

Doc 9937
AN/477



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

Approved by the Secretary General
and published under his authority

First Edition — 2010

International Civil Aviation Organization

AVA Documents
Document Sharing Hub

Doc 9937
AN/477



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

Approved by the Secretary General
and published under his authority

First Edition — 2011

International Civil Aviation Organization

Published in separate English, French, Russian and Spanish editions by the
INTERNATIONAL CIVIL AVIATION ORGANIZATION
999 University Street, Montréal, Quebec, Canada H3C 5H7

For ordering information and for a complete listing of sales agents
and booksellers, please go to the ICAO website at www.icao.int

**Doc 9937, *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***
Order Number: 9937
ISBN 978-92-9231-679-2

© ICAO 2011

All rights reserved. No part of this publication may be reproduced, stored in a
retrieval system or transmitted in any form or by any means, without prior
permission in writing from the International Civil Aviation Organization.

AMENDMENTS

The issue of amendments is announced regularly in the *ICAO Journal* and in the supplements to the *Catalogue of ICAO Publications and Audio-visual Training Aids*, which holders of this publication should consult. The space below is provided to keep a record of such amendments.

RECORD OF AMENDMENTS AND CORRIGENDA

[illegible][illegible]

FOREWORD

The requirements and procedures for the introduction of a 300 m (1 000 ft) vertical separation between FL 290 and FL 410, generally referred to as the reduced vertical separation minimum (RVSM), were developed by the Review of the General Concept of Separation Panel (RGCSP), which has since been renamed the Separation and Airspace Safety Panel (SASP). The provisions necessary for the application of RVSM have been incorporated into Annex 2 — *Rules of the Air*, Annex 6 — *Operation of Aircraft*, Annex 11 — *Air Traffic Services* and the *Procedures for Air Navigation Services — Air Traffic Management* (PANS-ATM, Doc 4444). More detailed guidance material is provided in the *Manual on Implementation of a 300 m (1 000 ft) Vertical Separation Minimum Between FL 290 and FL 410 Inclusive* (Doc 9574).

In order to ensure that the overall safety objectives of the air traffic services (ATS) system can be met, all aircraft operating in airspace where RVSM is implemented are required to hold an approval, issued by the State of the Operator or State of Registry as appropriate, indicating that they meet all the technical and operational requirements for such operations. This requirement, and the responsibility of States with regard to the issuance of these approvals, are specified in 7.2.4 b) of Annex 6, Parts I and II.

Doc 9574 states that there is a need for system performance monitoring both during implementation planning and the post-implementation operational use of RVSM. The principles and objectives of monitoring are described in Chapter 6 of Doc 9574. In all regions where RVSM has been implemented, regional monitoring agencies (RMAs) have been established by the appropriate planning and implementation regional groups (PIRGs) to undertake these functions. The objectives of the RVSM monitoring programme include, inter alia:

- a) verification that the RVSM approval process remains effective;
- b) verification that the target level of safety will be met upon implementation of RVSM and will continue to be met thereafter;
- c) monitoring of the effectiveness of the altimetry system modifications which have been implemented to enable aircraft to meet the required height-keeping performance criteria; and
- d) evaluation of the stability of altimetry system error (ASE).

TABLE OF CONTENTS

	<i>Page</i>
Explanation of terms	(ix)
List of abbreviations and acronyms	(xi)
Publications	(xiii)
Chapter 1. Introduction	1-1
1.1 Purpose of the manual	1-1
1.2 General description of RMA functions	1-1
1.3 Requirements for establishment and operation of an RMA	1-1
Chapter 2. Working principles common to all regional monitoring agencies.....	2-1
2.1 Establishment and maintenance of an RVSM approvals database	2-1
2.2 Monitoring and reporting aircraft height-keeping performance and the occurrence of large height deviations	2-2
2.3 Conducting safety and readiness assessments and reporting results before RVMS implementation.....	2-7
2.4 Safety reporting and monitoring operator compliance with State approval requirements after RVMS implementation	2-12
2.5 Remedial actions	2-13
Appendix A. Duties and responsibilities of a regional monitoring agency	App A-1
Appendix B. States and designated RMAs for the reporting of RVSM approvals	App B-1
Appendix C. RMA forms for use in obtaining records of RVSM approvals from a State authority.....	App C-1
Appendix D. Content and format of an RVSM approvals database and procedures for exchanging data.....	App D-1
Appendix E. Merits and requirements of height-monitoring systems	App E-1
Appendix F. Guidance on reducing minimum monitoring requirements	App F-1
Appendix G. Action to be taken when an individual airframe is assessed as being non-compliant with altimetry system error performance requirements.....	App G-1
Appendix H. Recommended height-keeping performance monitoring data to be maintained in electronic form by an RMA for each monitored aircraft.....	App H-1

Appendix I. Action to be taken when a monitoring group is assessed as being non-compliant with altimetry system error performance requirements.....	App I-1
Appendix J. Large height deviation reporting form	App J-1
Appendix K. Scrutiny group composition, objectives and methodology.....	App K-1
Appendix L. Suggested form for ATC unit monthly reporting of large height deviations	App L-1
Appendix M. Sample content and format for collection of sample traffic movements	App M-1
Appendix N. Collision risk models used to estimate technical and operational risk.....	App N-1
Appendix O. Letter to a State authority requesting clarification of the RVSM approval status of an operator	App O-1

EXPLANATION OF TERMS

The following definitions are intended to clarify specialized terms used in this document.

Aberrant aircraft. Aircraft which exhibit measured height-keeping performance that is significantly different from the core height-keeping performance measured for the whole population of aircraft operating in RVSM airspace.

Aircraft-type group. Aircraft are considered to be members of the same group if they are designed and assembled by one manufacturer and are of nominally identical design and build with respect to all details that could influence the accuracy of height-keeping performance.

Altimetry system error (ASE). The difference between the altitude indicated by the altimeter display, assuming a correct altimeter barometric setting, and the pressure altitude corresponding to the undisturbed ambient pressure.

