THE GUIDANCE MATERIAL

ON

THE IMPLEMENTATION OF A 300 M (1000 FT) VERTICAL SEPARATION MINIMUM (VSM) BETWEEN FL290 and FL410 INCLUSIVE FOR APPLICATION IN THE AIRSPACE OF THE CARIBBEAN AND SOUTH AMERICAN REGIONS

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Foreword

This document is intended to provide guidance for operators and service providers in preparation for the implementation of RVSM in the Caribbean and South American Regions. It takes into account the result of years of international study and analysis, and reflects both the international safety standards developed by the Review of the General Concept of Separation Panel (RGCSP), and the experience gained in other regional implementations. ICAO Doc 9574, *Manual on Implementation of a 300 m (1 000 ft) Vertical Separation Minimum Between FL 290 and FL 410 Inclusive;* and North Atlantic (NAT) Doc 002, *Guidance Material on the Implementation of a 300 m (1000 ft) Vertical Separation Minimum in the Minimum Navigation Performance Specifications Airspace of the North Atlantic Region*; and *Guidance Material on the Implementation of a 300 m (1000 ft) Vertical Separation Minimum Between FL290 and FL410 Inclusive for Application in the Airspace of the Asia Pacific Region,* provided mature source material for this document.

This document was developed by ATS authorities, airworthiness experts, and airspace users in the Caribbean and South American Regional Planning and Implementation Group (GREPECAS) RVSM Task Force. It contains a brief history of the development of ICAO guidance material; and provides guidance on aircraft and operator approvals, air traffic services and flight crew requirements and procedures, and airspace monitoring in an RVSM environment.

It is hoped that the publication of this guidance material will assist in preparation for the implementation of RVSM by providing the needed information for airspace users to obtain approval, and for ATS authorities to make appropriate procedural and automation changes in a timely manner.

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LIST OF ACRONYMS

AAD	assigned altitude deviation
AKD	altitude-keeping device
APANPIRG	Asia Pacific Air Navigation Planning and Implementation Regional Group
APARMO	Asia Pacific Approvals Registry and Monitoring Organization
ASE	altimetry system error
ATC	air traffic control
ATS	air traffic services
CAR	Caribbean
CFL	cleared flight level
CMA	central monitoring agency
CRM	collision risk model
FL	flight level
FTE	flight technical error
GMS	global positioning system monitoring system
GMU	global positioning system monitoring unit
GNE	gross navigational error
GPS	global positioning system
GREPECAS	Caribbean and South American Regional Planning and Implementation Group
HMU	height monitoring unit
ICAO	International Civil Aviation Organization
in. Hg	inches of Mercury
JAA	Joint Airworthiness Authorities
MASPS	minimum aircraft system performance specification
NAT	North Atlantic
NAT SPG	North Atlantic Systems Planning Group
OTS	organized track system
PAC	Pacific
PEC	position error correction
$P_y(0)$	lateral overlap probability for aircraft on the same route (i.e., no lateral distance planned between aircraft on the same route)
$P_z(1000)$	vertical overlap probability for aircraft with 1000 ft planned separation between flight levels
RGCSP	Review of the General Concept of Separation Panel
RPG	Regional Planning Group
RVSM	reduced vertical separation minimum of (300m) 1000 ft between flight levels
SAM	South American
SD	standard deviation
SDB	State database
SSEC	static source error correction
SSR	secondary surveillance radar
TLS	target level of safety
TVE	total vertical error
VSM	vertical separation minimum

LIST OF DEFINITIONS

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

Aircraft type groupings.
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 which 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 distribution.
The distribution of an aggregate of altimetry system errors.

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

Automatic altitude-keeping device.
Any equipment which is designed to control the aircraft automatically 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. (Note – one collision is considered to produce two accidents).

Cross-track frequency.
The frequency of events in which two aircraft are within a specified distance and are traveling on crossing routes at adjacent flight levels and at the planned vertical separation.

Equivalent opposite direction passing frequency.
A single value computed from a combination of same and opposite direction passing frequencies that makes the same contribution to the collision risk assessment. Allows easy comparison of different sets of same and opposite direction passing frequencies.

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

Height-keeping capability.
Aircraft height-keeping performance which 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 cleared flight level.

Non-compliant aircraft.
An aircraft whose true absolute TVE, ASE or AAD is greater than the maximum acceptable value for RVSM-approved aircraft

***Occupancy*.**
A parameter of the collision risk model which is twice the count 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.
A vertical deviation from the correct flight level due to an ATC-Pilot loop error or an incorrect clearance

***Planned vertical separation*.**
Planned vertical separation is the planned spacing provided between aircraft in the vertical plane to avoid collision.

***Position error*.**
That portion of the static source error due to the position of the static probe/port on the aircraft (See static source error).

***Static source error*.**
The difference between the pressure sensed by the static system at the static port and the undisturbed ambient pressure in a given condition.

***Static source error correction (SSEC)*.**
A correction which may be applied to compensate for the static source error associated with an aircraft.

Technical Error.
Refers either to Altimetry System Errors or Flight Technical Errors

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

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

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

PART 1 – INTRODUCTION

1.1 Background

1.1.1 In the mid-1970s, world fuel shortages and increased fuel costs heightened awareness of the need for more efficient use of airspace. These forces highlighted the need for a detailed examination of the feasibility of reducing the vertical separation minimum (VSM) above flight level (FL) 290 from 600 m (2000 ft) to 300 m (1000 ft). Consequently, at its fourth meeting (in 1980), the International Civil Aviation Organization (ICAO) Review of the General Concept of Separation Panel (RGCSP) concluded that, despite the cost and time involved, the potential benefits of this measure were so great that States should be encouraged to conduct the major evaluations necessary.

1.1.2 In 1982, coordinated by the RGCSP, States initiated comprehensive programs to study the question of reducing the VSM above FL 290. Studies were carried out by eight States: Canada, Japan, France, the former Federal Republic of Germany, Kingdom of the Netherlands and the United Kingdom, the former Union of Soviet Socialist Republics and the United States of America. In December 1988 the results were presented to the RGCSP at its sixth meeting (RGCSP/6).

1.1.3 These studies employed quantitative methods of risk assessment to support operational decisions concerning the feasibility of reducing the VSM. The risk assessment consisted of two elements. First, risk estimation which concerns the development and use of methods and techniques with which the actual level of risk of an activity can be estimated; and second, risk evaluation which concerns the level of risk considered to be the maximum tolerable value for a safe system. The level of risk that is deemed acceptable is termed the target level of safety (TLS).

1.1.4 Integral to the process of risk estimation for the vertical plane was the determination of the accuracy of height-keeping performance of the aircraft population operating at and above FL 290. This was achieved through the use of high precision radars to determine the actual geometric height of aircraft in straight and level flight. The radar measured aircraft height was then compared with the geometric height of the FL to which the aircraft had been assigned to determine the total vertical error (TVE) of the aircraft in question. Given this knowledge for the aircraft population, it was possible to estimate the risk of collision solely as a consequence of vertical navigation errors of aircraft to which procedural vertical separation had been correctly applied. Similarly, while the RGCSP assessment of TLS was derived to apply to this contribution to collision risk only, it did not encompass the contributions from other sources of vertical collision risk such as emergency descents or any form of human error.

1.1.5 The recognition of the fact that there were several sources of vertical risk error in addition to vertical navigation errors played a role in the choice of TLS values by States during their studies. Several approaches were followed in order to establish an appropriate range of values; these included taking all en route mid-air collisions and the implicit period between collisions, and adjusting the TLS until the period of time became acceptable. However, the primary approach, and the traditional manner, was to use historical data from global sources, predicted forward to about the year 2000 to provide a safety improvement and to apportion resultant risk budgets to derive the vertical collision risk element.

1.1.6 The derived values for the TLS ranged between 1×10^{-8} and 1×10^{-9} fatal accidents per flight hour. On the basis of these figures, the RGCSP employed an assessment TLS of 2.5×10^{-9} fatal accidents per aircraft flight hour to assess the technical feasibility of a 300 m (1000 ft) VSM above

FL 290. That same TLS was used to develop aircraft height-keeping capability requirements for operating in a 1000 ft VSM.

1.1.7 Using the assessment TLS of 2.5×10^{-9} fatal accidents per aircraft flight hour, RGCSP/6 concluded that a 300 m (1000 ft) VSM above FL 290 was technically feasible. This technical feasibility refers to the fundamental capability of aircraft height-keeping systems, which can be built, maintained, and operated in such a manner that the expected, or typical, performance is consistent with safe implementation and use of a 300 m (1000 ft) VSM above FL 290. In reaching this conclusion about technical feasibility, the panel found it necessary to establish:

a) airworthiness performance requirements embodied in a comprehensive minimum aircraft system performance specification (MASPS) for all aircraft utilizing the reduced separation;

b) new operational procedures; and

c) a comprehensive means of monitoring the safe operation of the system.

1.1.8 At the seventh meeting of the RGCSP (November 1990), the Panel completed the global guidance material for the implementation of the 1000 ft reduced vertical separation minimum (RVSM). The main purpose of the material (Doc 9574) was to provide regional planning groups (RPG) with the criteria, requirements and methodology for the development of documents, procedures and programs to enable the introduction of the RVSM within their particular region. The panel also noted that further detailed work by RPGs would be required to establish the conditions for the implementation of the RVSM in each region individually, and that any necessary amendment to the ICAO Regional Supplementary Procedures (ICAO Doc 7030) should be developed by the RPG concerned. In particular, the panel drew the attention of RPGs to the need to employ operational judgment in the determination of the tolerable level of risk attributable to those error causes not encompassed by the global TLS (i.e., assessment TLS of 2.5×10^{-9}). The panel also considered that the NAT Region would be suitable for the early implementation of the RVSM because of the essentially uni-directional flow of the NAT traffic and the better than average height-keeping accuracy of the minimum navigation performance specification (MNPS) approved aircraft population.

