SERs relates to the desired properties of the AFI RVSM system monitoring. They were developed in the PISC (cf. Section 3.3 and Appendix C of reference [22]) as follows:

- SM1: “The exclusion of non-RVSM approved non-State aircraft from AFI RVSM airspace shall be monitored”
- SM2: “The height-keeping performance of RVSM-approved aircraft shall be monitored”
- SM3: “Data on operational errors shall be collected for collision risk estimation”
- SM4: “Data on risk exposure shall be collected for collision risk estimation”
- SM5: “Data on ACAS/TCAS events shall be collected and evaluated”

The review of these, carried out in light of the experience from the development of the present POSC and in conjunction with ARMA, leads to the following conclusions:

- SM1 is confirmed as the exclusion of non-RVSM approved civil aircraft from AFI RVSM airspace is a fundamental requirement of the AFI RVSM concept
- SM2 is confirmed as adequately addressing the need to collect data on RVSM-approved aircraft height-keeping performance for the purpose of the assessment of the technical vertical collision risk (AFI RVSM Safety Objective (v))
- SM5 is confirmed as the ACAS/TCAS events can be the causes of large height-deviations which are used as input to the assessment of the total vertical collision risk (AFI RVSM Safety Objective (iv))
- SM4 is confirmed as addressing the provision for measures to collect data on risk exposure (traffic flows, navigation accuracy) for use in the assessment of the technical and total vertical collisions risks (AFI RVSM Safety Objectives (iv) and (v))
- SM3 addresses the collection and analysis of data on vertical separation incidents. Such data are used not only in the collision risks assessment (AFI RVSM Safety Objectives (iv) and (v)) but also, as set out in Section 5.5, in the assessment of the minimisation of RVSM contribution to the risk of an accident (AFI RVSM Safety Objective (ii)). SM3 is reworded as follows to be more precise in that regard (however there is no need to modify its core meaning): “Data on operational errors shall be collected for collision risk and RVSM contribution to the risk of an accident estimations”

The SM SERs reviewed thereby adequately address the properties of the monitoring of the AFI RVSM system. They are presented in Appendix A.

Consequently, **Argument A1.1.2 is valid.**

4.2.3 Completeness and correctness of reviewed SER

A1.1.3: “Reviewed set of SER is, within reason, complete and correct (i.e. complies with Cr01)”

As set out in Section 4.1, only the SERs related to the system integrity and monitoring have been reviewed in light of the operational experience, in order to update the set of mitigations associated with the FHA hazards and the system monitoring (SM) desired properties respectively. The SER resulting from the High Level Safety Monitoring (other than SM) are confirmed and continue to be complete and correct as demonstrated in the PISC (cf. Section 3.3 of reference [22]).

The following elements provide evidence of the completeness of the AFI RVSM risk mitigation strategy and of the resulting integrity SERs, as updated as part of the FHA review:

- The structured and logical approach used for specifying the SERs ensures, within reason, that all the possible mitigations are addressed; and the allocation of the requirements to the AFI RVSM system elements in the form of SERs ensures, within reason, the completeness of the decomposition of the mitigations. Detailed evidence is provided in Section 7.3 of reference [18].
- The causes which served as input data for the above mentioned approach, and the AFI RVSM hazards from which these causes were derived, are considered as complete on the basis of the methods used (functional approach for hazard identification, and structured and logical fault tree technique for causes modelling), of the validation against the previous FHA and of the validation carried out by the experts participating to the FHA review meetings (see Appendix C). Detailed evidence is provided in Sections 3.8 and 4.8 of reference [18].

The reviewed integrity SERs are considered as correct (i.e. compliant with safety criteria Cr01), as adequately addressing the AFI RVSM Safety Objectives (i) and (ii)⁹. Indeed, the integrity SERs resulting from the FHA review represent:

- The necessary and sufficient conditions for the risks arising from the FHA hazards to be tolerable in accordance with the applicable Risk Classification Scheme (see Appendix C); and,
- Together with the other SERs, the means by which the RVSM contribution to the risk of an aircraft accident in AFI can be minimised.

The review of the monitoring SERs leads to confirming the previous PISC ones, with a minor change in the wording of one of them which does not affect its core meaning. They are therefore considered as being complete and correct, as they were demonstrated as such in the PISC. The execution of the review in conjunction with ARMA provides further evidence of this.

As a conclusion, the reviewed integrity and monitoring SERs are considered to be complete and correct (i.e. complies with Cr01). Consequently, **Argument A1.1.3 is valid.**

⁹ The other AFI RVSM Safety Objectives are not relevant in the context of the integrity SERs, as exclusively addressed by the other SERs.

4.3 Backing evidence

4.3.1 SER reviewed by competent staff

A1.2.1: “SER reviewed by competent staff”

The FHA review [18] was performed by the same staff who had carried out the previous FHA [23] and developed the PISC [22]. The work was conducted under the management of ARMA, in close cooperation with IATA, and with the support of a group of experts from the AFI Tactical Action Group (TAG) during the FHA review meetings. The composition of the group (cf. [18], Appendix B) is representative of the AFI RVSM operations and of the various operational environments in which they are being conducted. It appropriately covers the profiles of people involved in the operations and the maintenance of the AFI RVSM system, as shown in Appendix C.

The review of the system monitoring SER was carried out by ARMA.

Based on the above, the SER review staff is considered as being competent and representative of AFI RVSM. Consequently, **Argument A1.2.1 is valid.**

4.3.2 Validation of FHA review process

A1.2.2: “FHA review process is valid”

As set out in Appendix C.3, the FHA review covered typical FHA and PSSA activities, referring to the experience in the EUROCONTROL areas [34] as was done in the previous FHA, and was based on the same severity and risk classification schemes as approved by the AFI RVSM Task Force and used in the PISC [22]. The methods used primarily consist in a structured brainstorming approach based on standard safety assessment techniques, and were shown to be consistent with the relevant ICAO guidance material contained in the Safety Management Manual Doc. 9859 [7]. The validation of the findings against the previous FHA results provides additional confidence in the FHA review process.

Further evidence can be found in Appendix A of the FHA review report [18].

Based on the above, **Argument A1.2.2 is valid.**

4.4 Conclusion

Based on the argument and evidence detailed above, Section 4 shows:

- That the AFI RVSM safety requirements have been reviewed in light of the operational experience, in particular:
 - In relation to the system integrity, that the previous FHA mitigations are confirmed, except one which is no longer considered relevant, and that the new mitigations resulting either from a new issue that has risen either since the implementation, or from the technique used in the review, are adequately addressed
 - In relation to the system monitoring, that the previous SM requirements are confirmed, with a minor change in the wording of one of them which does not affect its core meaning;
- That these requirements are complete and meet the safety criteria Cr01;
- That the SER review (including FHA review) staff is competent;
- That the FHA review process is valid; and,
- Consequently, that AFI RVSM continues to be safe 'in principle'.

It can be concluded that **Argument A1 is valid**.

5. Argument 2: Safety of the AFI RVSM concept

- ☞ This objective of this Section is to set out the detailed arguments, strategies and evidence that the principal safety argument A2 is valid.

5.1 Strategy

A2: “The AFI RVSM concept is safe”

A2 asserts the on-going safety of the AFI RVSM. It addresses, following the strategy **St00.1**, the realisation, in the design of the constituent elements of the AFI RVSM System, of the AFI RVSM safety requirements and therefore of the safety criteria **Cr01**.

The strategy **St02** to show that Argument **A2** is valid consists primarily in:

- Showing that the AFI RVSM safety requirements are achieved by the AFI RVSM Concept (i.e. the AFI RVSM System as designed), on the basis of the available data over the time period 25 September 2008 - 30 September 2009.

As set out in Section 4, the set of AFI RVSM safety requirements addresses the desired functionality, performances, capacity, integrity, and monitoring thereof, properties of the AFI RVSM System. As a result of its review in light of the operational experience, it is composed of System Element Requirements (SERs) and of two high-level safety requirements not allocated to a particular element and maintained at AFI RVSM system level, namely RVSM5 and RVSM6. The SERs includes ‘confirmed’ PISC safety requirements, as well as ‘new’ safety requirements. As set out in Section 4, the ‘new’ SERs exclusively relate to the integrity of the AFI RVSM System.

Ideally, to show that Argument A2 is valid, each element of the AFI RVSM System is to be demonstrated as successfully addressing the SERs allocated to it, and the AFI RVSM System is to be demonstrated as designed in compliance with RVSM5 and RVSM6. As in the PISC, such demonstration is to be carried out in two steps:

- Firstly, to show how the considered element of the System has to address each individual requirement (this is so-called “approach of satisfaction”); and,
- Secondly, to provide evidence of the requirements realisation following the pre-defined approach.

Regarding the SERs developed in the PISC and confirmed by the review, such demonstration was not possible as part of the present POSC: the evidence baseline developed in the PISC is, to a larger extent, no longer relevant. The main reason is that some of the documents promulgated by the AFI RVSM Programme have changed since the implementation; some are no longer applicable whereas the contents of others have been removed to be incorporated in documentation non specific to the AFI Region or to RVSM. The demonstration would therefore require a review of the approach of satisfaction and of a collect of evidence within a new documentary baseline, rather than only a review of the evidence contained in the documents defined in the PISC. Such work relies on the management of the documentation applicable to AFI RVSM which is an ICAO responsibility and is beyond the scope of the POSC.

As a consequence, it has been decided not to demonstrate, as part of Argument **A2**, the realisation of the ‘confirmed’ SERs, except¹⁰ AC1 and those related to the system monitoring, but rather to address it through an assumption (**A02**) which validation is an ICAO responsibility.

¹⁰ Such exception is justified as AC1 and SM SERs do not fall into the above mentioned limitations about evidence documentary baseline.

The figure below shows the argument and evidence structure supporting Argument **A2**:

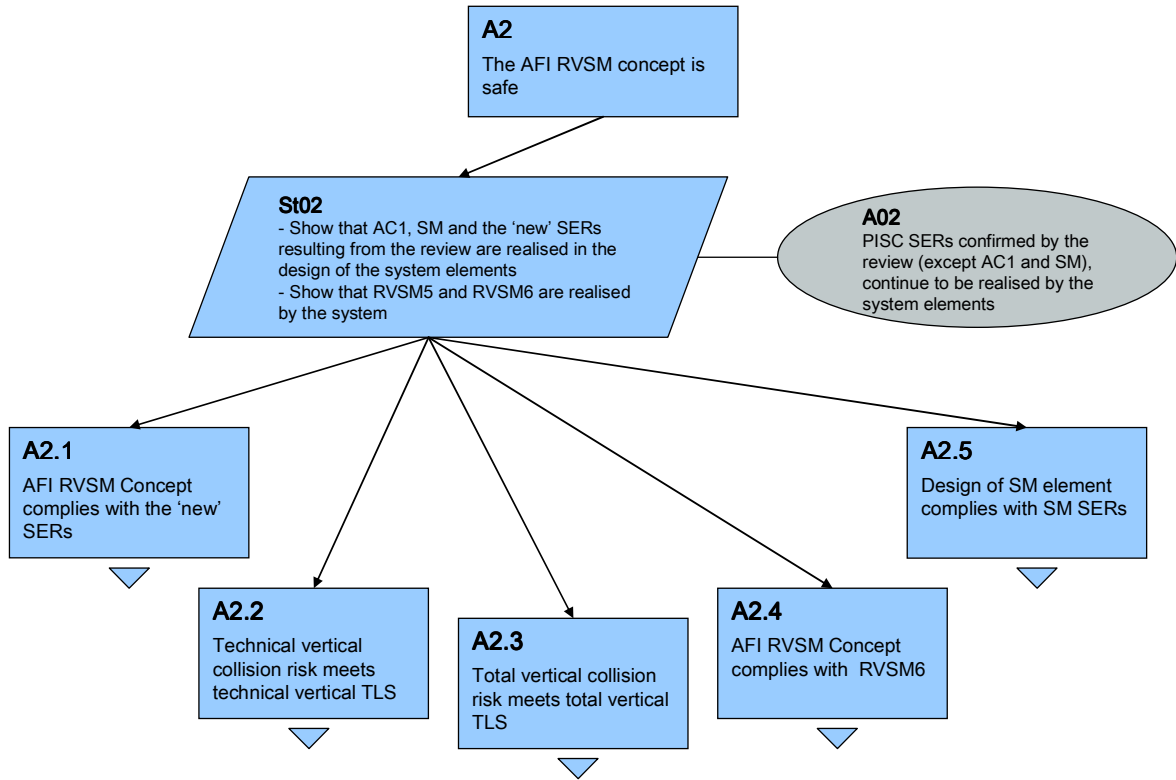


Figure 3: Argument A2 – Argument and evidence structure

5.2 New integrity requirements

5.2.1 Strategy

A2.1: “AFI RVSM Concept complies with ‘new’ SERs”

A2.1 asserts the realisation by the AFI RVSM Concept (i.e. in the design of the constituent elements of the AFI RVSM System) of the ‘new’ SERs resulting from the review in light of the operational experience.

As set out in Section 4, these ‘new’ SERs exclusively relate to the integrity of the AFI RVSM System and to its following constituent elements.

As set out in Section 5.1, the strategy to demonstrate the ‘new’ SERs realisation would ideally comprise, in a similar way to the PISC [22], two steps, namely the definition of the ‘approach of satisfaction’ and the provision of evidence following this approach. As for the PISC SERs confirmed as part of the review, the provision of evidence relies on the management of the documentation to AFI RVSM which is beyond the scope of the POSC.

In this context, the strategy **St02.1** to show that Argument **A2.1** is valid consists in:

- Developing the ‘approach of satisfaction’ for each individual ‘new’ SER
- Forwarding the defined approach to ICAO for consideration and subsequent development and provision of evidence in compliance to this approach.

The figure below shows the argument and evidence structure supporting Argument **A2.1**:

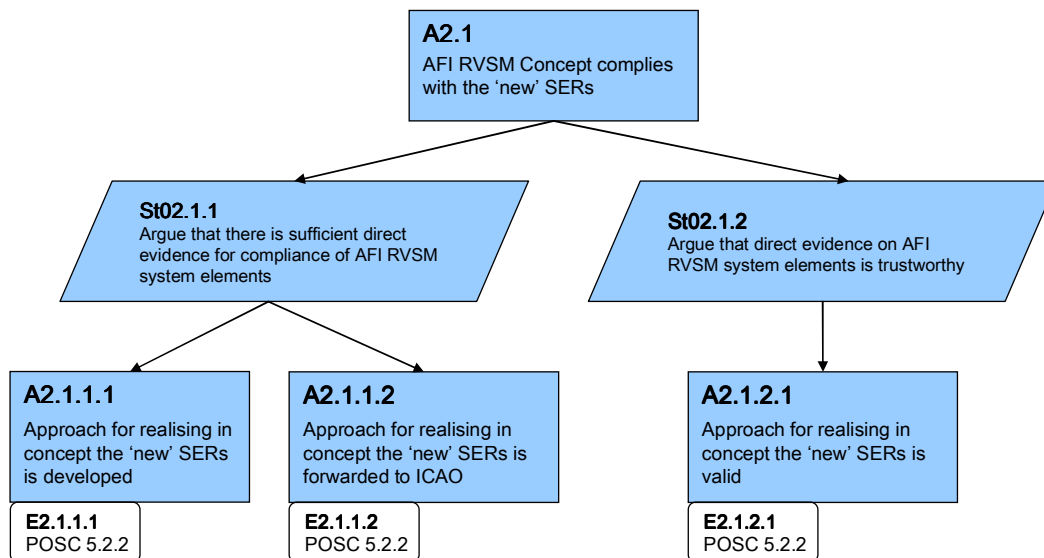


Figure 4: Argument A2.1 - Argument and evidence structure

5.2.2 Direct evidence

A2.1.1.1 : “Approach for realising in concept the ‘new’ SERs is developed”

For each individual system element, the approach followed the same principles as in the PISC (cf. Appendix D of [22])

Detailed evidence is provided in Appendix D.2.

On this basis, **Argument A2.1.1.1 is valid**

A2.1.1.2 : “Approach for realising in concept the ‘new’ SERs is forwarded to ICAO”

The present POSC intends to be managed by ICAO/ARMA and to be forwarded to APIRG/17. The necessity for developing and providing evidence in compliance with the defined approach is recalled in the conclusions of the present document.

Implicitly, **Argument A2.1.1.2 is valid**.

5.2.3 Backing evidence

A2.1.2.1 : “Approach for realising in concept the ‘new’ SERs is valid”

The approach was developed in consistency with that of the PISC [22] which was shown as complete and correct, as adequately addressing the means by which the SERs can be realised in concept. Although the documentary baseline about the AFI RVSM concept has changed since the implementation, the principles remain the same.

Consequently, **Argument A2.1.2.1 is valid**.

5.2.4 Conclusion

Based on the argument and evidence detailed above, Section 5.2 shows:

- That the design of the AFI RVSM system complies with the ‘new’ system element requirements, provided that appropriate evidence is developed in accordance with the pre-defined approach of satisfaction; and,
- Consequently, that **Argument A.2.1 is valid provided that** the new requirements are successfully addressed in the ICAO regional documentation supporting the AFI RVSM Concept.

5.3 Aircraft height-keeping performance

5.3.1 Strategy

A2.2: “Technical vertical collision risk meets technical vertical TLS”

A2.2 asserts the realisation of the requirement AC1 by the AC element, i.e. the consistency of the RVSM-approved aircraft height-keeping performance with the technical vertical TLS of 2.5×10^{-9} fatal accidents per flight hour in the time period 25 September 2008 - 30 September 2009.

The strategy **St02.2** to show that **A2.2** is valid consists in:

- Assessing the technical vertical collision risk¹¹ against the technical vertical TLS, using the same methods and collision risk model (CRM) as the PISC-related CRAs (cf. [24] [25] [26]) with parameter values updated on the basis of the aircraft population and traffic flow data available for the considered time period.

Direct evidence is based on the results of the Collision Risk Assessment (CRA) for the technical vertical collision risk.

Backing evidence is based on the validity of the CRA process, on the competence of the CRA staff and on the adequacy of the CRA input data.

The figure below shows the argument and evidence structure supporting Argument **A2.2**:

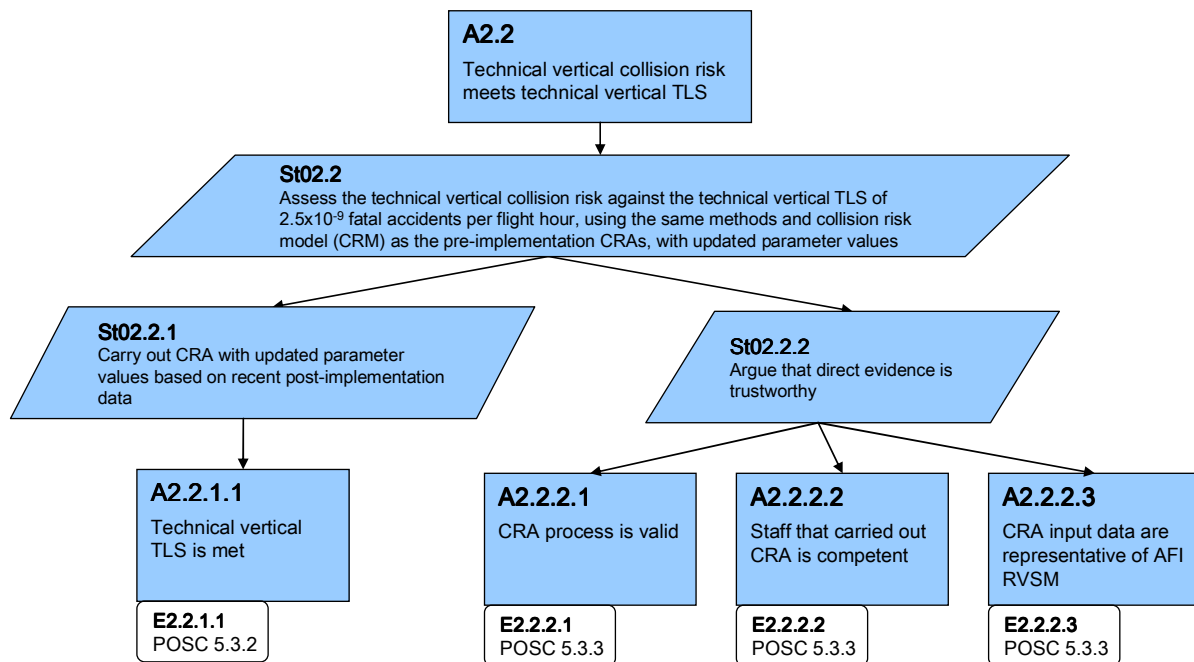


Figure 5: Argument A2.2 - Argument and evidence structure

¹¹ Vertical collision risk due solely to aircraft technical height-keeping performance

5.3.2 Direct evidence

A2.2.1.1: “Technical vertical TLS is met”

The technical vertical collision risk represents the risk of a collision between aircraft on adjacent flight levels due to typical height deviations of RVSM approved aircraft.

As set out in the CRA report [17], the technical vertical collision risk estimate for the time period 25 September 2008 - 30 September 2009 is 2.7×10^{-10} fatal accidents per flight hour, i.e. approximately an order of magnitude below the technical vertical TLS. The risk is essentially due the loss of vertical separation between opposite direction traffic at adjacent flight levels of a route. The results were derived by the CRM using aircraft population and traffic flow data obtained from the ARMA processes.

The risk estimate is to be considered in the context of several uncertainties like data limitations (cf. Section 5.3.3) and the proportion of aircraft using GNSS-based navigation. However, the current margin between the estimate and the TLS is deemed to be sufficient to cover the effect of these factors.

It can be concluded that the technical vertical TLS is met over the considered time period. All evidence details are provided in the CRA report [17].

Based on the above, **Argument A2.2.1.1 is valid.**

5.3.3 Backing evidence

A2.2.2.1: “CRA process is valid”

The CRA [17] was conducted using essentially the same methods and models as the pre-implementation CRAs [24], [25] and [26], with parameter values updated on the basis of the data available for the time period 25 September 2008 - 30 September 2009. These methods and models are based on suitable extensions and modifications of models previously used in ICAO and EUROCONTROL work for determining safe separation minima, and were thereby demonstrated as valid in the PISC [22].

Based on the above, **Argument A2.2.2.1 is valid.**

A2.2.2.2: “Staff that carried out CRA is competent”

The post-implementation CRA [17] was performed by the same staff who carried out the CRAs for the pre-implementation phase [24] [25] [26] and developed the PISC. That staff was also involved in the safety assessment of RVSM in the NAT and EUR Regions. Its competence was demonstrated as valid in the PISC (cf. Appendix G of reference [22]).

