

GUIDANCE MATERIAL ON THE APPROVAL OF OPERATORS/AIRCRAFT FOR RVSM OPERATIONS

Subject: APPROVAL OF AIRCRAFT
AND OPERATORS FOR FLIGHT
IN AIRSPACE ABOVE FLIGHT
LEVEL (FL) 290 WHERE A
1,000 FOOT VERTICAL
SEPARATION MINIMUM IS APPLIED

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*1. PURPOSE. This document establishes an acceptable means, but not the only means, that can be used in the approval of aircraft and operators to conduct flight in airspace or on routes where Reduced Vertical Separation Minimum (RVSM) is applied. It contains guidance on airworthiness, continuing airworthiness, and operations programs for RVSM operations. (Appendix 7 contains a table of contents which lists where these issues are addressed in the document.) (RVSM airspace is any airspace or route between FL 290 and FL 410 inclusive where aircraft are separated vertically by 1,000 ft (300 m)).

* a. Paragraphs containing new or amended material are preceded by an asterisk.

*2. RELATED TITLE 14 CODE OF FEDERAL REGULATIONS (14 CFR) SECTIONS. 14 CFR Part 43, 14 CFR Section 91.180, 14 CFR Section 91.411, 14 CFR Section 91.705, 14 CFR Section 91.706, 14 CFR Part 145, 14 CFR Part 121, 14 CFR Part 135.

3. RELATED READING MATERIAL.

a. International Civil Aviation Organization (ICAO) Doc. 9574, *Manual on the Implementation of a 300 m (1,000 ft) Vertical Separation Minimum Between FL 290 - FL 410 Inclusive*. Copies may be obtained from ICAO, Document Sales Unit, 999 University Street, Montreal, Quebec H3C 5H7, Canada; Tel.: (514) 954-8022; Fax: (514) 954-6769; E-mail: {HYPERLINK "mailto:sales_unit@icao.org"}

b. ICAO Doc. 9536, Review of the General Concept of Separation Panel (RGCSP), Sixth Meeting, Montreal, 28 November - 15 December 1988. Copies may be obtained from address above.

c. ICAO Doc. 9572, RGCSP, Seventh Meeting, Montreal, 30 October - 20 November 1990. Copies may be obtained from address above.

4. BACKGROUND.

a. In mid-1981, the FAA established a Vertical Studies program with the objective of collecting data on aircraft height-keeping performance, developing program requirements for the reduction of vertical separation, and providing technical and operational representation on the working groups studying the subject. In early 1982, the FAA hosted a Public meeting on vertical separation. This meeting recommended that the Radio Technical Commission for Aeronautics (RTCA) should be the forum for the development of the minimum system performance standards (MSPS) for RVSM. RTCA Special Committee (SC) 150 was formed in March 1982 for this purpose.

b. In the international arena, the FAA committed resources to the ICAO RGCSP which was tasked in 1974 to add the study of vertical separation to its work program.

c. The data and analysis developed in the FAA Vertical Studies Program was reviewed by the national and international working groups studying RVSM. The major results and conclusions of this program are contained in the "Summary Report of United States Studies on 1,000 foot Vertical Separation Above Flight Level 290" which was completed in July 1988. (This report was incorporated in its entirety into Volume II of the RGCSP/6 report. Volume II is a compilation of reports from EUROCONTROL and four individual states on vertical studies).

d. RTCA SC 150 was established with the purpose of developing minimum system performance requirements, identifying required aircraft equipment improvements and operational procedure changes and assessing the impact of RVSM implementation on the aviation community. SC 150 served as the focal point for the study and development of RVSM criteria and programs in the U.S. from 1982 to 1987. SC 150 completed its "Initial Report on Minimum System Performance Standards for Vertical Separation Above Flight Level 290 in November 1984. This report contains information on the methodology for evaluating safety, factors influencing vertical separation, and strawman system performance standards. RTCA also developed a draft "Minimum System Performance Standard for 1,000-Foot Vertical Separation Above Flight Level 290." The draft MSPS continued to develop over a period of years. Draft 7 of the material was developed in August 1990.

e. In 1987, the FAA concentrated its resources for the development of RVSM programs in the ICAO RGCSP. The U.S. delegation to RGCSP used the material developed by SC 150 in developing U.S. positions and proposals on RVSM criteria and programs.

f. The ICAO RGCSP published two major reports which have provided the basis for the development of RVSM implementation documents. The Report of RGCSP/6 (Montreal, 28 November-15 December 1988) was published in two volumes. Volume 1

summarized the major conclusions reached by the panel and by individual states. Volume 2 presented the complete RVSM study reports of EUROCONTROL, the U.S., Japan, Canada, and the USSR. The major conclusions of this report are that:

(1) RVSM is "technically feasible without imposing unreasonably demanding technical requirements on the equipment"

(2) RVSM would provide "significant benefits in terms of economy and en route airspace capacity."

g. The second major report published by RGCSP was the Report of RGCSP/7 (Montreal, 30 October - 20 November 1990). This report contains the draft "Manual on Implementation of a 300 M (1,000 ft) Vertical Separation Minimum (VSM) Between FL 290 and 410 Inclusive." This material was approved by the ICAO Air Navigation Commission in February 1991 and published as ICAO Document 9574. This manual provides guidance for RVSM implementation planning, airworthiness requirements, flight crew procedures, ATC considerations, and system performance monitoring.

h. Appendix 6 provides a discussion of certain major conclusions detailed in Doc. 9574 which have served as the foundation for the development of the specific aircraft and operator approval criteria and programs contained in the guidance.

5. DEFINITIONS. The following definitions are intended to clarify certain specialized terms used in this advisory material:

a. Aircraft Group. A group of aircraft that are of nominally identical design and build with respect to all details that could influence the accuracy of height keeping performance (see paragraph 9b(2)).

b. Altimetry System Error (ASE). The difference between the pressure altitude displayed to the flightcrew when referenced to ISA standard ground pressure setting (29.92 in. Hg/1013.25 hPa) and free stream pressure altitude.

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

d. Automatic Altitude Control System. Any system which is designed to automatically control the aircraft to a referenced pressure altitude.

e. Avionics Error (AVE). The error in the processes of converting the sensed pressure into an electrical output, of applying any static source error correction (SSEC) as appropriate, and of displaying the corresponding altitude.

f. Basic RVSM Envelope. The range of Mach numbers and gross weights within the altitude ranges FL290 to FL410 (or max available altitude) where an aircraft can reasonably be expected to operate most frequently. (See paragraph 9b (4) (ii)).

g. Full RVSM Envelope. The entire range of operational Mach numbers, w/δ , and altitude values over which the aircraft can be operated within RVSM airspace. (See paragraph 9b(4)(i)).

h. Height-Keeping Capability. Aircraft height-keeping performance which can be expected under nominal environmental operating conditions with proper aircraft operating practices and maintenance.

i. Height-Keeping Performance. The observed performance of an aircraft with respect to adherence to a flight level.

j. Non-Group Aircraft. An aircraft for which the operator applies for approval on the characteristics of the unique airframe rather than on a group basis. (see paragraph 9b(3)).

k. Residual Static Source Error. The amount by which static source error (SSE) remains undercorrected or overcorrected after the application of SSEC.

l. Static Source Error. The difference between the pressure sensed by the static system at the static port and the undisturbed ambient pressure.

m. Static Source Error Correction (SSEC). A correction for static source error.

n. Total Vertical Error (TVE). Vertical geometric difference between the actual pressure altitude flown by an aircraft and its assigned pressure altitude (flight level).

o. W/δ . Aircraft weight, W , divided by the atmospheric pressure ratio, δ .

6. THE APPROVAL PROCESS.

a. General. Airspace where RVSM is applied should be considered special qualification airspace. Both the individual operator and the specific aircraft type or types which the operator intends to use should be approved by the appropriate FAA offices before the operator conducts flight in RVSM airspace. This document provides guidance for the approval of aircraft types and operators for flight in airspace where RVSM is applied.

b. Approval of Aircraft. Each aircraft type that an operator intends to use in RVSM airspace should have received FAA approval in accordance with paragraph 9 prior to the operational approval being granted. Paragraph 9 provides guidance for the approval of aircraft which have already entered service and for new build aircraft.

(1) In-service Aircraft: 14 CFR Parts 121, 125, and 135 Operations. Aircraft manufacturers should coordinate with the appropriate Aircraft Certification Office (ACO) to determine the process and procedures for RVSM airworthiness approval. An individual operator seeking approval for its aircraft should contact the manufacturer of the specific aircraft type and their assigned Certificate Management Office (CMO) or the Flight Standards District Office (FSDO) which holds their operating certificate to determine/coordinate the process for RVSM approval. Final approval will require coordination between the operator, the CMO or FSDO, the ACO, and the aircraft manufacturer or design organization.

(2) In-service Aircraft: 14 CFR Part 91 Operations. An aircraft manufacturer should contact their assigned ACO to determine the process and procedures for RVSM airworthiness approval. An individual operator seeking approval for its aircraft should contact the manufacturer of the specific aircraft type and their local FSDO to determine/coordinate the process for RVSM approval.

(3) New Build Aircraft. A manufacturer that desires to have a specific aircraft type approved for the RVSM operations should contact the appropriate ACO within its assigned geographical area. Manufacturers will be able to receive airworthiness approval only.