1.1.9 In parallel with the work of RGCSP, the North Atlantic Systems Planning Group (NAT SPG) initiated studies in May 1990 (NAT SPG/26) to examine the application of the RVSM in the NAT Region. At its twenty-seventh meeting (June 1991), the NAT SPG agreed that:

a) the RVSM should be effected within the dimensions of the existing MNPS airspace;

b) the transition areas should have a vertical extent of FL 290 to FL 410, inclusive; be contained within horizontal dimensions determined by provider States either individually or in consultation; be adjacent to, overlapping or within MNPS airspace and have, wherever practicable, radar coverage and direct controller/pilot communications;

c) it would be necessary to adopt a broader definition of vertical risk that encompassed all sources of error. The definition would include equipment errors for which MASPS had been developed as well as pilot and controller operational errors. Accordingly it was agreed that the TLS be increased from 2.5×10^{-9} to 5×10^{-9} in order to be consistent with the new definition. The NAT SPG concluded (Conclusion 27/22) that:

i) the TLS for collision risk in the vertical dimension due to all causes be 5×10^{-9} fatal accidents per flight hour and that the overall collision risk in the vertical plane be assessed against this TLS; and

ii) the TLS would not be partitioned into separate components for different types of risk. However, assessments of height keeping performance would need to be conducted with reference to a safety constraint of 2.5×10^{-9}, as this is the value which has been used to derive the MASPS.

1.1.10 The MASPS were developed by specialist groups who translated the TVE distribution requirements into detailed specifications and procedures controlling the height-keeping standards of aircraft operating in RVSM airspace. The detailed specifications and procedures were developed for use by designers, manufacturers, operators and approval authorities, and are applicable for airworthiness approval to groups of aircraft and to individual aircraft.

1.1.11 The Tenth GREPECAS meeting, held in 2001, concluded (Conclusion 10/11) that the RVSM Task Force of the ATM/CNS/SG should undertake the implementation of RVSM in the Caribbean and South American Regions. This initial conclusion specified that RVSM be implemented in two phases, the first being FL350 to FL390 in April 2004. The second phase would include the remaining altitudes (FL290 to FL410, inclusive) at a date to be determined.

1.1.12 The third meeting of the Air Traffic Management Authorities and Planners (AP/ATM/3) concluded (Conclusion 3/18) that the RVSM Task Force study the possibility of harmonizing the CAR/SAM and United States RVSM implementation programs. Additionally, it was noted that the UNDP/ICAO Project RLA/98/003 could be used as a mechanism to assist States in the implementation of RVSM in the CAR/SAM regions.

1.1.13 This guidance material has been developed for the Caribbean and South American Regions based on the ICAO Manual on Reduced Vertical Separation Minimum (Doc 9574), the current work of the RGCSP, NAT Doc 002, and the Guidance Material on the Implementation of a 300 m (1000 ft) Vertical Separation Minimum (VSM) Between FL290 and FL410 Inclusive for Application in the Airspace of the Asia / Pacific Region. Additionally this material takes into consideration the experience gained during the NAT and Asia / Pacific RVSM implementations, which were implemented in three phases:

Verification Phase. The region continues to operate with 2000 ft VSM while data is collected to verify that the system would be safe with 1000 ft VSM.

Trial Phase. 1000 ft operations begin and all systems are monitored to ensure safe operation.

Operational Phase. Full RVSM. Monitoring and risk assessment continue to build confidence in the continued safe operation of RVSM.

1.2 Scope and purpose of the document

1.2.1 This document seeks to address all aspects of implementation and operation of a 1000 ft VSM within the Caribbean and South American Regions. Designated RVSM routes and airspace will be specified by NOTAM and published in the ICAO Regional Supplementary Procedures (ICAO Doc 7030).

1.2.2 Aircraft intending to operate using RVSM will be required to carry and use such equipment as detailed in the RVSM MASPS. These MASPS have been derived in order to achieve a minimum vertical navigation accuracy or height-keeping performance that will support the introduction of the 1000 ft RVSM.

1.2.3 The purpose of this guidance material is to:

a) consolidate the RGCSP guidance material on the implementation of a 300 m (1000 ft) VSM, in order to meet the particular demands of the Caribbean and South American airspace;

b) provide guidance to State aviation authorities on the measures necessary to ensure that the criteria and requirements are met within their various areas of responsibility (e.g., provision of ATC services, airworthiness approvals and monitoring of airspace);

c) provide information for operators to enable them to comply with requirements for operations in airspace designated for RVSM and to assist in the development of operating manuals and flight crew procedures; and

d) form a basic reference document for use by State authorities in developing procedures and documentation for aircraft and operator approval.

PART 2 – OPERATION OF THE RVSM AIRSPACE

2.1 Basic requirements

2.1.1 The overriding consideration in the introduction and continued operation of the 1000 ft RVSM in Caribbean and South American airspace is that the risk of collision as a consequence of a loss of vertical separation, from any cause, is less than the agreed TLS of 5×10^{-9} fatal accidents per flight hour. This condition gives rise to the following basic requirements:

a) All aircraft intending to operate in the RVSM airspace must be equipped and maintained in accordance with the MASPS and the associated State airworthiness procedures. Appropriate guidance is provided in Part 3 as well as in the appendices.

b) All aircraft intending to operate in the RVSM airspace must have the specific approval for such operations from either the aviation authority of the State in which the aircraft is registered or the aviation authority of the operator. The approval will encompass the aircraft equipage, aircraft maintenance, airworthiness procedures, flight crew training, and operating procedures. The responsibility for gaining the necessary approval rests with the aircraft operator. State aviation authorities, however, will be expected to maintain regular checks and records of the approvals which they have granted. The relevant guidance is detailed in Part 4.

c) The flight crew should operate the aircraft in accordance with recommended operating procedures. These procedures will be approved by the appropriate State authority and should be based on the material in Part 5.

d) The ATS provider States will be responsible for developing the procedures necessary to support RVSM. Further guidance is provided in Part 6 of this document. ATS provider States should be aware that the transition to/from adjacent 2000 ft airspace should be effected, wherever possible, within radar coverage and where direct controller/pilot communications are available.

e) The fifth basic requirement is a means to monitor the system performance in order to ascertain that the foregoing measures have the desired effect (i.e., the TLS is being met). As the vertical TLS encompasses all causes of vertical risk, it is important that all known assigned altitude deviations (AAD) are reported. Sources of information include:

   i) data from height monitoring systems;

   ii) AAD from Mode C deviations reported by air traffic control (ATC);

   iii) routine position reports to ATC which identify operations at incorrect FLs;

   iv) incident reports; and

   v) specific data collections (e.g., aircraft digital flight data recorders, Mode C, etc.)

2.1.2 It is most important that ATS providers record and report to the regional monitoring agency all instances of height deviations in the Caribbean and South American Regions. The detailed procedures are described in Part 8 of this document.

2.2 The Global System Performance Specification and the RVSM MASPS

2.2.1 Although the NAT Region was the first to implement RVSM, it was anticipated that other regions would follow. When developing requirements for RVSM operations, RGCSP considered worldwide conditions. It is important, particularly in respect of aircraft performance, that consistent specifications be applied in all RVSM airspace. Therefore the aircraft height keeping performance requirements which were applied in the NAT Region and are to be applied in the Caribbean and South American Regions will be based on the global requirements developed by RGCSP. An important secondary objective during the implementation of RVSM in the Caribbean and South American Regions will be the demonstration that the global requirements are being met.

2.2.2 In order to determine requirements for the height keeping performance of aircraft for use in an RVSM environment, three pieces of information are required. These are the TLS, the vertical passing frequency and the lateral navigation accuracy of the aircraft population.

2.2.3 As described in the introduction, the TLS for the global implementation of RVSM derived by RGCSP is 2.5×10^{-9} fatal accidents per flight hour. This TLS value applies to the risk of collision associated with vertical navigation performance, termed “height-keeping performance.” It does not address the risk arising from either errors in ATC instructions or loss of vertical separation associated with in-flight emergencies.

2.2.4 The vertical passing frequency is a measure of the number of times that aircraft are on adjacent flight levels at the planned vertical separation. This parameter reflects both traffic densities and patterns, and its value varies considerably from region to region. The larger the value of passing frequency, the greater the collision risk per flight hour. In order to ensure that the required height keeping performance would ensure safe RVSM operations in any region, it was necessary to choose a value for the vertical passing frequency that would be unlikely to be exceeded in any airspace for some time. An equivalent opposite[1] direction passing frequency of 2.5 per flight hour was determined to be appropriate for any airspace up to the year 2005. (For comparison, the equivalent opposite direction passing frequency for the NAT Region in 1994 was approximately 0.25.)

2.2.5 Lateral navigation accuracy has an effect on the vertical collision risk, as this parameter determines the size of the probability of lateral overlap between two aircraft nominally on the same track. Therefore, the better the lateral navigation accuracy, the higher the vertical risk. To calculate the global performance requirements for technical height keeping capability, RGCSP chose a value of not less than 0.3 NM for the standard deviation of lateral navigation accuracy. This value was considered appropriate for en route navigation up to the year 2005. (For comparison, a standard deviation of lateral navigation accuracy of 1.76 NM was estimated in 1991 for NAT MNPS airspace.)

2.2.6 Using these values for the TLS, passing frequency and lateral navigation accuracy, the maximum allowable value for the vertical overlap probability can be calculated (i.e., the probability that two aircraft nominally separated by one separation standard are in fact in vertical overlap). The value for vertical overlap probability is determined by the height keeping performance of the population of aircraft. A value of 1.7×10^{-8} was derived by RGCSP.

2.2.7 Together, the passing frequency, lateral overlap probability and vertical overlap probability make up the global system performance specification. They are considered to be critical parameters that characterize a worst case airspace environment in terms of vertical collision risk. The levels of these parameters were derived to hold at least until the year 2005. The specification also defines height-keeping performance required from aircraft in order to ensure that the collision risk in such a

[1] Passing frequencies can be broken down into same direction and opposite direction. These two components can be combined to give an equivalent opposite direction passing frequency which makes the same contribution to collision risk.

worst case airspace would not exceed 2.5 x 10^{-9} fatal accidents per flight hour. The quantitative statement of the global system performance specification is:

a) a passing frequency equal to or less than the equivalent of 2.5 opposite-direction passings per aircraft flight hour;

b) a standard deviation (SD) of lateral path-keeping error equal to or greater than 0.3 NM; and

c) a probability that two aircraft, nominally separated by 1000 feet, will be in vertical overlap, P_z (1000), equal to or less than 1.7 x 10^{-8}.