Altimetry system error stability. Altimetry system error for an individual aircraft is considered to be stable if the statistical distribution of altimetry system error is within agreed limits over an agreed period of time.

Altitude. The vertical distance of a level, point or an object considered as a point, measured from mean sea level (MSL).

Assigned altitude deviation (AAD). The difference between the transponded Mode C altitude and the assigned altitude/flight level.

Automatic altitude-control system. A system that is designed to automatically control the aircraft to a referenced pressure altitude.

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

Note.— One collision is considered to result in two accidents.

Exclusionary RVSM airspace. Airspace in which flight cannot be planned by civil aircraft which do not hold a valid RVSM approval from the appropriate State authority.

Flight technical error (FTE). The difference between the altitude indicated by the altimeter display being used to control the aircraft and the assigned altitude/flight level.

Height. The vertical distance of a level, a point or an object considered as a point, measured from a specified datum.

Height-keeping capability. Aircraft height-keeping performance that can be expected under nominal environmental operating conditions with proper aircraft operating practices and maintenance.

Height-keeping performance. The observed performance of an aircraft with respect to adherence to flight crew prescribed flight level. This includes both technical and operational errors.

Large height deviation (LHD). A deviation of 90 m (300 ft) or more in magnitude from the cleared flight level.

Non-compliant aircraft. An aircraft configured to comply with the requirements of the RVSM MASPS which, through height monitoring, is found to have a total vertical error (TVE) or an assigned altitude deviation (AAD) of 90 m (300 ft) or greater, or an altimetry system error (ASE) greater than 75 m (245 ft).

Non-exclusionary RVSM airspace. Airspace where a vertical separation of 300 m (1 000 ft) is applied between RVSM-approved aircraft, but in which flight may be planned by civil aircraft that do not hold a valid RVSM approval from the appropriate State authority. In such airspace, a vertical separation of 600 m (2 000 ft) must be applied between any non-RVSM approved aircraft and all other aircraft.

Occupancy. A parameter of the collision risk model which is twice the number of aircraft proximate pairs in a single dimension divided by the total number of aircraft flying the candidate paths in the same time interval.

Operational error. Any vertical deviation of an aircraft from the correct flight level as a result of incorrect action by ATC or the flight crew.

Overall risk. The risk of collision due to all causes, which includes the technical risk (see definition) and the risk due to operational errors and in-flight emergencies.

Passing frequency. The frequency of events in which two aircraft are in longitudinal overlap when travelling in the same or opposite direction on the same route at adjacent flight levels and at the planned vertical separation.

RVSM airworthiness approval. The process by which the State authority ensures that aircraft meet the RVSM minimum aviation system performance specification (MASPS). Typically, this would involve an operator meeting the requirements of the aircraft manufacturer's service bulletin for the aircraft and having the State authority verify the successful completion of this work.

RVSM approval. The term is used synonymously with RVSM operational approval.

RVSM operational approval. The process by which the State authority ensures that an operator meets all the requirements for operating aircraft in RVSM airspace. RVSM airworthiness approval is a prerequisite for operational approval.

Target level of safety (TLS). A generic term representing the level of risk which is considered acceptable in particular circumstances.

Technical risk. The risk of collision associated with aircraft technical height-keeping performance, which specifically refers to the performance affected by the avionics of the aircraft, not the flight crew.

Total vertical error (TVE). The vertical geometric difference between the actual pressure altitude flown by an aircraft and its assigned pressure altitude (flight level).

Track. The projection on the earth's surface of the path of an aircraft, the direction of which path at any point is usually expressed in degrees from North (true, magnetic, or grid).

Vertical separation. The spacing provided between aircraft in the vertical plane.

Vertical separation minimum (VSM). VSM is documented in the *Procedures for Air Navigation Services — Air Traffic Management* (PANS-ATM, Doc 4444) as being a nominal 300 m (1 000 ft) below FL 290 and 600 m (2 000 ft) above FL 290 except where, on the basis of regional agreement, a value of less than 600 m (2 000 ft) but not less than 300 m (1 000 ft) is prescribed for use by aircraft operating above FL 290 within designated portions of the airspace.

LIST OF ABBREVIATIONS AND ACRONYMS

AAD	Assigned altitude deviation
AAMA	Australian Airspace Monitoring Agency
ACAS	Airborne collision avoidance system
ADS-B	Automatic dependent surveillance — broadcast
ADS-C	Automatic dependent surveillance — contract
AGHME	Aircraft geometric height measurement element
ARD	Altitude recording device
ARMA	AFI regional monitoring agency
ASE	Altimetry system error
ATC	Air traffic control
ATS	Air traffic services
CARSAMMA	Caribbean/South American Regional Monitoring Agency
CMA	Central Monitoring Agency
CRM	Collision risk model
EUR RMA	Regional Monitoring Agency for European EUR RVSM airspace
FAA	Federal Aviation Administration
FIR	Flight information region
GMS	GPS-based monitoring system
GMU	GPS-based monitoring unit
GPS	Global positioning system
HME	Height-monitoring equipment
HMU	Height-monitoring unit
JAA	Joint Aviation Authorities
KSN	Knowledge sharing network
LHD	Large height deviation
MAAR	Monitoring Agency for the Asia Region
MASPS	Minimum aircraft system performance specification
MID RMA	Middle East Regional Monitoring Agency
MLAT	Multilateration
MMR	Minimum monitoring requirements
NAARMO	North American Approvals Registry and Monitoring Organization
NAT	North Atlantic
NOAA	North Oceanic and Atmospheric Administration
PARMO	Pacific Approvals Registry and Monitoring Organization
PIRGs	Planning and implementation regional groups
RA	Resolution advisory
RGCSP	Review of the General Concept of Separation Panel
RMA	Regional monitoring agency
RVSM	Reduced vertical separation minimum
SASP	Separation and Airspace Safety Panel
SATMA	South Atlantic Monitoring Agency
SD	Standard deviation
SSR	Secondary surveillance radar
STC	Supplementary type certificate
TCAS	Traffic alert and collision avoidance system
TGL	Temporary guidance leaflet