Based on the above, **Argument A2.2.2.2 is valid.**

A2.2.2.3: “CRA input data are representative of AFI RVSM”

The technical vertical collision risk estimate is to be considered in the context of several uncertainties like the limitations of the data available for the time period 25 September 2008 - 30 September 2009 (cf. Section 2.4.2 of the CRA [17]). In particular, the limitations of the traffic flow data (cf. Appendix B of the CRA), collected through ARMA Form 4¹², affect the passing frequency estimation and the annual flying time estimation in the AFI RVSM

¹² Cf. reference [9]

airspace¹³. This uncertainty is difficult to quantify but is believed to be less than an order of magnitude.

As set out Section 4.3 of the CRA, the current margin between the technical vertical TLS and the estimate of the technical vertical collision risk is believed to be sufficient to cope with the data limitations and the other uncertainties.

As a conclusion, the CRA input data are considered to be limited but not to affect the achievement of the technical vertical TLS of 2.5×10^{-9} fatal accidents per flight hour.

Therefore **Argument A2.2.2.3 is valid**, but steps must be taken to improve ARMA Forms 2 and 4 reporting, in particular to make the passing frequency more reliable. This particular issue is discussed under the requirement SM4 in Section 5.6.5.

5.3.4 Conclusion

Based on the argument and evidence detailed above, Section 5.3 shows:

- That the estimate of the technical vertical collision risk meets the technical vertical TLS of 2.5×10^{-9} fatal accidents per flight hour, that the requirement AC1 was therefore achieved over the time period 25 September 2008 - 30 September 2009; and consequently that **Argument A2.2 is valid**; and,
- That the traffic flow data reporting through ARMA operating procedures must be reinforced.

¹³ As addressed by the POSC, cf. Section 1.4

5.4 Total vertical collision risk

5.4.1 Strategy

A2.3: “Total vertical collision risk meets total vertical TLS”

A2.3 asserts the realisation of the requirement RVSM5 by the AFI RVSM system, i.e. that the probability of any failure within the AFI RVSM system leading to a mid-air collision due to the loss of vertical separation is within the total vertical TLS of 5×10^{-9} fatal accidents per flight hour, for the time period 25 September 2008 - 30 September 2009.

The strategy **St02.3** to show that **A2.3** is valid consists in:

- Assessing the total vertical collision risk against the total vertical TLS, using the same methods and collision risk model (CRM) as the PISC-related CRAs (cf. [24] [25] [26]) on the basis of the traffic flow and reported large atypical height-deviation data available for the considered time period.

In a similar way as for the technical vertical collision risk in Section 5.3, direct evidence is based on the results of the CRA for the total vertical collision risk, and backing evidence is based on the validity of the CRA process, on the competence of the CRA staff and on the adequacy of the CRA input data.

The figure below shows the argument and evidence structure supporting Argument **A2.3**:

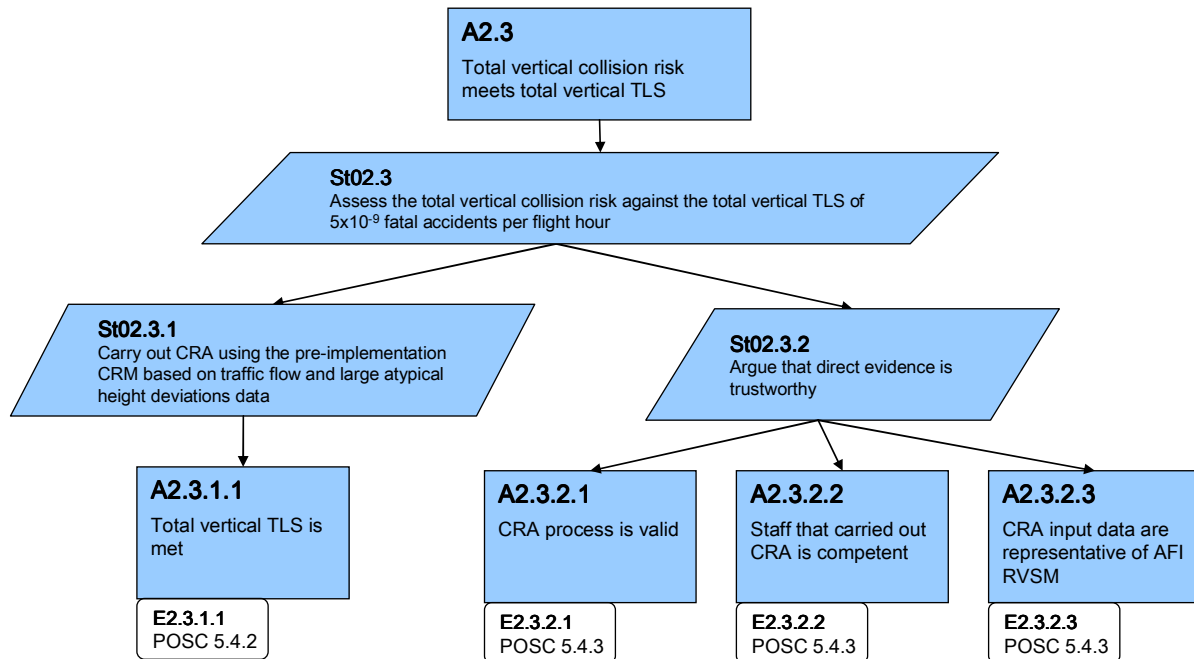


Figure 6: Argument A2.3 - Argument and evidence structure

5.4.2 Direct evidence

A2.3.1.1: “Total vertical TLS is met”

The total vertical collision risk represents the risk of a collision between aircraft due to all causes including normal typical and abnormal large atypical height deviations. The risk is therefore the combined effect of normal technical causes and of all additional causes. The estimate of the risk due to atypical height deviations is derived using data obtained via ARMA by three appropriate models:

- Large height deviations not involving whole numbers of flight levels
- Aircraft climbing or descending through a flight level without a proper clearance
- Aircraft levelling off at wrong level

As set out in the CRA report [17], the total vertical collision risk estimate for the time period 25 September 2008 - 30 September 2009 is 31.2×10^{-9} fatal accidents per flight hour, exceeding the total TLS by a factor of approximately 6.

The most critical component was found to be the vertical collision risk due to aircraft levelling-off at wrong flight level. This component has increased by almost an order of magnitude compared to the last pre-implementation CRA [26]. This is caused by increases in the number of reported events and the amount of time spent at a wrong flight level.

The risk estimate is to be treated with caution as it is conditional on many factors, the most important one being the completeness and representation of the traffic flow and large atypical height-deviation data available for the assessment. Another specific factor concerns the proportion of aircraft using GNSS-based navigation which is assumed to be of 50%. The effect of traffic flow data limitations and GNSS usage is essentially similar to that on the on the technical vertical collision risk.

It can be concluded that the total vertical TLS of 5×10^{-9} fatal accidents per flight hour is not met over the considered time period. All details are provided in the CRA report [17].

Based on the above, **Argument A2.3.1.1 is NOT valid.**

5.4.3 Backing evidence

A2.3.2.1: “CRA process is valid”

Evidence is provided in Section 5.3.3. On this basis, **Argument A2.3.2.1 is valid.**

A2.2.2.2: “Staff that carried out CRA is competent”

Evidence is provided in Section 5.3.3. On this basis, **Argument A2.3.2.2 is valid.**

A2.2.2.3: “CRA input data are representative of AFI RVSM”

The total vertical collision risk estimate is conditional on many factors, the most important one being the completeness and representation of the traffic flow and large atypical height-deviation data available for the assessment.

The most important parameter of the vertical collision risk models is the probability of vertical overlap due to large atypical height deviations. Two data sources have been used to estimate this parameter, namely, firstly, AFI ATS Incident Analysis Working Group’s (AIAG) 2008 and 2009 AIRPROX reports [27] [28] and, secondly ARMA Form 1 data¹⁴. Although both these data sources were very useful for the assessment, there remains considerable concern as to whether a complete and fully representative sample of vertical separation incident data has been obtained (cf. Section 3.3 of the CRA [17]). Regarding the risk due to aircraft levelling-off at wrong flight level, which was found to dominate the total vertical risk estimate, the times spent at wrong opposite- and same-direction flight levels had to be estimated conservatively due to a lack of precise data.

As for the technical vertical collision risk, the limitations of the traffic flow data (cf. Section 2.4.2 of the CRA) affect the passing frequency estimation and the annual flying time in the AFI RVSM airspace¹⁵. The probabilities of vertical overlap due to atypical large height deviations are sensitive to the flight hour estimates for the FIRs concerned, especially for the Cape Town and Johannesburg FIRs¹⁶.

As a conclusion, the CRA input data are considered to be limited but not to affect the estimation that the total vertical TLS of 5×10^{-9} fatal accidents per flight hour is not met.

Therefore **Argument A2.2.2.3 is deemed to be valid**, although steps must be taken to improve traffic flow and large height-deviation data reporting through ARMA processes, to make the passing frequency, the annual flying time, and the probability of vertical overlap estimation more reliable, and therefore to give a higher degree of confidence in the results. This particular issue is discussed under the requirements SM3 and SM4 in Sections 5.6.4 and 5.6.5 respectively.

¹⁴ Cf. reference [9].

¹⁵ As addressed by the POSC, cf. Section 1.4

¹⁶ Represent 43% of the total number of flight hours used for the risk component due to large height deviations.

5.4.4 Conclusion

Based on the argument and evidence detailed above, Section 5.4 shows:

- That the estimate of the total vertical collision risk exceeds the total vertical TLS of 5×10^{-9} fatal accidents per flight hour by a factor of approximately 6, that the requirement RVSM5 was therefore not achieved over the time period 25 September 2008 - 30 September 2009; and consequently that **Argument A2.3 is NOT valid**; and,
- That the traffic flow data reporting through ARMA operating procedures must be reinforced.
- That the vertical separation incident (large height-deviations) reporting through ARMA and AIAG processes must be consistent and reinforced.

5.5 ATM-induced accidents and serious incidents

5.5.1 Strategy

A2.4: “AFI RVSM Concept complies with RVSM6”

A2.4 asserts that the number of ATM-induced accidents and serious or risk-bearing incidents in AFI RVSM airspace have not increased from CVSM levels, and where possible have decreased.

Safety occurrences are reported in the AFI Region through three mechanisms, namely the AFI ATS Incident Analysis Working Group (AIAG), the AFI Tactical Action Group (TAG) and the AFI Regional Monitoring Agency (ARMA).

Lack of quantitative data on safety occurrences prior to the introduction of RVSM¹⁷ means that a direct ‘before and after’ comparison would be very uncertain, and an absolute approach is therefore needed.

The strategy **St02.4** to show that **A2.4** is valid consists in:

- Assessing absolute risks arising from AFI RVSM hazards on the basis of the safety occurrences data available for the time period 25 September 2008 - 30 September 2009.

It should be noted that the risks have been mitigated as far as practical, as a result of the review of the risk mitigation strategy specified prior to RVSM introduction (cf. Section 4.2.1).

Direct evidence is based on the results of the risk assessment conducted as part of the FHA review [18] and backing evidence is based on the validity of the FHA models, risk assessment process and input data.

The figure below shows the argument and evidence structure supporting Argument **A2.4**:

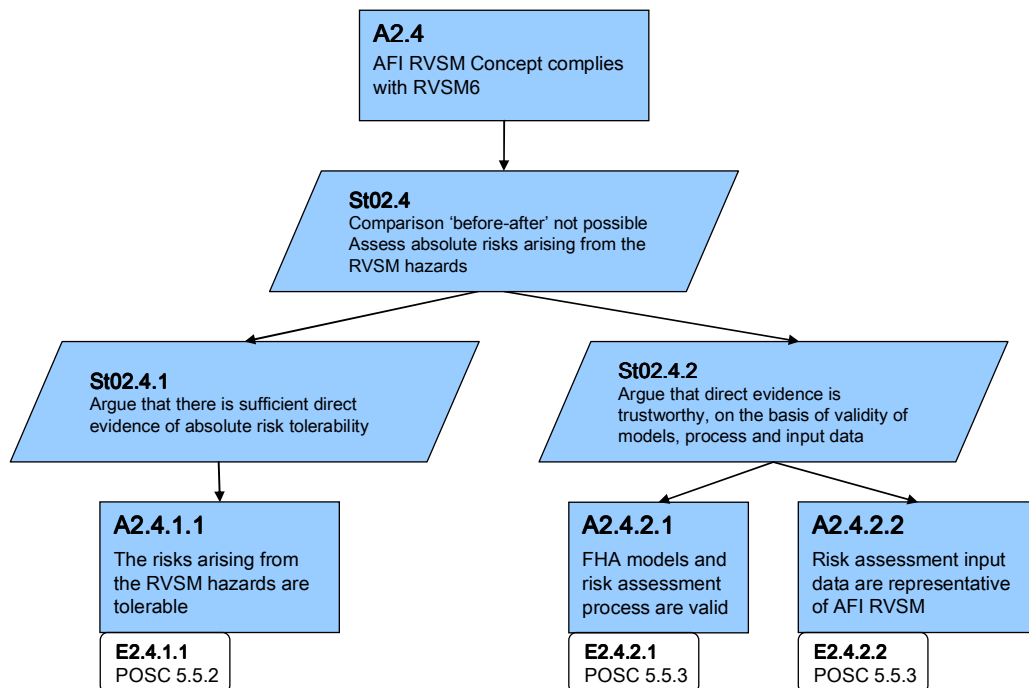


Figure 7: Argument A2.4 - Argument and evidence structure

¹⁷ The AFI Tactical Action Group UCRs have been established after RVSM introduction and AIAG final report for 2009 is not available to date.

5.5.2 Direct evidence

A2.4.1.1: “The risks arising from the FHA hazards are tolerable”

The risks arising from the identified hazards have been assessed through an estimation of the frequency of occurrence of the hazards, on the basis of the reported safety occurrences over the time period September 2008 - September 2009, completed by operational judgment of the FHA review experts, and assessed against the specified safety objectives.

The risks from a non-RVSM aircraft being given 1000 feet separation (H1) have been assessed as tolerable (H1a, undetected by ATS) and acceptable (H1b, detected by ATS at initial contact on frequency). They may increase in the future due to dormant conditions related to the presence of non-RVSM civil aircraft in the AFI RVSM airspace, A/G communications and coordination between ATS units.

The risk from a non-RVSM civil aircraft operating in the AFI RVSM airspace (H2) has been assessed as acceptable. It may increase in the future due to dormant condition related to the presence of non-RVSM civil aircraft in the AFI RVSM airspace.

The risk from an aircraft being assigned a potentially conflicting flight level (H3) has been assessed as not tolerable. It means that the associated risk mitigation strategy is not completely and correctly implemented by the States. The main risk contributing factors are failures related to A/G communications, ATS performance, coordination between ATS units and flight crew discipline. In addition, the risk may increase in the future due to dormant conditions in the above mentioned areas.

The risk from an aircraft deviating from cleared flight level (situation unknown by flight crew, H4a) has been assessed as not tolerable. The main contributing factors are undetermined due to safety occurrences data limitation.

The risk from an aircraft deviating from cleared flight level (situation known by flight crew, H4b) has been assessed as tolerable. It may increase in the future due to dormant conditions related to A/G communications and flight crew discipline.

It should be noted that the non tolerability of hazards H3 and H4a is to some extent consistent with the assessment of the total vertical collision risk (cf. Section 5.4) which was showed to exceed the total vertical TLS and, moreover, to be dominated by the risk due to aircraft levelling-off at wrong flight level.

Further evidence can be found in Appendix C.5.4 and in reference [18].

Based on the above, **Argument A2.4.1.1 is NOT valid.**

5.5.3 Backing evidence

A2.4.2.1: “FHA models and risk assessment process are valid”

Evidence is provided in Section 4.3.2. On this basis, **Argument A2.4.2.1 is valid.**

A2.4.2.2: “Risk assessment input data are representative of AFI RVSM”

As set out in Appendix E.1 of reference [18], the reported safety occurrences data included:

- AIAG: AIRPROX (ATS incidents) reports [27] [28] and ATS irregularities reports [29] [30]
- TAG: ‘New’ and ‘Resolved’ Unsatisfactory Condition Reports (UCR) [31] [32]
- ARMA Form 1¹⁸ data [33]

As set out in Appendix E.4 of reference [18], these data were limited as not covering the entire September 2008 - September 2009 time period and as providing limited information making the occurrence classification sometimes not possible. In addition, safety occurrences in the AFI region (like in any other region) are underreported as shown by a close examination of the data reported to the ARMA.

These limitations were taken into account when completing the frequency occurrence estimation by operational expert judgment, and did not have a bearing effect on the risk assessment results.

As a conclusion, the risk assessment input data are considered to be limited but not to affect the estimations made thereon.

Therefore **Argument A2.4.2.2 is deemed to be valid**, although steps must be taken to improve the safety occurrences reporting and assessment in the AFI Region to support mapping with the AFI RVSM hazard models and to make the subsequent risk assessment more reliable. This particular issue is discussed under the requirement SM3 in Section 5.6.4.

5.5.4 Conclusion

Based on the argument and evidence detailed above, Section 5.5 shows:

- That the risks arising from an aircraft being assigned a potentially conflicting flight level (H3) and from an aircraft deviating from cleared flight level (situation unknown by flight crew, H4a) are not tolerable over the time period 25 September 2008 - 30 September 2009; that the requirement RVSM6 is not achieved, and consequently that **Argument A2.4 is NOT valid**; and,
- That the safety occurrences reporting and assessment through TAG, AIAG and ARMA mechanisms must be reinforced.

¹⁸ Cf. reference [9].

5.6 AFI RVSM system monitoring

5.6.1 Strategy

A2.5: “Design of SM element complies with SM SERs”

A2.5 asserts the realisation of the system monitoring requirements by the AFI RVSM Concept (i.e. in the design of the AFI RVSM system):

- SM1: “The exclusion of non-RVSM approved non-State aircraft from AFI RVSM airspace shall be monitored”
- SM2: “The height-keeping performance of RVSM-approved aircraft shall be monitored”
- SM3: “Data on operational errors shall be collected for collision risk estimation”
- SM4: “Data on risk exposure shall be collected for collision risk estimation”
- SM5: “Data on ACAS/TCAS events shall be collected and evaluated”

The five requirements SM1 - SM5 were addressed before the implementation by the development of appropriate arrangements operated by the ARMA in conformity with the operating procedures contained in the ARMA Manual [9]. Due account were taken from the experience gained in other ICAO Regions where RVSM had been implemented in a previous stage.

The strategy **St2.5** to show that **A2.5** is valid consists in showing that the monitoring arrangements operated by ARMA are effective, in light of the ARMA experience and of the experience following the development of the present POSC.

The figure below shows the argument and evidence structure supporting Argument **A2.5**:

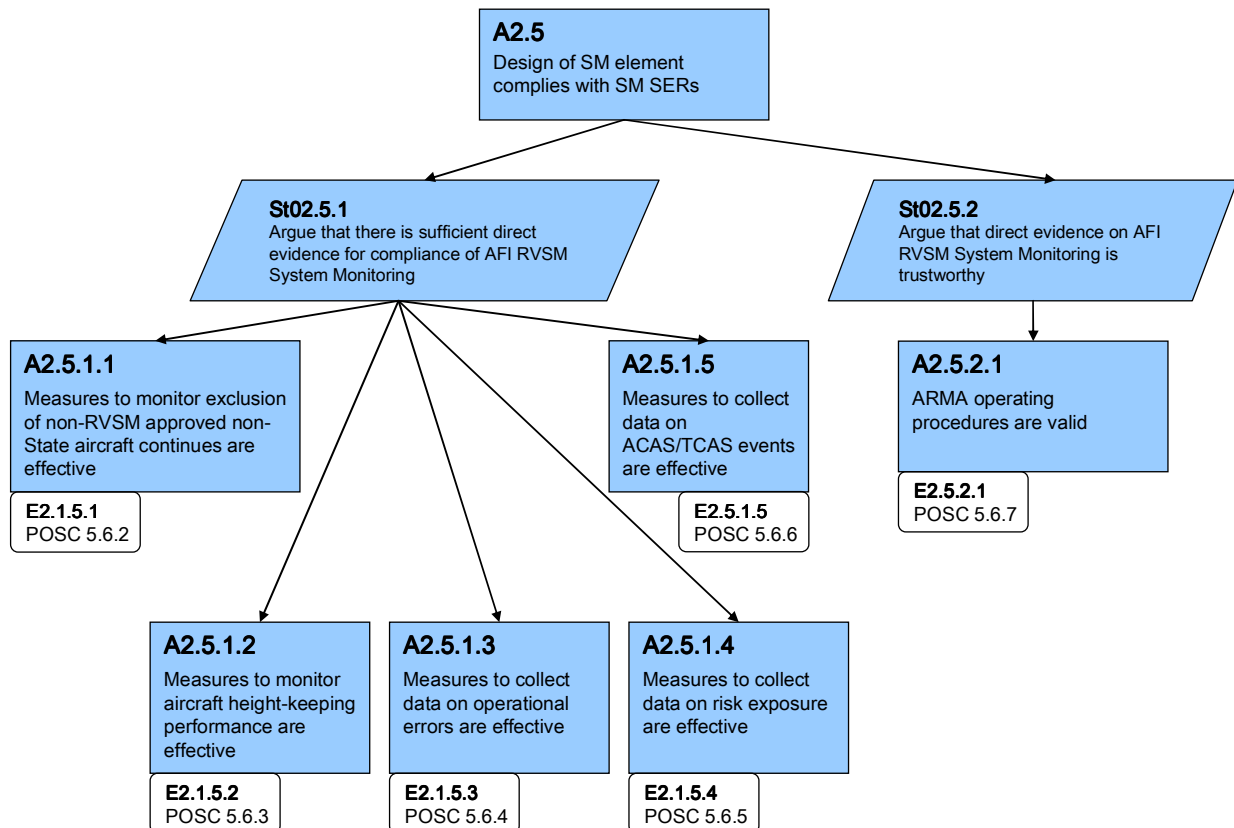


Figure 8: Argument A2.5 - Argument and evidence structure

5.6.2 Measures to monitor exclusion of non-RVSM approved non-State aircraft from AFI RVSM airspace

A2.5.1.1 : “Measures to monitor exclusion of non-RVSM approved non-State aircraft from AFI RVSM airspace are effective”

As one of its core functions [9], the ARMA has established and maintains a database of RVSM approvals, on the basis of the information reported by the States through ARMA Form 2 (approval) and Form 3 (approval withdrawal) processes. The database is available on the ARMA webpage (cf. www.atns.co.za) where the General Aviation Community can view the status of the AFI RVSM compliant fleet as submitted by States/CAAs.