(4) Other Aircraft. For RVSM operations conducted within the United States under 14 CFR Part 129, aircraft should be approved by the state of the operator or registry. Experimental aircraft should be approved through special flight authorizations.

c. Operator Approval. Paragraph 10 contains guidance on the continuous airworthiness (maintenance) programs for RVSM operations. Paragraph 11 contains guidance on the operational procedures and programs which an operator should adopt for RVSM operation. Each individual operator should plan on presenting these programs to the FAA at least 60 days prior to proposed operation. Paragraph 11 discusses the timing, process, and maintenance and operations material which the operator should submit for FAA review and evaluation. The appropriate FAA offices which should be contacted to start the process are as follows:

(1) Part 121, 125, and 135 Operators. The operator should notify the CMO or FSDO which holds its operating certificate of its intent to obtain approval for RVSM operations. The operator can expect the CMO or FSDO to consult the Air Transportation Operations Inspector's Handbook, FAA Order 8400.10, and Airworthiness

the Inspector's Handbook, FAA Order 8300.10, for guidance on RVSM approval and for sources of technical assistance.

(2) 14 CFR Part 91 Operators. 14 CFR Part 91 operators should contact their local FSDO to start the process to receive a letter of authorization (LOA) which will grant authorization for RVSM operations. The operator can expect the FSDO to consult FAA General Aviation Operations Inspector's Handbook, FAA Order 8700.1, and the Airworthiness Inspector's Handbook, FAA Order 8300.10, as necessary for guidance on RVSM approval and for sources of technical assistance.

7. RVSM PERFORMANCE.

a. General. The statistical performance statements of ICAO Doc. 9574 for a population of aircraft (see Appendix 6) have been translated into airworthiness standards by assessment of the characteristics of ASE and altitude control. The following standards differ in some respects from that document, but they are consistent with the requirements of RVSM.

b. RVSM Flight Envelopes. For the purposes of RVSM approval, the aircraft flight envelope may be considered in two parts: the Basic RVSM Envelope and the Full RVSM Envelope. (The parameters for these envelopes are detailed in paragraph 9b(4)). The Basic RVSM Envelope is the part of the flight envelope where aircraft operate the majority of time. The Full RVSM Envelope includes parts of the flight envelope where the aircraft operates less frequently and where a larger ASE tolerance is allowed (See paragraphs 7c(3) and 7c(4)).

c. Altimetry System Error.

(1) In order to evaluate a system against the ASE performance statements established by RGCSP (see Appendix 6, paragraph 3), it is necessary to quantify the mean and three standard deviation values for ASE, expressed as ASE_{mean} and ASE_{3SD} . In order to do this, it is necessary to take into account the different ways in which variations in ASE can arise. The factors which affect ASE are as follows:

- (i) Unit to unit variability of avionics.
- (ii) Effect of environmental operating conditions on avionics.
- (iii) Airframe to airframe variability of static source error.
- (iv) Effect of flight operating condition on static source error.

(2) Assessment of ASE, whether based on measured or predicted data, must, therefore, cover paragraphs 7c(1)(i), 7c(1)(ii), 7c(1)(iii) and 7c(1)(iv). The effect of item (iv) as a variable can be eliminated by evaluating ASE at the most adverse flight condition in an RVSM flight envelope.

(3) The requirements in the Basic RVSM Envelope are as follows:

(i) At the point in the Basic RVSM Envelope where mean ASE reaches its largest absolute value, the absolute value should not exceed 80 ft (25m).

(ii) At the point in the Basic RVSM Envelope where mean ASE plus three standard deviations of ASE reaches its largest absolute value, the absolute value should not exceed 200 ft (60m).

(4) The requirements in the Full RVSM Envelope are as follows:

(i) At the point in the Full RVSM Envelope where mean ASE reaches its largest absolute value, the absolute value should not exceed 120 ft (37m).

(ii) At the point in the Full RVSM Envelope where mean ASE plus three standard deviations of ASE reaches its largest absolute value, the absolute value should not exceed 245 ft (75m).

(iii) If necessary, for the purpose of achieving RVSM approval for an aircraft group, an operating restriction may be established to restrict aircraft from conducting RVSM operations in areas of the Full RVSM Envelope where the absolute value of mean ASE exceeds 120 ft (37m) and/or the absolute value of mean ASE plus three standard deviations of ASE exceed 245 ft (75m). When such a restriction is established, it should be identified in the data package and documented in appropriate aircraft operating manuals; however, visual or aural warning/indication systems should not be required to be installed on the aircraft.

* (5) Aircraft types for which application for type certification or major change in type design is made after April 9, 1997 should meet the criteria established for the Basic Envelope in the Full RVSM Envelope. (See paragraph 7c(3)). The FAA will consider factors that provide an equivalent level of safety in the application of this criteria as stated in 14 CFR section 21.21b(1).

(6) The requirement of ICAO Doc. 9574 that each individual aircraft in the group should be built to have ASE contained within ± 200 ft (± 60 m) is discussed in paragraph 9b(5)(iv)(F).

(7) The standards of paragraphs 7c(3), 7c(4) and 7c(5) cannot be applied to nongroup aircraft approval because there can be no group data with which to develop airframe to airframe variability. Therefore, a single ASE value has been established that controls the simple sum of the altimetry system errors. In order to control the overall population distribution, this limit has been set at a value less than that for group approval.

(8) Accordingly the standard for aircraft submitted for approval as nongroup aircraft, as defined in paragraph 9b(3) is as follows:

(i) For all conditions in the Basic RVSM Envelope:

$$|\text{Residual static source error} + \text{worst case avionics}| \leq 160 \text{ ft (50 m)}$$

(ii) For all conditions in the Full RVSM Envelope:

$$|\text{Residual static source error} + \text{worst case avionics}| \leq 200 \text{ ft (60 m)}$$

Note. Worst case avionics means that combination of tolerance values, specified by the manufacturer for the altimetry fit into the aircraft, which gives the largest combined absolute value for residual SSE plus avionics errors.

d. Altitude Keeping. An automatic altitude control system should be required and it should be capable of controlling altitude within ± 65 ft (± 20 m) about the acquired altitude when operated in straight and level flight under nonturbulent, nongust conditions.

* *Note.* Aircraft types for which application for type certification or major change in type design is made on or before April 9, 1997 which are equipped with automatic altitude control systems with flight management system/performance management system inputs allowing variations up to ± 130 ft (± 40 m) under nonturbulent, nongust conditions do not require retrofit or design alteration.

8. AIRCRAFT SYSTEMS.

a. Equipment for RVSM Operations. The minimum equipment fit should be as follows:

(1) Two independent altitude measurement systems. Each system should be composed of the following elements:

(i) Crosscoupled static source/system, provided with ice protection if located in areas subject to ice accretion;

(ii) Equipment for measuring static pressure sensed by the static source, converting it to pressure altitude and displaying the pressure altitude to the flightcrew;

(iii) Equipment for providing a digitally coded signal corresponding to the displayed pressure altitude, for automatic altitude reporting purposes;

(iv) Static source error correction (SSEC), if needed to meet the performance requirements of paragraphs 7c(3) and 7c(4), or 7c(8), as appropriate; and

(v) The equipment fit should provide reference signals for automatic control and alerting at selected altitude. These signals should preferably be derived from an altitude measurement system meeting the full requirements of this document, but must in all cases enable the requirements of paragraphs 8b(6) and 8c to be met.

(2) One SSR altitude reporting transponder. If only one is fitted, it should have the capability for switching to operate from either altitude measurement system.

(3) An altitude alert system.

(4) An automatic altitude control system.

b. Altimetry.

(1) System Definition. The altimetry system of an aircraft comprises all those elements involved in the process of sampling free stream static pressure and converting it to a pressure altitude output. The elements of the altimetry system fall into two main groups:

(i) Airframe plus static sources.

(ii) Avionics and/or instruments.

(2) Altimetry System Outputs. The following altimetry system outputs are significant for RVSM operations:

(i) Pressure altitude (Baro Corrected) display.

(ii) Pressure altitude reporting data.

(iii) Pressure altitude or pressure altitude deviation for an automatic altitude control device.

(3) Altimetry System Accuracy. The total system accuracy should satisfy the requirements of paragraphs 7c(3) and 7c(4), or 7c(8), as appropriate.

(4) SSEC. If the design and characteristics of the aircraft and altimetry system are such that the standards of paragraphs 7c(3) and 7c(4), or 7c(8), are not satisfied by the location and geometry of the static sources alone, then suitable SSEC should be applied automatically within the avionic part of the altimetry system. The design aim for static source error correction, whether aerodynamic/geometric or avionic, should be to produce a minimum residual static source error, but in all cases it should lead to satisfaction of the standards of paragraphs 7c(3) and 7c(4), or 7c(8), as appropriate.

(5) Altitude Reporting Capability. The aircraft altimetry system should provide an output to the aircraft transponder in accordance with regulations of the approving authority.

(6) Altitude Control Output.

(i) The altimetry system shall provide an output which can be used by an automatic altitude control system to control the aircraft at a commanded altitude. The output may be used either directly or combined with other sensor signals. If SSEC is necessary in order to satisfy the requirements of paragraphs 7c(3) and 7c(4), or 7c(8) of this document, then an equivalent SSEC must be applied to the altitude control output. The output may be an altitude deviation signal, relative to the selected altitude, or a suitable absolute altitude output.

(ii) Whatever the system architecture and SSEC system the difference between the output to the altitude control system and the altitude displayed must be kept to the minimum .