TLS	Target level of safety
TMU	Total vertical error monitoring unit
TVE	Total vertical error
VSM	Vertical separation minimum

PUBLICATIONS

(referred to in this manual)

Annexes to the Convention on International Civil Aviation

Annex 2 — Rules of the Air

Annex 6 — Operation of Aircraft

Part I — International Commercial Air Transport — Aeroplanes

Part III — International Operations — Helicopters

Annex 10 — Aeronautical Telecommunications

Volume II — Communication Procedures including those with PANS status

Annex 11 — Air Traffic Services

Procedures for Air Navigation Services

ATM — Air Traffic Management (Doc 4444)

Manuals

Aircraft Type Designators (Doc 8643)

Designators for Aircraft Operating Agencies, Aeronautical Authorities and Services (Doc 8585)

Location Indicators (Doc 7910)

Manual on Implementation of a 300 m (1 000 ft) Vertical Separation Minimum Between FL 290 and FL 410 inclusive (Doc 9574)

Reports of Meetings

Report of the Sixth Meeting of the Review of the General Concept of Separation Panel (RGCSPP/6) (Doc 9536)¹

1. This document is permanently out of print.

Chapter 1

INTRODUCTION

1.1 PURPOSE OF THE MANUAL

The intent of this manual is to provide guidance on RMA operating procedures, in order to achieve a standardized approach to the way in which RMAs carry out these functions and the associated detailed duties and responsibilities of Doc 9574. It is not intended to provide exhaustive guidance on how to operate an RMA. Information on what is required of an RMA will be found in the *Manual on Implementation of a 300 m (1 000 ft) Vertical Separation Minimum Between FL 290 and FL 410 Inclusive* (Doc 9574).

1.2 GENERAL DESCRIPTION OF RMA FUNCTIONS

1.2.1 An RMA supports the implementation and continued safe use of RVSM within a designated airspace. In the context of RVSM, “safe” has a quantitative meaning: satisfaction of the agreed safety goal, or target level of safety (TLS). Section 2.1 of Doc 9574 describes the safety objectives associated with RVSM implementation and use.

1.2.2 RMA duties and responsibilities are described in Doc 9574, 6.4.4 and 6.4.5, as well as in Appendix A to this manual. For the purposes of this overview, the functions of an RMA can be summarized as:

- a) establish and maintain a database of RVSM approvals;
- b) monitor aircraft height-keeping performance and the occurrence of LHDs and report the results appropriately;
- c) conduct safety and readiness assessments and report the results appropriately;
- d) monitor operator compliance with State approval requirements; and
- e) initiate necessary remedial actions if RVSM requirements are not met.

1.2.3 Appendix A to this manual also lists the RMA responsible for the provision of monitoring and safety assessment activities in each FIR in which RVSM has been implemented.

1.3 REQUIREMENTS FOR ESTABLISHMENT AND OPERATION OF AN RMA

1.3.1 An RMA must have both the authority and technical competence to carry out its functions. In establishing an RMA, it is therefore necessary to ensure that:

- a) the organization receives authority to act as an RMA as the result of a decision by a State, a group of States or a PIRG; and

- b) the organization acting as an RMA has adequate personnel with the technical skills and experience to carry out the functions listed in 1.2.2.

1.3.2 It is the responsibility of the body authorizing establishment of an RMA to ensure that these requirements are met. An example of a process satisfying this requirement would be for the organization intending to be an RMA to participate in a training programme under the guidance of one of the established RMAs. For an organization with no prior experience with RVSM monitoring, such a programme could take as long as one year and should include both formal and on-the-job training.

Chapter 2

WORKING PRINCIPLES COMMON TO ALL REGIONAL MONITORING AGENCIES

This chapter presents the working principles common to all RMAs and describes the activities associated with the five main RMA functions listed in Chapter 1, Section 1.2. More detailed information, including agreed data formats, required communication links and appropriate references to ICAO documents and regional materials, is provided in the Appendices.

2.1 ESTABLISHMENT AND MAINTENANCE OF AN RVSM APPROVALS DATABASE

2.1.1 One of the functions of an RMA is to establish a database of aircraft approved by its State authority for operations in RVSM airspace in the region for which the RMA has responsibility. This information is necessary for two reasons:

- a) the RMA is responsible for verifying the approval status of all aircraft operating within its region; and
- b) height-keeping performance data must be correlated to an approved airframe.

This information is of vital importance if the height-keeping performance data collected by the height-monitoring systems are to be effectively utilized in the risk assessment.

2.1.2 Aviation is a global industry and many aircraft operating in a region where RVSM has not previously been implemented may nevertheless be approved for RVSM operations and have their approvals registered with another RMA. While each RMA will need to establish an RVSM approvals database, there is considerable scope for database sharing. So while a region introducing RVSM will need its own RMA to act as a focal point for the collection and collation of RVSM approvals for aircraft operating under its jurisdiction, it may not need to maintain a complete database of all aircraft in the world that are RVSM-approved. It will, however, need to establish links with other RMAs in order to determine the RVSM status of aircraft it has monitored, or intends to monitor, so that a valid assessment of the technical height-keeping risk can be made.

2.1.3 To avoid duplication by States in registering approvals with RMAs, the concept of a designated RMA for the processing of approval data has been established in this guidance material. Under the designated RMA concept, all States are associated with a particular RMA for the processing of RVSM approvals. Appendix B proposes a listing of States and the respective designated RMA for RVSM approvals. However, this list should be endorsed by PIRGs and/or bilateral agreements detailing the respective responsibilities. RMAs may contact any State to address safety matters without regard to the list of designated RMAs. The correspondence between the RMA and each particular State should be coordinated with the respective designated RMA.

2.1.4 Appendix C provides the pertinent forms, together with a brief description of their use, that an RMA should supply to a State authority to obtain information on aircraft RVSM approval status.

2.1.5 To facilitate data sharing each RMA should maintain its approvals database in a common format and in electronic form.