2.2.8 The assessment of compliance with the global vertical overlap probability requirement is a complex mathematical process. In order to relate these requirements to aircraft height keeping performance, a global height keeping performance specification was derived. This specification must be met by the aggregate of TVE performance in the airspace. The global height keeping performance specification requires the simultaneous satisfaction of the following four conditions.

a) the proportion of TVE beyond 300 ft in magnitude is less than 2.0 x 10^{-3};

b) the proportion of TVE beyond 500 ft in magnitude is less than 3.5 x 10^{-6};

c) the proportion of TVE beyond 650 ft in magnitude is less than 1.6 x 10^{-7};

d) the proportion of TVE between 950 and 1050 ft in magnitude is less than 1.7 x 10^{-8}.

2.2.9 To ensure that aircraft operating in the Caribbean and South American Regions meet the requirements of the global height keeping performance specification, a MASPS has been developed. The MASPS consists of detailed specifications and procedures for designers, manufacturers, operators and approval authorities. The requirements of the MASPS are described in Part 3. The mechanisms proposed to show that the requirements of the global system performance specification are met are outlined in Part 7 of this document.

2.2.10 It should be emphasized that compliance with the global system performance specification will not automatically ensure that the overall system TLS of 5 x 10^{-9} fatal accidents per flight hour is met. Additional sources of error must also be monitored and the contribution of these to the overall collision risk must be assessed.

2.3 Planning for Monitoring

2.3.1 The plan for assessing height-keeping performance in the Caribbean and South American Regions during the verification and operational trial period, as well as after full implementation, takes into account the following factors:

a) the size of the data sample necessary to assess the overall airspace system safety based on such factors as the level of statistical confidence;

b) the priorities for specific monitoring targets to achieve a representative sample from the monitoring programs. This will include consideration of priorities for individual aircraft types, individual aircraft types used by individual operators, and individual airframes; and

c) the capability to monitor for AAD, operational errors, and large height deviations.

2.4 Verification and Trials

General

2.4.1 During the verification phase, each aircraft group of each operator not previously approved for RVSM operations must undergo verification of height keeping performance. This should be accomplished by carriage of a Global Positioning System (GPS) Monitoring Unit (GMU) since there will not be a fixed location height monitoring unit available within the regions for the Caribbean and South American verification and trials.

> *Note:* Although GMU carriage does not necessarily have to be done on a Caribbean or South American flight, it must be carried out in level flight between FL 290 and FL 410.

2.4.2 During operational trials and after RVSM implementation, each operator must cooperate with the regional monitoring agency in the collection of altitude keeping performance data for each aircraft type in order to be approved to operate that aircraft type in RVSM airspace.

Verification Phase

2.4.3 Before implementing RVSM and while in a 2000 ft environment, it will be necessary to verify that the level of safety of the proposed RVSM system would remain at or below the TLS. This verification phase is planned to continue for one year and to demonstrate that:

a) the TLS of 5.0×10^{-9} fatal accidents per flight hour due to the loss of vertical separation would be met in a 1000 ft environment;

b) aircraft approved for RVSM have height-keeping performance consistent with the MASPS discussed in Part 3. This will be achieved by ensuring that:

   i) the causes of height-keeping errors which were found to be inconsistent with the global height-keeping performance specification are remedied and the aircraft re-monitored;

   ii) any adverse trends or errors which might ultimately result in unacceptable performance for any individual aircraft or group of aircraft are remedied and, if necessary, re-monitored to demonstrate compliance;

   iii) additional emphasis be placed on monitoring aircraft groups that are known to exceed MASPS requirements before airworthiness procedures were applied;

   iv) aircraft registrations reported to the regional monitoring agency are properly recorded; and

   v) the height monitoring program observed a sample of aircraft and operators approved for RVSM which is representative of the full population such that those aircraft not observed are expected to have performance consistent with the MASPS.

c) operational procedures adopted for RVSM operations are effective and appropriate; and

d) the height monitoring program is effective.

2.4.4 The data collected during the verification phase is used to assess whether the risk in the system will remain at or below the TLS into the future with consideration given to traffic increases and lateral navigation improvements due to new technology.

2.4.5 The number of approved aircraft is used to assess if the trial phase of RVSM can support the implementation of RVSM at all flight levels between 290 and 410, inclusive. This assessment should include consideration for aircraft not capable of attaining approval.

Trial Phase

2.4.6 After the 2000 ft verification phase, a further one year trial period of operation with 1000 ft separation will occur. During this trial phase, all the verifications performed in the 2000 ft environment will continue. The purpose of this phase is to ensure that the predictions and simulations performed during the Verification Phase accurately reflected the true performance of the system. The operation of the system will be identical to that which will be in place for the Operational Phase, but performance and safety will be more closely monitored to ensure that nothing was overlooked during the Verification Phase. Studies performed during this trial phase will be used to confirm and then to build statistical confidence that the risk in the system is at or below the TLS and to assess whether it will remain so, taking into account increases in traffic and improvements in lateral navigation performance.

2.4.6.1 In addition, this trial phase is planned to demonstrate that:

a) aircraft not approved are effectively restricted from RVSM airspace,

b) the causes of altimetry system errors (ASE) which exceed MASPS requirements are identified and remedied, and

c) the operator of any airframe that exceeds ASE requirements is notified and restricted from RVSM airspace until the problem with airframe performance is corrected, the airframe is re-monitored and demonstrates ASE compliance.

Operational Phase

2.4.8 Once the Trial Phase is successfully completed, the Operational Phase will begin. This entails the normal operation and monitoring of the performance of RVSM in the Caribbean and South American Regions. The assessment of the safety of the system will be limited to an annual appraisal. Data on the height keeping performance of aircraft in the region will continue to be collected in order to build confidence that the global performance specification is being met. The effectiveness of the monitoring program will be reviewed annually.

PART 3 - AIRWORTHINESS

3.1 Introduction

3.1.1 The MASPS have been published by the Federal Aviation Administration (FAA) as interim guidance (Appendix A) and by the Joint Aviation Authorities (JAA) as a temporary guidance leaflet (Appendix E). These documents detail the airworthiness, continuing airworthiness, and operations programs necessary to approve operators and airplanes to conduct flight in airspace where RVSM is implemented.

3.1.2 The following characteristics have been used to develop aircraft engineering requirements for RVSM aircraft approval. For in-service aircraft, the airworthiness approval documents have taken the form of aircraft manufacturers' Service Bulletins, Aircraft Service Changes, and Supplemental Type Certificates. These documents are available for most in-service aircraft. RVSM requirements have also been incorporated into the certification of most newly manufactured aircraft.

3.1.3 Characteristics were developed in accordance with the conclusions of the RGCSP/6 Meeting (ICAO Doc 9536) to satisfy the distribution limits on TVE and to result in aircraft airworthiness having negligible effect on meeting the requirements. They are applicable statistically to individual groups of nominally identical aircraft operating in the airspace. Furthermore, they describe the performance which the groups need to be capable of achieving in service, exclusive of human factors errors and extreme environmental influences, if the airspace system TVE requirements are to be satisfied. The requirements, which were the basis for development of the MASPS, are as follows:

a) the mean ASE of the group shall not exceed ±25 m (±80 ft);

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

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

3.1.4 The above characteristics should be used to derive type approval standards for design capability, but they address primarily the central part of the TVE distribution requirements. In order to restrict the aircraft and equipment aspects of the tail distribution, it will also be necessary to develop detailed specifications and procedure covering production release, and continued airworthiness.

3.2 Airworthiness approval

Introduction

3.2.1 Airworthiness approval must in all cases be against the requirements of the MASPS, which comprise specifications and procedures for the separate aspects of type approval, release from production, and continued airworthiness. These separate aspects of approval, and their applicability to the approval of existing aircraft, are presented below.

3.2.2 All approvals are applicable to an individual aircraft or to a group of aircraft which are nominally identical in aerodynamic design and items of equipment contributing to height-keeping accuracy, as defined in paragraph 3.1.3 above.

Definition of aircraft type groupings

3.2.3 When grouping similar aircraft together, from the viewpoint of approval or evaluation of height-keeping standards or requirements, it must be recognized that aircraft with closely similar or apparently identical type or series designations are in some cases substantially different in aerodynamic design and avionics equipment. Conversely, aircraft with different series designations can be identical in all characteristics contributing to height-keeping ability.

3.2.4 It is therefore necessary to ensure that all individual aircraft deemed to comprise a group are of identical design and build with respect to all details which could influence the accuracy of height-keeping performance. All aircraft of the same group must have been designed and assembled by one manufacturer. The airframes' pitot/static system must be installed in an identical manner and position, and, if required, the same corrective actions must be embodied to meet the RVSM requirements. All aircraft in a group must have the same altimetry, altitude-hold, and altitude-alert systems as originally installed and must be able to meet compliance with RVSM requirements. Any variation in the above from initial installation must have clearance by the airframe manufacturer or recognized design organization to show RVSM compliance has not been impaired.

3.2.5 This should not be taken to exclude approval by similarity, but where there are differences, the possible influence of all these details should be assessed before granting approval or extending approval to cover such variations.

Aircraft type approval

3.2.6 Care should be taken when assessing an approval package that flight calibration data used as a basis for evaluating residual position error are representative of the aircraft and its typical operational envelope in RVSM airspace. All error sources and variations, including uncertainties inherent in such flight calibration data, should be accounted for in the approval process. In addition, data should be developed for the operating extremes of the aircraft in the RVSM operational envelope.

3.2.7 Good design, manufacturing, certification and maintenance practices produce a level of equipment reliability that supports RVSM. In order to ensure that overall system integrity remains at a high level, it should be demonstrated analytically during the airworthiness approval process that the occurrence of undetected altimetry system failure should be better than 1×10^{-5} per flight hour. It is acceptable in this analysis to take into account the requirement for redundant altimetry systems and the ability of the flight crew to detect altimetry system failure through cross-checking procedures.

Release for flight from production

3.2.8 Specifications and procedures are incorporated into the MASPS to ensure that all individual aircraft covered by a group approval, which are manufactured or modified to meet approval standards subsequent to the granting of that approval, satisfy the requirements. These procedures would ideally include a flight test at a minimum of one point in the operational envelope on all aircraft to demonstrate production similarity. Flight test requirements may be relaxed to an appropriate level of sample testing, depending on the level of production repeatability which the manufacturer is able to validate. It may be possible to use data already available from TVE measurements to demonstrate a particular manufacturer's capability for production repeatability. In that case it must also be shown that the uncertainties associated with the data, including their applicability to the individual aircraft group under consideration, do not invalidate the conclusions.