(7) Altimetry System Integrity. During the RVSM approval process it must be verified analytically that the predicted rate of occurrence of undetected altimetry system failures does not exceed 1×10^{-5} per flight hour. All failures and failure combinations whose occurrence would not be evident from cross cockpit checks, and which would lead to altitude measurement/display errors outside the specified limits, need to be assessed against this budget. No other failures or failure combinations need to be considered.

* c. Altitude Alert. The altitude deviation warning system should signal an alert when the altitude displayed to the flightcrew deviates from selected altitude by more than a nominal value. For aircraft for which application for type certification or major change in type design is on or before April 9, 1997, the nominal value shall not be greater than ± 300 ft (± 90 m). For aircraft for which application for type certification or major change in type design is made after April 9, 1997, the nominal value should not be greater than

± 200 ft (± 60 m). The overall equipment tolerance in implementing these nominal threshold values should not exceed ± 50 ft (± 15 m).

d. Automatic Altitude Control System.

(1) As a minimum, a single automatic altitude control system should be installed which is capable of controlling aircraft height within a tolerance band of ± 65 ft (± 20 m) about the acquired altitude when the aircraft is operated in straight and level flight under nonturbulent, nongust conditions.

** Note. Aircraft types for which application for Type Certification is on or before April 9, 1997, which are equipped with automatic altitude control system with flight management system/performance management system inputs which allow variations up to ± 130 ft (± 40 m) under nonturbulent, nongust conditions do not require retrofit or design alteration.*

(2) Where an altitude select/acquire function is provided, the altitude select/acquire control panel must be configured such that an error of no more than ± 25 ft (± 8 m) exists between the display selected by the flightcrew and the corresponding output to the control system.

9. AIRWORTHINESS APPROVAL.

a. General. Obtaining RVSM airworthiness approval is a 2 step process. First, the manufacturer or design organization develops the data package through which airworthiness approval should be sought, and submits the package to the appropriate Aircraft Certification Office (ACO) for approval. Once the ACO approves the data package, the operator applies the procedures defined in the package to obtain approval from the FSDO or CMO (as appropriate) to utilize its aircraft to conduct flight in RVSM airspace. Paragraph 9b specifically addresses the data package requirements.

b. Contents of the Data Package.

(1) Scope. As a minimum, the data package should consist of the following items:

(i) A definition of the aircraft group or non-group aircraft to which the data package applies.

(ii) A definition of the flight envelope(s) applicable to the subject aircraft.

(iii) The data needed to show compliance with the requirements of paragraphs 7 and 8.

(iv) The compliance procedures to be used to ensure that all aircraft submitted for airworthiness approval meet RVSM requirements.

(v) The engineering data to be used to ensure continued in-service RVSM approval integrity.

(2) Definition of Aircraft Group. For aircraft to be considered as members of a group for purposes of RVSM approval, they should satisfy all of the following conditions:

(i) Aircraft should have been manufactured to a nominally identical design and be approved by the same Type Certificate (TC), TC amendment, or supplemental TC, as applicable.

Note. For derivative aircraft it may be possible to utilize the database from the parent configuration to minimize the amount of additional data required to show compliance. The extent of additional data required will depend on the nature of the changes between the parent aircraft and the derivative aircraft.

(ii) The static system of each aircraft should be installed in a nominally identical manner and position. The same SSE corrections should be incorporated in all aircraft of the group.

(iii) The avionics units installed on each aircraft to meet the minimum RVSM equipment requirements of paragraph 8a should be manufactured to the manufacturer's same specification and have the same part number.

Note. Aircraft which have avionic units which are of a different manufacturer or part number may be considered part of the group, if it is demonstrated that this standard of avionic equipment provides equivalent system performance.

(iv) The RVSM data package should have been produced or provided by the airframe manufacturer or design organization.

(3) Definition of Nongroup Aircraft. If an airframe does not meet the conditions of paragraphs 9b(2)(i), 9b(2)(ii), 9b(2)(iii), and 9b(2)(iv) to qualify as a member of a group or is presented as an individual airframe for approval, then it must be considered as a non-group aircraft for the purposes of RVSM approval.

(4) Definition of Flight Envelopes. The RVSM flight envelope is defined as the Mach number, W/δ , and altitude ranges over which an aircraft can be operated in cruising flight within the RVSM airspace (see Appendix 1 for an explanation of W/δ). As noted in

paragraph 7b, the RVSM operational flight envelope for any aircraft may be divided into two zones as defined below:

(i) Full RVSM Envelope:

(A) The Full RVSM Envelope will comprise the entire range of operational Mach number, W/δ , and altitude values over which the aircraft can be operated within RVSM airspace. Table 1 establishes the parameters which should be considered.

Table 1. Full RVSM Envelope Boundaries.

	Lower Boundary is defined by:	Upper Boundary is defined by:
Altitude	<ul style="list-style-type: none"> FL 290 	The lower of the following <ul style="list-style-type: none"> FL 410 Airplane maximum certified altitude Altitude limited by: cruise thrust; buffet; other aircraft flight limitations
Mach or Speed	The lower of the following: <ul style="list-style-type: none"> Maximum endurance (holding) speed Maneuver speed 	The lower of the following <ul style="list-style-type: none"> Mmo/Vmo Speed limited by: Cruise thrust; buffet; other aircraft flight limitations
Gross Weight	<ul style="list-style-type: none"> The lowest gross weight compatible with operation in RVSM airspace 	<ul style="list-style-type: none"> The highest gross weight compatible with operation in RVSM airspace

(ii) Basic RVSM Envelope:

(A) The boundaries for the Basic RVSM Envelope are the same as those for the Full RVSM Envelope except in regard to the upper Mach boundary.

(B) For the Basic RVSM Envelope, the upper Mach boundary may be limited to a range of airspeeds over which the aircraft group can reasonably be expected to operate most frequently. This boundary should be declared for each aircraft group by the manufacturer or design organization. It may be defined as equal to the upper Mach/airspeed boundary defined for the Full RVSM Envelope or a specified lower value. This lower value

should not be less than the Long Range Cruise Mach Number plus .04 Mach unless limited by available cruise thrust, buffet, or other aircraft flight limitations:

Note: Long Range Cruise Mach Number is the Mach for 99% of best fuel mileage at the particular W/δ under consideration.

(5) Data Requirements. The data package should contain data sufficient to substantiate that the accuracy standards of paragraph 7 are met.

(i) General.

(A) ASE will generally vary with flight condition. The data package should provide coverage of the RVSM envelope sufficient to define the largest errors in the Basic and Full RVSM envelopes. Note that in the case of group approval the worst flight condition may be different for each of the requirements of paragraph 7c(3) and 7c(4), and each should be evaluated.

(B) Where precision flight calibrations are used to quantify or verify altimetry system performance they may be accomplished by any of the following methods. Flight calibrations should only be performed once appropriate ground checks have been completed. Uncertainties in application of the method must be assessed and taken into account in the data package.

(1) Precision tracking radar in conjunction with pressure calibration of atmosphere at test altitude.

(2) Trailing cone.

(3) Pacer aircraft.

(4) Any other method acceptable to the FAA or approving authority.

Note. When using pacer aircraft it should be understood that the pacer aircraft must have been directly calibrated to a known standard. It is not acceptable to calibrate a pacer aircraft by another pacer aircraft.

(ii) Altimetry System Error Budget. It is implicit in the intent of paragraph 7c, for group approvals and for non-group approvals, that a trade may be made between the various error sources which contribute to ASE (as noted in Appendix 2). This document does not specify separate limits for the various error sources which contribute to the mean and variable components of ASE as long as the overall ASE accuracy requirements of paragraph 7c are met. For example, in the case of group approval, the smaller the mean of

the group and the more stringent the avionics standard, the larger the available allowance for SSE variations. In all cases the trade-off adopted should be presented in the data package in the form of an error budget which includes all significant error sources. This is discussed in more detail in the following sections and the discussion of altimetry system error sources provided in Appendix 2.

(iii) Avionics. Avionics equipment should be identified by function and part number. It must be demonstrated that the avionics equipment can meet the requirements established according to the error budget when the equipment is operated in the environmental conditions expected to be met during RVSM operations.

(iv) Groups of Aircraft. Where approval is sought for an aircraft group, the data package must be sufficient to show that the requirements of paragraph 7c(3) and 7c(4) are met. Because of the statistical nature of these requirements, the content of the data package may vary considerably from group to group.

(A) The mean and airframe-to-airframe variability of ASE should be established based on precision flight test calibration of a number of aircraft. Where analytical methods are available, it may be possible to enhance the flight test data base and to track subsequent change in the mean and variability based on geometric inspections and bench test or any other method acceptable to the approving authority. In the case of derivative aircraft it may be possible to utilize data from the parent as part of the data base. (An example would be the case of a fuselage stretch where the only difference in mean ASE between groups could be reliably accounted for by analytical means.)

(B) An assessment of the aircraft-to-aircraft variability of each error source should be made. The error assessment may take various forms as appropriate to the nature and magnitude of the source and the type of data available. For example, for some error sources (especially small ones) it may be acceptable to use specification values to represent 3SD. For other error sources (especially larger ones) a more comprehensive assessment may be required; this is especially true for airframe error sources where "specification" values of ASE contribution may not have been previously established.

(C) In many cases one or more of the major ASE error sources will be aerodynamic in nature (such as variations in the aircraft surface contour in the vicinity of the static pressure source). If evaluation of these errors is based on geometric measurements, substantiation should be provided that the methodology used is adequate to ensure compliance. An example of the type of data which could be used to provide this substantiation is provided in figure 3-2 of Appendix 3.