ARMA retrospectively processes the traffic data received from States to verify the validity of the RVSM approval status as filed by the operators. States/CAAs are queried in cases where discrepancies are found in order to minimise the likelihood of non-RVSM approved aircraft entering into AFI RVSM airspace. Where an aircraft has not been approved, ARMA requests the State/CAA to take remedial action and reports to the TAG for follow-up in order to obtain a satisfactory result.

The experience has shown the following:

- Many States/CAAs in conjunction with their aircraft operators have chosen to ignore the AFI RVSM operational approvals requirements and often do not respond to ARMA requests to update their fleets' status. This necessitates the ARMA continually contacting States/CAAs for verifications and update.
- Some aircraft based in the Region complies with MASPS but are not State approved: there is a gap between some States' commitments in the NSPs with regards to RVSM approval processes and the reality

The assessment of the risks associated with the RVSM hazards (cf. Section 5.5) has shown that the risk from a non RVSM civil aircraft operating in the AFI RVSM airspace is acceptable. However, the review of the safety occurrences carried out as part of the assessment has shown that an important number of non-RVSM civil aircraft operate in the AFI RVSM airspace. This constitutes a dormant condition within the AFI RVSM System which can generate in the future a degradation of the risk level.

On this basis, **Argument A2.5.1.1 is valid**, although the following is recommended:

- Survey of State-level practises and procedures related to the handling of non-RVSM civil aircraft in RVSM airspace
- Reinforcement of States' capabilities and diligence with regards to operator and aircraft RVSM approval
- Reinforcement of States' diligence with regards to ARMA Forms 2 and 3 reporting.

5.6.3 Measures to monitor aircraft height-keeping performance

A2.5.1.2 : “Measures to monitor aircraft height-keeping performance are effective”

As one of its core functions [9], the ARMA maintains the AFI Height Monitoring database and has a GMU Height Monitoring Service provider that monitors airframes that are restricted to AFI or that do not fly over the HMU installations in Europe. The AFI Height Monitoring plan is available on the ARMA webpage.

The experience has shown that many AFI States/CAAs in conjunction with their aircraft operators have chosen to ignore the AFI RVSM height monitoring requirements (see Appendix E) and often does not respond to ARMA requests as to their to plan to remedy this deficiency. The General Aviation Community can view on the ARMA webpage the non compliant States/CAAs and by implication the offending aircraft operator.

As the AFI Height Monitoring processes are valid (see also Section 5.6.7), **Argument A2.5.1.2 is valid**, although States/CAAs and aircraft operators must be urged to comply with the applicable height monitoring requirements.

5.6.4 Measures to collect data on operational errors

A2.5.1.3 : “Measures to collect data on operational errors are effective”

As one of its core functions [9], ARMA monitors the occurrence of the operational errors. Such errors are reported by the States/ANSPs through ARMA Form 1 process. The collected data are used in the assessment of the total vertical collision risk (cf. Section 5.4).

As part of the present POSC, the data have also been used in the assessment of the risks arising from the AFI RVSM hazards, as part of the assessment of the ATM-induced accidents and serious incidents (cf. Section 5.5). In addition, they have been completed by two other sources, namely:

- AIAG data : AIRPROX (ATS incidents) reports [27] [28] and ATS irregularities reports [29] [30]
- TAG¹⁹ data: ‘New’ and ‘Resolved’ Unsatisfactory Condition Reports (UCR) [31] [32]

The experience has shown that:

- There remains considerable concerns as to whether a complete and fully representative sample of data has been obtained (cf. Sections 5.4.3 and 5.5.3)
- The information on individual operational errors was limited (cf. Section 5.5.3)

Although limited, the data were very useful and have been shown as not affecting the estimations made thereon.

Based on the above, **Argument 2.5.1.3 is valid**, although, in order to make the assessments more reliable:

- The discipline of reporting by the States of the operational errors through ARMA, AIAG and TAG operating procedures should be improved
- The outcome of the ARMA and AIAG processes should be consistent
- The AIAG and/or TAG (as appropriate) processes should be improved to provide the information necessary to support the mapping with the AFI RVSM hazard models

¹⁹ TAG data have not been used in the assessment of total vertical collision risk

5.6.5 Measures to collect data on risk exposure

A2.5.1.4 : “Measures to collect data on risk exposure are effective”

As set out in Section 3 of ICAO Doc 9754 [8], two methods exist for estimating risk exposure, namely the use of flight progress information or radar data. As set out in Section 4.3.9.6 of the PISC [22], the flight progress information method is used for AFI RVSM. The data are collected through ARMA Form 4²⁰ process and are used in the assessment of the total and technical vertical collision risks.

As set out in Sections 5.3.3 and 5.4.3, the experience in the CRA [17] has shown that the traffic flow data were limited. In particular, this has affected the passing frequency and annual flying time estimations.

As the data collection procedures are valid (see Section 5.6.7), it is concluded that the limitations results from a deficient reporting discipline within the States affiliated to ARMA (cf. Section 1.1).

On this basis, **Argument A2.5.1.4 is valid**, although steps must be taken to improve ARMA Form 2 reporting discipline.

5.6.6 Measures to collect data on ACAS/TCAS events

A2.5.1.5 : “Measures to collect data on ACAS/TCAS events are effective”

ACAS/TCAS events are reported through AIAG [16] and ARMA Form 3 [9] mechanisms. Where applicable, the events reported for the time period 25 September 2008 - 30 September 2009 have been worded in the CRA [17]. The experience has shown that they were satisfactory.

On this basis, **Argument A2.5.1.5 is valid**.

5.6.7 Backing evidence

A2.5.2.1 : “ARMA operating procedures are valid”

ARMA operating procedures with regards to AFI RVSM System monitoring are contained in the ARMA Handbook [9] which provides guidance in order to achieve a standardized approach to the way in which RMA in each region carry out its functions and the associated detailed duties and responsibilities as set out in ICAO Doc 9574 [8].

ARMA operating procedures are thereby harmonised on a worldwide basis, taking account of the experience gained in each Region. In this regard, ARMA reports certain activities to ICAO Montreal and belongs to the Global RMA committee following which the ARMA Handbook is updated as necessary.

On this basis, **Argument A2.5.2.1 is valid**.

²⁰ Cf. reference [9]

5.6.8 Conclusion

Based on the argument and evidence detailed above, Section 5.6 shows:

- That RVSM system monitoring arrangements operated by ARMA are effective and valid, and consequently that **Argument A2.5 is valid**.
- That States' capabilities and diligence with regards to operator and aircraft RVSM approval should be reinforced
- That State-level practises and procedures related to the handling of non-RVSM civil aircraft in RVSM airspace should be surveyed
- That States' discipline with regard to RVSM approvals and traffic flow data reporting through ARMA operating procedures should be improved
- That States and aircraft operators should be urged to comply with the applicable height monitoring requirements.
- That States' discipline with regards to operational errors reporting through ARMA, AIAG and TAG operating procedures should be improved
- That the outcome of the ARMA and AIAG operational errors reporting and assessment processes should be consistent
- That the AIAG and/or TAG (as appropriate) processes should be improved to provide the information necessary to support the mapping of the operational errors with the AFI RVSM hazard models

5.7 Conclusion

Based on the argument and evidence detailed above, it has been particularly shown in this Section 5:

- That the design of the AFI RVSM system complies with the 'new' system element requirements, provided that appropriate evidence is developed in accordance with the pre-defined approach of satisfaction;
- That the estimate of the technical vertical collision risk meets the technical vertical TLS of 2.5×10^{-9} fatal accidents per flight hour, and that the requirement AC1 was therefore achieved over the time period 25 September 2008 - 30 September 2009;
- That the estimate of the total vertical collision risk exceeds the total vertical TLS of 5×10^{-9} fatal accidents per flight hour by a factor of approximately 6, and that the requirement RVSM5 was therefore not achieved over the time period 25 September 2008 - 30 September 2009;
- That the risks arising from an aircraft being assigned a potentially conflicting flight level (H3) and from an aircraft deviating from cleared flight level (situation unknown by flight crew, H4a) are not tolerable over the time period 25 September 2008 - 30 September 2009; and that the requirement RVSM6 is not achieved;

On this basis, it can be concluded that **Argument A2 is NOT valid**.

Page intentionally left blank.

6. Argument 3: Validity of PISC

- ☞ This objective of this Section is to set out the detailed arguments, strategies and evidence that the principal safety argument A3 is valid.

6.1 Strategy

A3: “The issues that were outstanding in the PISC, and the assumptions made therein, have been addressed satisfactorily”

A3 asserts the confirmation of the validity of the PISC, following the strategy **St00.2**. It addresses the PISC outstanding issues that would have a bearing on the AFI RVSM safety.

The strategy **St03** to show that Argument **A3** is valid consists in:

- Showing that:
 - Switchover on 25 September 2008 was entirely successful
 - Issues regarding level busts have been addressed satisfactorily
 - All PISC assumptions are addressed as an integral part of the POSC
 - All PISC actions have been addressed satisfactorily
 - Issues regarding airspace classification have been addressed satisfactorily

The figure below shows the argument and evidence structure supporting Argument **A3**:

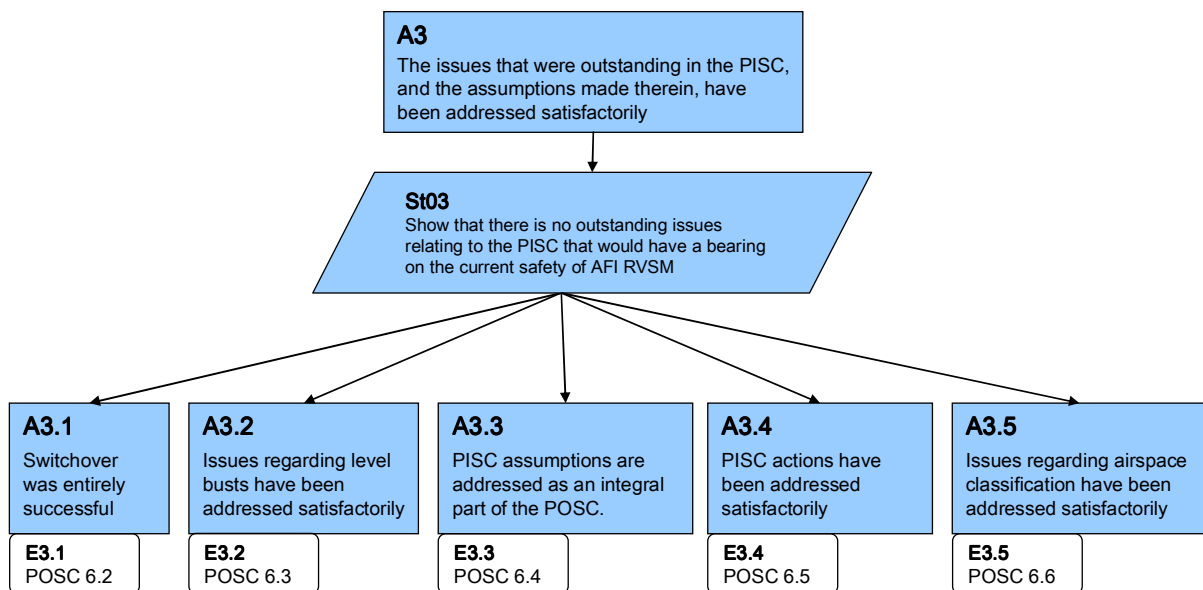


Figure 9: Argument A3 - Argument and evidence structure

6.2 Switchover

A3.1: “Switchover was entirely successful”

As set out in the Section 6.3.1.1 of the PISC [22], a detailed Switch-Over Plan was issued by the ARTF/9 and documented in reference [21]. It addressed the principal concerns of the General Aviation Community and aimed to provide guidance for the development of States Switch-Over Plans, particularly on the mitigations related to the switch-over hazards.

In application of this plan, an AFI RVSM Quick Response Team was established and managed by ARPO and ARMA with the support of ASECNA, ATNS and IATA in order to ensure that the switchover operations on 25 September 2009 were effectively monitored. ARPO/ARMA in South Africa and ASECNA in Senegal served as a focal point during the switchover providing assistance on RVSM implementation matters to the States, ANSPs and Aircraft Operators on an on-demand basis. States/ANSPs were required to report through NPM all significant events occurring in their area of operations.

A close down report of AFI RVSM Implementation [20] was published on 29 September 2008 by ARPO and ARMA as follows:

“The implementation of RVSM in AFI took place as published in the various aeronautical publications on 25 September 2008 0001 UTC.

ARPO & ARMA are pleased to record that the implementation proceeded without any safety problems and to date no incidents involving operational errors leading to Large Height Deviations were recorded.

The RVSM system is being closely monitored providing an indication that there are a few minor administrative problems resulting from flight planning and the RVSM approval of aircraft which is being addressed on a continuous basis by ARMA, ARPO and the respective NPM’s. These can be considered as initial post implementation administrative problems which will be resolved as all parties grow accustomed to RVSM and the practicalities.

The quick response teams based in Dakar Senegal and Johannesburg South Africa have closed operations however ARMA & ARPO are still available in their respective offices to take queries and attend to any incidents that may arise, including operational errors.

The Dakar Quick response team and all FIR’s have reported back to ARMA and ARPO that RVSM has been successfully implemented and is operational without any undue problems. All reports received have also indicated that there have been no large height deviations recorded as a result of operational errors. This will be continuously monitored and addressed by ARMA if the need arises.

In summary AFI RVSM has been implemented in an orderly and safe manner and both ARPO & ARMA have emphasized to all ACCs that RVSM must now be maintained to the high standards that were evident during implementation. RVSM vigilance must be maintained at all times which will be monitored by ARMA as tasked.

In closing the respective ACCs are to continue with the safe management of RVSM in their respective FIRs”

On this basis, it can be concluded that the AFI RVSM switchover went very smoothly without any safety issues, meaning that the switchover mitigations resulting from the PISC were implemented and effective.

Consequently, **Argument A3.1 is valid.**

6.3 Level busts

A3.2: “Issues regarding level busts have been addressed satisfactorily”

The previous FHA [23] had concluded that the risk of flight crew deviating from clearance as not tolerable because the expected rate of occurrence exceeded the limit for hazards of the assessed level of severity. However, as set out in Section 4.7.2 in the PISC [22], it was concluded, taking into account different factors, that the rate of occurrence was potentially overestimated.

The FHA review [18] reassessed the risk from level busts as part of the hazard H4a “Aircraft deviates from cleared flight level (situation unknown by flight crew)” and concluded about its non tolerability.

Level busts or large height deviations are taken into account as operational errors in the assessment of the total vertical collision risk. As set out in Section 5.4.2, the total vertical TLS have been assessed as exceeded by a factor of approximately 6 and the component of the total vertical collision risk due to improper flight level crossings is of the same order of magnitude as in the last pre-implementation CRA [26].

It is therefore concluded that level busts remain an important concern of AFI RVSM safety, and that measures should be pursued to reduce their occurrence. Such measures should be based on the mitigation strategy developed for the hazard H4a, cf. Appendix D.

Based on the above, **Argument A3.2 is NOT valid.**

6.4 PISC assumptions

A3.3: “PISC assumptions are addressed as an integral part of the POSC”

The assumptions made in the PISC were resulting from the previous FHA and CRA. No specific assumption was made in the PISC itself; see Section 7 of reference [22].

The table below shows that the previous CRA assumptions have been addressed as part of the present safety case.

| | |
|---|----------------------------------|
| 50% of the flying time is GNSS navigation flying time | Cf. Section 7.2 |
| 50% of the flying time is conventional navigation flying time | Cf. Section 7.2 |
| Traffic samples are representative of AFI traffic | Cf. Sections 5.3.3, 5.4.3, 5.6.5 |
| There is an under reporting of operational errors | Cf. Section 5.4.3, 5.6.4 |
| The total flying hours for AFI are correct | Cf. Sections 5.3.3, 5.4.3 |

The previous FHA assumptions have been validated conclusively as an integral part of the AFI RVSM System as the subject of the FHA review report, see reference [18].

Based on the above, **Argument A3.3 is valid.**

6.5 PISC actions

A3.4: “PISC actions have been addressed satisfactorily”

The actions raised at the time of the PISC concerned the switch-over from CVSM to RVSM as well as the commitments contained within the National Safety Plans produced by the participating State.

The switch-over actions are evidently considered to be completed.

The NSP actions are beyond the scope of the present POSC, as set out in Section 1.4.

Based on the above, **Argument A3.2 is valid.**

6.6 Airspace classification

A3.5: “Issues regarding airspace classification has been addressed satisfactorily”

The entire AFI RVSM airspace is meant to be a Class A, a controlled airspace where positive air traffic control (ATC) service is provided uniformly, in consistency with Recommendation 5/21 of the Seventh AFI Regional Air Navigation Meeting (AFI/7, 1997) [13].

This issue was raised at the time of the development of the PISC [22] and during the FHA review [18] carried out as part of the present POSC.

The discussions from the FHA review meetings has shown that there are continuing concerns about those airspace or air route portions within AFI RVSM airspace which still remain in Class F and Class G, that is with only advisory air traffic service and flight information service respectively.

This has an increasing effect:

- in the complexity of the provision of ATC by air traffic controllers and in the potential ATC errors due to an heterogeneous set of rules applicable in a given airspace
- consequently in the risk of an aircraft levelling-off at wrong level addressed as part of the total vertical collision risk showed as not meeting the total vertical TLS (cf. Section 5.4) and of the risk of an aircraft being assigned a potentially conflicting flight level - hazard H3 - showed as not acceptable (cf. Section 5.5).

Based on the above, **Argument A.3.5 is NOT valid.**

6.7 Conclusion

Based on the argument and evidence detailed above, Section 6 shows:

- That the switch-over was entirely successful
- That all PISC assumptions are addressed as an integral part of the POSC
- That all PISC actions have been addressed satisfactorily
- That level busts and airspace classification issues continue to be outstanding
- Consequently, that not all the issues that were outstanding in the PISC have been addressed satisfactorily

On this basis, it can be concluded that **Argument A3 is NOT valid.**

7. Assumptions

- ☞ This Section summarises the assumptions made at various points of the development of the present Safety Case, and of its two main contributions that are the CRA report [17] and the FHA review report [18].

7.1 Assumptions made in the POSC

The present POSC is based on the following assumptions:

| Id. | Assumption | Comment |
|-----|---|--|
| A02 | PISC SERs confirmed by the review (except AC1 and SM), continue to be realised by the system elements | Evidence documentary baseline as changed since the PISC. Management of applicable AFI RVSM documentation is an ICAO responsibility. Cf. Section 5.1. |

Table 4: Assumptions made in the POSC

7.2 Assumptions made in the CRA

The CRA is based on the usual assumptions made in the field of aircraft collision risk modelling and estimation, see references [17] [24] - [26] and the references to collision risk modelling therein.

One specific assumption made for the post-implementation CRA for AFI RVSM is:

| Id. | Assumption | Comment |
|------|--|--|
| CRA1 | 50% of the flying time in AFI RVSM airspace is made with GNSS navigation and the remaining 50% with VOR/DME conventional navigation. | Precision of lateral navigation as an increasing effect on the vertical collision risks estimates. |

Table 5: Assumptions made in the CRA

7.3 Assumptions made in the FHA review

The FHA review is based on several assumptions made along the process, especially for the assignment of safety objectives to the identified hazards, see reference [18]. The final and qualitative results of the review (integrity SERs, risk assessment) are however not sensitive to these assumptions.

Page intentionally left blank.

8. Outstanding safety issues

☞ This Section the outstanding safety issues to be resolved for the POSC claim to be true, provided that the assumptions made are valid.

| Id. | Outstanding safety issues | Remarks |
|-----------------|---|--|
| 1 ²¹ | Evidence of the realisation of the new integrity requirements is not provided. | AFI RVSM Safety Objective (i) Argument A.2.2 validity is <u>subject to</u> successful management of the requirements in the ICAO regional documentation for AFI RVSM, cf. Section 5.2 |
| 2 | Total vertical TLS of 5×10^{-9} fatal accidents per flight hour is exceeded by a factor of approximately 6. | AFI RVSM Safety Objective (iv) Argument A2.3 <u>not</u> valid, cf. Section 5.4 |
| 3 | The risks arising from an aircraft being assigned with a wrong flight level and from an aircraft deviating from cleared flight level (situation unknown by flight crew) have been assessed as not tolerable | AFI RVSM Safety Objective (ii) Argument A2.4.1.1 <u>not</u> valid, cf. Section 5.5 PISC outstanding issue Argument A3.2 <u>not</u> valid, cf. Section 6.3 |
| 4 | The entire AFI RVSM airspace is not in class A, there are airspace or air route portions which remain in Class F and Class G. | PISC outstanding issue Argument A3.6 <u>not</u> valid, cf. Section 6.6 |

Table 6: POSC outstanding safety issues

²¹ This is considered as outstanding (i.e. clearance thereof is necessary for the claim can be valid) though the lack of evidence on SER realisation is not an evidence of the lack of SER realisation.

Page intentionally left blank.