Continued airworthiness

3.2.9 Specifications and procedures should be developed and incorporated in the maintenance requirements of the MASPS for ensuring that all individual aircraft continue during the service life to satisfy the requirements developed according to paragraph 3.1.3 above. These procedures should include some type of periodic flight test demonstration of height-keeping accuracy. The interim guidance material at Appendix A illustrates these procedures. It may be acceptable to use independent TVE monitoring facilities to satisfy this requirement, provided that the errors and uncertainties associated with the measurements are shown to be consistent with the requirements, and provided the separate contributions to TVE of airframe, avionics and flight technical error (FTE) can be assessed. The periodic interval required will not necessarily be the same for all aircraft, and it may be possible to use data already available from TVE measurements to determine the appropriate validation interval.

Approval of existing aircraft

3.2.10 The following guidance is given regarding how the elements of the MASPS should be applied:

a) Type approval. The MASPS requirements in Appendix A are applicable. In many cases it is likely that there will already be sufficient flight test data available from the type development program to satisfy that part of the approval requirements. In other cases, it may be possible to use independent TVE data to satisfy the flight test approval requirements. In this case, a detailed assessment of the type groupings to which those data are applicable can be made, and the errors and uncertainties associated with those data are shown to be consistent with the requirements. If the original flight test data and independent TVE data are insufficient to support the approval requirements, it will then be necessary to generate new data. When assessing design capability from data obtained from aircraft which have been in service for an extended period, it is permissible to make an allowance for degradation with age attributable to ASE, within the limits imposed by item b) of paragraph 3.1.2 above. Specialists should assess whether there are also aging effects due to autopilot systems. When using performance data to assess design capability, it will be necessary to gather more extensive data, for a given level of confidence, than if design capability could be assessed directly.

b) Repeatability control and continued airworthiness.

   i) For in-service aircraft, it will be necessary to consider the requirements of paragraphs 3.2.8 and 3.2.9 together. It is unlikely that many existing aircraft can be shown to have undergone the production release controls envisaged in paragraph 3.2.8, but the objectives of those requirements may well be satisfied for aircraft which have been in service for an extended period by the continued airworthiness requirements of paragraph 3.2.9. Such aircraft should individually undergo the appropriate continued airworthiness checks developed under paragraph 3.2.9 above, as well as meeting the type approval requirements, before being granted approval.

   ii) For young in-service aircraft it should be acceptable to assume that normal production repeatability has been achieved except where there is evidence of unusually large variations. It should be a requirement to reveal such evidence. Translation of such evidence, as is available for some aircraft from independent TVE data, into additional and specific approval requirements will depend on how well the manufacturer and/or operator can identify the source of the problem and whether it is identified as originating in production or in service.

Note: The definitions of "extended period" and "young", as used above, should be interpreted relative to the appropriate continued airworthiness validation interval developed against paragraph 3.2.9.

PART 4 - STATE APPROVAL OF AIRCRAFT FOR RVSM OPERATIONS

4.1 Approval process

4.1.1 From an agreed date of applicability, aircraft which operate in designated airspace within the Caribbean and South American Regions and wish to receive the benefits from RVSM must be approved for such operations. The responsibility for gaining the necessary approval rests with the aircraft operator. State aviation authorities, however, are expected to maintain regular checks and records of the approvals that they have granted. Approval encompasses 1) airworthiness approval, including continuing airworthiness, 2) operational approval, and 3) provision for monitoring.

4.2 Airworthiness and continued airworthiness approval

4.2.1 State airworthiness authorities approve aircraft as meeting the height-keeping capability requirements for operations in RVSM airspace.

4.2.2 Additionally, aircraft operators must maintain altimetry and height-keeping equipment in accordance with approved procedures and servicing schedules.

4.3 Operational approval

4.3.1 Each aircraft type or group and each airframe to be used in RVSM operations must receive airworthiness approval. The authorities granting operational approval should evaluate the airworthiness documents for each aircraft type or group and each airframe. In most cases, the airworthiness documents are expected to give the authority confidence that height-keeping will be performed at required levels. In certain cases, it may be necessary for the operator to demonstrate height-keeping performance for the aircraft type.

4.3.2 The approving authority must be satisfied that operational programs are adequate. Flight crew training as well as operations manuals should be evaluated.

4.3.3 Operational approval should be granted to conduct RVSM operations for each individual aircraft type or group. Each aircraft should receive airworthiness approval prior to being approved for use by the operator.

4.3.4 The approving authorities must develop procedures to give them confidence to grant operational approval based on paragraph 3.2.10. b) above.

4.3.5 If in-service experience shows that the height-keeping performance of a particular aircraft type utilized by an operator exceeds the requirements of paragraph 3.1.3 b) and c) above, then the operator should be required to take steps to improve performance to required levels. If performance is not improved, then operational approval for the aircraft type should be withdrawn. In cases where height-keeping performance is observed to be grossly in error, approval should be withdrawn immediately.

4.4 Provision for monitoring of aircraft

4.4.1 The operator should provide a plan for participation in the verification/monitoring program of aircraft height-keeping performance. This program should normally entail a check of at least a portion of the operator's aircraft by an independent height-monitoring system. This program is considered a necessary element of RVSM implementation. Verification and monitoring programs have the primary objective of observing and evaluating aircraft height-keeping performance to gain confidence that airspace users are applying the aircraft and/or operator approval process in an effective manner and that safety will be maintained when RVSM is implemented. It is anticipated that the necessity for such a program may be diminished or possibly eliminated after confidence is gained that the RVSM program is working as planned.

4.5 State Data Base (SDB)

4.5.1 In order to adequately monitor the RVSM airspace in the vertical plane, State aviation authorities will be expected to maintain an SDB of all approvals that they have granted for operations within the RVSM airspace. The details of the compilation and formatting of the data and the system operating parameters are under development. Ideally, the SDBs will input to the regional monitoring agency on a regular basis, which will facilitate the tactical monitoring of aircraft approval status and the exclusion of non-approved users. The Caribbean and South American Monitoring Agency (CARSAMMA) serves as the regional monitoring authority for the Caribbean and South American Regions.

4.6 Monitoring and Database Information on CARSAMMA Website

4.6.1 *The CARSAMMA website is currently under construction, in the interim* **-** The FAA RVSM website contains current information on monitoring and database requirements and procedures. The website address is ***www.faa.gov/ats/ato/rvsm1.htm***.

PART 5 - FLIGHT CREW OPERATING PROCEDURES

5.1 Introduction

5.1.1 Generally, flight crew operating procedures in RVSM airspace are no different than those in any other airspace; however, the implementation of RVSM may necessitate changes to some procedures, e.g., contingency procedures (Part 7). Given the safety requirements and the effect large height deviations could have on the risk levels, crews should be reminded to exercise increased vigilance to minimize the occurrence of deviations from the assigned flight level. To this end, during routine training, flight crews should be reminded of the importance of adhering to the following in-flight procedures.

5.1.1 Appendix 4 of the FAA Interim Guidance (91-RVSM) or the JAA Temporary Guidance Leaflet–6 (TGL-6), found appended to this guidance material, should be used as source documents for the development of pilot and, if applicable, dispatch training programs for normal operations. Appendix 5 of the FAA Interim Guidance should be used as the source document for pilot and, if applicable, dispatch training on contingency procedures for operations.

5.1.2 Operators must also incorporate into training programs the procedures and information related to RVSM operation published in NOTAMS and State Aeronautical Information Publications.

5.2 In-flight procedures within RVSM airspace

5.2.1 Before entering RVSM airspace, the pilot should review the status of required equipment. The following equipment should be operating normally:

a) two primary altitude measurement systems;

b) one automatic altitude-keeping device; and

c) one altitude-alerting device.

5.2.2 In the event that any of the required equipment fails prior to the aircraft entering RVSM airspace, the pilot should request a new clearance so as to avoid flight in this airspace.

5.2.3 The following actions should be accomplished while in flight:

a) emphasis should be placed on promptly setting the sub-scale on all primary altimeters to 29.92 inches Hg/1013.2 hPa when passing the transition altitude and rechecking for proper altimeter setting when reaching the initial cleared flight level (CFL);

b) in level cruise it is essential that the aircraft be flown at the CFL. This requires that particular care is taken to ensure that ATC clearances are fully understood and complied with. Except in the event of an emergency, the aircraft should not intentionally depart from the CFL without a positive clearance from ATC;

c) during cleared transition between levels, the aircraft should not overshoot or undershoot the old or new FL by more than 45 m (150 ft);

d) an automatic altitude-keeping device (AKD) should be operative and engaged during level cruise, except when circumstances, such as the need to retrim the aircraft or turbulence, require disengagement. In any event, adherence to cruise altitude should be done by reference to one of the two primary altimeters;

e) the altitude-alerting device should be operative and engaged;

f) at intervals of approximately one hour, cross-checks between the primary altimeters should be made. A minimum of two must agree within 60 m (200 ft). Failure to meet this condition requires that the altimetry system be reported as defective and notified to ATC;

Note: Consideration should be given to making use of the third altimeter, if installed, as a means of keeping the system operational. Future systems may make use of altimeter comparators in lieu of regular checks.

g) the operating altitude-reporting transponder should be connected to the altimetry system being used to control the aircraft;

h) the pilot should notify ATC of contingencies (equipment failures, weather conditions) which affect his ability to maintain his CFL and co-ordinate a plan of action. If unable to notify ATC and obtain an ATC clearance prior to deviating from the CFL, the pilot should follow established contingency procedures detailed in Part 7 to leave the assigned route or track and obtain ATC clearance as soon as possible. Examples of equipment failures and weather conditions that should be notified to ATC are:

  i) failure of all automatic AKDs aboard the aircraft;

  ii) loss of redundancy of altimetry systems, or any part of these, aboard the aircraft;

  iii) loss of thrust on an engine necessitating descent;

  iv) any other equipment failure affecting the ability to maintain CFL; and

  v) greater than moderate turbulence.

i) Pilots should use the phrase "UNABLE RVSM DUE EQUIPMENT" to advise ATC that the aircraft does not meet the requirements to operate within airspace designated for RVSM.