(D) An error budget should be established to ensure that the standards of paragraphs 7c(3) and 7c(4) are met. As noted in 9b(5)(i)(A), the worst flight condition may be different for each of these standards and therefore the component error values may also be different.

(E) In showing compliance with the overall requirements, the component error sources should be combined in an appropriate manner. In most cases this will involve the algebraic summation of the mean components of the errors, root-sum-square (rss) combination of the variable components of the errors, and summation of the rss value with the absolute value of the overall mean. (Care should be taken that only variable component error sources which are independent of each other are combined by rss.)

(F) The methodology described above for group approval is statistical in nature. This is the result of the statistical nature of the risk analysis and the resulting statistical statements of Appendix 6, paragraphs 5a and 5b. In the context of a statistical method, the statements of Appendix 6, paragraph 5c required reassessment. This item states that "each individual aircraft in the group shall be built to have ASE contained within ± 200 feet". This statement has not been taken to mean that every airframe should be calibrated with a trailing cone or equivalent to demonstrate that ASE is within 200 ft. Such an interpretation would be unduly onerous considering that the risk analysis allows for a small proportion of aircraft to exceed 200 ft. However, it is accepted that if any aircraft is identified as having an error exceeding ± 200 ft then it should receive corrective action.

(v) Nongroup Aircraft. Where an aircraft is submitted for approval as a nongroup aircraft, the data should be sufficient to show that the requirements of paragraph 7c(8) are met. The data package should specify how the ASE budget has been allocated between residual SSE and avionics error. The operator and the FAA should agree on what data is needed to satisfy approval requirements. The following data should be established:

(A) Precision flight test calibration of the aircraft to establish its ASE or SSE over the RVSM envelope should be required. Flight calibration should be performed at points in the flight envelope(s) as agreed by the certifying authority. One of the methods prescribed in paragraph 9b(5)(i)(B) should be used.

(B) Calibration of the avionics used in the flight test as required to establish residual SSE. The number of test points should be agreed by the certifying authority. Since the purpose of the flight test is to determine the residual SSE, specially calibrated altimetry equipment may be used.

(C) Specifications for the installed altimetry avionics equipment indicating the largest allowable errors will be presented.

(D) Using paragraphs 9b(5)(v)(A), 9b(5)(v)(B), and 9b(5)(v)(C) demonstrate that the requirements of paragraph 7c(8) are met. If subsequent to aircraft approval for RVSM operation avionic units which are of a different manufacturer or part number are fitted, it should be demonstrated that the standard of avionic equipment provides equivalent altimetry system performance.

(6) Compliance Procedures. The data package must include a definition of the procedures, inspections/tests and limits which will be used to insure that all aircraft approved against the data package "conform to type," that is all future approvals, whether of new build or in-service aircraft, meet the budget allowances developed according to paragraph 9b(5)(ii). The budget allowances will be established by the data package and include a methodology that allows for tracking the mean and SD for new build aircraft. Compliance requirements must be defined for each potential source of error. A discussion of error sources is provided in Appendix 2. Examples of compliance procedures are presented in Appendix 3.

(7) Where an operating restriction has been adopted (see paragraph 7c(4)(iii)), the package should contain the data and information necessary to document and establish that restriction.

(8) Continued Airworthiness.

(i) The following items should be reviewed and updated as appropriate to include the effects of RVSM implementation:

(A) The Structural Repair Manual with special attention to the areas around the static source, angle of attack sensors and doors if their rigging can affect airflow around the previously mentioned sensors.

(B) The MMEL.

(ii) The data package should include descriptions of any special procedures which are not covered in paragraph 9b(8)(i) but may be needed to insure continued compliance with RVSM requirements as follows:

(A) For nongroup aircraft where airworthiness approval has been based on flight test, the continuing integrity and accuracy of the altimetry system shall be demonstrated by periodic ground and flight tests of the aircraft and its altimetry system at periods to be agreed with the approving authority. However, alleviation of the flight test requirement may be given if it can be adequately demonstrated that the relationship between any subsequent airframe/system degradation and its effects on altimetry system accuracy is understood and adequately compensated/corrected for.

(B) To the extent possible, in-flight defect reporting procedures should be defined to facilitate identification of altimetry system error sources. Such procedures could cover acceptable differences between primary and alternate static sources, and others as appropriate.

(C) For groups of aircraft where approval is based on geometric inspection, there may be a need for periodic re-inspection, and the interval required should be specified.

c. Data Package Approval. All necessary data should be submitted to the appropriate ACO for action.

d. RVSM Airworthiness Approval. The approved data package should be used by the operator to demonstrate compliance with RVSM performance standards.

e. Post Approval Modification. Any variation/modification from the initial installation that affects RVSM approval should require clearance by the airframe manufacturer or approved design organization and be cleared with the FAA to show that RVSM compliance has not been impaired.

10. CONTINUED AIRWORTHINESS (MAINTENANCE REQUIREMENTS).

a. General.

(1) The integrity of the design features necessary to ensure that altimetry systems continue to meet RVSM standards should be verified by scheduled tests and/or inspections in conjunction with an approved maintenance program. The operator should review its maintenance procedures and address all aspects of continuing airworthiness which are affected by RVSM requirements.

(2) Each person or operator should demonstrate that adequate maintenance facilities are available to ensure continued compliance with the RVSM maintenance requirements.

b. Maintenance Program Approval Requirements. Each operator requesting RVSM operational approval should submit a maintenance and inspection program which includes any maintenance requirements defined in the approved data package (paragraph 9) as part of a continuous airworthiness maintenance program approval or an equivalent program approved by the FAA. Although air carriers operating aircraft subject to a continuous airworthiness maintenance program do not have to comply with the provisions of 14 CFR Section 91.411 pertaining to altimeter system and altitude reporting equipment test and

inspections, an effective maintenance and inspection program will, typically, incorporate these provisions as a requirement for maintenance program approval.

c. Maintenance Documents Requirements. The following items should be reviewed as appropriate for RVSM maintenance approval:

- (1) Maintenance Manuals.
- (2) Structural Repair Manuals.
- (3) Standards Practices Manuals.
- (4) Illustrated Parts Catalogs.
- (5) Maintenance Schedule.
- (6) MMEL/MEL.

d. Maintenance Practices.

(1) If the operator is subject to an ongoing approved maintenance program, that program should contain the maintenance practices outlined in the applicable aircraft and component manufacturer's maintenance manuals for each aircraft type. The following items should be reviewed for compliance for RVSM approval and if the operator is not subject to an approved maintenance program the following items should be followed:

(i) All RVSM equipment should be maintained in accordance with the component manufacturer's maintenance requirements and the performance requirements outlined in the approved data package.

(ii) Any modification, repair, or design change which in any way alters the initial RVSM approval, should be subject to a design review by persons approved by the approving authority.

(iii) Any maintenance practices which may affect the continuing RVSM approval integrity, e.g., the alignment of pitot/static probes, dents, or deformation around static plates, should be referred to the approving authority or persons delegated by the authority.

(iv) Built-in Test Equipment (BITE) testing is not an acceptable basis for system calibrations, (unless it is shown to be acceptable by the airframe manufacturer with the approval authorities agreement) and should only be used for fault isolation and troubleshooting purposes.

(v) Some aircraft manufacturers have determined that the removal and replacement of components utilizing quick disconnects and associated fittings, when properly connected, will not require a leak check. While this approach may allow the aircraft to meet static system certification standards when properly connected, it does not always ensure the integrity of the fittings and connectors, nor does it confirm system integrity during component replacement and reconnections. Therefore, a system leak check or visual inspection should be accomplished any time a quick disconnect static line is broken.

(vi) Airframe and static systems should be maintained in accordance with the airframe manufacturer's inspection standards and procedures.

(vii) To ensure the proper maintenance of airframe geometry for proper surface contours and the mitigation of altimetry system error, surface measurements or skin waviness checks should be made if needed to ensure adherence to the airframe manufacturer's RVSM tolerances. These tests and inspections should be performed as established by the airframe manufacturer. These checks should also be performed following repairs, or alterations having an effect of airframe surface and airflow.

(viii) The maintenance and inspection program for the autopilot should ensure continued accuracy and integrity of the automatic altitude control system to meet the height-keeping standards for RVSM operations. This requirement will typically be satisfied with equipment inspections and serviceability checks.

(ix) Where the performance of existing equipment is demonstrated as being satisfactory for RVSM approval, it should be verified that the existing maintenance practices are also consistent with continued RVSM approval integrity. Examples of these are:

- (A) Altitude alert.
- (B) Automatic altitude control system
- (C) ATC altitude reporting equipment (transponders 14 CFR 91.215)
- (D) Altimetry systems.

e. Maintenance Practices for Noncompliant Aircraft. Those aircraft positively identified as exhibiting height-keeping performance errors which require investigation as specified in paragraph 11i(1) should not be operated in airspace where RVSM is applied until the following actions have been taken:

(1) The failure or malfunction is confirmed and isolated by maintenance action and,

(2) Corrective action is carried out as required to comply with paragraph 9b(5)(iv)(F) and verified to ensure RVSM approval integrity.

f. Maintenance Training Requirements. It is expected that new training requirements will be introduced by the RVSM approval processes. Areas that may need to be highlighted for initial and recurrent training of shop and line personnel are:

- (1) Aircraft geometric inspection techniques.
- (2) Test equipment calibration/usage techniques.
- (3) Any special documentation or procedures introduced by RVSM approval.

g. Test Equipment.