2.1.6 Appendix D suggests the minimum database content and the format in which it should be maintained by an RMA. Appendix D also describes the data to be shared by RMAs and the procedures for sharing such data.

2.2 MONITORING AND REPORTING AIRCRAFT HEIGHT-KEEPING PERFORMANCE AND THE OCCURRENCE OF LARGE HEIGHT DEVIATIONS

2.2.1 An RMA must be prepared to collect the information necessary to assess the in-service technical height-keeping performance of the aircraft operating in the airspace for which it has monitoring responsibility. In addition, it must establish procedures for the collection of information concerning large deviations from the cleared flight level and operational errors caused by non-compliance with ATC instructions or loop errors within the ATC system.

2.2.2 Experience has shown that monitoring of aircraft technical height-keeping performance is a challenging task requiring specialized systems. Experience has also shown that organizing and overseeing the collection of LHD information necessitates special procedures. These two topics will be treated separately in this section.

Monitoring of aircraft height-keeping performance

2.2.3 Monitoring of aircraft height-keeping performance is a demanding enterprise, particularly as regards estimation of ASE. The following discussion of height-keeping performance monitoring first considers the technical requirements for a monitoring system and then examines the application of monitoring before and after RVSM implementation in an airspace. Guidance on monitoring requirements for RVSM-approved aircraft is also provided along with suggested formats for storing monitoring data to facilitate data exchange with other RMAs.

Establishment of a technical height-monitoring function

2.2.4 The principal objectives of an RVSM monitoring programme are to provide:

- a) evidence of the effectiveness of the RVSM MASPS, and altimetry system modifications made in order to comply with the MASPS, in achieving the desired height-keeping performance;
- b) confidence that the technical TLS will be met when RVSM is implemented and will continue to be met thereafter; and
- c) evidence of ASE stability.

2.2.5 In order to achieve these objectives, a technical height-monitoring function has to be established. To date, regions which have implemented RVSM have used either ground-based HMUs or air portable GMUs. Whatever system(s) a region decides to use, the quality and reliability of the monitoring infrastructure and its output data must be ensured through correct specification of the systems and thorough verification of performance.

2.2.6 It is particularly important for RMAs to verify that height-monitoring data from whatever sources they use can be combined for the purposes of the data analysis. The combination of data for collision risk evaluation should be avoided unless the error characteristics of the two monitoring systems have been determined to be identical. This is especially important in any work to establish ASE stability because the different measurement errors in individual systems can distort the results and indicate ASE instability when none exists, or vice versa.

2.2.7 As a means of ensuring both adequate accuracy in estimating TVE and transferability of monitoring results, an RMA must establish that any TVE estimation system which it administers has a mean measurement error close to

zero and a standard deviation of measurement error not greater than 15 m (50 ft). Estimates of measurement errors associated with the HMU and the GMS, which employs GMUs, should indicate that each system satisfies these requirements.

2.2.8 An RMA should coordinate with the PIRG for its region to ensure that a suitable monitoring infrastructure is available to meet the region's requirements. A suitable monitoring infrastructure can be established through an arrangement to share GMU facilities with an existing RMA, the acquisition of fixed ground-based monitoring facilities within the region, or by engaging a suitable contractor to operate the monitoring programme. If the latter option is selected, the choice of support contractors should take into account their prior experience and the suitability of the monitoring procedures and facilities which they propose using.

2.2.9 For further information on the merits and requirements of height-monitoring systems, see Appendix E. If a new method of monitoring is proposed, the new system should, in addition to meeting the requirements of 2.2.7, be evaluated against existing systems to ensure that the results are comparable.

2.2.10 For regions that have a limited monitoring capability, data from other regions may be acceptable for the evaluation of technical risk. This should be considered before determining the minimum technical height-monitoring facilities necessary to meet the requirements of Annex 11.

Technical height-monitoring requirements

2.2.11 The three objectives of aircraft height-keeping performance monitoring stated in Doc 9574 and noted in 2.2.4 above are applicable to both the pre- and post-implementation phases. However, in general, evidence of ASE stability would not normally be expected to be a product of the pre-implementation phase monitoring because this is a long-term consideration.

2.2.12 During the pre-implementation phase of an RVSM programme, it is necessary to verify that a sufficiently high proportion of the anticipated RVSM aircraft population meets the requirements of the RVSM MASPS. This is the purpose of a pre-implementation technical height-monitoring programme.

2.2.13 The majority of current aircraft types are eligible for RVSM airworthiness approval under group approval provisions. These provisions permit the defining of aircraft-type groups consisting of aircraft types which are designed and assembled by one manufacturer and are of nominally identical design and build with respect to all details that could influence the accuracy of height-keeping performance. It is not normally necessary to monitor all airframes within a monitoring group providing an adequate sample is available and the performance of the group is within the parameters specified below. The minimum monitoring requirements (MMR) document lists the aircraft types which are eligible for RVSM approval under the group provisions and the groups to which they belong. It also suggests the level of monitoring that should be expected for each operator. The MMR table is available on the RMA's website and is reviewed periodically. Guidance on how to reduce MMR is provided in Appendix F.

2.2.14 The analysis of aircraft technical height-keeping performance should demonstrate that:

- a) the technical TLS of 2.5×10^{-9} fatal accidents per flight hour has been met;
- b) the number of aircraft monitored for each operator/aircraft-type combination must meet a predetermined level;
- c) aircraft-type groups must demonstrate performance such that the absolute value of the group mean ASE is not in excess of 25 m (80 ft) and that the sum of the absolute value of the mean ASE and 3 SD of ASE is not in excess of 75 m (245 ft). No individual measurement should exceed 245 ft in magnitude, excluding monitoring system measurement error; and

- d) no individual measurement of ASE for each aircraft approved on a non-group basis for RVSM operations may exceed 49 m (160 ft) in magnitude, excluding monitoring system measurement error.

Note 1.— Data from other regions may be used to meet the above objectives providing they are contemporary with the assessment period.

Note 2.— With reference to 2.2.14 b), the minimum number of aircraft in a particular group to be monitored is normally expressed as a percentage of the operator's fleet of that group, with a further provision that the number of aircraft must not be less than two unless the operator has only a single airframe in the group.