Note: Specific contingency procedures for flight crew and controllers are contained in Part 7.

5.3 Special emphasis items: flight crew training

5.3.1 The following items should also be emphasized in flight crew training programs:

a) knowledge and understanding of standard ATC phraseology used in each area of operations;

b) importance of crew members' cross-checking each other to ensure that ATC clearances are promptly and correctly complied with;

c) use and limitations in terms of accuracy of standby altimeters in contingencies. Where applicable, the pilot should review the application of static source error correction (SSEC) and position error correction (PEC) through the use of correction cards;

d) problems of visual perception in sighting other aircraft at a distance of 300 m (1000 ft) vertical separation during night conditions, when encountering northern lights, for opposite and same direction traffic, and during turns;

e) characteristics of aircraft altitude capture systems which may lead to the occurrence of overshoots;

f) relationship between the altimetry, automatic altitude control and transponder systems in normal and abnormal situations; and

g) aircraft operating restrictions (if required for the specific aircraft group) related to airworthiness approval.

5.6 Operations manuals and checklists

5.6.1 The appropriate manuals and checklists should be revised to include information and/or guidance on standard operating procedures and altimeter error limitations for ground checks. Appropriate manuals and checklists should be submitted for authority review as part of the application process.

PART 6 – ATC PROCEDURES

6.1 General

6.1.1 Implementation of RVSM requires that:

a) increased vigilance be applied to:

i) the issuance of clearances to aircraft; and

ii) verifying that flight crews properly understand and comply with clearances;

b) measures be taken as necessary to cope with potential concentration of traffic; and

c) controllers be advised of their responsibilities in respect of the action to be taken:

i) when aircraft known not to be suitably equipped are flight planned into the RVSM airspace;

ii) when informed that an aircraft has lost its capability to maintain CFL appropriate to RVSM requirements;

iii) when the pilot requests traffic information to assist in alleviating potential visual perception problems;

iv) to safeguard separation between aircraft when advised by the pilot that the AKD ability has degraded below RVSM airspace requirements; and

v) when displayed altitude differs from CFL by 300 ft or more.

6.2 Military operations

6.2.1 States are reminded of the recognized responsibility in regard to military traffic as specified in the *Procedures for Air Navigation Services /Air Traffic Management* (PANS-ATM, Doc 4444), Part II, Section 6. In this regard, procedures must be developed to accommodate military flight operations that do not meet the equipment requirements listed in Part 3 of this document. These procedures shall specify how non-RVSM approved military flight operations will be conducted in RVSM airspace while being segregated from air traffic provided with a 1000 ft VSM above FL 290. Methods of operation may include:

a) the provision of temporary airspace reservations;

b) the provision of block altitudes;

c) the provision of special routes applicable only to military aircraft; and

d) the provision of special routes applicable to military aircraft requiring a 2000 ft VSM above FL 290.

6.3 Verification of approval status

6.3.1 A secondary responsibility is placed upon ATS authorities to institute routine checks of the approval status of aircraft intending to operate in an RVSM airspace. This responsibility is met by:

a) scrutinizing ATS flight plans;

b) withholding ATC clearances for operations that are not in compliance with the airspace requirements.

6.3.1.1 Individual ATS providers in a position to do so, may also expand the verification to include

a) conducting cross-checks against the central data base, and

b) questioning operators not in compliance with the airspace requirements.

6.4 Tactical monitoring of Exclusionary RVSM airspace

6.4.1 The controller shall verify the aircraft's RVSM approval status if a pilot requests to operate in RVSM airspace and the aircraft equipment suffix does not indicate the aircraft is approved. If the pilot does not confirm that the aircraft has State approval, then, except for an emergency situation, the controller shall not issue a clearance to operate in RVSM airspace.

6.4.2 ATS providers should provide information to the CARSAMMA on flights that are not accommodated in RVSM airspace.

PART 7 - PILOT AND CONTROLLER CONTINGENCY PROCEDURES

7.1 Objective

7.1.1 The following material is provided to give the pilot and the air traffic controller guidance on actions to take under certain conditions of equipment failure and encounters with turbulence. It is recognized that the pilot and controller will use judgment to determine the action most appropriate to any given situation. The guidance material recognizes that for certain equipment failures, the safest course of action may be for the aircraft to continue in RVSM airspace while the pilot and controller take precautionary action to protect separation. For extreme cases of equipment failure, however, the safest course of action may be for the aircraft to leave RVSM airspace by obtaining a revised ATC clearance or, if unable to obtain prior ATC clearance, by executing the contingency maneuver specified in the Regional Supplementary Procedures (ICAO Doc 7030) to leave the assigned route or track. Track offset procedures have been developed for publication in the ICAO Doc 7030. These procedures are applicable to aircraft operating in an organized track system (OTS) only.

7.1.2 In addition to emergency conditions that require immediate descent, such as loss of thrust or pressurization, ATC shall be made aware of the less explicit conditions that may make it impossible for an aircraft to maintain its CFL while in RVSM airspace. Controllers must react to such conditions but these actions cannot be specified, as they will be dynamically affected by the real-time situation.

7.2 Pilot in command responsibility

7.2.1 The following guidance for contingency procedures should not be interpreted in any way that prejudices the final authority and responsibility of the pilot in command for the safe operation of the airplane.

7.3 Automatic AKDs fail (e.g., autopilot altitude hold)

	The Pilot should	The Controller should
Initially	maintain CFL and evaluate the aircraft's capability to maintain altitude through manual control	
Subsequently	watch for conflicting traffic both visually and by reference to ACAS, if equipped if considered necessary, alert nearby aircraft by making maximum use of exterior lights; and broadcasting position, FL, and intentions on 121.5 MHz (as a back-up, the VHF inter-pilot air-to-air frequency may be used)	
	notify ATC of the failure using the phrase "UNABLE RVSM DUE EQUIPMENT" and the intended course of action. Possible courses of action include:	Obtain pilot's intentions and pass essential traffic information
	maintaining CFL provided that the aircraft can maintain level;	if the pilot intends to continue in RVSM airspace, assess the traffic situation to determine if the aircraft can be accommodated through provision of lateral, longitudinal or conventional vertical separation and if so, apply the appropriate minimum
	requesting ATC clearance to climb above or descend below RVSM airspace if the aircraft cannot maintain CFL, and ATC cannot establish lateral, longitudinal or conventional vertical separation; or	if the pilot requests clearance to exit RVSM airspace, accommodate expeditiously, if possible
	executing the Doc 7030 contingency maneuver to offset from the assigned track and altitude if ATC clearance cannot be obtained and the aircraft cannot maintain CFL	if adequate separation cannot be established and it is not possible to comply with the pilot's request for clearance to exit RVSM airspace, advise the pilot of essential traffic information, notify other aircraft in the vicinity and continue to monitor the situation notify adjoining ATC facilities/sectors of the situation

7.4 Loss of redundancy in primary altimetry systems, if the remaining altimetry system is functioning normally

The Pilot should	The Controller should
If the remaining altimetry system is functioning normally, couple that system to the automatic altitude control system, notify ATC of the loss of redundancy and maintain vigilance of altitude keeping.	acknowledge the situation and continue to monitor progress

7.5 All primary altimetry systems fail or are considered unreliable

The Pilot should	The Controller should
maintain CFL by reference to the standby altimeter (if the aircraft is so equipped)	
alert nearby aircraft by making maximum use of exterior lights and broadcasting position, FL and intentions on 121.5 MHz (as a back-up, the VHF inter-pilot air-to-air frequency may be used)	
Consider declaring an emergency. Notify ATC of the failure and intended course of action using the phrase "UNABLE RVSM DUE EQUIPMENT". Possible courses of action include:	assess the traffic situation to determine if the aircraft can be accommodated through the provision of lateral, longitudinal, or conventional vertical separation and, if so, apply the appropriate minimum
maintaining CFL and route provided that ATC can provide lateral, longitudinal, or conventional vertical separation	if unable to provide separation, advise pilot of essential traffic information and request pilot's intentions
	if the pilot requests clearance to exit RVSM airspace, accommodate expeditiously if possible;
requesting ATC clearance to climb above or descend below RVSM airspace if ATC cannot establish adequate separation from other aircraft	if unable to issue clearance to exit airspace, notify the pilot of traffic information, advise aircraft in the vicinity and monitor the situation
executing the Doc 7030 contingency maneuver to offset from assigned track and FL if ATC clearance cannot be obtained	notify adjoining ATC facilities/sectors of the situation

7.6 The primary altimeters diverge by more than 200 ft

The Pilot should
attempt to determine the defective system through established trouble-shooting procedures and/or comparing the primary altimeter displays to the standby altimeter (as corrected by correction cards, if required)
if the defective system can be determined, couple the functioning altimetry system to the AKD and proceed as in 7.4 above
if the defective system cannot be determined, follow the guidance in paragraph 7.5 above regarding failure or unreliable altimeter indications of all primary altimeters.

7.7 Turbulence (greater than moderate) which the pilot believes will impact the aircraft's capability to maintain CFL

The Pilot should	The Controller should
Watch for conflicting traffic both visually and by reference to ACAS, if equipped	
Alert nearby aircraft by making maximum use of exterior lights and broadcasting call sign, position, FL, nature and severity of turbulence and intentions on 121.5 MHz (as a back-up, VHF inter-pilot air-to-air frequency may be used)	
Notify ATC of intended course of action as soon as possible. Possible courses of action include: maintaining CFL and route provided ATC can provide lateral, longitudinal or conventional vertical separation requesting a FL change, if necessary executing the Doc 7030 contingency maneuver to offset from the assigned track and FL if ATC clearance cannot be obtained and the aircraft cannot maintain CFL	Assess the traffic situation to determine if the aircraft can be accommodated through the provision of lateral, longitudinal, or increased vertical separation and, if so, apply the appropriate minimum If unable to provide separation, advise pilot of traffic information and request pilot's intentions; notify other aircraft in the vicinity and monitor the situation. Notify adjoining ATC facilities/sectors of the situation ***Note: The ATS provider, based on this information, should consider suspending RVSM operations***

7.8 Failure of the transponder

The Pilot should	The Controller should
Notify ATC prior to entering airspace where a transponder is normally required	Take such action as prescribed by the provider State.