(1) General. The test equipment should have the capability to demonstrate continuing compliance with all the parameters established for RVSM approval in the initial data package or as approved by the approving authority.

(2) Standards. Test equipment should be calibrated utilizing reference standards whose calibration is certified as being traceable to the national standard approved. It should be calibrated at periodic intervals as agreed by the approving authority. The approved maintenance program should encompass an effective quality control program which includes the following:

- (i) Definition of required test equipment accuracy.
- (ii) Regular calibrations of test equipment traceable to a master inhouse standard. Determination of calibration interval should be a function of the stability of the test equipment. The calibration interval should be established on the basis of historical data so that degradation is small in relation to the required accuracy.
- (iii) Regular audits of calibration facilities both inhouse and outside.
- (iv) Adherence to acceptable shop and line maintenance practices.
- (v) Procedures for controlling operator errors and unusual environmental conditions which may affect calibration accuracy.

11. OPERATIONAL APPROVAL.

a. Purpose and Organization. Paragraph 6 describes in general the administrative process which an operator should follow to receive approval to operate an aircraft in RVSM airspace. Paragraph 11 is intended to provide detailed guidance on the content of operational programs, practices, and procedures. It also describes specifically the steps in the operational approval process: application for authority, FAA evaluation of this application, and granting of approval to operate. Appendices 4 and 5 are related to this paragraph and contain essential information for operational programs.

b. General. The FAA should ensure that each operator can maintain high levels of height-keeping performance.

* (1) Source of Information. The FAA RVSM Homepage can be accessed at { HYPERLINK "<http://www.faa.gov/ats/ato/rvsm1.htm>" }. The RVSM Documentation Webpage contains current guidance and information on the aircraft and operator approval process. The RVSM Documentation Webpage and webpages providing information on RVSM programs in various areas of the world are linked to the RVSM Homepage.

* (2) The FAA should be satisfied that operational programs are adequate. Flightcrew training/pilot knowledge as well as operations manuals should be evaluated. Approval should be granted for each individual operator.

(3) Approval should be granted for each individual aircraft group and each individual aircraft to be used by the operator in RVSM operations. Each aircraft should receive airworthiness approval in accordance with paragraph 9 prior to being approved for use by the operator. (Aircraft group is defined in paragraph 9b(2)).

(4) Aircraft Approval for Worldwide RVSM Operations. Aircraft that have been approved for RVSM can be used in RVSM operations worldwide. This includes RVSM operation in continental areas such as Europe and the U.S.. Aircraft equipage and altitude-keeping performance requirements were developed using the highest density traffic counts in the world so that aircraft could receive one-time approval for worldwide operations.

(5) Operational Approval for New RVSM Areas of operation. Operators that are starting RVSM operations in an RVSM area of operations that is new to them should ensure that their RVSM programs incorporate any operations or continued airworthiness requirements unique to the new area of operations. (See Paragraph 11g for information on the form of RVSM authority for new areas of operations).

c. Pre-application Meeting. A pre-application meeting should be scheduled between the operator and the CMO or FSDO. The intent of this meeting is to inform the operator of FAA expectations in regard to approval to operate in a RVSM environment. The content of the operator RVSM application, FAA review and evaluation of the application, validation

flight requirements, and conditions for removal of RVSM authority should be basic items of discussion.

* d. Content of Operator RVSM Application. The following paragraphs describe the material which an operator applying for RVSM authority should provide to the FAA for review and evaluation at least 60 days prior to the intended start of RVSM operations. Part 121, 125, and 135 operators applying for authority to conduct operations in an RVSM area of operations that is new to them may modify the application content to address those items unique to the new area of operations. Part 91 operators, and Part 125 operators holding a deviation that allows operation under Part 91 that have obtained an LOA for RVSM operations are not required to obtain a separate LOA for individual areas of operation where RVSM is applied. (See Paragraph 11g).

* (1) Airworthiness Documents. Sufficient documentation should be available to show that aircraft comply with RVSM standards.

* (i) In-service aircraft. Documents that contain the inspections and/or modifications that are required to make an in-service aircraft RVSM compliant can take the form of approved Service Bulletins, Aircraft Service Changes, Supplemental Type Certificates or any other format the FAA finds acceptable. Maintenance records document completion of required inspections and/or modifications.

(ii) In-production or New-production aircraft. For such aircraft, statements of eligibility to conduct RVSM operations can be included in the Airplane Flight Manual. Also, Type Certification Data Sheets can be used to show RVSM eligibility by describing RVSM related avionics configurations and continued airworthiness criteria or providing reference to FAA approved documentation in the form of a report. Eligibility can be shown in any other format found acceptable to the FAA.

(2) Description of Aircraft Equipment. The applicant should provide a configuration list which details all components and equipment relevant to RVSM operations. (Paragraph 8 discusses equipment for RVSM operations).

* (3) Operations Training Programs and Operating Practices and Procedures. Practices and procedures in the following areas should be standardized using the guidelines of Appendix 4: flight planning, preflight procedures at the aircraft for each flight, procedures prior to RVSM airspace entry, inflight procedures, and flightcrew training procedures. Appendix 4, paragraph 7 contains special emphasis items for flightcrew training. Also, pilots and, where applicable, dispatchers should be knowledgeable on contingency and other procedures unique to specific areas of operation. (See Appendix 4 for sources of information on such procedures. Also, Appendix 5 contains guidance on oceanic contingency procedures).

(i) 14 CFR Part 121, 125 and 135 Operators. Such operators should submit training syllabi and other appropriate material to the FAA to show that the operating practices and procedures and training items related to RVSM operations are incorporated in

initial and, where warranted, recurrent training programs. (Training for dispatchers should be included, where appropriate).

* (ii) 14 CFR Part 91 Operators and Part 125 Operators holding a deviation that allows operation under Part 91. These operators should show the FAA that pilot knowledge of RVSM operating practices and procedures will be adequate to warrant granting of approval to conduct RVSM operations. The following are acceptable means for the operator to show the FAA that its pilots will have adequate knowledge of the RVSM operating practices and procedures: the FAA may accept 14 CFR part 142 training center certificates without further evaluation; may accept certificates documenting completion of a course of instruction on RVSM policy and procedures; may accept an operator's in-house training program or may evaluate a training course prior to accepting a training certificate.

* (4) Operations Manuals and Checklists. Manuals and checklists should be submitted for FAA review as part of the application process. Generally operations manuals are accepted by the FAA. The FAA generally approves only those documents that are required by regulation to be approved. The appropriate manuals and checklists should be revised to include information/guidance on standard operating procedures detailed in Appendix 4 and in the appendices that address area of operations unique procedures (e.g., Appendix 5). Appropriate manuals should include a statement of the airspeeds, altitudes and weights considered in RVSM aircraft approval to include identification of any operations restrictions established for that aircraft group (see paragraph 7c(4)(iii)).

(5) Past Performance. An operating history should be included in the application. The applicant should show any events or incidents related to poor height keeping performance which may indicate weaknesses in training, procedures, maintenance, or the aircraft group intended to be used.

* (6) Minimum Equipment List. The following applies to operators that conduct operations under a minimum equipment list (MEL). An MEL, adopted from the master minimum equipment list (MMEL), should include items pertinent to operating in RVSM airspace.

(7) Maintenance. The operator should submit a maintenance program for approval in accordance with paragraph 10 at the time the operator applies for operational approval.

* (8) Plan for participation in RVSM Monitoring Programs. The operator should provide a plan for participation in the RVSM monitoring program. This program should normally entail a check of at least a portion of the operator's aircraft by an independent height-monitoring system. Guidance on monitoring programs for specific areas of operation can be found on the FAA RVSM Documentation website. Access the RVSM Homepage ({ HYPERLINK "<http://www.faa.gov/ats/ato/rvsm1.htm>" }) and then click on "RVSM Documentation". (See paragraph 11h for further discussion of RVSM monitoring programs).

e. FAA Review and Evaluation of Applications.

(1) Once the application has been submitted, the FAA will begin the process of review and evaluation. If the content of the application is insufficient, the FAA will request additional information from the operator.

(2) When all the airworthiness and operational requirements of the application are met, the authority will proceed with the approval process.

* f. Validation Flight(s) for Part 91, Part 121, Part 125 and 135 operators. In some cases, the review of the RVSM application and programs may suffice for validation purposes. However, the final step of the approval process may be the completion of a validation flight. The FAA may accompany the operator on a flight through airspace where RVSM is applied to verify that operations and maintenance procedures and practices are applied effectively. If the performance is adequate, operational approval for RVSM airspace should be granted. If performance is not adequate, then approval should be delayed.

g. Form of Authorizing Documents.

(1) 14 CFR Part 121, Part 125, and Part 135 Operators. Approval to operate in RVSM airspace should be granted through the issuance of an operations specifications paragraph from Part B (En route Authorizations, Limitation, and Procedures) and Part D (Aircraft Maintenance). Each aircraft type group for which the operator is granted authority should be listed in OpSpecs. Approval to conduct RVSM operations in an RVSM area of operations that is new to the operator should be granted by adding the part B RVSM OpSpecs paragraph number to the appropriate area of operations in the Part B paragraph: Authorized Areas of En Route Operation. Limitations and Provisions.