Note 3.— With reference to 2.2.14 a), the technical TLS is normally evaluated only on an annual basis or as determined by the PIRG. The other activities may be continuous.

2.2.15 Guidance regarding the conduct of a safety assessment leading to an estimate of risk for comparison with the TLS referred to in 2.2.14 a) is provided in Section 2.3.

2.2.16 With regard to 2.2.14 b), the MMR should be reviewed at regular intervals and coordinated with all RMAs. The reviewed version should be available on the RMA's website. An RMA in conjunction with its PIRG may require a higher level of monitoring than defined in the MMR. The MMR itself should be subject to periodic review, either in collaboration with other RMAs or through ICAO. This review should be based on quality and quantity of data available.

2.2.17 It is especially important that an RMA take appropriate action if the height-keeping performance monitoring system detects an individual aircraft whose ASE, after accounting for measurement error, is in excess of the 75 m (245 ft) limit noted in 2.2.14 c). Similarly, appropriate action should be taken if either an aircraft's observed TVE after accounting for measurement error, or its AAD, is 90 m (300 ft) or more. In all cases, the action should include notifying the aircraft operator and the State authority which granted the aircraft's RVSM approval. Appendix G contains an example of such a letter of notification.

2.2.18 Procedures also need to be established whereby the PIRG is provided with timely notification of all actions taken under the provisions of 2.2.17.

2.2.19 In order to facilitate the exchange of aircraft height-keeping performance monitoring data between RMAs, an RMA should maintain the minimum information identified in the exchange of height measurement data table in Appendix H for each observation of aircraft height-keeping performance obtained from the airspace within which it exercises its functions.

Reporting of aircraft height-keeping performance statistics

2.2.20 Where an RMA is employing a height-keeping performance monitoring system producing substantial estimates of aircraft ASE, tabulations of ASE by aircraft-type groups, as identified in the MMR, should be kept. For each group, the magnitude of mean ASE and the magnitude of mean ASE + 3 SD of ASE should be calculated and compared to the group performance limits, which are 25 m (80 ft) and 75 m (245 ft), as noted above. Groups exceeding the performance requirements must be investigated and reported annually, or more frequently as required, to the body which authorized the establishment of the RMA. Note that a minimum data set of results is required before the group results can be considered valid.

2.2.21 In order to provide for situations where one or both of these limits is exceeded for an aircraft-type group, an RMA should have a process in place to examine the findings, e.g. through consultation with airworthiness and operations specialists. This could be achieved, where necessary, by establishing a group within the region consisting of specialists in these fields. Alternatively, and in particular in cases where the observed performance deficiency is affecting more than one region, it may be possible to achieve this through cooperation with other regions which have established airworthiness and operations groups.

2.2.22 It is the RMA's responsibility to bring performance issues having an impact on safety to the attention of State authorities, aircraft manufacturers and PIRGs. Should the examination of monitoring results indicate a potential systematic problem in group performance, the RMA, or other appropriate body, should notify both the State authority that issued the airworthiness approval for the aircraft-type group in question and the aircraft manufacturer. Where applicable, the RMA may also propose remedial measures. An RMA does not have the regulatory authority to require that improvements to performance be made; only the State which approved the RVSM airworthiness documents for the aircraft-type group has such authority. However, the State is required, under the provisions of Annex 6, Parts I and II, to take immediate corrective action with regard to aircraft which are reported by an RMA as not complying with the height-keeping requirements.

2.2.23 RVSM airworthiness approval documents in the form of an approved service bulletin, supplementary type certificate (STC) or similar State-approved material provide directions to an operator regarding the steps necessary to bring an aircraft type into compliance with RVSM requirements. If there is a flaw in the ASE performance of an aircraft type, the ultimate goal of the RMA is to influence appropriate corrections to the compliance method, which would then be incorporated into the applicable RVSM airworthiness approval documents. An RMA's actions to achieve this goal should be the following:

- a) assemble all ASE monitoring data for the aircraft type from the airspace for which the RMA is responsible in accordance with the approach shown in Appendix I;
- b) assemble the measurement-error characteristics of the monitoring system or systems used to produce the results in a);
- c) as deemed relevant by the RMA, assemble all summary monitoring data (consisting of mean ASE, ASE SD, minimum ASE, maximum ASE, and details of any flights found to be non-compliant with ASE requirements) from other regions or airspace where the aircraft type has been monitored; and
- d) by means of an official RMA letter, similar in form to that shown in Appendix I, inform the State authority that approved the airworthiness documents for the aircraft-type group, and the manufacturer, of the observation of allegedly inadequate ASE performance, citing:
 - 1) the requirement that the absolute value of an aircraft-type group's mean ASE be no greater than 25 m (80 ft), and that the sum of the absolute value of the group's mean ASE and 3 SD of ASE be no greater than 75 m (245 ft);
 - 2) the data described in a) and b) and, as necessary, c), which will be provided on request;
 - 3) the need for compliance with these requirements in order to support safe RVSM operations; and
 - 4) a request to be informed of consequent action taken by the State and/or manufacturer to remedy the cause or causes of the observed performance, including any changes to the State airworthiness approval documents.

Monitoring the occurrence of large height deviations

2.2.24 Experience has shown that LHDs — errors of 90 m (300 ft) or more in magnitude — have had significant influence on the outcome of safety assessments before and after implementation of RVSM. RMAs play a key role in the collection and processing of reports of such occurrences.

2.2.25 The causes of such errors have been found to be:

- a) an error in the altimetry or automatic altitude control system of an aircraft;
- b) turbulence and other weather-related phenomena;
- c) the crew not following established contingency procedures during an emergency descent by an aircraft;
- d) the response to airborne collision avoidance system (ACAS) resolution advisories;
- e) not following an ATC clearance, resulting in flight at an incorrect flight level;
- f) an error in issuing an ATC clearance, resulting in flight at an incorrect flight level; and
- g) coordination errors between adjacent ATC units in the transfer of control responsibility for an aircraft, resulting in flight at an incorrect flight level.