7.9 Meteorological conditions

7.9.1 Meteorological conditions can cause turbulence that can be detrimental to accurate height-keeping. If an aircraft reports greater than moderate turbulence and is within 5 minutes of another aircraft at 1000 ft vertical spacing, ATC will endeavor to establish 2000 ft separation by climbing/descending either aircraft.

7.9.2 It should be understood that any ATC facility may request an increase in separation minima due to adverse weather conditions which could lead to the temporary suspension of RVSM in selected areas of RVSM airspace.

PART 8 - SYSTEM PERFORMANCE MONITORING

8.1 General

8.1.1 The following material is intended to provide guidance on the monitoring of the operation of RVSM in the Caribbean and South American Regions. Monitoring will 1) ensure that the level of collision risk does not exceed the regional TLS, and 2) assess the compliance of aircraft with the global height keeping performance specification (section 2.2 refers). Information gathered by the monitoring agency will be one factor taken into account by decision-makers in judging whether overall safety goals applicable to Caribbean and South American RVSM airspace are being achieved.

8.1.2 The criterion for safety in the Caribbean and South American Regions is that the TLS of five fatal accidents in 10^9 flying hours (representing the risk due to the loss of vertical separation from any cause) is satisfied.

8.1.3 The height-keeping errors that lead to collision risk can be divided into two categories; technical errors and large height deviations. Technical errors are caused by inaccuracies in the height-keeping equipment of aircraft: ASE and FTE. Large height deviations are caused by:

a) operational errors (aircraft at other than the assigned flight level due to ATC pilot-loop errors and incorrect clearances);

b) aircraft contingency events occurring in situations where the pilot cannot initially follow normal contingency procedures and is forced to descend through flight levels before diverting from track;

c) deviations due to the effect of high level meteorological conditions, and

d) deviations due to TCAS resolution advisories.

8.1.4 Aircraft in the Caribbean and South American airspace are often controlled through the application of procedural separation, with ATC monitoring being restricted to pilot position reports at waypoints. Therefore, large height deviations make a more significant contribution to the overall collision risk than in a radar-monitored environment. The TLS has been chosen to take account of the risk from both technical errors and large height deviations.

8.1.5 In order to ensure that the TLS is not exceeded, it is necessary initially to monitor both the occurrence of vertical errors and some CRM parameter values; other CRM parameters should be monitored on a continuing basis. Many of the parameter values used in the CRM are based on a planning horizon of approximately 10 years and require periodic monitoring.

8.1.6 CRM parameters fall into two groups from the standpoint of monitoring requirements. The first group consists of three parameters that are critical for safety assessment, in the sense that the actual risk in the airspace changes in proportion to changes in their values. The first parameter is the proportion of time spent by aircraft nominally separated by 1000 ft in vertical overlap and is a measure of the height-keeping performance of the overall aircraft population. It is termed the "vertical overlap probability" and denoted by $P_z(1000)$. The second is a measure of the number of aircraft passing events per aircraft flying hour, termed the "passing frequency". The third is a measure of the lateral path-keeping performance, termed the "lateral overlap probability" and denoted as $P_y(0)$.

8.1.7 The second group of CRM parameters is less demanding either because the CRM is relatively insensitive to their values, or because they are not expected to change substantially over the planning horizon of this document. After their initial assessment, they should be re-assessed periodically to ensure that their values reflect the current RVSM airspace system.

8.1.8 It must be emphasized that the monitoring requirements, in particular the measurement of TVE, were established at a stringent level appropriate to an initial application in the first region to implement an RVSM. As a result of that initial work, the data collected, and operational experience gained, some relaxation may be possible in monitoring requirements in other regions where the RVSM is introduced as a part of the global implementation process. For example, some of the operators and aircraft types that utilize NAT, EUR and Asia/PAC RVSM airspace also operate in the Caribbean and South American Regions. The monitoring requirements for these operators should be greatly reduced.

8.1.9 It is important to remember that all of the measures which combine to constitute, or to verify, the height-keeping performance of an aircraft play a part in the concept of monitoring which will be applied throughout that aircraft's life and contribute to risk reduction. The measures include:

a) the requirement for aircraft to carry the equipment defined in the RVSM MASPS;

b) initial installation procedures, tests and, where necessary, flight checks of aircraft altimetry equipment;

c) compliance with State airworthiness approval procedures;

d) compliance with continued airworthiness requirements;

e) adherence to ATC procedures; and

f) adherence to pre-flight and in-flight operating procedures.

8.1.10 All of the foregoing measures have been addressed in the relevant parts of this guidance material. However, these measures do not give a direct indication that the overall criterion for safety is met. This can be achieved only through independent system performance monitoring.

8.2 Collision Risk Modeling (CRM)

8.2.1 The method used to evaluate the collision risk of the system within the Caribbean and South American Regions is to be the same as that which was used in the original determination of RVSM feasibility, the Reich CRM. This model brings together factors of the operational system, through probabilistic and deterministic elements, to produce an estimate of the long-term average system risk for aircraft collision. For the vertical dimension, the statement of the model is given in six parts. Part 1 applies to level flight; part 2 applies to aircraft descending through flight levels; part 3 applies to aircraft adhering to the incorrect flight level; part 4 applies to intersecting routes; part 5 applies to formation flight; and part 6 applies to aircraft in vertical alignment for the entire crossing at adjacent flight levels. Each of the 6 parts of the collision risk model for the vertical dimension are given in Appendix B.

8.3 Monitoring and Assessing the Parameters of the CRM Specification

8.3.1 In order to ensure that the collision risk in Caribbean and South American RVSM operations does not exceed the regional TLS, the parameters of the CRM must be monitored and assessed on a continuing basis.

8.4 Monitoring Technical Errors and Large Height Deviations to Assess $P_z(1000)$

8.4.1 The agreed TLS for the Caribbean and South American Regions of 5.0×10^{-9} fatal accidents per flight hour for RVSM operations requires that an assessment of total system vertical overlap probability ($P_z(1000)$) be performed. This requires that the duration of all large errors in the vertical plane be reported and assessed. In addition to technical errors detected through the height monitoring system (that is, TVE, ASE and AAD), large height deviations need to be reported.

8.4.2 An assessment of TVE is critical to an assessment of $P_z(1000)$. As a result, the accuracy with which TVE can be measured is an important concern. TVE can be measured by comparing the geometric height of an aircraft, as measured by an HMU or GMS or any other suitable system, to the geometric height of its assigned FL as measured by a suitable meteorological model. The accuracy of the measurement of TVE should be such that the mean error is 0 ft and the SD of the error does not exceed 50 ft.

8.4.3 These measured TVE data are fundamental to the monitoring process. Large amounts of such TVE data are needed to draw inference from the monitoring process with a high level of confidence. Part 2 above describes a process to support the introduction of RVSM in the Caribbean and South American Regions on the basis of the monitoring data.

8.4.4 Large height deviations can be divided into four main types:

a) operational errors (ATC-pilot loop errors and incorrect clearances);

b) aircraft contingency events;

c) deviations due to meteorological effects; and

d) deviations due to TCAS resolution advisories

8.4.5 Operational errors are likely to result in aircraft flying at integral multiples of the separation standard from their correct level. The long intervals between position reports, and the communication methods used, mean that operational errors make a far more significant contribution to the overall collision risk than would be the case in an airspace with air traffic control based on radar surveillance and direct communication systems. Calculations based on NAT reported occurrences of such large vertical errors indicate that these provide a dominant contribution to collision risk. The calculation of the contribution of the vertical overlap probability from these types of errors is therefore very important. Information on these types of events are obtained via ATC and pilot reports. It is vital that reports of all operational errors be sent by provider States to the regional monitoring agency

8.4.6 System risk is directly proportional to the amount of total flight time spent by aircraft at an incorrect FL. The estimates of such times will be one of the key elements to be used in determining whether or not the system is in compliance with the TLS, using appropriate mathematical and statistical methods.

8.4.7 Data sources for estimating time spent by aircraft at incorrect FLs will include reports to the regional monitoring agency by ATC authorities and airlines, as well as the results of special data gathering exercises using suitable monitoring systems.

8.4.8 Contingency events could impose a particularly large risk in oceanic airspace due to the lack of surveillance and use of indirect communications. Contingency procedures are designed to minimize these risks, but it is important that they be included in the overall analysis. If the above procedures are followed, the risk of collision with another aircraft should be minimized in most scenarios. However, it is possible that the nature of the emergency will mean that the aircraft is forced to descend through one or more levels before being able to divert from the original track. It is this descent through potentially occupied levels which will contribute the most to the collision risk. To enable the assessment of the risk, the number of levels transited before commencing the diversion from the track should be made part of the contingency report required from pilots.

8.4.9 Meteorological deviations include the effects of air turbulence and could also include rarer events such as the effects of volcanic dust clouds. Only inadvertent deviations due to external conditions are included in this category; the effects of deviations arising as a result of the deliberate avoidance of adverse weather, etc., can be determined as for contingency events.

8.4.10 When an aircraft enters turbulent air, such as that inside storm systems, its height keeping capability can deteriorate considerably. This may result in excursions from the correct pressure level which, in some cases, may be more than 1000 ft. This type of excursion will obviously add to the risk of collision and the size of the risk will be larger with smaller separation standards. The incidence of deviations caused by turbulence will require continued monitoring and analysis in order to ensure that the risk associated with such events is not excessive.

8.4.11 TCAS is an airborne collision avoidance system that is mandated by some States for all large commercial aircraft. Consequently, a large percentage of aircraft operating in the Caribbean and South American Regions are TCAS equipped. TCAS may give traffic advisories (TA) and resolution advisories (RA) where standard separation exists in an RVSM environment. It is necessary to evaluate the exact number and type of TAs and RAs.

8.4.12 It is important, if the extent of the height deviation is significant, that the event leading to a TCAS RA is included in the collision risk process. In Caribbean and South American RVSM airspace, genuine TCAS RAs will only be issued as a result of one of the height deviation categories already described (or as a result of a lateral deviation). Nuisance RAs, on the other hand, will mostly request the pilot to return the aircraft to its original level. TCAS RAs will not normally add any “unaccounted for” risk to the system although, very occasionally, TCAS could induce a loss of separation as a result of an inappropriate RA. Each TCAS event, therefore, needs to be considered on an individual basis.