9. Recommendations

- ☞ This Section provides a set of safety recommendations to the attention of ICAO for further action, and consideration at State, Air Navigation Services Providers and Aircraft Operator levels. The recommendations relate to actions proposed at various points in this Safety Case and in its two main contributions, namely the CRA report [17] and the FHA review report [18].

| Id. | Recommendations | Rationale / Comment |
|-----------------------------------|---|---|
| AFI RVSM system monitoring | | |
| 1 | States' discipline with regards to RVSM approvals data reporting through ARMA operating procedures should be improved | ARMA experience, Cf. Section 5.6.2 |
| 2 | States/CAAs and aircraft operators should be urged to comply with the AFI Height Monitoring requirements. | ARMA experience, Cf. Section 5.6.3 TAG, IATA and APIRG to be used as vehicles to apply the required pressure in order to obtain conformance. |
| 3 | States' discipline with regards to operational errors reporting through ARMA, AIAG and TAG operating procedures should be improved | Limitations affect the reliability of the probability of vertical overlap due to large height deviations used for the assessment of the total vertical collision risk (CRA); and of the assessment of the risks arising from the AFI RVSM hazards (FHA review). Cf. Section 5.6.4. |
| 4 | The outcome of the ARMA and AIAG operational errors reporting and assessment processes should be consistent | Limitations affect the reliability of the probability of vertical overlap due to large height deviations used for the assessment of the total vertical collision risk (CRA); Cf. Section 5.6.4. |
| 5 | The AIAG and/or TAG (as appropriate) processes should be improved to provide the information necessary to support the mapping of the operational errors with the AFI RVSM hazard models | Limitations affect the reliability of the assessment of the risks arising from the AFI RVSM hazards (FHA review) Cf. Section 5.6.4. |

| Id. | Recommendations | Rationale / Comment |
|--|--|--|
| 6 | States' discipline with regards to traffic flow data reporting through ARMA operating procedures should be improved. | <p>Limitations affect the reliability of the passing frequency and the annual AFI RVSM flying time used for the assessment of the vertical collision risks (CRA).</p> <p>ARMA experience</p> <p>Cf. Section 5.6.5.</p> |
| 7 | Proportion of aircraft using GNSS-based navigation use in the AFI RVSM airspace should be monitored. | <p>Increasing proportion in AFI (PBN initiatives).</p> <p>Assumption CRA1.</p> |
| AFI RVSM safety requirements | | |
| 8 | Evidence of the realisation in the ICAO AFI RVSM documentation of the new integrity safety requirements should be developed on the basis of the proposed strategy. | <p>Outstanding safety issue 1.</p> <p>Proposed strategy is provided in Appendix D.</p> |
| 9 | The continuing realisation in the ICAO AFI RVSM documentation of the PISC safety requirements should be verified | <p>Assumption A02.</p> <p>Management of the AFI RVSM Concept and subsequent applicable documentation is an ICAO responsibility.</p> |
| AFI RVSM system possible improvements | | |
| 10 | Strategic Lateral Offset Procedures should be implemented in the AFI RVSM airspace in compliance with PANS-ATM provisions [6]. | <p>Outstanding safety issue 2: SLOPs counteract the adverse effect of GNSS navigation accuracy on the vertical collision risks (CRA).</p> <p>Outstanding safety issue 3: possible mitigation for hazard H4</p> |
| 11 | Strategic Lateral Offset Procedures for AFI RVSM should be harmonised on a regional basis. | <p>Non uniform use of SLOP was observed in the reported safety occurrences (FHA review report).</p> |
| 12 | The use of ATS surveillance systems in the provision of area air traffic control service should be reinforced where appropriate | <p>Outstanding safety issue 3:</p> <p>Possible additional mitigation (hazard H4)</p> |
| 13 | The use of CPDLC application in the provision of area air traffic control service should be reinforced where appropriate | <p>Outstanding safety issue 3:</p> <p>Possible additional mitigation (hazards H1, H3 and H4)</p> |
| 14 | Unidirectional and/or parallel tracks should be implemented where appropriate. | <p>Outstanding safety issue 3:</p> <p>Possible additional mitigation (hazard H4)</p> |

| Id. | Recommendations | Rationale / Comment |
|---|--|--|
| AFI RVSM system operations | | |
| 15 | States/ANSPs should be urged to implement class A airspace in their entire RVSM area of responsibility. | Outstanding safety issue 4 |
| 16 | State-level practises and procedures related to the handling of non-RVSM civil aircraft in RVSM airspace should be surveyed | Identified dormant conditions (H1a, H1b and H2) Cf. Section 5.6.2 |
| 17 | States' capabilities and diligence with regards to operator and aircraft RVSM approval should be reinforced. | Experience reported to ARMA: gap between States' commitments contained in the NSP and the reality. Cf. Section 5.6.2 |
| AFI RVSM system safety performance | | |
| 18 | Measures to significantly improve ATS performance (organisation, equipment, procedures, proficiency) should be taken as a matter of highest priority | Outstanding safety issue 3: Main contributory factor (hazard H3, not tolerable) |
| 19 | Measures to significantly improve A/G communications performance (e.g. coverage, reliability) should be taken as a matter of highest priority | Outstanding safety issue 3: Main contributory factor (hazards H3 and H4b, not tolerable) Identified dormant conditions (H1a, H3 and H4b) |
| 20 | Measures to significantly improve the performance of the coordination between ATS units (G/G communications, procedures, training) should be taken as a matter of highest priority | Outstanding safety issue 3: Main contributory factor (hazard H3, not tolerable) Identified dormant conditions (H1a, H1b and H3) |
| 21 | Flight crew discipline should be reinforced | Outstanding safety issue 3: Main contributory factor (hazard H3 and H4b, not tolerable) Identified dormant conditions (H3 and H4b) |
| 22 | The implementation of the strategy, for mitigating the risk arising from an aircraft being assigned by ATS a wrong (i.e. potentially conflicting) flight level, should be reinforced as a matter of highest priority | Outstanding safety issue 3: Hazard H3, not tolerable Strategy provided in Appendix D |

| Id. | Recommendations | Rationale / Comment |
|-----|---|---|
| 23 | The implementation of the strategy, for mitigating the risk arising from an aircraft deviating from cleared flight level (situation unknown by flight crew), should be reinforced as a matter of highest priority | Outstanding safety issue 3: Hazard H4a, not tolerable - Level busts issue Strategy provided in Appendix D |

Table 7: Safety recommendations

Page intentionally left blank.

10. Conclusions

The aim of the POSC is to show by means argument and supporting evidence (assurance) that AFI RVSM is safe in operational service, i.e. that the on-going application of the ICAO RVSM concept in the AFI Region satisfies the key AFI RVSM Safety Objectives set out in the AFI RVSM Safety Policy [1] in the time period 25 September 2008 - 30 September 2009.

On the basis of the information developed in the document, the conclusions are:

It has been shown by means of Argument A1 that AFI RVSM continues to be safe in principle on the basis of the completeness and correctness of the AFI RVSM safety requirements, necessary means by which the AFI RVSM Safety Objectives can be achieved, which have been reviewed in light of the operational experience. The review confirms the requirements developed in the PISC and also develops new requirements related to the integrity of the AFI RVSM System. The last ones address a number of hazard causes and mitigations that were not explicitly revealed in the previous FHA. No specific requirement addressing the new issues that has risen since the implementation was found necessary.

It can not be concluded under Argument A2 that the AFI RVSM Concept is safe:

On the basis of the available data, the AFI RVSM safety requirements were not shown to be achieved by the AFI RVSM System as designed. The total vertical TLS of 5×10^{-9} fatal accidents per flight hour is exceeded by a factor of approximately 6 (Argument A2.3).

The risks arising from an aircraft being assigned a wrong (i.e. potentially conflicting) flight level and from an aircraft deviating from cleared flight level (situation unknown by flight crew) have been assessed as not acceptable. In addition, some important failures dormant in the AFI RVSM System have been identified in the areas of A/G communications, ATS performance, coordination between adjacent ATSU and flight crew discipline, and in relation to the presence of non-RVSM civil aircraft in the AFI RVSM airspace (Argument A2.4).

The realisation of the 'new' safety requirements is subject to subsequent successful provision of evidence in the ICAO regional documentation supporting the AFI RVSM Concept (Argument A.2.2).

The monitoring arrangements operated by ARMA were shown to be effective. However application thereof was shown to be affected as some States/CAAs have chosen to ignore requirements in the areas of RVSM approvals, traffic flow data and operational errors reporting, and height monitoring.

It can not be concluded under Argument A3 that the issues, that were outstanding at the time the PISC was issued, have been addressed satisfactorily, as level busts and AFI RVSM airspace classification A issues continue to be outstanding.

As an overall conclusion, it can NOT be concluded that AFI RVSM is safe in operational service in the time period 25 September 2008 - 30 September 2009.

The AFI RVSM Safety Objectives (ii) and (iv) have not been shown to be achieved. In addition, the achievement of the AFI RVSM Safety Objective (i) is subject to successful management of the safety requirements in the ICAO regional documentation for AFI RVSM.

A set of safety recommendations is provided to the attention of ICAO for further action, and consideration at State, Air Navigation Services Providers and Aircraft Operators levels. These recommendations are issued to improve the safety of AFI RVSM in operational service as well as the reliability of the next POSCs. The need for such improvement is amplified by the fact that the effect of traffic growth had not been considered in this POSC and that the risks under AFI RVSM may increase in the future.

Based on the above, a second POSC is recommended to be produced in one year.

Page intentionally left blank.

Appendix A POSC safety argument and evidence structure

- ☞ This appendix sets out how, in the same way as it was in the PISC, the GSN methodology was applied to AFI RVSM, and contains the relevant diagrams which illustrate the POSC argument and evidence structure.

A.1 Overview of GSN methodology

A.1.1 Introduction

The Goal Structuring Notation (GSN) is a good practice [34] and which is commonly used for developing and presenting the Safety Argument, forming the framework of a Safety Case, in a rigorous, hierarchical and easily-understood manner. It provides graphical means of:

- setting out hierarchical safety arguments, with textural annotations and references to supporting evidence; and of,
- capturing essential explanatory and contextual information including assumptions, context and justification, within the argument framework

GSN provides thereby a logical approach to capture the process used for the safety arguments derivation (explanatory and contextual information) and the solutions produced as a result of carrying out that process (arguments and evidence).

GSN was used for the development of the PISC and its application for the purpose of the POSC is set out in the following Sections of this Appendix.

A.1.2 Notation

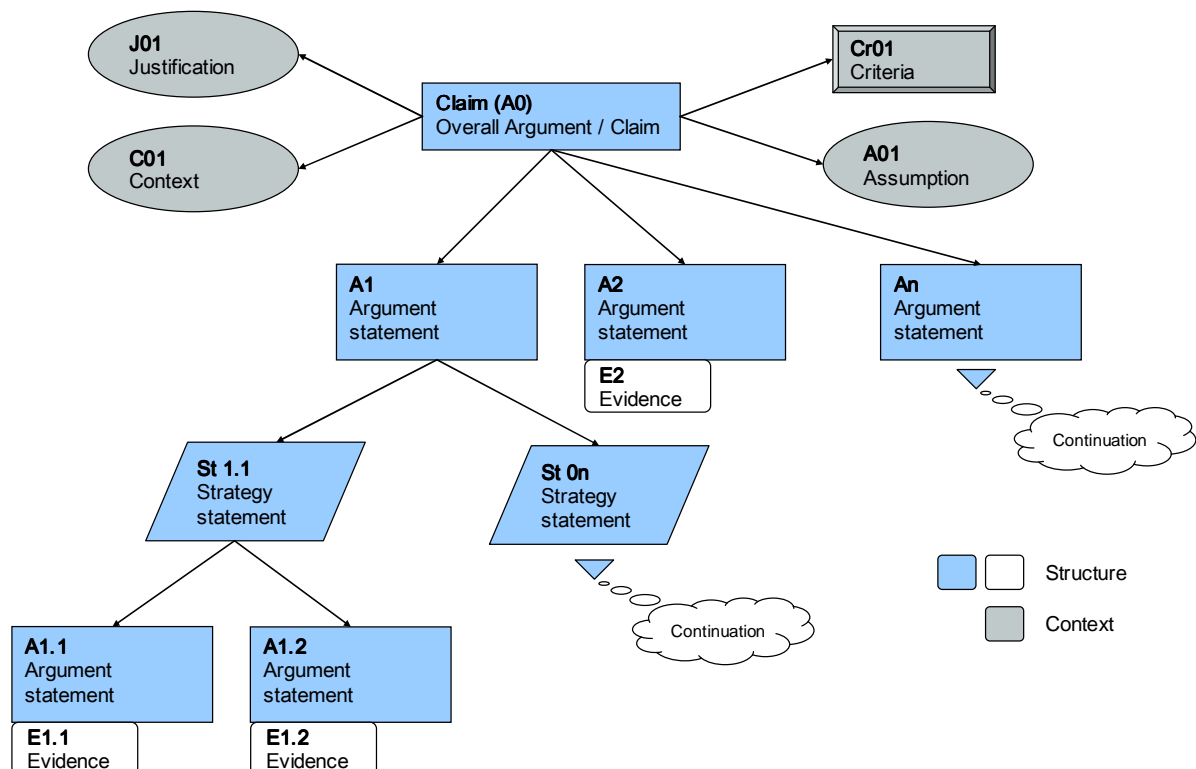


Figure 10: GSN Symbology

Structural elements are used to form the Argument and Evidence structure resulting from logical decomposition of the safety arguments into lower-level arguments. They are mainly:

- Argument (A): Statement claiming about the safety properties of the considered system, or some target to be met. An argument should be formulated as a predicate, i.e a simple predicate which can be shown to be only TRUE or FALSE.
- Strategy (St): Element of explanation introduced into the argument structure. It helps to show how the safety arguments are constructed and broken down into sub-arguments. A strategy is not a predicate; rather it is there purely for explanation of the argument decomposition;
- Evidence (E): Evidence of direct satisfaction of an argument. Evidence always appear at the bottom level of the GSN decomposition and are attached to the argument they support.

Contextual information elements are connected to the GSN structure, providing additional understanding and clarity. They do not form part of, however are attached to, the logical argument and evidence structure. They capture important items such as:

- Assumption (A): Statement, principle and/or premises offered without proof, whose validity has to be relied upon;
- Criteria (Cr): Means by which the satisfaction of an Argument can be checked;
- Justification (J): Rationale given for the use or satisfaction of a particular Argument or Strategy. It is generally used to justify the change that is the subject of the Safety Case; and,
- Context (C): Information necessary for an Argument to be understood and amplified.

A.1.3 Methodology

A safety argument structure is built starting from the top-level claim of the safety case, i.e. what the safety case is trying to show.

Demonstration that the top-level claim is true is achieved by further decomposition into sub-arguments. Logically, an argument is valid if, and only if (necessary and sufficient condition) all sub-arguments are valid. For a safety argument structure to be sufficient, it is essential to ensure that, at each level of the decomposition:

- The set of arguments covers everything that is needed in order to show that the parent argument is true; and,
- There is no valid (counter) argument that could undermine the parent argument.

Following these principles, it is necessary to show only that each argument at the very bottom of the structure is satisfied, in order to assert that the top-level claim has been satisfied.

Satisfaction of the lowest-level arguments is the purpose of Evidence. To this end, an argument is decomposed to a level at which clear Evidence of the validity of the sub-arguments can be identified.

For a safety argument structure to be considered complete, every branch must be terminated in an item of Evidence that supports the argument to which it is attached. For the structure to be sufficient, it is essential to ensure that, at every branch of structure:

- Evidence is appropriate to, and necessary to support, the related argument; and,
- Evidence is sufficient to support the related argument
- Strategies are mainly used to highlight a clear distinction between, and correct use of:
 - Direct (product-based) arguments and related evidence; and,
 - Backing, or supporting (process-based), arguments and related evidence.

Direct argument and evidence are used to show that a particular objective has been achieved (i.e. that the higher level argument has been shown to be true). Direct evidence is obtained from the observable properties of a product (i.e. the output of a process), supporting a logical argument as to how the product satisfies its safety objectives and requirements, as appropriate.

Backing argument and evidence are used to show that the Direct evidence is trustworthy (i.e. that it can be relied upon). Backing evidence is obtained from the properties of the processes by which the direct evidence was obtained. It aims to show that those processes (e.g. tools, techniques, human resources) were appropriate, adequate and properly deployed.

A.1.4 Traceability and numbering

For the purpose of the POSC:

- Arguments (A) are numbered hierarchically (e.g. A1, A1.1 etc...) to reflect their logical structure,
- Evidences (E) are numbered according to the higher-level argument they support / are attached to (e.g. E1.1 supports Arg1.1). They are referenced by the appropriate Section of the document (e.g. POSC 1.1.1) in which they can be found in the form of a text or a reference to a relevant appendix or an external document.
- Strategies (St), Assumptions (A), Criteria (Cr) etc... are numbered sequentially (e.g. St01.1, St 01.2) on the basis of the argument they are connected to.