2.2.26 The aircraft technical height-keeping performance monitoring programme administered by an RMA addresses the first of these causes. There is, however, a need to establish, at a regional level, the means to detect and report the occurrence of LHDs due to the remaining causes. A sample LHD reporting form is included in Appendix J. While the RMA will be the recipient and archivist for reports of LHDs, it is important to note that the RMA alone cannot be expected to conduct all activities associated with a comprehensive programme to detect and report LHDs. This needs to be addressed through the appropriate PIRG and its subsidiary bodies, as part of an overall regional safety management programme.

2.2.27 Typically, a programme to assess LHDs will usually include a regional or State-based Scrutiny Group to support the RMA monitoring function. A Scrutiny Group is comprised of operational and technical subject-matter experts who support the evaluation and classification of LHDs. The RMA should coordinate with the PIRG to establish a Regional Scrutiny Group, or relevant State organizations to establish a State-based Scrutiny Group that will examine reports of large height deviations. Scrutiny Group guidance is contained in Appendix K.

2.2.28 Experience has shown that the primary sources of reports of LHDs are the ATC units providing air traffic control services in the airspace where RVSM is or will be applied. The information available to these units, in the form of voice reports, ADS-C reports and through the use of ATS surveillance systems such as radar, ADS-B or MLAT, provides the basis for identifying LHDs. A programme for identifying LHDs should be established and ATC units should report such events monthly. A recommended monthly report form is provided in Appendix L. It is the responsibility of the RMA to collect this information and to provide periodic reports of observed height deviations to the appropriate PIRG and/or its subsidiary bodies, in accordance with procedures prescribed by the PIRG.

2.2.29 For all involved aircraft the individual LHD reports from ATC units to the RMA should contain, as a minimum, the following information:

- a) reporting unit;
- b) location of deviation, either as latitude/longitude or a bearing and distance from a significant point;
- c) date and time of the LHD;
- d) sub-portion of airspace, such as established route system, if applicable;
- e) flight identification and aircraft type;
- f) assigned flight level;
- g) final reported flight level or altitude and basis for establishment (e.g. pilot report or Mode C);
- h) duration at incorrect level or altitude;

- i) cause of deviation;
- j) any other traffic in potential conflict during deviation;
- k) crew comments when notified of deviation; and
- l) remarks from the ATC unit making the report.

2.2.30 Other sources for reports of LHDs should also be explored. For example, an RMA should investigate, in conjunction with the responsible PIRG, whether operators within the airspace for which it is responsible would be prepared to share pertinent summary information from internal safety occurrence databases. Arrangements should also be made for access to information which may be pertinent to the RVSM airspace from State databases of air safety incident reports and voluntary reporting safety databases, such as the Aviation Safety Reporting System administered by the United States National Aeronautics and Space Administration (NASA), all of which could be possible sources of information concerning LHD incidents in the airspace for which the RMA is responsible.

2.3 CONDUCTING SAFETY AND READINESS ASSESSMENTS AND REPORTING RESULTS BEFORE RVSM IMPLEMENTATION

2.3.1 A safety assessment consists of estimating the risk of collision associated with RVSM and comparing this risk to the agreed RVSM safety goal, the TLS. An RMA needs to acquire an in-depth knowledge of the use of the airspace within which RVSM will be implemented. This requirement will continue after implementation. Experience has shown that such knowledge can be gained, in part, through a review of charts and other material describing the airspace, and through periodic collection of samples of traffic movements within the airspace. However, it is also important that RMA personnel have sufficient understanding of the way in which an ATC system operates to enable them to correctly interpret the information from these sources.

2.3.2 It should also be noted that currently there is no standard CRM applicable to all airspace. Development and application of a CRM is a complicated activity and should be conducted only by trained and experienced personnel. Emerging RMAs that do not have the requisite skills should seek assistance from external sources or established RMAs before adapting a CRM or attempting to conduct risk calculations. Additional guidance can be obtained from previous RGCSP and SASP documentation. It will be necessary to adapt existing CRM parameters to take account of regional variations.

2.3.3 A readiness assessment is an examination of the approval status of operators and aircraft using airspace where RVSM is planned in order to evaluate whether a sufficiently high proportion of operations will be conducted by approved operators and aircraft when RVSM is introduced.

2.3.4 An RMA is responsible for conducting both safety and readiness assessments prior to RVSM implementation. The responsibility for conducting safety assessments continues after RVSM is introduced.

Safety assessment

2.3.5 One of the principal duties of an RMA is to conduct a safety assessment prior to RVSM implementation. It is strongly recommended that an RMA conduct a series of safety assessments prior to RVSM implementation. These should start at least one year prior to the planned implementation date in order to provide the body overseeing RVSM introduction with early indications of any problems which must be remedied before RVSM can be implemented.

2.3.6 The PIRG will specify the safety reporting requirements for the RMA.

Establishing the competence necessary to conduct a safety assessment

2.3.7 Conducting a safety assessment is a complex task requiring specialized skills that are not widely available. As a result, an RMA will need to pay special attention to ensuring that it has the necessary competence to complete this task prior to and after RVSM implementation.

2.3.8 Ideally, an RMA should have the internal competence to conduct a safety assessment. However, recognizing that personnel with the required skills may not be available internally, it may be necessary for the RMA to augment its internal staff capabilities through arrangements with another RMA or some other organization possessing the necessary competence.

2.3.9 If it is necessary to use an external organization to conduct a safety assessment, the RMA must nevertheless have the internal competence to judge that such an assessment is done properly. This competence should be acquired through an arrangement with an RMA that has experience in the conduct of safety assessments.

Preparations for conduct of a safety assessment

2.3.10 In preparing to support RVSM implementation, the responsible RMA needs to ensure that the safety assessment takes account of all the factors which influence collision risk within the airspace where RVSM will be applied. RMAs therefore need to establish the means for collecting and organizing the pertinent data and other information that is needed to adequately assess all the relevant airspace factors. As is noted below, some data sources from other airspace where RVSM has been implemented may assist an RMA in conducting a safety assessment. However, the overall safety assessment results from another portion of worldwide airspace may not be used as the sole justification for concluding that the TLS will be met in the airspace where the RMA has safety assessment responsibility.