8.5 Monitoring of $P_z(1000)$

8.5.1 There are two methods that are used to estimate $P_z(1000)$. In the first method an analytical probability density function is derived directly from the proportion of TVEs of a given magnitude through statistical distribution models and then used to derive an estimate $P_z(1000)$. The second method is in two parts. For part one, analytical probability density functions are derived for each aircraft type from the proportion of ASEs of a given magnitude and then re-combined in the proportions that these aircraft types are in level flight within Caribbean and South American airspace. For part two, analytical probability density functions are derived directly from AAD data and large height deviations not involving aircraft deviations at incorrect flight levels. The aggregate ASE statistical distribution model is then numerically combined with the analytical probability density function of the AAD data and large height deviations to produce a TVE statistical distribution which is then used to derive an estimate $P_z(1000)$. The first method has the advantage of directly using the monitored TVE data. The second method has the advantage of removing some of the sampling bias that may be introduced by the monitoring process and using sources of large height deviations outside of the height monitoring coverage areas.

8.6 Forecast of RVSM aircraft occupancy (passing frequencies) before RVSM implementation

8.6.1 Once RVSM has been implemented, estimated values for occupancies or passing frequencies will be obtained from a sampling program of actual operations. However, during the Verification Phase, a method is needed to forecast occupancies (or passing frequencies) in a 1000 ft VSM environment, to allow an assessment of the expected collision risk under RVSM.

8.6.2 For the NAT, RVSM analyses were conducted using a computerized NAT Traffic Allocation Model (NATTAM). A computer simulation of this type, developed by Canada, is needed in the Caribbean and South American for predicting the future occupancy for use in collision risk assessment prior to implementation of RVSM in the Caribbean and South American Regions. To provide background and to assess the scope and capabilities of the simulation model needed for the Caribbean and South American a brief description of the NATTAM is presented in Appendix C. The capabilities of the Caribbean and South American simulation model should include:

a) allocation of routes, flight levels and times of flights;

b) traffic volumes and patterns;

c) structure of the airspace and track system;

d) concentration of traffic towards tracks and flight levels that aircraft operators prefer; and

e) estimation of vertical occupancies and passing frequencies.

8.6.3 Another source of input for the simulation model that could be used to refine the reallocation of flights, concentration towards core tracks and conflict resolution could be obtained by analyzing the changes that occurred in the NAT before and after RVSM implementation.

8.6.7 In addition to the capabilities in the NAT simulation, the Caribbean and South American simulation will need to forecast cross-track frequencies under RVSM.

8.7 Monitoring aircraft passing frequencies after RVSM implementation

8.7.1 Aircraft same, opposite and cross-track passing frequencies in the Caribbean and South American Regions will be assessed on a monthly basis by the regional monitoring agency using traffic data supplied by the ATC authorities. The additional high level of crossing traffic in the Caribbean and South American necessitates the assessment of cross-track frequency at route intersections. It is anticipated that the level of passing frequencies will remain considerably lower than that used to derive the aircraft height-keeping performance in the global system performance specification.

8.8 Monitoring lateral overlap probability

8.8.1 The lateral overlap probability ($P_y(0)$) is the probability that two aircraft nominally on the same track are within a distance λ_y (the average aircraft wingspan) from each other laterally. The value of this parameter depends upon the accuracy of the lateral navigation of aircraft in the region and aircraft wingspan. The more accurate the navigation or the larger the wingspan, the larger the lateral overlap probability. For calculations of vertical collision risk, the errors of aircraft *entering* the ocean are used in the determination of $P_y(0)$. The standard deviation for these errors is expected to be smaller than that seen for errors of aircraft *leaving* the Asia Pacific Region, but its use ensures that the average vertical collision risk is not under-estimated. The form of the distribution used to model navigation performance in the core region also affects the value of $P_y(0)$.

8.8.2 Because, all other factors remaining constant, better lateral path-keeping accuracy increases the risk of collision due to the loss of a 1000 ft vertical separation, the regional monitoring agency will examine cross-track errors in the airspace periodically using data supplied by ATS authorities. The global height-keeping performance specification for TVE was developed under the assumption of lateral navigation accuracy with an SD of 0.3 NM. Authorities should recognize that the CRM is directly affected by changes in aircraft lateral path-keeping accuracy and should conduct periodic reviews to assess the potential effects resulting from any mandatory changes or otherwise in aircraft navigational equipage.

8.9 Monitoring other CRM parameters

8.9.1 The remaining CRM parameters within the Caribbean and South American RVSM airspace are average aircraft speed, relative speed between aircraft, and average aircraft length, width and height. As stated previously, either the risk of a mid-air collision is relatively insensitive to these parameter values, or the values are not expected to change substantially over the planning horizon of this document. Once initially estimated, intensive monitoring of the values of these parameters should not be necessary. The regional monitoring agency should be aware of their relative importance in the overall process of ensuring that system safety is maintained and should assess their likely values on a periodic basis using whatever means are deemed appropriate.

8.9.2 The parameters relating to the physical characteristics of aircraft can all be estimated from direct observations of the system. The aircraft dimensions ($\lambda_x, \lambda_y, \lambda_z$) are obtained using the wingspan, length and height of different types of aircraft. The mean values for the Caribbean and South American aircraft population are then calculated using weightings based on the frequency of crossings made by each of the types.

8.9.3 The average absolute aircraft air speed ($\overline{|V|}$) is derived using the cleared speeds of aircraft operating in the region. The accuracy of this estimate is determined by the size of the sample used. To estimate the average absolute relative along track speed ($\overline{|\Delta V|}$), traffic data for pairs of aircraft on adjacent levels are used. As with average air speed, the accuracy of this estimate is dependent upon the size of the sample.

8.9.4 The average absolute relative cross-track speed ($\overline{|\dot{y}|}$) is assessed using radar data on aircraft leaving the Caribbean and South American system. This parameter is expected to be fairly stable with time, changing only gradually as new navigation systems with significantly better performance are introduced.

8.9.5 The average absolute relative vertical speed ($\overline{|\dot{z}|}$) should in theory be determined for pairs of aircraft that have lost all vertical separation. In practice, a total loss of vertical separation is unlikely to be observed. The value is therefore estimated indirectly from precision radar measurements of relative velocities for pairs of aircraft with different deviations and extrapolating to that of the separation standard in force.

8.9.7 The additional parameters λ_{xz} (same) and λ_{xz} (opp) for the length of the path in the descending aircraft collision risk model need to be determined, at present, by simulation for Caribbean and South American aircraft.

8.10 Monitoring and Assessing Compliance with System Performance

8.10.1 After the parameters of the CRM have been monitored, the system can be assessed for compliance with the restrictions imposed by either the global or regional performance requirements. It is important to remember the distinction between global and regional system performance requirements. Global system performance requirements apply only to aircraft height-keeping and are designed to apply worldwide. As such, the restrictions on aircraft height-keeping and lateral performance are designed to be more stringent than may be required for regional compliance while the global restrictions on occupancy values are expected to be more lenient than the regional values (allowing for the large range of regional occupancies expected worldwide).

8.10.2 Regional system performance requirements apply to vertical deviations due to all causes. However, oceanic regional height-keeping requirements are expected to be more lenient than global requirements, since, 1) occupancies may be much lower than the values used to derive the global requirements (as is expected within oceanic airspace) and 2) lateral performance is not at the design levels used for global requirements,.

8.11 Regional System Performance

8.11.1 The determination of compliance with the regional TLS is made from two viewpoints. One perspective is gained by directly estimating the system risk by substituting each of the parameter estimates into the collision risk equations shown in section Appendix B. Following this viewpoint will result in a single estimated value for the collision risk and provides a measure which can be compared against the TLS. However, it is subject to the uncertainty imposed by each of the parameter estimates.

8.11.2 Another perspective is gained by assessing whether the TLS is being complied with to a high degree of statistical confidence. It can be applied as a forecast that the TLS will be met under RVSM or that the TLS is being met once RVSM is in place. This viewpoint does not require an estimate of the CRM parameter $P_z(1000)$. However, it relies on the confirming that the MASPS, which are designed to result in a negligible risk due to ASE for RVSM approved aircraft, are working and that the risk due to contingency events is negligible.[2] At the heart of this process is a sequential sampling risk assessment method. It compares the actual large height

[2] RGCSP work suggests that risk is negligible when it is about 2 orders of magnitude less than the TLS.

deviations, including operational errors and flight technical errors, to aid in deciding, with a high level of confidence, if the system is meeting the TLS, if the system is not meeting the TLS, or if more data is required.

8.11.3 Evidence from the sequential sampling risk assessment method for both the near term trial implementation and the year 2005 will be used to show whether there is a high degree of confidence that the TLS of 5×10^{-9} fatal accidents per flight hour will be complied with under RVSM or whether further monitoring of height-keeping errors (excluding ASE and contingency events) is required.

8.12 Global System Performance

8.12.1 In addition to the requirement that total system performance meet the overall TLS, the monitoring process will be used to ensure that the fleet of aircraft flying in RVSM airspace meets the global system performance specification from which the RVSM MASPS were derived (paragraph 2.2 above also refers).

8.12.2 Because the global system position performance specification, and in particular the $P_z(1000)$ of 1.7×10^{-8}, was used to derive aircraft height-keeping performance specifications which are expressed as requirements on TVE, only errors resulting from incorrectly operating equipment are included in this aspect of the monitoring program.

8.12.3 There are two methods that are used to assess the compliance of TVE with the global height-keeping requirements. One method directly estimates the proportion of TVEs of a given magnitude through statistical distribution models and compares the results to the TVE global requirements and one method assesses compliance with the MASPS.

8.13 Monitoring and Assessing Compliance with the MASPS

8.13.1 Given a measured TVE and a simultaneous difference between automatically reported Mode C altitude and assigned FL or AAD, it will be possible to develop an estimate of an aircraft's ASE as the difference between its TVE and AAD. It will be important to derive ASE values for airframes and for aircraft types in order to evaluate the component values of TVE, i.e., ASE and AAD.

8.13.2 The MASPS were designed so that the resulting TVE, as measured from the component values of ASE and AAD, would result in a negligible $P_z(1000)$. Assessing compliance with the global height-keeping performance specification will be made by verifying the basic assumptions used in the MASPS derivation and monitoring the performance of the component values of ASE and AAD against the MASPS requirements (paragraph 3.1.2 refers). A description of the assessment of ASE and AAD for compliance with the MASPS is given in Appendix D.