A.2 Application to the POSC

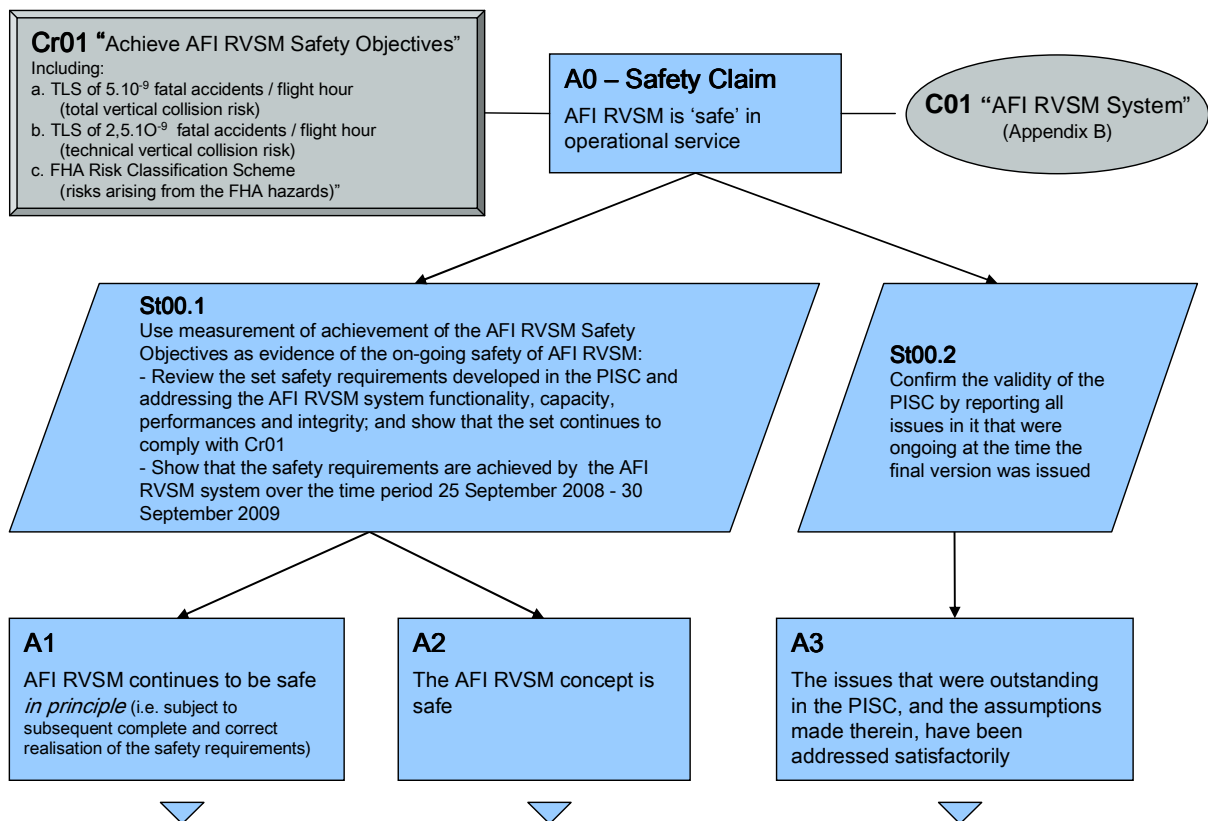


Figure 11: Overall strategy and argument

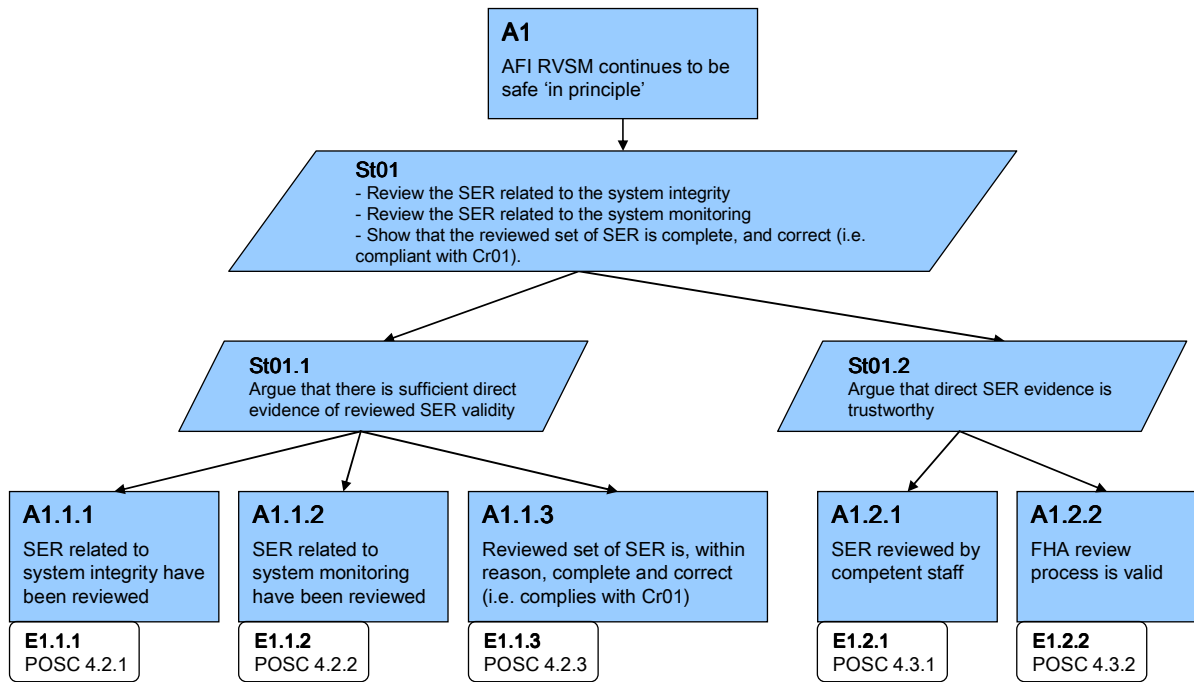


Figure 12: Argument A1 - Argument and evidence structure

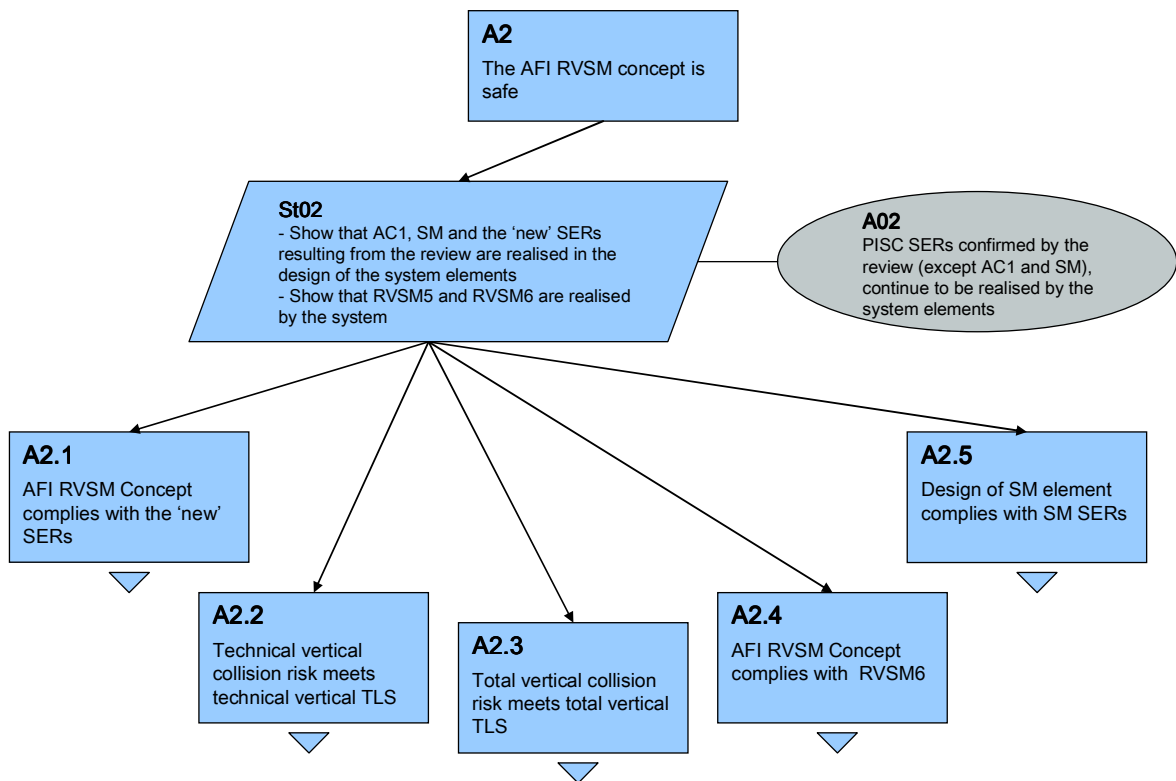


Figure 13: Argument A2 – Argument and evidence structure

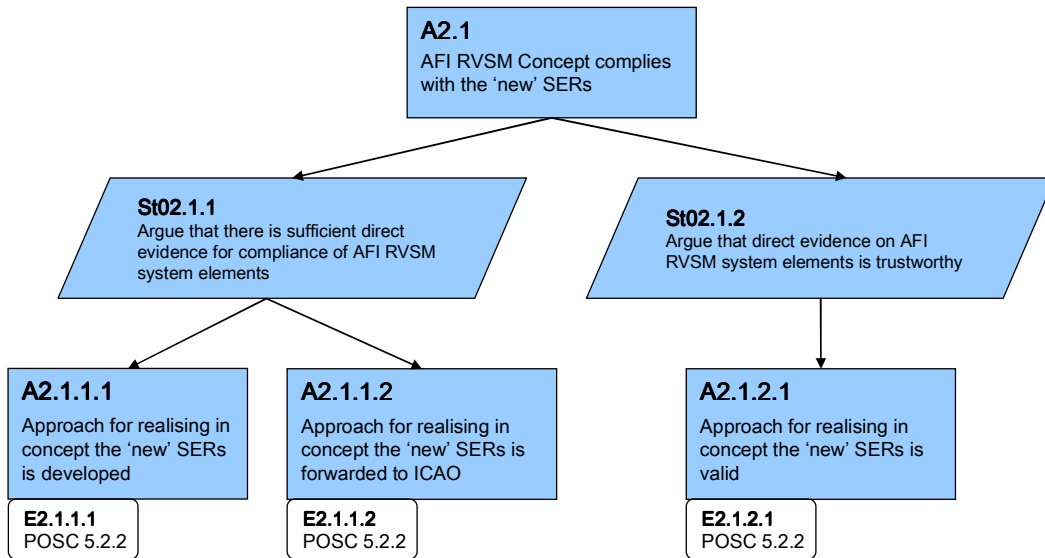


Figure 14: Argument A2.1 - Argument and evidence structure

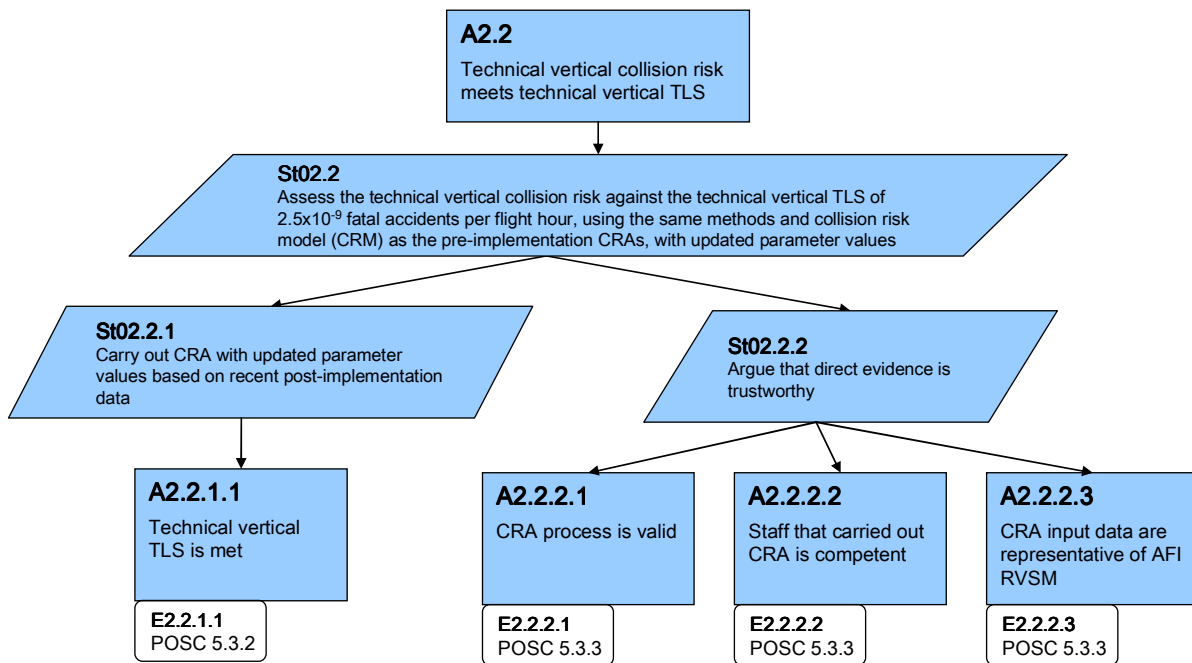


Figure 15: Argument A2.2 - Argument and evidence structure

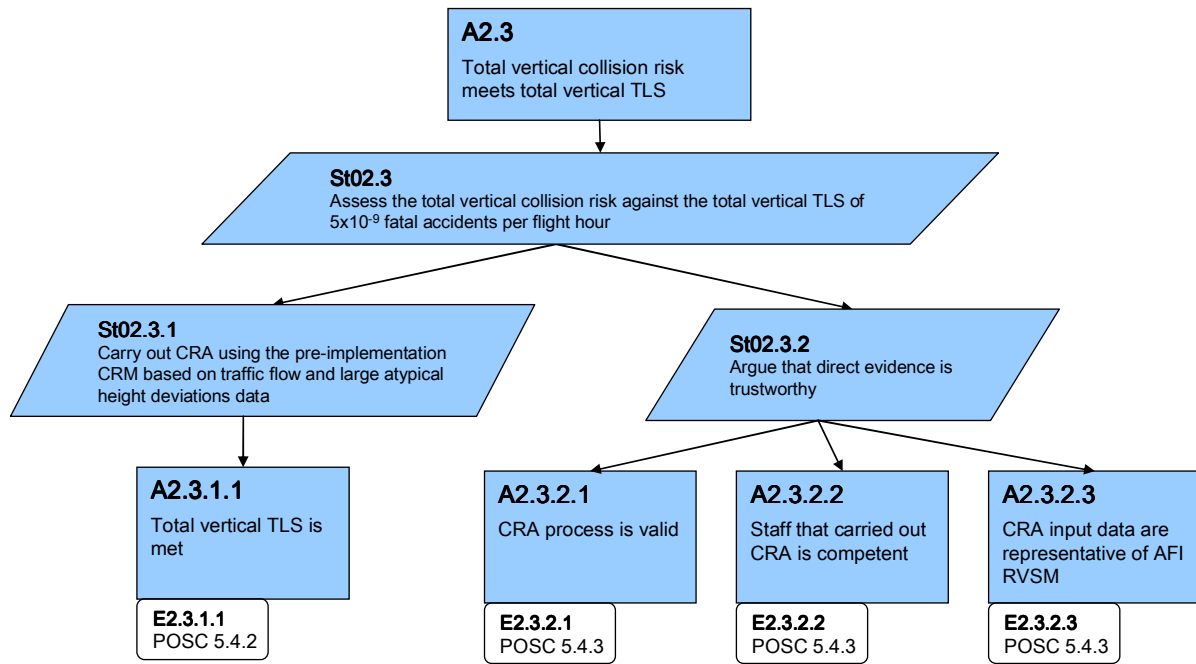


Figure 16: Argument A2.3 - Argument and evidence structure

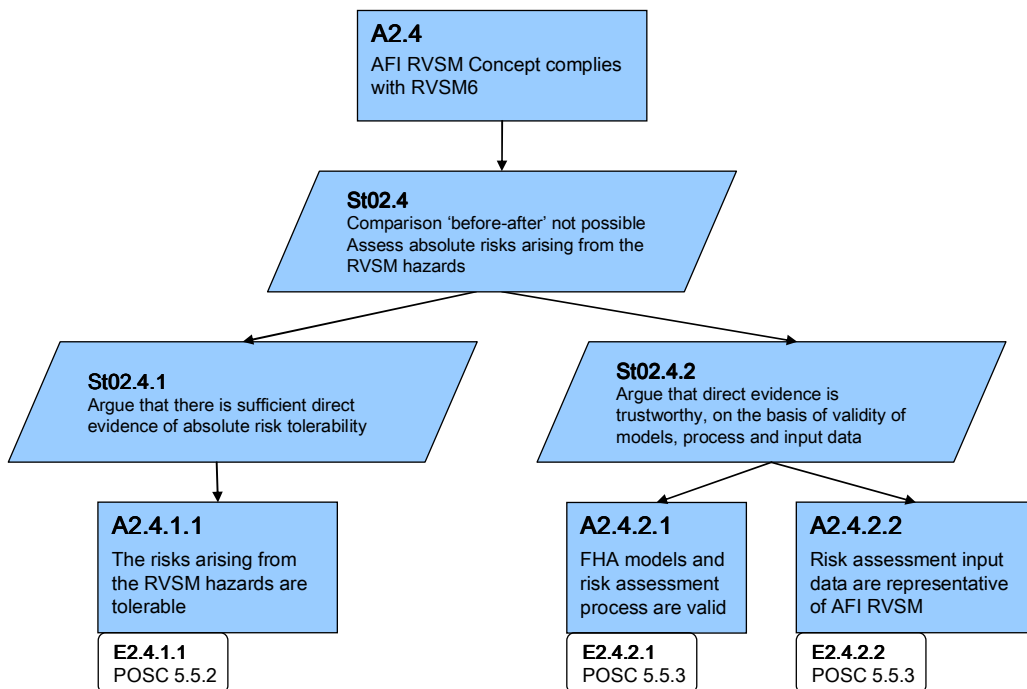


Figure 17: Argument A2.4 - Argument and evidence structure

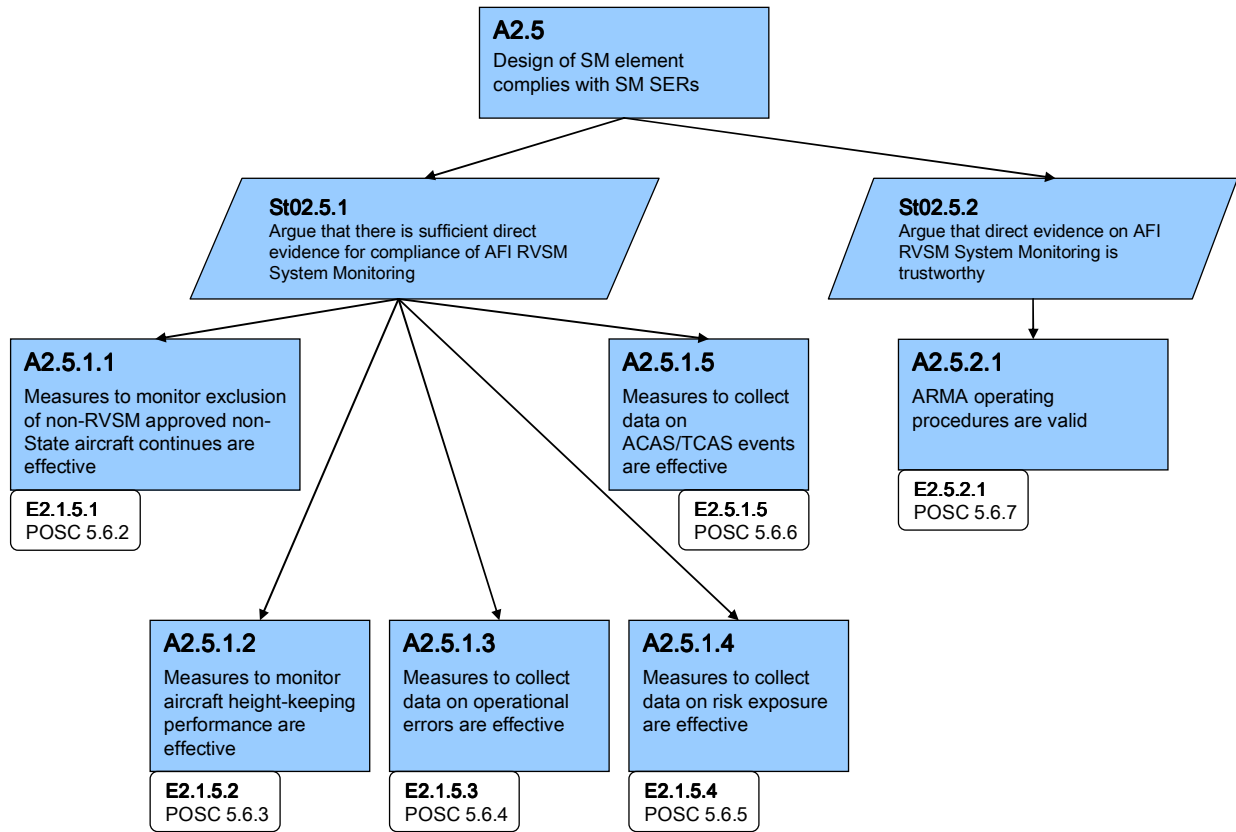


Figure 18: Argument A2.5 - Argument and evidence structure

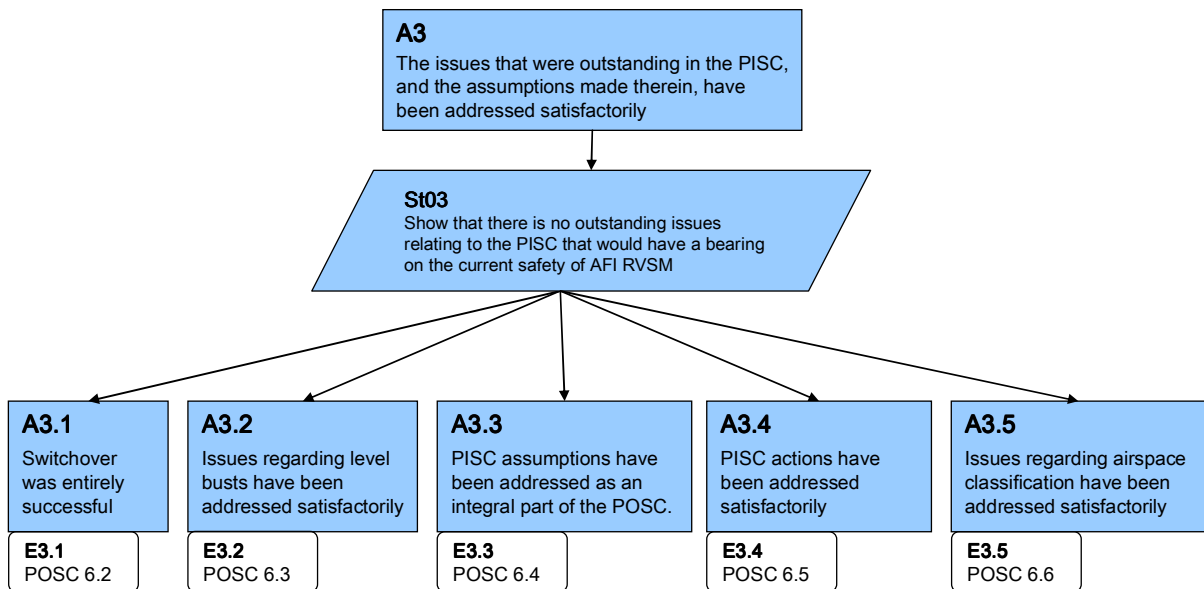


Figure 19: Argument A3 - Argument and evidence structure

Appendix B AFI RVSM System

- This appendix provides an overview of the AFI RVSM System, in the same way as it was considered in the PISC [22] following the application of the ICAO RVSM Concept in the AFI Air Navigation System.

B.1 Definition

The AFI RVSM System is defined as the elements of the AFI Air Navigation System (ANS) involved in RVSM operations. It is composed of a ground based ATM component and an airborne ATM component providing or operating RVSM services, and includes three constituent elements that are human, procedures and equipment (hardware and software). It assumes the existence of a supporting CNS system.

This AFI RVSM System is a generic system designed following the application of the ICAO RVSM Concept in the AFI Region. States are responsible for operating its elements into the airspace for which they have jurisdiction, in compliance with its generic design and with additional requirements that may prevail.

B.2 Purpose

The purpose of the AFI RVSM System is to provide - between FL290 and FL410 inclusive - a 1000 feet vertical separation service to Civil and State RVSM approved aircraft and 2000 feet to State aircraft. Non-RVSM approved civil aircraft are not allowed to operate within the AFI RVSM Airspace, however those intending to operate above FL410 can be cleared to transit through the RVSM airspace, subject to traffic levels, and provided that they have the capability to execute an uninterrupted climb and descent at no less than standard rate.

B.3 Boundaries

B.3.1 Geographical boundaries

As defined in the AFI Regional Supps [11], the AFI RVSM area of applicability is composed of the following FIRs:

| | | | |
|------------------|--------------|----------------|---------------|
| Accra | Addis Ababa | Algiers | Antananarivo |
| Asmara | Beira | Brazzaville | Canarias* |
| Cape Town | Dakar | Dakar Oceanic* | Dar es Salaam |
| Entebbe | Gaborone | Harare | Johannesburg |
| Johannesburg Oc. | Kano | Khartoum | Kinshasa |
| Lilongwe | Luanda | Lusaka | Mauritius |
| Mogadishu | Nairobi | N'Djamena | Niamey |
| Roberts | Sal Oceanic* | Seychelles | Tripoli |
| Windhoek | | | |

Table 8: AFI RVSM area of applicability

In comparison to the PISC, Cairo, Tunis and Casablanca FIRs have been removed from the AFI RVSM area of applicability.

AFI RVSM is thereby applicable within the six Areas of Routing (ARs) defined by APIRG (cf. [10], Appendix D), namely:

- AR-1: Europe South Atlantic (EUR/SAT)*
- AR-2: Atlantic Ocean (AFI-NAT/SAM interface)
- AR-3: Europe – Eastern Africa (including Oceanic Areas)
- AR-4: Europe – Southern Africa, including Continental Southern Africa routes
- AR-5: Continental Western Africa including coastal areas
- AR-6: Trans – Indian Ocean

Note*: Canarias, Sal Oceanic and Dakar Oceanic FIRs (AR-1) are not included in the scope of the POSC, as set out in Section 1.4.

B.3.2 Operational boundaries

AFI RVSM is operated between FL290 and FL410 inclusive.

B.4 Elements

In the same way as in the PISC, the AFI RVSM System is considered to comprise the following elements:

- Overall system (RVSM)
- System monitoring (SM)
- Airspace Design (AD)
- Flight Crew and Operator Procedures (FCOP), sub-composed of:
 - Normal Procedures (FCOP_1)
 - Planning Procedures (FCOP_2)
 - Contingency Procedures (FCOP_3)
 - Transiting Procedures (FCOP_4)
- Flight Crew and Operator Training (FCOT), sub-composed of:
 - Training for normal procedures (FCOT_1)
 - Training for planning procedures (FCOT_2)
 - Training for contingency procedures (FCOT_3)
 - Training for transiting procedures (FCOT_4)
- Aircraft and operator equipment (ACOE)
- ATS Procedures (ATSP) sub-composed of:
 - Normal Procedures (ATSP_1)
 - Contingency Procedures (ATSP_2)
 - Transiting Procedures (ATSP_3)
- ATS Training (ATST), sub-composed of:
 - Training for normal procedures (ATST_1)
 - Training for contingency procedures (ATST_2)
 - Training for transiting procedures (ATST_3)
- ATS Equipment (ATSE).

It should be noted that the ATS personnel encloses both civil and military ATS controllers, as well as the technical staff responsible for ATS equipment maintenance. The transiting procedures refer to the transit of non-RVSM civil aircraft through the RVSM airspace, as part of the AFI RVSM System purpose.

This structure of the AFI RVSM System gives six basic elements, namely FCOP, FCOT, ACOE, ATSP, ATST and ATSE, resulting from the subdivision into a ground and an airborne ATM components, and into the three constituent elements of the System (in the ATM sense): training, procedures and equipment (hardware and software).

These six basic elements are combined with three more elements at System level, namely RVSM, AD and SM.

Appendix C **FHA review**

- ☞ This appendix provides a brief summary of the AFI RVSM FHA review report [18] with the aim to provide understanding elements in the context of the POSC arguments. The complete details can be found in the document itself.

C.1 Objectives

The FHA review was carried out between November 2009 and February 2010 to support POSC arguments A1 and A2.4 (cf. Sections 4 and 5.5 respectively).

The objectives were to:

- Review in light of the operational experience the set of mitigations associated the AFI RVSM hazards, and therefore update the set of safety requirements related to the integrity of the AFI RVSM system; and,
- Assess the risks arising from the AFI RVSM hazards for the time period 25 September 2008 - 30 September 2009.

C.2 Scope

The FHA review aimed to address the AFI RVSM concept and to issue generic results at the AFI Region level. These results intend to be reviewed, further developed and locally adapted at State level as part of SSP/SMS activities, before subsequent realisation.