* (2) 14 CFR Part 91 Operators and Part 125 operators holding a deviation to operate under Part 91. Operators that conduct operations under Part 91 should be issued an initial letter of authorization (LOA) when the initial approval process has been completed. Part 91 operators are not required to obtain a new or amended LOA to operate in individual areas of operation where RVSM is implemented. For example, an operator that has obtained an LOA and is conducting RVSM operations in the North Atlantic is not required to obtain another LOA to conduct RVSM operations in the domestic United States. LOA's have a 24-month validity period.

* h. RVSM Monitoring Programs. A program to monitor or verify aircraft height-keeping performance is considered a necessary element of RVSM implementation. RVSM monitoring programs have the primary objective of observing and evaluating aircraft height-keeping performance to gain confidence that airspace users are applying the airplane/operator approval process in an effective manner and that an equivalent level of safety will be maintained when RVSM is implemented. It is anticipated that the necessity

for such programs may be diminished or possibly eliminated after confidence is gained that RVSM programs are working as planned.

* *Note: A height-monitoring system based on Global Positioning Satellites or an earth-based system may fulfill this function. See "Monitoring Requirements and Procedures" on the RVSM Documentation Webpage.*

i. Conditions for Removal of RVSM Authority.

(1) The incidence of height-keeping errors which can be tolerated in an RVSM environment is very small. It is incumbent upon each operator to take immediate action to rectify the conditions which caused the error. The operator should also report the event to the FAA within 72 hours with initial analysis of causal factors and measures to prevent further events. The requirement for follow up reports should be determined by the FAA. Errors which should be reported and investigated are: TVE equal to or greater than ± 300 ft (± 90 m), ASE equal to or greater than ± 245 ft (± 75 m), and AAD equal to or greater than ± 300 ft (± 90 m).

(2) Height-keeping errors fall into two broad categories: errors caused by malfunction of aircraft equipment and operational errors. An operator which consistently commits errors of either variety may be required to forfeit authority for RVSM operations. If a problem is identified which is related to one specific aircraft type, then RVSM authority may be removed for the operator for that specific type.

(3) The operator should make an effective, timely response to each height-keeping error. The FAA may consider removing RVSM operational approval if the operator response to a height-keeping error is not effective or timely. The FAA should also consider the operator's past performance record in determining the action to be taken. If an operator shows a history of operational and/or airworthiness errors, then approval may be removed until the root causes of these errors are shown to be eliminated and RVSM programs and procedures are shown to be effective. The FAA will review each situation on a case-by-case basis.

APPENDIX 1. EXPLANATION OF W/δ

1. Paragraph 9(b)(4) describes the range of flight conditions over which conformity to the ASE rules must be shown. The description includes reference to the parameter W/δ . The following discussion is provided for the benefit of readers who may not be familiar with the use of this parameter.
2. It would be difficult to show all of the gross weight, altitude, and speed conditions which constitute the RVSM envelope(s) on a single plot. This is because most of the speed boundaries of the envelopes are a function of both altitude and gross weight. As a result, a separate chart of altitude vs. Mach would be required for each aircraft gross weight. Aircraft performance engineers commonly use the following technique to solve this problem.
3. For most jet transports the required flight envelope can be collapsed to a single chart, with good approximation, by use of the parameter W/δ (weight divided by atmospheric pressure ratio). This fact is due to the relationship between W/δ and the fundamental aerodynamic variables M and lift coefficient as shown below.

$$W/\delta = 1481.4 C_L M^2 S_{\text{Ref}}, \text{ where:}$$

δ = ambient pressure at flight altitude divided by sea level standard pressure of 29.92126 inches Hg

W/δ = Weight over Atmospheric Pressure Ratio

C_L = Lift Coefficient

M = Mach Number

S_{REF} = Reference Wing Area

4. As a result, the flight envelope may be collapsed into one chart by simply plotting W/δ , rather than altitude, versus Mach Number. Since δ is a fixed value for a given altitude, weight can be obtained for a given condition by simply multiplying the W/δ value by δ .
5. Over the RVSM altitude range, it is a good approximation to assume that position error is uniquely related to Mach Number and W/δ for a given aircraft.

APPENDIX 2. ALTIMETRY SYSTEM ERROR COMPONENTS

1. INTRODUCTION. Paragraph 9b(5)(ii) states that an error budget must be established and presented in the approval data package. The requirements for this error budget are discussed in some detail in paragraph 9b(5)(iii) through 9b(5)(v) for group and non-group aircraft. The purpose of this appendix is to provide guidance to help ensure that all of the potential error sources are identified and included in the error budget for each particular model.

2. OBJECTIVE OF ASE BUDGET.

a. The purpose of the ASE budget is to demonstrate that the allocation of tolerances amongst the various parts of the altimetry system is, for the particular data package, consistent with the overall statistical ASE requirements. These individual tolerances within the ASE budget also form the basis of the procedures, defined in the airworthiness approval data package, which will be used to demonstrate that aircraft satisfy the RVSM requirements.

b. It is necessary to ensure that the budget takes account of all contributory components of ASE.

c. For group approval it is necessary to ensure either that the budget assesses the combined effect of the component errors in a way that is statistically realistic, or that the worst case specification values are used.

3. ALTIMETRY SYSTEM ERROR.

a. Breakdown. Figure 2-1 shows the breakdown of total ASE into its main components, with each error block representing the error associated with one of the functions needed to generate a display of pressure altitude. This breakdown encompasses all altimetry system errors which can occur, although different system architectures may combine the components in slightly different ways.

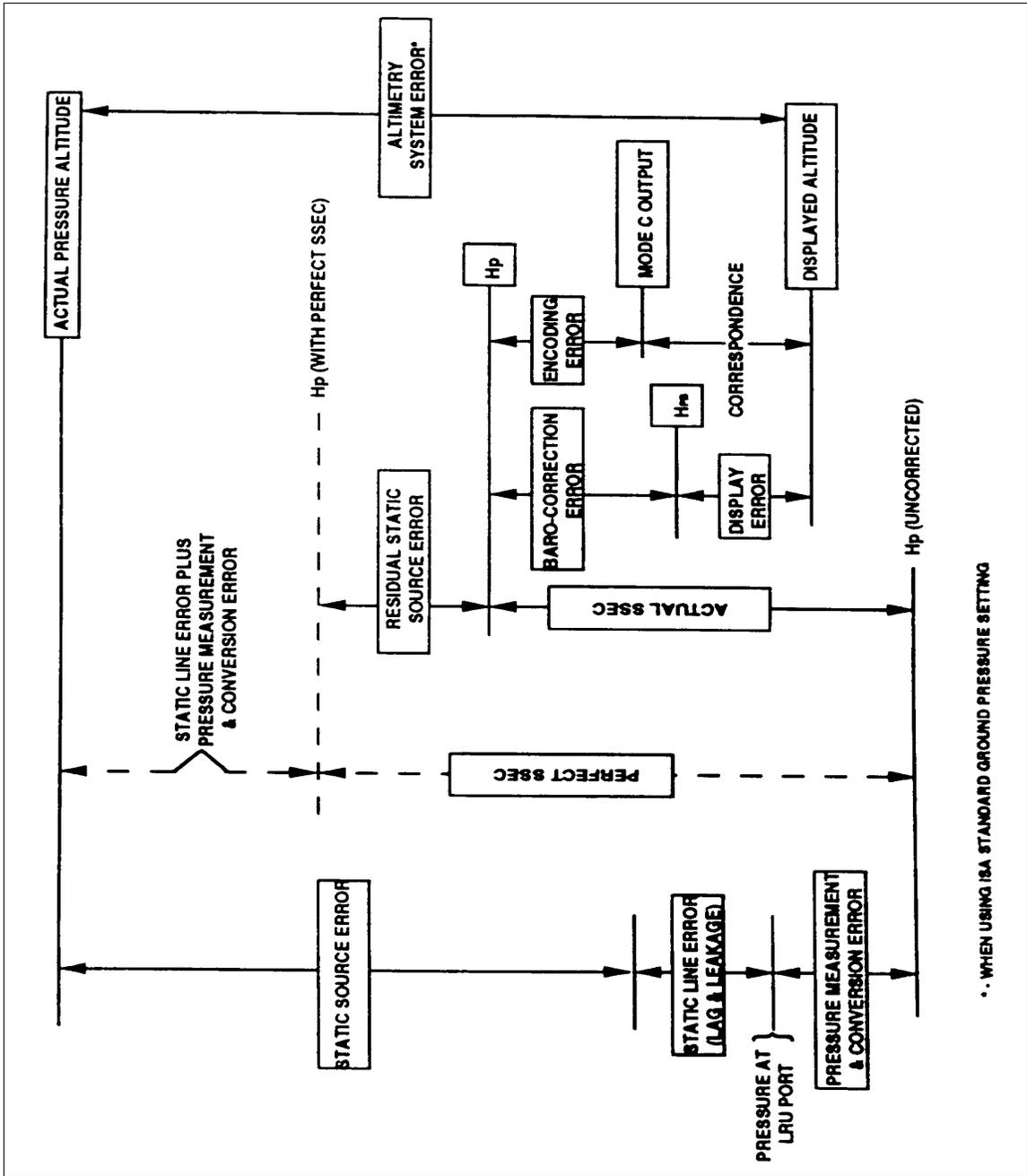
(1) The "Actual Altitude" is the pressure altitude corresponding to the undisturbed ambient pressure.