8.14 Assessment of the safety of Caribbean and South American RVSM operations

8.14.1 The airspace parameters derived from the monitoring procedures outlined above allow the collision risk in the system to be assessed against the regional TLS. The height-keeping performance of aircraft can also be assessed and compared to the requirements of the global height-keeping performance specification outlined in paragraph 3.1.3 above.

8.14.2 Prior to implementation of RVSM in the Caribbean and South American Regions, mathematical and statistical techniques will be used to provide detailed information on the forecast performance of the system in terms of collision risk and aircraft height-keeping performance. After implementation of RVSM the monitoring of the CRM parameters and the assessment of the system performance will continue so that any adverse trends may be quickly identified and corrected.

8.14.3 During the verification period and after implementation, tabulation of details will be used to provide detailed information on the forecast of air-miss data, near mid-air collision reports or any other similar source of information of the system in terms of collision risk and aircraft height-keeping performance.

8.15 Responsibilities of the regional monitoring agency

8.15.1 Monitoring will be carried out by the regional monitoring agency and will include the monitoring of height-keeping accuracy and vertical errors. The additional duties are as follows:

a) transferring and collating aircraft height-keeping performance data from other monitoring agencies;

b) receiving reports from height monitoring systems of those height deviations which are in magnitude equal to, or greater than, the following criteria:

 i) TVE : 300 ft;

 ii) ASE : 245 ft; or

 iii) AAD : 300 ft;

c) receiving reports from provider States of details of operational errors and large height deviations identified in the region;

d) take necessary action with the relevant State and operator to:

i) determine the likely cause of the height deviation; and

ii) verify the approval status of the relevant operator;

e) recommend, wherever possible, remedial action;

f) analyze data to detect height deviation trends and to take action as in d) above;

g) undertake data collections as required to:

 i) investigate height-keeping performance of the aircraft in the core of the distribution;

 ii) establish or add to a data base on the height-keeping performance of:

 a) the aircraft population;

 b) aircraft types or categories; and

 c) individual airframes;

 iii) provide additional data relevant to height-keeping performance needed to conduct studies which are deemed appropriate. Such studies might include analysis of FTE in the airspace based on the analysis of flight data recording;

h) collect data on all flights entering the region from all provider States. These data should include the aircraft registration numbers to facilitate a check or approval status against a data base of approved users;

i) monitor the level of risk of collision as a consequence of operational and technical errors and emergency procedures as follows:

   i) establish a mechanism for receipt of all reports of height deviations of 90 m (300 ft) or more resulting from the above errors and/or procedures;

   ii) determine, wherever possible, the root cause of the deviation together with its size and duration;

   iii) calculate frequency of occurrence;

   iv) assess level of risk in RVSM environment;

   v) compare level of risk due to operational errors with the level experienced in the 600 m (2000 ft) environment; and

   vi) initiate remedial action;

j) maintain a central data base of approved users and initiate checks on the "approval status" of aircraft operating in the relevant RVSM environment; and

k) circulate monthly reports on all height-keeping deviations together with such graphs and tables necessary to illustrate the estimated relation of the system risk to the TLS.

8.15.2 The Caribbean and South American Monitoring Agency (CARSAMMA) is the regional monitoring agency in the Caribbean and South American Regions. The CARSAMMA is responsible for the collection, collation and dissemination of data relevant to navigation performance. Additionally, it acts as a focal point for reports of height deviations of 300 feet or more. Although there is a formalized and universally agreed procedure for dealing with gross navigation errors (GNE), no such official procedure yet exists for dealing with height deviations. Accordingly, the regional monitoring agency, during and subsequent to the RVSM verification phase will, in addition to its existing tasks, be responsible for the following:

a) initiation of checks of the approval status of aircraft operating in RVSM through tactical monitoring of the airspace;

b) maintenance of a data base of aircraft approved to operate in RVSM airspace including details of GMS monitored performance;

c) maintenance of a data base of "rogue" aircraft collated from all monitoring sources;

d) maintenance of such other data bases as necessary to monitor the TLS in respect of observed height-keeping performance criteria;

e) taking appropriate measures to ensure the minimum aircraft monitoring targets are met;

f) follow-up action and initiation of investigation of height deviations in excess of a pre-determined magnitude and develop recommendations for remedial action; and

g) production of routine reports and dissemination of monitoring data as required.

8.16 Objectives of the Height Monitoring System

8.16.1 In order to recommend a monitoring system, it was necessary first to define overall monitoring targets. Following a review of information and data collected in the vertical studies programs, it was assumed that, for planning purposes, ASE for individual airframes would be stable for a period of two years. Important objectives of the verification period were therefore to characterize the ASE performance of the airframes which will be used in the Caribbean and South American Regions in RVSM operations and to confirm the stability of ASE. Ongoing monitoring of aircraft in the NAT and other RVSM airspace is continuing to evaluate the stability of ASE.

8.16.2 On the basis of the above assumption, it was possible to establish the objectives of the monitoring program and to consider how these objectives could be met. First, the ultimate objective would be to carry out a complete census of airframes. The monitoring system should therefore be designed to be capable, in principle, of performing such a census over a period of one year. Because a complete census is an impractical target for the verification phase, the minimum targets, listed below, were agreed to in the NAT Region. They should also permit the collection of sufficient information on the height keeping performance of aircraft operating in the Caribbean and South American Regions:

a) sufficient airframes are measured to ensure that a minimum of 90% of flights in the Caribbean and South American Regions during a year would be made by aircraft which had been monitored at least once;

b) not less than 60% of all RVSM MASPS-approved airframes are monitored at least once through the monitoring process in place for Caribbean and South American RVSM during the verification phase;

c) at minimum, a census of aircraft types with RVSM MASPS approvals are monitored;

d) at minimum, a census of the RVSM MASPS-approved aircraft types for every commercial operator are monitored; and

e) as many of the RVSM MASPS approved international general aviation (IGA) aircraft as possible are measured, and not less than 80% of the full population of RVSM MASPS-approved IGA aircraft. Extraordinary efforts should be made to complete a census of RVSM MASPS-approved IGA aircraft.

8.16.3 An examination of the operators and aircraft types in the Caribbean and South American airspace may reveal that many aircraft were monitored while operating in NAT RVSM and that it is now feasible to attain the objective of a census of aircraft planning to operate in Caribbean and South American RVSM. In that case, the monitoring goals should be adjusted to increase the likelihood of attaining a census during the Caribbean and South American verification period.

8.16.4 The NAT Region designed monitoring targets as minimum objectives to ensure that a good representative sample of RVSM MASPS-approved aircraft was obtained. The data obtained from a monitoring program that met these targets would be sufficient to provide:

a) further evidence of the stability of ASE;

b) guidance on the efficacy of the RVSM MASPS and on the effectiveness of altimetry system modifications;

c) assurance that aircraft height-keeping performance as measured in the NAT is transferable to the Caribbean and South American airspace; and

d) confidence that the TLS would be met.

8.16.5 The targets had been agreed to on the assumption that aircraft height-keeping performance would meet the global requirements. The collision risk due to this aspect of the system should then contribute only a very small part to the regional TLS. If the observed performance is significantly worse than the global height-keeping requirements, the minimum sampling requirements will be increased to ensure that the regional TLS would not be threatened.

8.17 Background Description of the NAT Height Monitoring System

8.17.1 The height monitoring system for the implementation of RVSM in the NAT Region consisted of a hybrid height monitoring system comprising HMUs and a GMS. The GMS consisted of portable GMUs, GPS reference stations, access to Mode C and MET information, post-flight processing facilities and adequate logistic support.

8.17.2 For the application of RVSM in the initial airspace it would have been very difficult to achieve the monitoring objectives with only one of the proposed monitoring systems - the HMU or the GMS. The HMUs allowed a large sample of airframes to be collected over a short time. Repeat samples of individual aircraft were collected in NAT RVSM airspace over long periods of time to help verify the assumption of ASE stability and to characterize the typical ASE range for a variety of aircraft types. Aircraft not monitored by the HMU system were candidates for monitoring by the GMS. The GMS allowed for repeat measurements of suspect airframes and monitoring to be targeted on sub-populations which were shown to be poor performers. Similarly the GMS was used to obtain samples of aircraft operators and/or types whose normal operations did not over-fly the geographical site of an HMU.

8.17.3 In addition, the constraint of the HMU's fixed location was offset by the GMS aircraft-specific capability. A complete census, by operator, type or airframe, was therefore more easily achieved by a combined system. The relatively expensive unit cost of the HMU was also counterbalanced by the reduced cost of a complementary GMS.

8.17.4 The relatively low volume of data gathered on a daily basis by the GMS was offset by the high daily data acquisition rate of the HMU. Whereas the performance of a GMS target aircraft may not have been typical “on the day”, HMU target aircraft, passively monitored, were more likely to be representative of their normal performance. The anticipated administrative and/or logistics problems of operating a stand-alone GMS was substantially relieved by the complementary contribution that the HMU system provided.

8.17.5 Therefore, the disadvantages of the HMU system were mitigated by the characteristics of the GMS and the disadvantages of the GMS were offset by the characteristics of the HMU system. In addition, there were further independent advantages associated with each system. A combination of HMUs and a GMS provided the most suitable means of achieving the verification and monitoring objectives in NAT RVSM. However, it was understood that, because of the complementary systems, both elements (HMU/GMS) were equally critical to the composition of the hybrid system.

8.18 Description of the Caribbean and South American Height Monitoring System

8.18.1 In the Caribbean and South American Regions, it is not certain that an HMU type fixed location system will be available. Thus, the advantages of the hybrid monitoring system are compromised. Although the fleet size of operators and aircraft types indicates that the monitoring goals census should be achievable with the GMS, some of the features of the HMU would need to be incorporated into the GMS. They include, but are not limited to, the following:

a) repeat measurement of airframes to assure the stability of ASE;

b) continued monitoring of aircraft to assure that compliant height-keeping performance is maintained. In the NAT Region data, large ASEs were found on three airworthiness-approved aircraft types. Although the problem was remedied for each airframe the cause of the failures remain unknown; and

c) continued assurance that the risk in the system is maintained at a level below the TLS.