The FHA review addressed the post-implementation situation, and therefore the hazards and risks associated with RVSM operations in the “AFI RVSM Core Airspace” (cf. [23]); it did not cover the “AFI RVSM switch-over period”.

C.3 Methodology

As set out in Section 2.2.1, although the methodology used for the previous FHA was fully successful, its application for the POSC would have presented some limitations and a new methodology framework was set up to support the assessment of the risks arising from the on-going AFI RVSM hazards. The objective therein was not to challenge the previous FHA results, but to model them differently for the purpose of the POSC, taking also account of the return on experience.

The methodology developed thereby for the purpose of the FHA review is described in Appendix A in the report [18]. It covered typical FHA and PSSA activities (referring to the experience in the EUROCONTROL area [34]), as did the previous FHA., and was based on the severity and risk classifications schemes approved for AFI RVSM by the AFI RVSM Task, and used in the PISC [22].

The methods used primarily consist in a structured brainstorming approach based on standard safety assessment techniques. They were shown to be consistent with the relevant ICAO guidance material contained in the Safety Management Manual Doc. 9859 [7].

In order to provide additional confidence in the results, the findings were validated against the previous FHA results.

The FHA review comprised 8 stages:

- Hazard identification
- Hazard causes modelling
- Hazard consequences modelling and assessment

- Risk assessment
- Risk mitigation strategy derivation
- Validation of results against the previous FHA
- Demonstration of results' completeness and correctness
- Update of PISC integrity safety requirements

Complete details can be found in Appendix A of reference [18].

C.4 FHA review meetings

As part of the structured brainstorming approach, FHA review meetings were organised within the framework of the AFI Tactical Action Group (TAG), established under the authority of the ICAO Special AFI Regional Air Navigation Meeting of 2008 [12], and operating under the reporting authority of APIRG.

As set out in Appendix B of [18], the FHA review meetings aimed to provide representative operational expertise for the following key areas: AFI RVSM hazards identification, causes and consequences modelling and risk assessment. On this basis, the meetings were structured on several brainstorming sessions, according to the following work plan:

| | Date | Sessions |
|-----|------------------|---|
| # 1 | 1 December 2009 | Hazard identification |
| # 2 | 4 December 2009 | Hazard identification - Causes modelling |
| # 3 | 9 December 2009 | Causes modelling - Consequences modelling |
| # 4 | 14 December 2009 | Consequences modelling |
| # 5 | 20 January 2010 | Risk assessment |
| # 6 | 29 January 2010 | Risk assessment |

Table 9: FHA review meetings work plan

The meetings were carried out through teleconferences hosted by IFALPA and chaired by ARMA.

Twelve (12) operational experts from ICAO Montreal, ICAO WACAF, ICAO ESAF, ASECNA, ATNS, Kenya, IATA, IFALPA and IFATCA, participated to the meetings. Those adequately covered the following profiles:

- Flight Crew (Users) operating daily the AFI RVSM airspace
- ATCOs (ANS providers): controllers providing ATS in the AFI RVSM airspace:
 - with the support of radar capability,
 - with the support of ADS/CPDLC capabilities,
 - without the support of any surveillance capability,
- ATM/RVSM experts (ANS providers, International Organisations) involved in the planning, development and maintenance of the AFI RVSM system.

Before the meeting #1, the experts were advised to get acquainted with dedicated briefing material [19] providing general information about the meetings, and guidelines and rules for the brainstorming activities to be conducted.

Before the meeting #6, the FHA review interim report was distributed to the participants for their review prior to the final release.

Complete details on FHA review meetings can be found in Appendix B of reference [18].

C.5 Results

C.5.1 Hazard identification

Following a functional approach, the following hazard model has been developed:

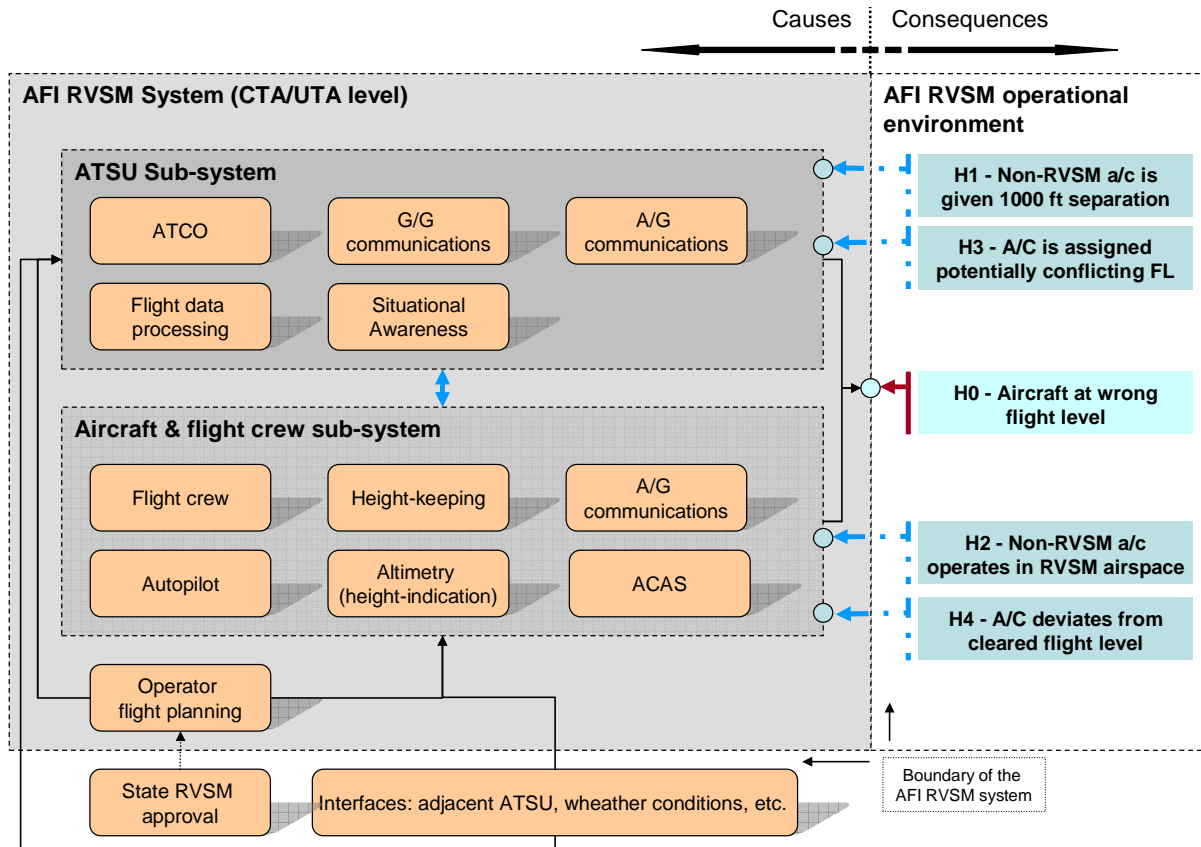


Figure 20: AFI RVSM hazard model

Four (4) individual hazards have been identified according to the principal RVSM functions of the ATS and aircraft/flight crew sub-systems. Described at the boundary of the AFI RVSM system at the level of a given CTA/UTA, they are as follows:

- H1** Non RVSM aircraft is given 1000 feet separation in AFI RVSM airspace
Undetected by ATS (a) or detected by ATS at first contact on frequency (b)
- H2** Non RVSM civil aircraft operates in the AFI RVSM airspace (detected by ATS)
- H3** Aircraft is assigned a potentially conflicting flight level
- H4** Aircraft deviates from cleared flight level
Unknown by flight crew (a) or known by flight crew (b) and undetected by ATS

These hazards are considered to be complete and correct, and to adequately cover the previous FHA hazards.

Details can be found in Section 3 of reference [18].

C.5.2 Causes modelling

The potential causes of the AFI RVSM hazards and associated (internal) mitigations have been modelled following a fault tree technique (FTA), which is a standard safety assessment technique, in particular successfully used for the EUR RVSM POSC [36].

The FTA technique as adapted for the purpose the AFI RVSM FHA review and the resulting fault trees are presented in appendix C of reference [18].

The causes as modelled are considered to be complete and correct, and to adequately cover the causes of the previous FHA hazards. As a result of the FTA technique, a number of causes and mitigations have emerged that were not explicitly revealed in the previous FHA.

Details can be found in Section 4 of reference [18].

C.5.3 Consequences modelling and assessment

The potential consequences of the AFI RVSM hazards and associated (external) mitigations have been modelled following an event tree technique (ETA), which is a standard safety assessment technique as FTA.

The ETA technique as adapted for the purpose the AFI RVSM FHA review and the resulting event trees are presented in Appendix D of reference [18]

The consequences as modelled are considered to be complete and correct, and to be consistent with the previous FHA.

The qualitative assessment of the severity of the final consequences was made in consistence with the criteria defined in the applicable severity classification scheme (SCS). Then, taking into account the estimated probabilities of success / failure of the mitigations and the maximum frequency at which the final consequences are expected to occur (in consistence with the applicable risk classification scheme RCS), the following safety objectives have been specified:

| | Per flight hour | AFI RVSM airspace |
|-----|-----------------------|---|
| H1a | 10^{-4} pfh | $2 \cdot 10^{-2}$ per h (once every 2 days) |
| H1b | 10^{-2} pfh | 2 per h |
| H2 | 10^{-4} pfh | $2 \cdot 10^{-2}$ per h (once every 2 days) |
| H3 | $2 \cdot 10^{-8}$ pfh | $4 \cdot 10^{-6}$ per h (once every 30 years) |
| H4a | $2 \cdot 10^{-8}$ pfh | $4 \cdot 10^{-6}$ per h (once every 30 years) |
| H4b | 10^{-5} pfh | $2 \cdot 10^{-3}$ per h (once very 3 weeks) |

Table 10: Safety objectives (FHA review)

Note: The number of flight hours per hour in the AFI RVSM airspace (as addressed by the POSC) is estimated to be around 200.

Details can be found in Section 5 of reference [18].

C.5.4 Risk assessment

The risks arising from the identified hazards have been assessed through an estimation of the frequency of occurrence of the hazards, on the basis of the safety occurrences which have been reported, over the time period September 2008 - September 2009, through AIAG, TAG and ARMA mechanisms. This estimation was completed by operational judgment of the FHA review experts and was assessed against the specified safety objectives as follows:

| | Safety Objective | Est. freq. of occurrence | Risks level |
|------------|------------------------|--------------------------|---------------|
| H1a | $4.10^{-2} / \text{h}$ | $4.10^{-2} / \text{h}$ | Tolerable |
| H1b | 2 / h | $4.10^{-2} / \text{h}$ | Acceptable |
| H2 | $2.10^{-2} / \text{h}$ | $4.10^{-2} / \text{h}$ | Tolerable |
| H3 | $2.10^{-6} / \text{h}$ | $3.10^{-3} / \text{h}$ | Not tolerable |
| H4a | $4.10^{-6} / \text{h}$ | $3,5.10^{-4} / \text{h}$ | Not tolerable |
| H4b | $2.10^{-3} / \text{h}$ | $3.10^{-3} / \text{h}$ | Tolerable |

Table 11: Assessment of the risks arising from the AFI RVSM hazards (1/2)

Note: above quantitative values are considered as orders of magnitude.

The results have been summarised as follows:

| Id. | Risk level | Conclusions |
|-----|---------------|--|
| H1a | Tolerable | Risk may increase in the future due to dormant conditions related to the presence of non-RVSM civil aircraft in the AFI RVSM airspace, A/G communications and coordination between ATS units. |
| H1b | Acceptable | |
| H2 | Tolerable | |
| H3 | Not tolerable | Risk mitigation strategy implementation is not complete/correct Main contributing factors: A/G communications, ATS performance, coordination between ATS units, flight crew discipline Risk may increase in the future due to dormant conditions related to A/G communications, coordination between ATS units and to flight crew discipline |
| H4a | Not tolerable | Risk mitigation strategy implementation is not complete/correct Main contributing factors undetermined due to incident data limitation. |
| H4b | Tolerable | Risk may increase in the future due to dormant conditions related to environmental conditions, A/G communications and flight crew discipline |

Table 12: Assessment of the risks arising from the AFI RVSM hazards (1/2)

Details can be found in Section 6 of reference [18].

C.5.5 Risk mitigation strategy

The AFI RVSM risk mitigation strategy has been derived in the form of integrity System Element Requirements (SER) allocated to the elements of the AFI RVSM System, which reflects the mitigations which can be used to prevent the occurrence of the AFI RVSM hazards.

The derived set of integrity SER is provided in Appendix D, together with the SER resulting from the High-Level Safety Requirements.

The risk mitigation strategy is considered to be complete and correct. It confirms the previous FHA mitigations, with one exception which is relevant in light of the operational experience (cf. Appendix G.3 of reference [18]), and includes new requirements which adequately address a number of causes and mitigations that were not explicitly revealed in the previous FHA²². No specific requirement addressing the new issues that has risen since the implementation was found necessary.

Details can be found in Section 7 of reference [18].

C.5.6 Safety recommendations

A set of safety recommendations have been issued to improve the level of these risks as well as the reliability of the assessment thereof as part of the next POSC.

Details can be found in Section 9 of reference [18].

This set of recommendations is picked-up in Section 9 of the present POSC.

²² A number of causes and mitigations of individual hazards have emerged as a result of the FTA technique used to model causes.

Appendix D AFI RVSM System Element Requirements

This appendix provides the set of AFI RVSM System Elements Requirements, as reviewed as part of the argument A1 (Section 4) and addressed in the design of the AFI RVSM System as part of the Argument A2 (Section 5).

D.1 Reviewed set of SERs

| System Element | Reference | System Element Requirement (SER) | Source | Previous FHA Backtrace ²³ |
|---|-----------|--|--|---|
| FCOP_1: Flight Crew and Operator Normal Procedures | FCOP1 | Flight Crew procedures shall be specified for RVSM operations (including use of new FLAS/FLOS) | AFI RVSM 2 | - |
| | FCOP_1-1 | Flight Crew procedures for read back shall be reinforced | Hazard H1a, Hazard H2, Hazard H3, Hazard H4 | Req Core_29 (AH Core 9, AH Core 10, AH Core 11) |
| | FCOP_1-2 | New operator procedures shall include the checking/assurance that for operation in AFI RVSM airspace, the aircraft equipment meets the RVSM MASPS requirements | Hazard H2, Hazard H4b | Req Core_1 (AH Core 1, AH Core 2, AH Core 3, AH Core 4) |
| | FCOP_1-3 | New Flight Crew Procedures to check RVSM Status before departure shall be specified | Hazard H1a | Req Core_60 (AH Core 17) |
| | FCOP_1-4 | Transferring procedure for flight crew shall be defined (e.g. State Level/RVSM Status before FIR entry) | Hazard H1, Hazard H3, Hazard H4 | Req Core_41 (AH Core 12) |
| | FCOP_1-5 | Flight Crew procedures to limit Climbing/descent rate during the level change to avoid nuisance RA (e.g.500ft/min to 1000ft/min) shall be defined | Hazard H4a | Req Core_87 (AH Core 25) |

²³ [FHASR]-([hazards])

| System Element | Reference | System Element Requirement (SER) | Source | Previous FHA Backtrace ²³ |
|--|---|---|---|--|
| FCOP_2: Flight Crew and Operator Planning Procedures | FCOP2 | Flight planning procedures shall be revised and reinforced for RVSM | AFI RVSM 1, Hazard H1 | Req Core_58 (AH Core 17, AH Core 18) |
| | FCOP_2-1 | Operators Flight planning procedures shall take into account weather forecast | Hazard H2, Hazard H4b | Req Core_66, Req Core_73 (AH Core 19 AH Core 20 AH Core 21) |
| | FCOP_2-2 | Weather forecast shall be in place to inform flight crew and operators about areas with potential severe turbulence and/or bad weather conditions | Hazard H2, Hazard H4b | Req Core_65 Req Core_72 (AH Core 19 AH Core 20 AH Core 28) |
| | FCOP_2-3 | Operator shall send CHG message when appropriate | Hazard H1 | Req Core_57 (AH Core 17, AH Core 18) |
| FCOP_3: Flight Crew and Operator Contingency Procedures | FCOP3 | Flight Crew in flight contingencies shall be specified | AFI RVSM 7 | - |
| | FCOP_3-1 | New Flight Crew Procedures to suspend RVSM shall be specified | Hazard H2, Hazard H4b | Req Core_101 (AH Core 19, AH Core 20) |
| | FCOP_3-2 | Flight Crew Procedures to report encountered vortices shall be defined | Hazard H2, Hazard H4b | Req Core_83 (AH Core 21) |
| | FCOP_3-3 | Flight Crew Contingency Procedures shall be defined to provide 2000 feet separation for non RVSM civil aircraft | Hazard H2, Hazard H4b | Req Core_2 (AH Core 1, AH Core 2, AH Core 3, AH Core 4, AH Core 5) |
| | FCOP_3-4 | Flight Crew Contingency Procedures shall be defined to execute lateral/level deviation from RVSM level for non RVSM civil aircraft | Hazard H2, Hazard H4b | Req Core_3 (AH Core 1, AH Core 2, AH Core 3, AH Core 4) |
| | FCOP_3-5 | Flight Crew Contingency Procedures shall be defined to exit non RVSM civil aircraft from RVSM Airspace | Hazard H2, Hazard H4b | Req Core_4 (AH Core 1, AH Core 2, AH Core 3, AH Core 4, AH Core 5) |
| | FCOP_3-6 | Flight Crew Radio Communications Failure procedures shall be defined | Hazard H1a, Hazard H3, Hazard H4b | Req Core_9 (AH Core 6, AH Core 7) |
| | FCOP_3-7 | Flight Crew Contingency procedures regarding not forecast severe turbulence shall be defined | Hazard H2, Hazard H4b | Req Core_69, Req Core_75 (AH Core 19, AH Core 20) |
| | FCOP_3-8 | Flight Crew Contingency procedures regarding wake turbulence shall be defined | Hazard H2, Hazard H4b | Req Core_80 (AH Core 21) |
| FCOP_3-9 | Flight Crew Contingency procedures for Non-RVSM civil aircraft facing severe icing or turbulence shall be defined | Hazard H2 | Req Core_98 (AH Core 28) | |

| System Element | Reference | System Element Requirement (SER) | Source | Previous FHA Backtrace ²³ |
|--|-----------|---|---------------------------------|--|
| | FCOP_3-11 | Flight Crew emergency contingencies shall be specified | Hazard H4 | Req Core_84 (AH Core 22, AH Core 23) |
| FCOP_4: Flight Crew and Operator Transiting Procedures | FCOP4 | Non RVSM-approved civil aircraft transiting procedures (including contingencies) shall be defined | AFI RVSM 3, Hazard H2 | AH Core 5 |
| | FCOP-4.1 | Flight crew procedures shall be defined to provide ATC with climbing/descending performance before transit clearance is issued. | Hazard H2 | - New requirement resulting from the FHA review |
| | FCOP-4.2 | Degradation of climbing/descending performance shall be reported by flight crew to ATC | Hazard H2 | - New requirement resulting from the FHA review |
| FCOT_1: Flight Crew and Operator Training for Normal Procedures | FCOT1 | Flight Crew shall be trained regarding AFI RVSM procedures | AFI RVSM 2 | - |
| | FCOT_1-1 | Flight Crew Training shall include use of procedures for the checking/assurance that, for operation in AFI RVSM airspace, the aircraft equipment meets the RVSM MASPS Requirement | Hazard H2, Hazard H4b | Req Core_1 (AH Core 1, AH Core 2, AH Core 3, AH Core 4) |
| | FCOT_1-2 | Flight crew shall be trained appropriately regarding RVSM Status checking before departure | Hazard H1a | Req Core_61 (AH Core 17) |
| | FCOT_1-3 | Flight Crew shall be trained to report negative RVSM Status on the initial call on any frequency within the AFI RVSM airspace | Hazard H1 | Req Core_64 (AH Core 18) |
| | FCOT_1-4 | Flight Crew shall be trained appropriately with regards to RVSM Procedures including correct use of FLAS | Hazard H3 | Req Core_25 (AH Core 9, AH Core 10, AH Core 11) |
| | FCOT_1-5 | Flight Crew shall be trained appropriately with regards to RVSM Procedures (including read back for clearance and leaving/reaching level) | Hazard H3, Hazard H4 | Req Core_31, Req Core_35 (AH Core 9, AH Core 10, AH Core 11) |
| | FCOT_1-6 | Flight Crew Training shall include use of procedures for limiting Climbing/descent rate during the level change to avoid nuisance RA (e.g.500ft/min to 1000ft/min) | Hazard H4a | Req Core_87 (AH Core 25) |
| | FCOT_1-7 | Pilots shall be trained appropriately to TCAS operations (initial and continuous training) | Hazard H2, Hazard H4a | Req Core_89 (AH Core 25, AH Core 26) |
| | FCOT_1-8 | Flight crew shall be trained appropriately with regards to the transfer procedures | Hazard H1, Hazard H3, Hazard H4 | Req Core_42 (AH Core 12) |
| | FCOT_1-9 | Pilots awareness on reporting accuracy shall be reinforced by training | Hazard H3 | Req Core_33 (AH Core 9, AH Core 10) |