(2) "Static Source Error" is the difference between the undisturbed ambient pressure and the pressure within the static port at the input end of the static pressure line.

(3) "Static Line Error" is any difference in pressure along the length of the line.

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Figure 2-1 ASE and Its Components



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(4) "Pressure Measurement and Conversion Error" is the error associated with the processes of transducing the pneumatic input seen by the avionics, and converting the resulting pressure signal into altitude. As drawn, figure 2-1 represents a self-sensing altimeter system in which the pressure measurement and altitude conversion functions would not normally be separable. In an air data computer system the two functions would be separate, and SSEC would probably then be applied before pressure altitude (H_p) was calculated.

(5) "Perfect SSEC" would be that correction which compensated exactly for the SSE actually present at any time. If such a correction could be applied, then the resulting value of H_p calculated by the system would differ from the actual altitude only by the static line error plus the pressure measurement and conversion error. In general this cannot be achieved, so although the "Actual SSEC" can be expected to reduce the effect of SSE, it will do so imperfectly.

(6) "Residual Static Source Error" is applicable only in systems applying an avionic SSEC. It is the difference between the SSE and the correction actually applied. The corrected value of H_p will therefore differ from actual pressure altitude by the sum of static line error, pressure measurement and conversion error, and residual SSE.

(7) Between H_p and displayed altitude occur the baro-correction error and the display error. Figure 2-1 represents their sequence for a self-sensing altimeter system. Air data computer systems can implement baro-correction in a number of ways which would modify slightly this part of the block diagram, but the errors would still be associated with either the baro-correction function or the display function. The only exception is that those systems which can be switched to operate the display directly from the H_p signal can eliminate baro-correction error where standard ground pressure setting is used, as in RVSM operations.

b. Components. The altimetry system errors presented in table 2-1 and described in paragraph 3a are discussed below in greater detail.

(1) Static Source Error. The component parts of SSE are presented in table 2-1, with the factors which control their magnitude.

(i) The reference SSE is the best estimate of actual SSE, for a single aircraft or an aircraft group, obtained from flight calibration measurements. It is variable with operating condition, characteristically reducing to a family of W/δ curves which are functions of Mach. It includes the effect of any aerodynamic compensation which may have been incorporated in the design once it has been determined, the reference SSE is fixed for the single aircraft or group, although it may be revised in the light of subsequent data.

APPENDIX 2. ALTIMETRY SYSTEM ERROR COMPONENTS

(ii) The test techniques used to derive the reference SSE will have some measurement uncertainty associated with them, even though known instrumentation errors will normally be eliminated from the data. For trailing-cone measurements the uncertainty arises from limitations on pressure measurement accuracy, calibration of the trailing-cone installation, and variability in installations where more than one are used. Once the reference SSE has been determined, the actual measurement error is fixed, but as it is unknown it can only be handled within the ASE budget as an estimated uncertainty.

(iii) The airframe variability and probe/port variability components arise from differences between the individual airframe and probe/port, and the example(s) of airframe and probe port used to derive the reference SSE.

(2) Residual Static Source Error.

(i) The components and factors are presented in Table 2-2. Residual SSE is made up of those error components which make actual SSE different from the reference value, components 2, 3, and 4 from Table 2-1, plus the amount by which the actual SSEC differs from the value which would correct the reference value exactly, components 2(a), (b) and (c) from Table 2-2.

(ii) There will generally be a difference between the SSEC which would exactly compensate the reference SSE, and the SSEC which the avionics is designed to apply. This arises from practical avionics design limitations. The resulting error component 2(a) will therefore be fixed, for a particular flight condition, for the single aircraft or group. Additional variable errors 2(b) and 2(c) arise from those factors which cause a particular set of avionics to apply an actual SSEC which differs from its design value.

(iii) The relationship between perfect SSEC, reference SSEC, design SSEC and actual SSEC is illustrated in Figure 2-2, for the case where static line errors and pressure measurements and conversion errors are taken as zero.

APPENDIX 2. ALTIMETRY SYSTEM ERROR COMPONENTS

**Table 2-1. Static Source Error
(Cause: Aerodynamic Disturbance to Free-Stream Conditions)**

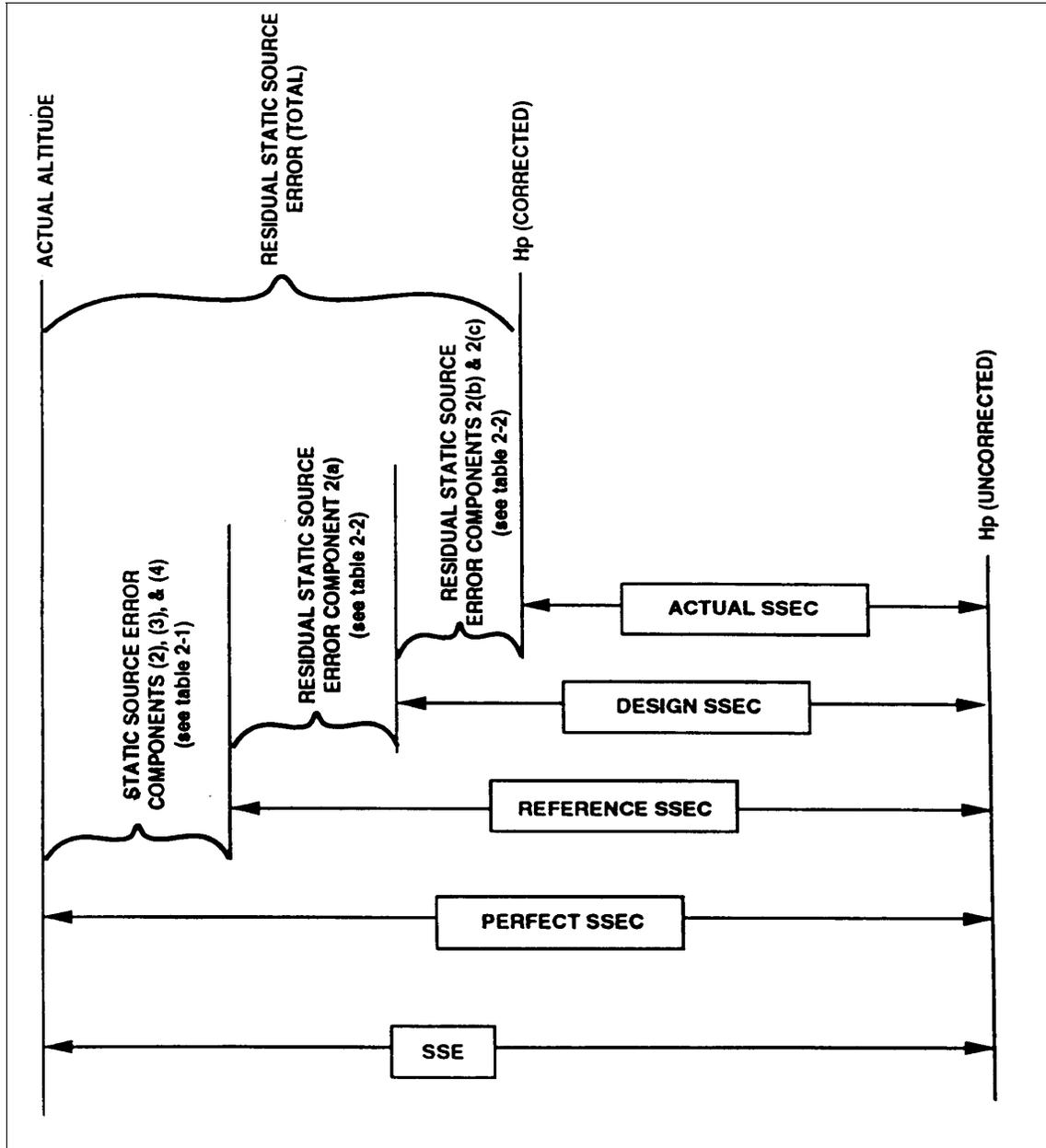
Factors		Error Components
Airframe Effects		1) Reference SSE values from flight calibration measurements. 2) Uncertainty of flight calibration measurements. 3) Airframe to Airframe variability 4) Probe/Port to Probe/Port variability
Operating Condition	(M, Hp, α , β)	
Geometry:	shape of airframe location of static sources variations of surface contour near the sources variations in fit of nearby doors, skin panels or other items	
Probe/Port Effects		
Operating Condition	(M, Hp, α , β)	
Geometry:	shape of probe/port manufacturing variations installation variations	

**Table 2-2. Residual Static Source Error (Aircraft with Avionic SSEC)
(Cause: Difference between the SSEC actually applied and the actual SSE)**

Factors	Error Components
1) As for Static Source Error <p style="text-align: center;"><u>PLUS</u></p> 2) Source of input data for SSEC function <ul style="list-style-type: none"> a) Where SSEC is a function of Mach: <ul style="list-style-type: none"> i) P_s sensing: difference in SSEC from reference SSE. ii) P_s measurement: pressure transduction error iii) P_T errors: mainly pressure transduction error b) Where SSEC is a function of Angle of Attack: <ul style="list-style-type: none"> i) geometric effects on alpha <ul style="list-style-type: none"> - sensor tolerances - installation tolerances - local surface variations ii) measurement error <ul style="list-style-type: none"> - angle transducer accuracy 	1) Static Source Error Components (2), (3), and (4) from table 2-1 <p style="text-align: center;"><u>PLUS</u></p> 2a) Approximation in fitting design SSEC to flight calibration reference SSE. 2b) Effect of production variability (sensors and avionics) on achieving design SSEC. 2c) Effect of operating environment (sensors and avionics) on achieving design SSEC.
3) Implementation of SSEC function <ul style="list-style-type: none"> a) Calculation of SSEC from input data b) Combination of SSEC with uncorrected height 	

APPENDIX 2. ALTIMETRY SYSTEM ERROR COMPONENTS

Figure 2-2 SSE/SSEC Relationships for ASE where Static Line, Pressure Measurement and Conversion Errors are Zero



APPENDIX 2. ALTIMETRY SYSTEM ERROR COMPONENTS

(iv) Factors which create variability of SSE relative to the reference characteristic must be accounted for in two ways. Firstly, as noted for the SSE itself in table 2-1, and secondly for its effect on the application of SSEC as in factor 2(a)(i) of table 2-2. Similarly the static pressure measurement error must be accounted for in two separate ways. The main effect will be via the "pressure measurement and conversion" component, but a secondary effect will be via Factor 2(a)(ii) Table 2-2.