Assembling samples of traffic movements for the airspace

2.3.11 Samples of traffic movements should be collected for the entire airspace where RVSM will be implemented. As a result, ATC providers within the airspace may need to cooperate in the collection of samples. In this case, the RMA will need to coordinate collection of traffic movement samples through the body overseeing RVSM implementation.

2.3.12 The first sample of traffic movement data should be collected as soon as is practicable after the decision to implement RVSM within a particular airspace has been made. However, it is also necessary that the operational details of the implementation be agreed prior to the data collection. For example, RVSM may be implemented as exclusionary airspace, in which an aircraft must have RVSM approval to flight plan through the airspace, or as non-exclusionary airspace, in which flight by non-RVSM approved aircraft is permitted. In the latter case, a minimum of 600 m (2 000 ft) vertical separation must be provided between the non-approved aircraft and all other aircraft. The RMA also needs to be aware of any changes to the ATS route structure, including changes to the permitted directions of flight on existing routes. Operational factors such as these need to be taken into account in the safety assessment.

2.3.13 The RMA should plan to collect at least two samples of traffic movement data prior to RVSM implementation, with the timing of the first as noted in the previous paragraph. The timing of the second sample should be as close to the planned time of implementation as is practicable in light of the time required to collect, process and analyse the sample and to extract information necessary to support final safety and readiness assessments.

2.3.14 In planning the time and duration of a traffic sample, the RMA should take into account the importance of capturing any periods of heavy traffic flow which might result from seasonal or other factors. The duration of any traffic sample should be at least 30 days, or any other statistically significant period, with a longer sample period left to the judgement of the RMA.

2.3.15 The following information should be collected for each flight in the sample:

- a) date of flight (mm/dd/yyyy) or (dd/mm/yyyy);
- b) flight identification or aircraft call sign, in standard ICAO format;
- c) aircraft type designator, as listed in Doc 8643;
- d) aircraft registration mark, if available;
- e) an indication that the operator and aircraft are RVSM approved (i.e. Does a "W" appear in Item 10 of the flight plan?);
- f) location indicator for the origin aerodrome, as listed in Doc 7910;
- g) location indicator for the destination aerodrome, as listed in Doc 7910;
- h) entry point into RVSM airspace (as a significant point or latitude/longitude);
- i) time at entry point;
- j) flight level at entry point;
- k) exit point from RVSM airspace (as a significant point or latitude/longitude);
- l) time at exit point;
- m) flight level at exit point; and
- n) as many additional position/time/flight-level combinations as the RMA judges necessary to capture the traffic movement characteristics of the airspace.

2.3.16 Where possible, in coordinating the collection of the sample, the RMA should specify that information be provided in electronic form, for example, in a spreadsheet. Appendix M contains a sample format for the collection of traffic movement data in electronic form, where the entries in the first column may be used as column headings on a spreadsheet template.

2.3.17 Acceptable sources for the information required in a traffic movement sample are one or more of the following: special ATC observations, ATC automation systems, automated air traffic management systems, and SSR reports.

Review of operational procedures and airspace organization

2.3.18 Experience has shown that the operational procedures and airspace organization associated with RVSM implementation can substantially affect the collision risk in RVSM airspace. A further example of this, in addition to those already given in 2.2.25, would be a decision to apply the table of cruising levels in Appendix 3 of Annex 2, while using routes in a unidirectional manner. The consequence of this decision would be to provide an effective 600 m (2 000 ft) vertical separation between aircraft at adjacent usable flight levels on these routes.

2.3.19 In light of such possibilities, the RMA should carefully review the proposed operational procedures and airspace organization in order to identify any features that might influence risk. The body responsible for the planning and oversight of the RVSM implementation should be informed about any aspects of the proposals which could adversely affect risk.

Agreed safety assessment process for determining whether the TLS is met

2.3.20 “Technical risk” is the term used to describe the risk of collision associated with aircraft height-keeping performance. Some of the factors which contribute to technical risk are:

- a) errors in aircraft altimetry and automatic altitude control systems;
- b) aircraft equipment failures resulting in unmitigated deviation from the cleared flight level, including those where not following the required procedures further increases the risk; and
- c) responses to false ACAS resolution advisories.

Intuitively, such factors affect risk more if the planned vertical separation between a pair of aircraft is 300 m (1 000 ft) than if a 600 m (2 000 ft) standard is in use.

2.3.21 The term “operational error” is used to describe any vertical deviation of an aircraft from the correct flight level as a result of incorrect action by ATC or the flight crew. Examples of such actions are:

- a) a flight crew misunderstanding an ATC clearance, resulting in the aircraft operating at a flight level other than that issued in the clearance;
- b) ATC issuing a clearance which places an aircraft at a flight level where the required separation from other aircraft cannot be maintained;
- c) a coordination failure between ATC units in the transfer of control responsibility for an aircraft, resulting in either no notification of the transfer or in the transfer at an unexpected flight level;
- d) inappropriate response to a valid ACAS resolution advisory; and
- e) incorrect pressure setting on the altimeters, e.g. QNH remains set.

2.3.22 On initial consideration, the relation between the required vertical separation and the risk due to operational errors may be less clear than is the case with technical risk. However, as will be pointed out during subsequent discussion of risk modelling, introduction of RVSM does increase the risk associated with such errors if all other factors remain unchanged when transitioning from a 600 m (2 000 ft) to a 300 m (1 000 ft) vertical separation minimum. When carrying out the risk assessment, care should be taken to avoid including a single event in both the assessment of technical and operational risk.