| System Element | Reference | System Element Requirement (SER) | Source | Previous FHA Backtrace ²³ |
|---|-----------|---|---|---|
| | FCOT_1-10 | Flight crew discipline with regards to ATC shall be reinforced | Hazard H1 Hazard H4 | - New requirement resulting from the FHA review |
| FCOT_2: Flight Crew and Operator Training for Planning Procedures | FCOT2 | Operator and flight crew shall be appropriately trained with regards to flight planning procedures revised for RVSM operations | AFI RVSM 1 Hazard H1 | Req Core_59 (AH Core 17) |
| | FCOT_2-1 | Operator staff shall be trained to send CHG message when appropriate | Hazard H1 | Req Core_57 (AH Core 17, AH Core 18) |
| | FCOT_2-2 | Operator and flight crew shall be appropriately trained with regards to the consideration of turbulence and bad weather forecast when flight planning | Hazard H2, Hazard H4b | Req Core_67, Req Core_74 (AH Core 19 AH Core 20, AH Core 28) |
| FCOT_3: Flight Crew and Operator Training for Contingency Procedures | FCOT3 | Flight crew shall be trained appropriately with regards to in flight contingencies | AFI RVSM 5 | - |
| | FCOT_3-1 | Flight crew shall be trained to report significant weather encountered en-route | Hazard H2, Hazard H4b | Req Core_68, Req Core_97 (AH Core 19, AH Core 20, AH Core 28) |
| | FCOT_3-2 | Flight Crew shall be trained appropriately regarding suspension of RVSM | Hazard H2, Hazard H4b | Req Core_104 (AH Core 19, AH Core 20) |
| | FCOT_3-3 | Flight crew shall be trained appropriately with regards to contingency procedures in case of MASPS requirements failure | Hazard H2, Hazard H4b | Req Core_6 (AH Core 1, AH Core 2, AH Core 3, AH Core 4) |
| | FCOT_3-4 | Flight crew shall be trained appropriately regarding contingency procedures related to not forecast turbulence | Hazard H2, Hazard H4b | Req Core_71, Req Core_77 (AH Core 19, AH Core 20) |
| | FCOT_3-5 | Flight crew shall be trained appropriately regarding contingency procedures related to wake turbulence | Hazard H2, Hazard H4b | Req Core_82 (AH Core 21) |
| | FCOT_3-6 | Flight crew operating Non-RVSM aircraft shall be trained appropriately to contingency procedures related to Non-RVSM aircraft facing severe icing or turbulence | Hazard H2 | Req Core_100 (AH Core 28) |
| | FCOT_3-7 | Flight crew shall be trained appropriately with regards to emergency contingencies | Hazard H4 | Req Core_85 (AH Core 22, AH Core 23) |
| | FCOT_3-8 | Flight crew shall be trained appropriately with regards to Radio Communications Failure procedures | Hazard H1a, Hazard H3, Hazard H4b | Req Core_11 (AH Core 6, AH Core 7) |

| System Element | Reference | System Element Requirement (SER) | Source | Previous FHA Backtrace ²³ |
|--|-----------|---|-----------------------|---|
| | FCOT_3-9 | Flight crew shall be trained appropriately with regards to ATS/DS failure (awareness training) | Hazard H1, Hazard H3 | Req Core_20 (AH Core 8) |
| | FCOT_3-10 | Flight crew awareness with regards to weather deviations procedures (including notification to ATC) shall be reinforced. | Hazard H4, Hazard H1 | - New requirement resulting from the FHA review |
| FCOT_4: Flight Crew and Operator Training for Transiting Procedures | FCOT4-1 | Flight crew shall be trained appropriately with regards to Non-RVSM approved civil aircraft transiting procedures (including contingencies) | Hazard H2 | Req Core_8 (AH Core 5) |
| ACOE_1: Operator and Aircraft Equipment | AC1 | RVSM- approved aircraft height-keeping shall be consistent with a TLS of 2.5×10^{-9} | RVSM 4 | - |
| | AC2 | RVSM- approved aircraft height-keeping shall <u>continue</u> to be consistent with a TLS of 2.5×10^{-9} | RVSM 8 | - |
| | ACOE_1-1 | Aircraft shall meet MASPS requirements | Hazard H2, Hazard H4 | Req Core_1 (AH Core 1, AH Core 2, AH Core 3, AH Core 4) |
| | ACOE_1-2 | Aircraft shall be equipped with ACAS II (TCAS version 7.0) | Hazard H4a | Req Core_88 (AH Core 25) |
| | ACOE_1-3 | Weather forecast equipment shall be in place to inform flight crew and operators about areas with severe turbulence | Hazard H2, Hazard H4b | Req Core_65 (AH Core 19) |
| | ACOE_1-4 | Weather forecast equipment shall be in place to inform flight crew and operators about bad weather conditions | Hazard H2, Hazard H4b | Req Core_72 (AH Core 20, AH Core 28) |
| | ACOE_1-5 | Operator equipment to send CHG message when appropriate shall be in place | Hazard H1 | Req Core_57 (AH Core 17, AH Core 18) |
| | ACOE_1-6 | Operator flight plan filling capabilities shall be reinforced | Hazard H1 | Req Core_58 (AH Core 17, AH Core 18) |
| ATSP_1: ATS Normal Procedures | ATSP1a | Clearance procedures shall be revised to clear only RVSM civil aircraft and State aircraft into the RVSM airspace | - | AFI RVSM 1 |
| | ATSP1b | ATS Procedures shall be specified for RVSM operations (including use of new FLAS/FLOS) | - | AFI RVSM 2 |

| System Element | Reference | System Element Requirement (SER) | Source | Previous FHA Backtrace ²³ |
|----------------|-----------|---|--|---|
| | ATSP_1-1 | ATS Procedures for read back shall be reinforced | Hazard H1a, Hazard H2, Hazard H3, Hazard H4 | Req Core_29 (AH Core 9, AH Core 10, AH Core 11) |
| | ATSP_1-2 | Crosscheck between controllers shall be performed | Hazard H3 | Req Core_28 (AH Core 9, AH Core 10) |
| | ATSP_1-3 | ATS Transfer procedures (including read back and RVSM/Non RVSM Status) shall be defined in LoA | Hazard H1, Hazard H3 | Req Core_16, Req Core_37, Req Core_39, Req Core_41, Req Core_56 (AH Core 8, AH Core 12, AH Core 16) |
| | | ATS Coordination procedures shall be defined in the Civil – Military LoA | Hazard H1, Hazard H3 | Req Core_91 (AH Core 27) |
| | ATSP_1-4 | ATS Procedures regarding knowledge of RVSM status shall be defined | Hazard H1 | Req Core_62 (AH Core 17) |
| | ATSP_1-5 | Climbing/descent rate shall be limited during the level change to avoid nuisance RA (e.g.500ft/min to 1000ft/min) | Hazard H4a | Req Core_87 (AH Core 25) |
| | ATSP_1-6 | Air/Ground Communications system maintenance procedures shall be defined to ensure a communication system recovery in MTTR defined in Service Level Agreement | H1a, H3, H4b | Req Core_13 (AH Core 7) |
| | ATSP_1-7 | Ground/Ground Communication system maintenance procedures shall be defined to ensure a communication system recovery in MTTR defined in Service Level Agreement | Hazard H1, Hazard H3 | Req Core_21 (AH Core 8) |
| | ATSP_1-8 | FDPS/RDPS/ ADS system maintenance procedures shall be defined to ensure a communication system recovery in MTTR defined in Service Level Agreement. | Hazard H3 | Req Core_45, Req Core_48, Req Core_52 (AH Core 13, AH Core 14, AH Core 15) |
| | | FDPS system maintenance procedures shall be defined to ensure a communication system recovery in MTTR defined in Service Level Agreement. | Hazard H3 | Req Core_48 (AH Core 14) |
| | ATSP_1-9 | Weather forecast procedures shall be in place to inform ATC about areas with potential severe turbulence and/or bad weather conditions | Hazard H2, Hazard H4b | Req Core_65, Req Core_72, (AH Core 19, AH Core 20, AH Core 28) |
| | ATSP_1-10 | Appropriate separation standards shall be specified with regards to wake turbulences | Hazard H2, Hazard H4b | Req Core_78 (AH Core 21) |

| System Element | Reference | System Element Requirement (SER) | Source | Previous FHA Backtrace ²³ |
|---|---|--|---|--|
| ATSP_2: ATS Contingency Procedures | ATSP2 | Revised contingency procedures shall be defined | AFI RVSM 7 | - |
| | ATSP_2-1 | ATS Procedures to suspend RVSM shall be defined | Hazard H2, Hazard H4b | Req Core_101 (AH Core 19, AH Core 20) |
| | ATSP_2-2 | ATS Procedures to coordinate RVSM suspension with adjacent ACC's shall be defined | Hazard H2, Hazard H4b | Req Core_102 (AH Core 19, AH Core 20) |
| | ATSP_2-3 | ATS Contingency Procedures shall be defined to provide 2000 feet separation for non RVSM civil aircraft | Hazard H2, Hazard H4b | Req Core_2 (AH Core 1, AH Core 2, AH Core 3, AH Core 4, AH Core 5) |
| | ATSP_2-4 | ATS Contingency Procedures shall be defined to exit non RVSM civil aircraft from RVSM Airspace | Hazard H2, Hazard H4b | Req Core_4 (AH Core 1, AH Core 2, AH Core 3, AH Core 4, AH Core 5) |
| | ATSP_2-5 | ATS Contingency Procedures shall be defined to execute lateral/level deviation from RVSM level for non RVSM civil aircraft | Hazard H2, Hazard H4b | Req Core_3 (AH Core 1, AH Core 2, AH Core 3, AH Core 4) |
| | ATSP_2-6 | ATS Radio Communications Failure procedures shall be defined | Hazard H1a, Hazard H3, Hazard H4b | Req Core_9 (AH Core 6, AH Core 7) |
| | ATSP_2-7 | ATS Procedures to revert to procedural control shall be specified (due to RDPS/ADS system failure) | Hazard H3 | Req Core_43 (AH Core 13) |
| | | ATS Procedures to revert to procedural control shall be specified (due to FDPS / RDPS/ADS system failure) | Hazard H3 | Req Core_50 (AH Core 15) |
| | ATSP_2-8 | ATS Procedures regarding Non-receipt of flight plan shall be defined | Hazard H1 | Req Core_54 (AH Core 16) |
| | ATSP_2-9 | ATS Contingency procedures regarding not forecast severe turbulence shall be defined | Hazard H2, Hazard H4b | Req Core_69, Req Core_75 (AH Core 19, AH Core 20) |
| ATSP_2-10 | ATS Contingency procedures regarding wake turbulence shall be defined | RVSM 5 Hazard H2, Hazard H4b | Req Core_80 (AH Core 21) | |
| ATSP_2-11 | ATS Contingency procedures for Non-RVSM aircraft facing severe icing or turbulence shall be defined | Hazard H2 | Req Core_98 (AH Core 28) | |

| System Element | Reference | System Element Requirement (SER) | Source | Previous FHA Backtrace ²³ |
|---|--|---|----------------------------------|--|
| | ATSP_2-12 | Emergency contingencies shall be specified | Hazard H4 | Req Core_84 (AH Core 22, AH Core 23) |
| | ATSP_2-13 | ATS Transfer procedures shall be defined in the LoA (including communication failure contingencies) | Hazard H1, Hazard H3, Hazard H4b | Req Core_16, Req Core_18 (AH Core 8) |
| | | Military – Civil coordination Contingency procedures shall be defined in the civil-military LoA | Hazard H1, Hazard H3 | Req Core_94 (AH Core 27) |
| | ATSP_2-14 | Silent transfer procedures shall be defined in the LoA between ATS units equipped with Radar systems, which are capable of communicating with each other. | Hazard H1, Hazard H3 | - New requirement resulting from the FHA review |
| ATSP_3: ATS transiting procedures | ATSP3 | Procedures facilitating the transit of non-RVSM civil aircraft through the RVSM airspace without intermediate stops shall be defined | AFI RVSM3, Hazard H2 | - |
| | ATSP3-1 | Minimum climbing/descending performance shall be requested by ATC before transit clearance is issued. | Hazard H2 | - New requirement resulting from the FHA review |
| ATST_1: ATS Training for Normal Procedures | ATST1a | Controllers shall be trained appropriately regarding revised clearance procedures | AFI RVSM 1 | - |
| | ATST1b | Controllers shall be trained appropriately regarding ATS procedures for RVSM operations | AFI RVSM 2 | - |
| | ATST_1-1 | Controllers shall be trained appropriately regarding knowledge of RVSM status procedures | Hazard H1 | Req Core_63 (AH Core 17) |
| | ATST_1-2 | Controllers shall be trained appropriately with regards to RVSM Procedures including correct use of FLAS | Hazard H3 | Req Core_24 (AH Core 9, AH Core 10) |
| | ATST_1-3 | Controllers shall be trained appropriately with regards to RVSM Procedures including read back for clearance | Hazard H3, Hazard H4 | Req Core_30 (AH Core 9) |
| | | Controllers shall be trained appropriately with regards to RVSM Procedures including read back for report leaving/reaching level | Hazard H3, Hazard H4 | Req Core_34 (AH Core 9, AH Core 10) |
| | ATST_1-4 | Controllers shall be trained appropriately with regards to RVSM Coordination Procedures | Hazard H1, Hazard H3 | Req Core_36 (AH Core 12) |
| ATST_1-5 | Controllers shall be trained appropriately with regards to RVSM civil - military Coordination Procedures | Hazard H1, Hazard H3 | Req Core_92 (AH Core 27) | |

| System Element | Reference | System Element Requirement (SER) | Source | Previous FHA Backtrace ²³ |
|--|-----------|--|----------------------------------|--|
| | | Military controllers shall be trained appropriately with regards to RVSM Coordination Procedures | Hazard H1, Hazard H3 | Req Core_93 (AH Core 27) |
| | ATST_1-6 | Controllers shall be trained appropriately with regards to transfer procedures | Hazard H1, Hazard H3, Hazard H4b | Req Core_17, Req Core_40 (AH Core 8, AH Core 12, AH Core 16) |
| | ATST_1-7 | Controllers shall be trained on limitation of Climbing/descent rate during the level change to avoid nuisance RA (e.g.500ft/min to 1000ft/min) | Hazard H4a | Req Core_87 (AH Core 25) |
| | ATST_1-8 | Air/Ground Communications Maintenance team shall be trained appropriately with regards to Air/Ground Communication system maintenance procedures | Hazard H1, Hazard H3, Hazard H4b | Req Core_14 (AH Core 7) |
| | | Maintenance team shall be trained appropriately with regards to Ground/Ground Communication system maintenance procedures | Hazard H1, Hazard H3 | Req Core_22 (AH Core 8) |
| | ATST_1-9 | Maintenance team shall be trained appropriately with regards to FDPS/RDPS/ADS systems maintenance procedures | Hazard H3 | Req Core_46, Req Core_53 (AH Core 13, AH Core 15) |
| | | Maintenance team shall be trained appropriately with regards to FDPS systems maintenance procedures | Hazard H3 | Req Core_49 (AH Core 14) |
| | ATST_1-10 | Controllers shall be trained appropriately regarding Appropriate separation standards related to wake turbulence | Hazard H2, Hazard H4b | Req Core_79 (AH Core 21) |
| | ATST_1-11 | ATCO shall be trained with regards to RVSM status handling into FDPS | Hazard H1 | - New requirement resulting from the FHA review |
| ATST_2: ATS Training for Contingency Procedures | ATST2 | Controllers shall be trained appropriately with regards to RVSM contingencies | AFI RVSM 7 | - |
| | ATST_2-1 | Controllers shall be trained appropriately regarding suspension of RVSM (including coordination with adjacent ACC's) | Hazard H2, Hazard H4b | Req Core_103 (AH Core 19, AH Core 20) |
| | ATST_2-2 | Controllers shall be trained appropriately with regards to contingency procedures in case of MASPS requirements failure | Hazard H2, Hazard H4b | Req Core_5 (AH Core 1, AH Core 2, AH Core 3, AH Core 4) |
| | ATST_2-3 | Controllers shall be trained appropriately with regards to ATS/DS failure contingency procedures | Hazard H1, Hazard H3 | Req Core_19 (AH Core 8) |

| System Element | Reference | System Element Requirement (SER) | Source | Previous FHA Backtrace ²³ |
|---|-----------|--|---|---|
| | ATST_2-4 | Controllers shall be trained appropriately with regards to Radio Communications Failure procedures | Hazard H1a, Hazard H3, Hazard H4b | Req Core_10 (AH Core 6, AH Core 7) |
| | ATST_2-5 | Controllers shall be trained appropriately to revert to procedural control in case of FDPS / RDPS/ADS system failure | Hazard H3 | Req Core_44, Req Core_51 (AH Core 13 AH Core 15) |
| | ATST_2-6 | Controllers shall be trained appropriately to operate without FDPS system (blank strip...) | Hazard H1, Hazard H3 | Req Core_47 (AH Core 14) |
| | ATST_2-7 | Controllers shall be trained appropriately regarding Non-receipt of flight plan | Hazard H1 | Req Core_55 (AH Core 16) |
| | ATST_2-8 | Controllers shall be trained appropriately with regards to coordination Contingency procedures (including Military coordination) | Hazard H1, Hazard H3 | Req Core_95 (AH Core 27) |
| | | Military Controllers shall be trained appropriately with regards to coordination Contingency procedures | Hazard H1, Hazard H3 | Req Core_96 (AH Core 27) |
| | ATST_2-9 | Controllers shall be trained appropriately regarding contingency procedures related to not forecast turbulence | Hazard H2, Hazard H4b | Req Core_70, Req Core_76 (AH Core 19, AH Core 20) |
| | | Controllers shall be trained appropriately regarding contingency procedures related to Non-RVSM aircraft facing severe icing or turbulence | Hazard H2 | Req Core_99 (AH Core 28) |
| | | Controllers shall be trained appropriately regarding contingency procedures related to wake turbulence | Hazard H2, Hazard H4b | Req Core_81 (AH Core 21) |
| | ATST_2-10 | Controllers shall be trained appropriately with regards to emergency contingencies | Hazard H4 | Req Core_86 (AH Core 22, AH Core 23) |
| ATST_3: ATS Training for Transiting Procedures | ATST3 | Controllers shall be trained appropriately with regards to Non-RVSM civil aircraft transiting procedures (including contingencies) | AFI RVSM 3, Hazard H2 | Req Core_7 (AH Core 5) |
| ATSE_1: ATS Equipment | ATSE1 | ATS equipment shall be modified to indicate and display RVSM status | AFI RVSM 1, Hazard H1, Hazard H3 | Req Core_26 (AH Core 9, AH Core 10) |

| System Element | Reference | System Element Requirement (SER) | Source | Previous FHA Backtrace ²³ |
|----------------|-----------|---|---|--|
| | ATSE2 | Existing conflict detection/alerting capabilities shall be updated to be consistent with RVSM operations | AFI RVSM 2, Hazard H3 | Req Core_32 (AH Core 9, AH Core 10, AH Core 11, AH Core 12) |
| | ATSE_1-1 | Air/Ground Communication system shall be designed to ensure a total coverage of the RVSM airspace with a minimum MTBF defined at CTA/UTA level | Hazard H1a, Hazard H3, Hazard H4b | Req Core_12 (AH Core 7) Requirement reworded as part of the FHA review |
| | | ATS/DS Communication system shall be designed to ensure point-to-point communications between all adjacent ACCs with a minimum MTBF defined at CTA/UTA level | Hazard H1, Hazard H3 | Req Core_15, Req Core_23 (AH Core 8) Requirement reworded as part of the FHA review |
| | ATSE_1-2 | RVSM/Non RVSM Status shall be provided by transferring controller (including when status is downgraded) | Hazard H1, Hazard H3 | Req Core_37 (AH Core12) |
| | ATSE_1-3 | Suitable and reliable ground communications means shall be implemented | Hazard H1, Hazard H3 | Req Core_38 (AH Core 12) |
| | ATSE_1-4 | Weather forecast equipment shall be in place to inform ATC about areas with severe turbulence | Hazard H2, Hazard H4b | Req Core_65 (AH Core 19) |
| | | Weather forecast equipment shall be in place to inform ATC about bad weather conditions | Hazard H2, Hazard H4b | Req Core_72 (AH Core 20, AH Core 28) |
| | ATSE_1-5 | AFTN communications availability/reliability and data rate transmission shall meet the Regional requirements | Hazard H1 | - New requirement resulting from the FHA review |
| | ATSE_1-6 | STCA capabilities shall be reinforced where appropriate | Hazard H3 | - New requirement resulting from the FHA review |
| | ATSE_1-7 | ATS equipment shall be developed with a minimum software assurance level to assure acceptable risk of data (e.g. surveillance information, flight plan) corruption" | Hazard H1 Hazard H3 Hazard H4 | - New requirement resulting from the FHA review |
| | ATSE_1-8 | FDPS/RDPS/ADS equipment shall be designed to ensure the achievement of a minimum MTBF defined at CTA/UTA level. | Hazard H3 Hazard H4 | - New requirement resulting from the FHA review |
| | ATSE_1-9 | FPDS shall check validity of RVSM status | Hazard H1 | - New requirement resulting from the FHA review |

| System Element | Reference | System Element Requirement (SER) | Source | Previous FHA Backtrace ²³ |
|--------------------------------------|-----------|---|------------|--|
| | ATSE_1-10 | MTCD capabilities shall be reinforced where appropriate | Hazard H3 | - New requirement resulting from the FHA review |
| AD: Airspace Design | AD1 | An appropriate Flight Level Orientation Scheme shall be developed | AFI RVSM 2 | - |
| | AD2 | Airspace facilities for emergency situations shall be provided | AFI RVSM 7 | - |
| SM: System Monitoring | SM1 | The exclusion of non-RVSM approved non-State aircraft from AFI RVSM airspace shall be monitored | AFI RVSM 1 | - |
| | SM2 | The height-keeping performance of RVSM-approved aircraft shall be monitored | AFI RVSM 8 | - |
| | SM3 | Data on operational errors shall be collected for collision risk and RVSM contribution to the risk of an accident estimations | AFI RVSM 8 | - |
| | SM4 | Data on risk exposure shall be collected for collision risk estimation | AFI RVSM 8 | - |
| | SM5 | Data on ACAS/TCAS events shall be collected and evaluated | AFI RVSM 8 | - |
| RVSM: Overall System | RVSM5 | The probability of any system failure leading to a mid-air collision shall be sufficiently low for the risk of mid-air collision due to the loss of vertical separation from all causes in AFI RVSM airspace to meet a TLS of 5×10^{-9} fatal accidents per flight hour. | AFI RVSM 5 | - |
| | RVSM6 | The system shall be sufficiently reliable for the number of ATM-induced accidents and serious or risk-bearing incidents in AFI RVSM airspace not to increase from current CVSM levels and, where, possible to decrease. | AFI RVSM 6 | - |

Table 13: AFI RVSM System Element Requirements

In comparison to the SERs developed in the PISC (cf. Appendix C of reference [22]):

- Requirement FCOP_3-10 “Flight crew specific procedures to avoid deviation due to incorrect visual perspective shall be defined” has been removed following the FHA review as not referring to a particular cause of hazard, flight crew being now familiar with operating 1000 feet separation under AFI RVSM.
- Requirements ATSE_1-1 “Air/Ground Communication system shall be designed to ensure a total coverage of the RVSM airspace with a minimum MTBF defined at CTA/UTA level” and “ATS/DS Communication system shall be designed to ensure point-to-point communications between all adjacent ACCs with a minimum MTBF defined at CTA/UTA level” have been reworded without modifying the initial meaning.
- The following requirements have been added as addressing causes and mitigations that were not explicitly revealed in the PISC FHA:

| | |
|-----------|---|
| FCOP-4.1 | Flight crew procedures shall be defined to provide ATC with climbing/descending performance before transit clearance is issued. |
| FCOP-4.2 | Degradation of climbing/descending performance shall be reported by flight crew to ATC |
| FCOT_1-10 | Flight crew discipline with regards to ATC shall be reinforced |
| FCOT_3-10 | Flight crew awareness with regards to weather deviations procedures (including notification to ATC) shall be reinforced. |
| ATSP_2-14 | Silent transfer procedures shall be defined in the LoA between ATS units equipped with Radar systems, which are capable of communicating with each other. |
| ATSP3-1 | Minimum climbing/descending performance shall be requested by ATC before transit clearance is issued. |
| ATST_1-11 | ATCO shall be trained with regards to RVSM status handling into FDPS |
| ATSE_1-5 | AFTN communications availability/reliability and data rate transmission shall meet the Regional requirements |
| ATSE_1-6 | STCA capabilities shall be reinforced where appropriate |
| ATSE_1-7 | ATS equipment shall be developed with a minimum software assurance level to assure acceptable risk of data (e.g. surveillance information, flight plan) corruption” |
| ATSE_1-8 | FDPS/RDPS/ADS equipment shall be designed to ensure the achievement of a minimum MTBF defined at CTA/UTA level. |
| ATSE_1-9 | FPDS shall check validity of RVSM status |
| ATSE_1-10 | MTCD capabilities shall be reinforced where appropriate |

Table 14: ‘New’ System Element Requirements

D.2 Approach for realising 'new' SERs in concept

| Requirement | Approach: the realisation is addressed by the design of ... |
|-------------|--|
| FCOP-4.1 | Specific procedures to be contained in PANS-ATM, Doc. 7030 or other appropriate material Procedures to obtain RVSM approval for operator requiring the submission to the approval authority of training programmes to be in line with applicable procedures (e.g. PANS-ATM, Doc 7030) |
| FCOP-4.2 | |
| FCOT_1-10 | Procedures to obtain RVSM approval for operator requiring the submission to the approval authority of training programmes to be in line with applicable procedures (e.g. PANS-ATM, Doc 7030) |
| FCOT_3-10 | |
| ATSP_2-14 | Specific procedures to be contained in PANS-ATM, Doc. 7030 or other appropriate material |
| ATSP3-1 | |
| ATST_1-11 | Specific training session to be detailed in the AFI RVSM Training Guidance Material |
| ATSE_1-5 | Specific requirement to be included in the RVSM ATC Operations Manual |
| ATSE_1-6 | |
| ATSE_1-7 | |
| ATSE_1-8 | |
| ATSE_1-9 | |
| ATSE_1-10 | |

Table 15: Approach for realising 'new' SERs in concept

Appendix E Height monitoring requirements

- ☞ This appendix briefly presents the AFI minimum height monitoring requirements discussed as part of aircraft height keeping performance monitoring under the argument A2.5.1.2 (Section 5.6.3).