2.3.23 The overall RVSM safety goal which must be satisfied is the one agreed at the regional level and expressed as the number of fatal accidents per flight hour due to all causes of risk associated with RVSM. However, as noted in 1.2.1, there is also an upper limit to the permissible technical risk. In order to declare that the safety goal has been met, the RMA must therefore show that the following two conditions are satisfied simultaneously:

- a) the technical risk does not exceed 2.5×10^{-9} fatal accidents per flight hour; and
- b) the sum of the technical risk and the risk resulting from operational errors does not exceed the agreed regional number of fatal accidents per flight hour.

2.3.24 While there is a firm bound on technical risk of 2.5×10^{-9} fatal accidents per flight hour, there is no similar maximum tolerable value for risk due to operational errors. Thus, it is possible that the application of risk modelling can result in an estimate of technical risk less than 2.5×10^{-9} fatal accidents per flight hour and an estimate of operational risk in excess of this value, with the sum of the two still satisfying the overall TLS. On the other hand, if the estimate of

technical risk exceeds 2.5×10^{-9} fatal accidents per flight hour, it is not possible to satisfy the overall safety goal, even if the sum of the estimated technical and operational risks does not exceed the agreed regional number of fatal accidents per flight hour.

The collision risk model used in safety assessment

2.3.25 This guidance will not present derivation or details of the CRM to be used in conducting a safety assessment. An RMA should acquire that background knowledge through review of the following publications:

- a) *Report of the Sixth Meeting of the Review of the General Concept of Separation Panel (RGCSP/6)* (Doc 9536),¹ Montreal, 28 November to 15 December 1988, Volume 1 (*History and Report*) and Volume 2 (*Annexes A to E*);
- b) *Risk Assessment and System Monitoring*,² August 1996 (available from the ICAO European and North Atlantic Office);
- c) *EUR RVSM Mathematical Supplement*, Document RVSM 830, European Organisation for the Safety of Air Navigation (Eurocontrol), August 2001; and
- d) *Guidance Material on the Implementation of a 300 m (1 000 ft) Vertical Separation Minimum (VSM) for Application in the Airspace of the Asia Pacific Region*, Appendix C, ICAO Asia and Pacific Office, Bangkok, October 2000.

2.3.26 The report of RGCSP/6 contains the derivation of the basic mathematical vertical collision risk model, as well as a description of the choice of a value for the portion of the TLS applied to technical risk.

2.3.27 The North Atlantic and Eurocontrol documents contain the detailed safety assessment processes and procedures applied in the two regions in preparation for RVSM implementation. Appendix N of this manual presents an overview of the mathematical models used in the North Atlantic safety assessment process.

Readiness assessment

2.3.28 A readiness assessment is a comparison of the actual and predicted proportion of operations conducted by State-approved operators and aircraft in an airspace prior to RVSM implementation to a threshold proportion established by the body overseeing the implementation. Such an assessment is most meaningful when the oversight body has agreed that RVSM will be applied on an exclusionary basis, that is, all flights planned to be operated in the airspace must be conducted by an operator and aircraft with State RVSM approval.

2.3.29 A readiness assessment requires information from two sources:

- a) a sample of traffic movements in the relevant airspace; and
- b) the database of State RVSM approvals.

2.3.30 The RMA should organize the traffic movement sample by the number of operations for each operator/aircraft-type pair and then, if registration marks are available in the sample, by the number of operations for the

1. This document is permanently out of print.

2. This material is contained in NAT Doc 002 which is no longer in print; however, the Supplement is still available.

individual aircraft within each operator/aircraft-type pair. The approval status of each aircraft should then be checked using the database of State approvals. If registration marks are not available in the sample data, it will be necessary to make some assumptions about the proportion of the operations by the operator/aircraft-type pair in question that were flown by RVSM-approved aircraft. In the absence of more specific data, this can be based on the proportion of the operator's fleet of aircraft of that type which were RVSM-approved.

2.3.31 Once all operations have been classified as approved or non-approved, the sum of RVSM-approved operations is divided by the total number of operations in the sample, to give the proportion of operations conducted by RVSM-approved operators and aircraft. This can then be compared to the readiness threshold.

2.3.32 The RMA should prepare periodic reports of the readiness status of operators and aircraft during the period of preparation for RVSM implementation. Typically such a report would be provided for each meeting of the body overseeing RVSM implementation.

2.3.33 Experience indicates that it is important to take into account the future plans of operators regarding RVSM approval when conducting a readiness assessment. The RMA should therefore attempt to establish the intentions of operators regarding the approval of existing aircraft and acquisition of new aircraft types and include this information as a companion report to the readiness assessment.

2.4 SAFETY REPORTING AND MONITORING OPERATOR COMPLIANCE WITH STATE APPROVAL REQUIREMENTS AFTER RVSM IMPLEMENTATION

2.4.1 The responsibilities of an RMA continue after RVSM implementation. The overall function of RMA activities after implementation is to support the continued safe use of RVSM.

2.4.2 After RVSM implementation, the RMA should conduct periodic safety assessments in order to determine whether the TLS continues to be met. The frequency of these reports is as required by the responsible PIRG. The minimum requirement should be annual reports.

2.4.3 One important post-implementation activity is to carry out periodic checks of the approval status of operators and aircraft using airspace where RVSM is applied. This activity is especially important in FIRs or other areas of responsibility where RVSM is applied on an exclusionary basis. This activity is termed monitoring operator compliance with State approval requirements.

2.4.4 An RMA will require two sources of information to monitor operator compliance with State approval requirements:

- a) a listing of the operators and the type and registration marks of aircraft operating in the airspace; and
- b) the database of State RVSM approvals.

2.4.5 Ideally, this compliance monitoring should be done for the entire airspace on a daily basis. However, difficulties in accessing traffic movement information may make such daily monitoring impossible. As a minimum, the responsible RMA should conduct compliance monitoring of the complete airspace for at least a 30-day period annually.

2.4.6 When conducting compliance monitoring, the filed RVSM approval status shown on the flight plan of each traffic movement should be compared to the database of State RVSM approvals. When a flight plan shows an aircraft as RVSM-approved, but the approval is not recorded in the database, the appropriate State authority should be contacted for clarification of the discrepancy. The RMA should use a letter similar in form to that shown in Appendix O for the official notification.