1. UPDATING MONITORING REQUIREMENTS TABLE AND WEBPAGE

As additional data is obtained, monitoring requirements for specific aircraft types may be added or amended. When the table is updated, all reasonable notification methods will be used to notify AFI Civil Aviation Authorities and AFI Operators. The updated table will be posted on the ARMA webpage. The website address is: www.atns.co.za

2. AIRCRAFT REQUIREMENT FOR HEIGHT MONITORING

Aircraft engineering work that is required for the aircraft to apply for RVSM airworthiness approval from the State Civil Aviation Authority must be completed prior to the aircraft being monitored. The aircraft must have received State RVSM Operational Approval from the Appropriate Civil Aviation Authority. The afore-mentioned approval must be registered with the ARMA

3. HEIGHT MONITORING REQUIREMENTS

All AFI registered operators that operate or intend to operate in RVSM airspace are required to participate in the Height Monitoring Program. The table of monitoring requirements establishes requirements that need to be met.

4. APPLICABILITY OF HEIGHT MONITORING RESULTS FROM OTHER REGIONS

Monitoring data obtained in conjunction with RVSM monitoring programs from other regions may be used to meet AFI RVSM monitoring requirements. ARMA, which is responsible for managing the AFI RVSM monitoring program, has access to monitoring data from other regions which could contribute towards operators achieving their monitoring targets.

5. HEIGHT MONITORING PRIOR TO STATE RVSM OPERATIONAL APPROVAL

Height monitoring prior to State RVSM Operational Approval is not a requirement in AFI

6. FOLLOW - ON HEIGHT MONITORING

Height Monitoring is an on-going program that will continue after the State RVSM Operational Approval process and shall not be at intervals longer than 24 months.

7. AIRCRAFT GROUPS NOT LISTED IN THE TABLE

Contact the ARMA for clarification if an aircraft group is not listed in the Minimum Monitoring Requirements table.

8. MONITORING OF AIRCRAFT THAT ARE RVSM COMPLIANT ON DELIVERY.

If an operator adds new RVSM compliant aircraft of an aircraft type for which it already has RVSM operational approval and has completed monitoring requirements for the type in accordance with the attached table, the new aircraft are not required to be monitored. If an operator adds new RVSM compliant aircraft of an aircraft type for which it has NOT previously received RVSM operational approval, then the operator should complete monitoring in accordance with the attached table.

| Cat. | Data confidence | Aircraft Group | Minimum Operator Monitoring Requirements |
|------|--|--|--|
| 1 | Aircraft group for which there is sufficient monitoring data providing confidence and indicating performance in accordance with RVSM standards | A300, [A319,A320,A321], A330, A340, [A342, A343], A346, [B733, B734, B735], [B736,B737, B738,B739], B744(10" probe), B752, B764, CRJ7, F100, GLF5, LJ31, LJ60, MD11, [MD81, MD82, MD83, MD87, MD88] | <p>Minimum 2 aircraft or 10% from each fleet type of an operator to be monitored however not later than 6 months after the issue of RVSM operational approval</p> <p>Note 1. For the purposes of height monitoring, aircraft within brackets [], may be considered as belonging to the same height monitoring group. E.g. an operator with six A319 and four A321 aircraft may monitor one A319 and one A321 or two A319 aircraft or two A321 aircraft</p> <p>Note 2: When 10% of the fleet produces 2.4 aircraft 2 aircraft will be required for height monitoring. When 10% of the fleet produces 2.5 aircraft 3 aircraft will be required for height monitoring.</p> |
| 2 | Aircraft group for which there is sufficient monitoring data however reduced confidence | A306, [A312GE, A313GE], [A312PW, A313PW], B753, [B762, B763], B772, B773, BE40, C56X, [CRJ1, CRJ2], CL60(601/602), CL60(604), DC10, GLF4, MD90, [RJ1H, RJ70,RJ85] | <p>Minimum 2 aircraft or 30% from each fleet type of an operator to be monitored however not later than 6 months after the issue of RVSM operational approval</p> <p>Note 2: When 30% of the fleet produces 2.4 aircraft 2 aircraft will be required for height monitoring. When 30% of the fleet produces 2.7 aircraft 3 aircraft will be required for height monitoring.</p> |
| 3 | Aircraft group for which there is sufficient monitoring data and insufficient confidence available | A318, A345, A3ST, [B721, B722], B732, B737(Cargo), B744(5" probe), [B741, B742, B743], [BE20, BE30,BE350] C500, C550(552 Citation II), C550(Bravo), [C550, C551], C560, C650, C750, CRJ9, CL30, GL5T, [DC86, DC87], DC93, DC95, [E135, E145], E170, F2TH, F70, F900, FA20, FA50, GLEX, GLF2, GLF2(B), GLF3, H25B(700), H25B(800), H25C, J328, L101, [LJ35, LJ36], LJ40, LJ45, LJ55, PRM1, T134, [T204, T224, T234] | <p>60% from each fleet type of an operator to be monitored however not later than 6 months after the issue of RVSM operational approval</p> <p>Note: If 60% of the fleet type produces a fractional number, round up to the next whole aircraft</p> |
| 4 | Aircraft group for which there is insufficient monitoring data available. | D328, IL76 | <p>100% from each fleet type of an operator to be monitored however not later than 6 months after the issue of RVSM operational approval</p> |

| Cat. | Data confidence | Aircraft Group | Minimum Operator Monitoring Requirements |
|------|-----------------|---|---|
| 5 | Non Group | Non Group approved aircraft: B701, B703, DC85, DC91, DC92, DC94, FA10, F28-4 H25A, LJ23, LJ24, LJ,25 | 100% from each fleet type of an operator to be monitored however not later than 6 months after the issue of RVSM operational approval |

Table 16: AFI RVSM Height Monitoring Requirements

Note: monitoring prior to the issue of State RVSM approval is not a requirement.

Group definition:

Aircraft that have been manufactured to a nominally identical design and build and for RVSM Airworthiness approval fall into a group established in an RVSM certification document (e.g. Service Bulletin, Supplemental Type Certificate, Type Certificate Data Sheet).

Non-group definition

Aircraft that do not fall under the group definition and for RVSM Airworthiness Approval are presented as an individual airframe.

Annex 1 Definitions and Acronyms

1.1 Explanation of terms

| A | |
|---------------------------|--|
| Accident | <p>An occurrence associated with the operation of an aircraft which takes place between the time any person boards the aircraft with the intention of flight until such time as all such persons have disembarked, in which:</p> <p>a) a person is fatally or seriously injured as a result of:</p> <ul style="list-style-type: none"> - being in the aircraft, or - direct contact with any part of the aircraft, including parts which have become detached from the aircraft, or - direct exposure to jet blast, <p><i>except</i> when the injuries are from natural causes, self-inflicted or inflicted by other persons, or when the injuries are to stowaways hiding outside the areas normally available to the passengers and crew; or</p> <p>b) the aircraft sustains damage or structural failure which:</p> <ul style="list-style-type: none"> - adversely affects the structural strength, performance or flight characteristics of the aircraft, and - would normally require major repair or replacement of the affected component, <i>except</i> for engine failure or damage, when the damage is limited to the engine, its cowlings or accessories; or for damage limited to propellers, wing tips, antennas, tires, brakes, fairings, small dents or puncture holes in the aircraft skin; or <p>c) the aircraft is missing or is completely inaccessible.</p> |
| Aircraft proximity | A situation in which, in the opinion of a pilot or air traffic services personnel, the distance between aircraft as well as their relative positions and speed have been such that the safety of the aircraft involved may have been compromised. |
| Airprox | The code word used in an air traffic incident report to designate aircraft proximity. |
| Air Traffic Services | A generic term meaning variously, flight information service, alerting service, air traffic advisory service, air traffic control, service (area control service, approach, control service or aerodrome control, service). |
| Air Traffic Services Unit | A generic term meaning variously, area control centre approach control office or aerodrome control tower. In the AFI RVSM context, only area control centre are considered. |
| Argument | A statement asserting a fact that can be shown to be true (valid) or false |
| Assessment | An evaluation based on engineering, operational judgment and/or analysis methods. |
| Assumption | Statement, principle and/or premises offered without proof. |
| B | |
| Backing <entity> | <p>Arguments, strategies or evidence that help to support and validate</p> <p>Direct evidence of the satisfaction of a goal/argument/claim</p> |

| | |
|-------------------------------------|--|
| C | |
| Causes | Actions, omissions, events, conditions, or a combination thereof, which can lead to the accident or incident. |
| D | |
| Deviation from cleared flight level | An event in which an aircraft does not reach and maintain flight levels under conditions specified by the ATS unit or other appropriate authority. |
| Direct <entity> | Arguments, strategies or evidence that directly support the satisfaction of a goal/argument/claim. |
| E | |
| - | |
| F | |
| Failure | The inability of any element of a system to perform its intended function or to perform it correctly within specified limits. |
| G | |
| Good practice | A practise that is sufficiently recognised by various people/organisations to allow it to be used as an informal standard. |
| H | |
| Hazard | Any condition, event, or circumstance which could induce an accident. |
| Height-keeping performance | The observed performance of an aircraft with respect to adherence to cleared flight level. |
| I | |
| Incident | An occurrence, other than an accident, associated with the operation of an aircraft, which affects or could affect the safety of operation. |
| J | |
| - | |
| K | |
| - | |
| L | |
| Large height deviation | A vertical deviation of more than 300 feet. |
| M | |
| Minor height deviation | A vertical deviation of less than 300 feet. |
| Mitigation | Steps taken to control or prevent a hazard from causing harm and reduce risk to a tolerable or acceptable level. |
| N | |

| | |
|--------------------------------|--|
| - | |
| O | |
| Operational error | Any vertical deviation of an aircraft from the correct flight level as a result of incorrect action by ATC or the aircraft crew. |
| P | |
| - | |
| Q | |
| - | |
| R | |
| Risk | The combination of the overall probability, or frequency of occurrence of a harmful effect induced by a hazard and the severity of that effect. |
| RVSM approval | The term used to describe the successful completion of airworthiness approval and operational approval (if required). |
| S | |
| Safety | Safety is the state in which the risk of harm to persons or of damage to property is reduced to, and maintained at or below, an acceptable level through a continuing process of hazard identification and risk management |
| Safety argument | A statement (or a set of statements) that is used to assert that the service or system concerned is safe. |
| Safety evidence | Information, based on established fact or expert judgment, which is presented to show that the Safety Argument to which it relates is valid (true). |
| Safety objective | A safety objective is a planned safety goal stated in a safety policy. More specifically in the context of the FHA review, a safety objective is a qualitative or quantitative statement that defines the maximum frequency or probability at which a RVSM hazard can be expected to occur. |
| Safety occurrence | Accidents, serious incidents and incidents as well as other defects or malfunctioning of an aircraft, its equipment and any element of the Air Navigation System which is used or intended to be used for the purpose or in connection with the operation of an aircraft or with the provision of an air traffic management service or navigational aid to an aircraft |
| Separation minima infringement | A situation in which prescribed separation minima were not maintained between aircraft (whether or not it led to the submission of an AIRPROX report). |
| Short time conflict alert | An automated system that alerts air traffic controllers to potential conflicts between aircraft via an Air Traffic Situation Display. |
| System | A combination of physical components, procedures and human resources organised to perform a function. |
| T | |

| Target Level of Safety | A generic term representing the level of risk which is considered acceptable in particular circumstances. |
|------------------------|---|
| U | |
| - | |
| V | |
| - | |
| W | |
| - | |
| X | |
| - | |
| Y | |
| - | |
| Z | |
| - | |

1.2 Acronyms

| | |
|--------|---|
| A/G | Air to Ground |
| ACAS | Airborne Collision Avoidance System |
| ADS | Automatic Dependent Surveillance |
| AIAG | AFI ATS Incidents Analysis Group |
| AIS | Aeronautical Information Services |
| AFI | Africa and Indian Ocean Region |
| ANC | Air Navigation Commission |
| ANS | Air Navigation Services |
| ANSP | Air Navigation Services Provider |
| APIRG | AFI Planning and Implementation Regional Group |
| ARMA | AFI Regional Monitoring Agency |
| ARPO | AFI RVSM Programme Office |
| AR | Area of Routing |
| ARTF | AFI RVSM Task Force |
| ASECNA | Agence pour la Sécurité Aérienne en Afrique et à Madagascar |
| ATC | Air Traffic Control |
| ATCO | Air Traffic Control Officer |
| ATM | Air Traffic Management |
| ATNS | Air Traffic Navigation Services (South Africa) |
| ATS | Air Traffic Services |
| ATSU | Air Traffic Services Unit |
| CAA | Civil Aviation Administration |
| CHG | Change message |
| CPDLC | Controller Pilot data Link Communications |
| CRA | Collision Risk Assessment |
| CRM | Collision Risk Model |
| CTA | Control Area |
| DME | Distance Measuring Equipment |
| ESAF | Eastern and South Africa |
| ETA | Event Tree Analysis |
| EUR | Europe |
| FHA | Functional Hazard Assessment |
| FHASR | FHA Safety Requirement |
| FIR | Flight Information Region |
| FL | Flight Level |
| FLAS | Flight Level Allocation Scheme |
| FPL | Filed Flight Plan |
| FTA | Fault Tree Analysis |
| G/G | Ground to Ground |
| GMU | GPS-based Monitoring Unit |

| | |
|-----------|---|
| GNSS | Global Navigation Satellite System |
| GSN | Goal Structuring Notation |
| HLSR | High Level Safety Requirement |
| HMU | Height Monitoring Unit |
| IATA | International Air Transport Association |
| IATA SO&I | IATA Safety, Operations and Infrastructure |
| ICAO | International Civil Aviation Organisation |
| IFALPA | International Federation of Airline Pilots' Associations |
| IFATCA | International Federation of Air Traffic Controllers' Associations |
| LoA | Letter of Agreement |
| MID RMA | Middle East Regional Monitoring Agency |
| NAT | North Atlantic |
| NPM | National Program Manager |
| NSP | National Safety Plan |
| PFH | Per Flight Hour |
| PISC | Pre-Implementation Safety Case |
| POSC | Post-Implementation Safety Case |
| PSSA | Preliminary System Safety Assessment |
| RAN | Regional Air Navigation meeting |
| RCS | Risk Classification Scheme |
| RMA | Regional Monitoring Agency |
| RVSM | Reduced Vertical Separation Minimum |
| SAM | South America |
| SAR | Search and Rescue |
| SARP | Standard and Recommended Practise |
| SAT | South Atlantic |
| SATMA | South Atlantic Monitoring Agency |
| SCS | Severity Classification Scheme |
| SER | System Element Requirement |
| SLOP | Strategic Lateral Offset Procedures |
| SM | System Monitoring |
| SMS | Safety Management System |
| SSP | State Safety Program |
| STCA | Short Term Conflict Alert |
| TAG | AFI Tactical Action Group |
| TCAS | Traffic Collision Avoidance System |
| TLS | Target Level of Safety |
| UCR | Unsatisfactory Condition Report (AFI TAG Terminology) |
| UTA | Upper Traffic Area |
| VOR | VHF Omni-directional Range |
| WACAF | Western and Central Africa |

Annex 2 Applicable and reference documents

2.1 Applicable documents

- [1] AFI Reduced Vertical Separation Minimum (RVSM) RVSM Safety Policy, ICAO ARPO, 30 July 2004.
- [2] Report of the Tenth Meeting of APIRG ATS/AIS/SAR Sub-group, May 2009.

2.2 Reference documents

ICAO

- [3] ICAO Annex 2, Rules of the Air, ninth edition - July 1990, including all amendments and corrigenda up to applicability date
- [4] ICAO Annex 6, Operation of Aircraft, including all amendments and corrigenda up to applicability date
- [5] ICAO Annex 11, Air Traffic Services, thirteenth edition - July 2011, including all amendments and corrigenda up to applicability date
- [6] ICAO PANS-ATM - Procedures for Air Navigation Services, Doc. 4444
- [7] ICAO Safety Management Manual, Doc. 9859, second edition, 2009
- [8] Manual on Implementation of a 300m (1000ft) Vertical Separation minimum Between FL290 and FL410 Inclusive, ICAO Doc 9574
- [9] RMA Handbook - Manual of Operating Procedures and Practices for Regional Monitoring Agencies in relation to the use of a 300 m (1 000 ft) Vertical Separation Minimum Between FL 290 and FL 410 inclusive, ICAO, unedited version, February 2010
- [10] Africa-Indian Ocean Regional Traffic Forecasts 2004-2020, ICAO Doc 9859

AFI

- [11] Regional Supplementary Procedures, ICAO Doc 7030
- [12] ICAO Special AFI Regional Air Navigation Meeting, SP AFI RAN (2008)
- [13] ICAO Seventh AFI Regional Air Navigation Meeting (AFI/7, 1997)
- [14] Report of the 15th meeting of AFI RVSM Task Force (ARTF), Dakar, Senegal, 11 May 2009
- [15] Report of the 14th meeting of the AFI Planning and Implementation Regional Group (APIRG), Yaoundé, Cameroon, 23-27 June 2003
- [16] Description of AFI ATS Incidents Analysis Working Group (AIAG) and AFI Tactical Action Group, International Air Transport Association, October 2009

AFI RVSM Safety Management

- [17] Post-Implementation Collision Risk Assessment for RVSM in the Africa Indian Ocean Region, NLR Air Transport Safety Institute, NLR-CR-2009-688, February 2010
- [18] AFI RVSM FHA review report, ARMA, edition 1.0, February 2010
- [19] Briefing material - AFI FHA review brainstorming session, ARMA, edition 2.0, 26 November 2009
- [20] AFI RVSM Close Down Report, ICAO/ARPO-ARMA, 29 September 2008
- [21] AFI RVSM Switch-Over Plan, ICAO/ARPO

-
- [22] AFI RVSM Pre-Implementation Safety Case, ICAO ARPO/ARMA, Final Edition, February 2008.
 - [23] AFI RVSM Functional Hazard Assessment, Altran, AT/SDI/05-024A/05-003, May 2005.
 - [24] Pre-Implementation Collision Risk Assessment for RVSM in the Africa Indian Ocean Region, NLR Air Transport Safety Institute, NLR-CR-2005-443, August 2005
 - [25] Revised Pre-Implementation Collision Risk Assessment for the Africa Indian Ocean Region, NLR Air Transport Safety Institute, NLR-CR-2008-509, September 2008
 - [26] Collision Risk Assessment 3 for RVSM in the Africa Indian Ocean Region, NLR Air Transport Safety Institute, NLR-CR-23007-637, September 2007
 - [27] Extract of AIAG incidents reports for the time period 25 September 2008 - 31 December 2009, International Air Transport Association, January 2010
 - [28] Extract of AIAG incidents reports for the time period 1 January 2009 - 30 June 2009, International Air Transport Association, January 2010
 - [29] Extract of AIAG irregularity reports for the time period 25 September 2008 - 31 December 2009, International Air Transport Association, January 2010
 - [30] Extract of AIAG irregularity reports for the time period 1 January 2009 - 30 June 2009, International Air Transport Association, January 2010
 - [31] Extract of new UCR's detail for the time period 1 January 2009 - 30 September 2009
 - [32] Extract of resolved UCR's detail for the time period 1 January 2009 - 30 September 2009
 - [33] Extract of ARMA Form 1 database, AFI Regional Monitoring Agency, January 2010

Others

- [34] Air Navigation System Safety Assessment Methodology, EUROCONTROL
- [35] Safety Case Development Manual, EUROCONTROL, DAP/SSH/091, version 2.1, 13 October 2006
- [36] The EUR RVSM Post-Implementation Safety Case, EUROCONTROL, RVSM A1190, version 2.0, 28 July 2004
- [37] The EUR RVSM Pre-Implementation Safety Case, EUROCONTROL, RVSM 691, version 2.0, 14 August 2001