(3) Static Line Error. Static line errors arise from leaks and pneumatic lags. In level cruise these can be made negligible for a system which is correctly designed and correctly installed.

(4) Pressure Measurement and Conversion Error.

(i) The functional elements are static pressure transduction, which may be mechanical, electromechanical or solid-state, and the conversion of pressure signal to pressure altitude.

(ii) The error components are:

- (A) calibration uncertainty;
- (B) nominal design performance;
- (C) unit to unit manufacturing variations; and
- (D) effect of operating environment.

(iii) The equipment specification is normally taken to cover the combined effect of the error components. If the value of pressure measurements and conversion error used in the error budget is the worst case specification value, then it is not necessary to assess the above components separately. However, calibration uncertainty, nominal design performance and effect of operating environment can all contribute to bias errors within the equipment tolerance. Therefore if it is desired to take statistical account of the likely spread of errors within the tolerance band, then it will be necessary to assess their likely interaction for the particular hardware design under consideration.

(iv) It is particularly important to ensure that the specified environmental performance is adequate for the intended application.

APPENDIX 2. ALTIMETRY SYSTEM ERROR COMPONENTS

(5) Baro-Setting Error. This is defined as the difference between the value displayed and the value applied within the system. For RVSM operation the value displayed should always be ISA standard ground pressure, but setting mistakes, although part of TVE, are not components of ASE.

(i) The components of Baro-Setting Error are:

(A) resolution of setting knob/display ("Setability");

(B) transduction of displayed value; and

(C) application of transduced value.

(ii) The applicability of these factors and the way that they combine depends on the particular system architecture.

(iii) For systems in which the display is remote from the pressure measurement function there may be elements of the transduction and/or application or transduced value error components which arise from the need to transmit and receive the setting between the two locations

(6) Display Error. The cause is imperfect conversion from altitude signal to display. The components are:

(i) conversion of display input signal;

(ii) graticule/format accuracy, and

(iii) readability.

(7) In self-sensing altimeters the first of these would normally be separate from the pressure measurement and conversion error

APPENDIX 3: ESTABLISHING AND MONITORING STATIC SOURCE ERRORS

1. The requirements for the data package are discussed in general terms in paragraph 9b. It is stated, in paragraph 9b(5)(iv)(C) that the methodology used to establish the static source error must be substantiated. It is further stated in paragraph 9b(6) that procedures be established to ensure conformity of newly manufactured airplanes. There may be many ways of satisfying these requirements; two examples are discussed below.

2. Example 1.

a. One process for showing compliance with RVSM requirements is shown in Figure 3-1. Figure 3-1 illustrates that flight test calibrations and geometric inspections will be performed on a given number of aircraft. The flight calibrations and inspections will continue until a correlation between the two is established. Geometric tolerances and SSEC will be established to satisfy RVSM requirements. For aircraft being manufactured, every Nth aircraft will be inspected in detail and every Mth aircraft will be flight test calibrated, where N and M are determined by the manufacturer and agreed to by the approving authority. The data generated by N inspections and M flight calibrations shall be used to track the mean and 3 SD values to insure continued compliance of the model with the requirements of paragraph 7. As additional data are acquired, they should be reviewed to determine if it is appropriate to change the values of N and M as indicated by the quality of the results obtained.

b. There are various ways in which the flight test and inspection data might be used to establish the correlation. The example shown in Figure 3-2 is a process in which each of the error sources for several airplanes is evaluated based on bench tests, inspections and analysis. Correlation between these evaluations and the actual flight test results would be used to substantiate the method.

c. The method illustrated in Figures 3-1 and 3-2 is appropriate for new models since it does not rely on any pre-existing data base for the group.

3. Example 2.

a. Figure 3-3 illustrates that flight test calibrations should be performed on a given number of aircraft and consistency rules for air data information between all concerned systems verified. Geometric tolerances and SSEC should be established to satisfy the requirements. A correlation should be established between the design tolerances and the consistency rules. For aircraft being manufactured, air data information for all aircraft should be checked in term of consistency in cruise conditions and every Mth aircraft should be calibrated, where M is determined by the manufacture and agreed to by the approving authority. The data generated by the M flight calibrations should be used to

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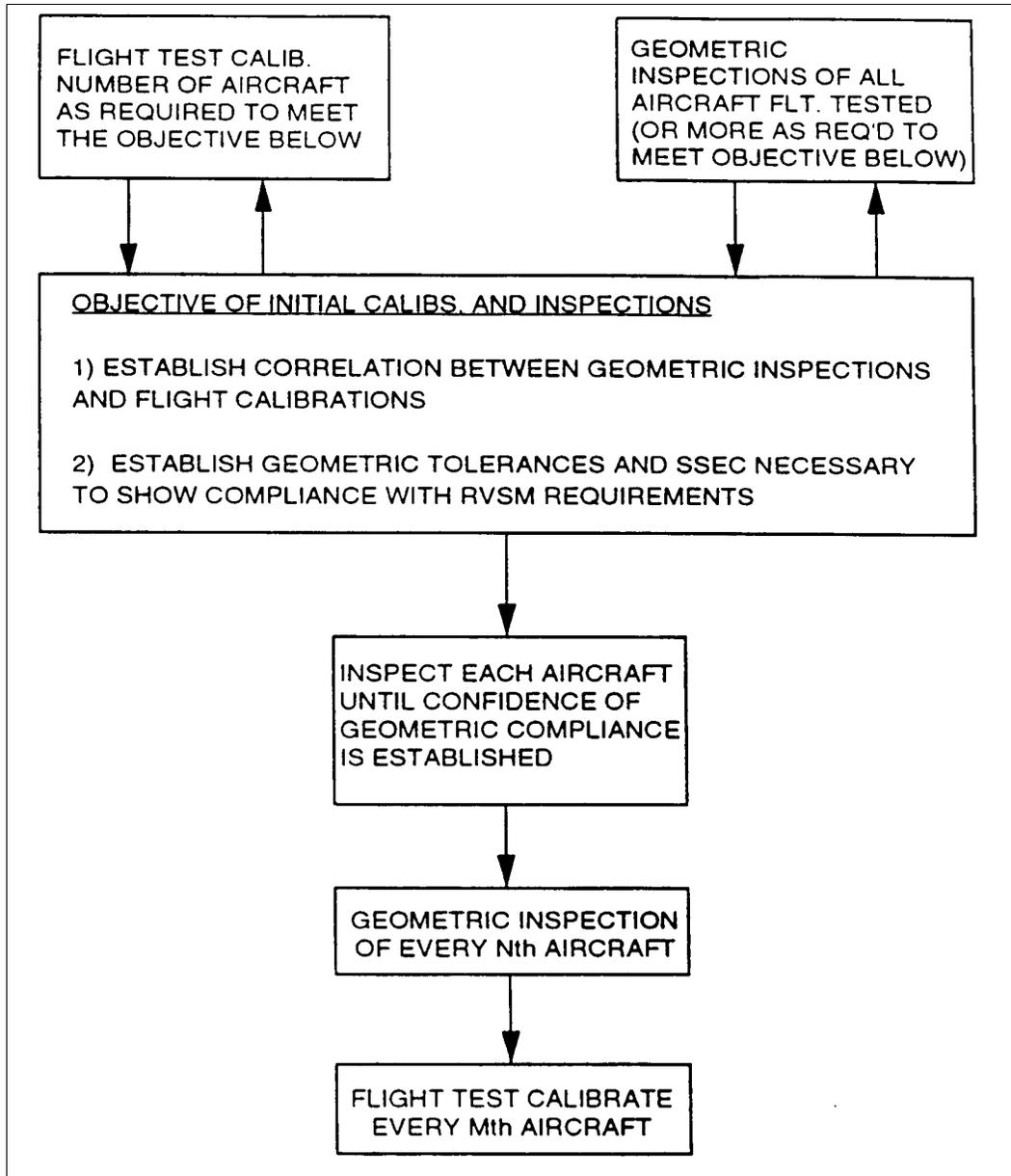
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APPENDIX 3: ESTABLISHING AND MONITORING STATIC SOURCE ERRORS

track the mean and 3SD values to ensure continued compliance of the group with the requirements of paragraph 7.

APPENDIX 3: ESTABLISHING AND MONITORING STATIC SOURCE ERRORS

Figure 3-1 Process for Showing Initial and Continues Compliance of Airframe Static Pressure System



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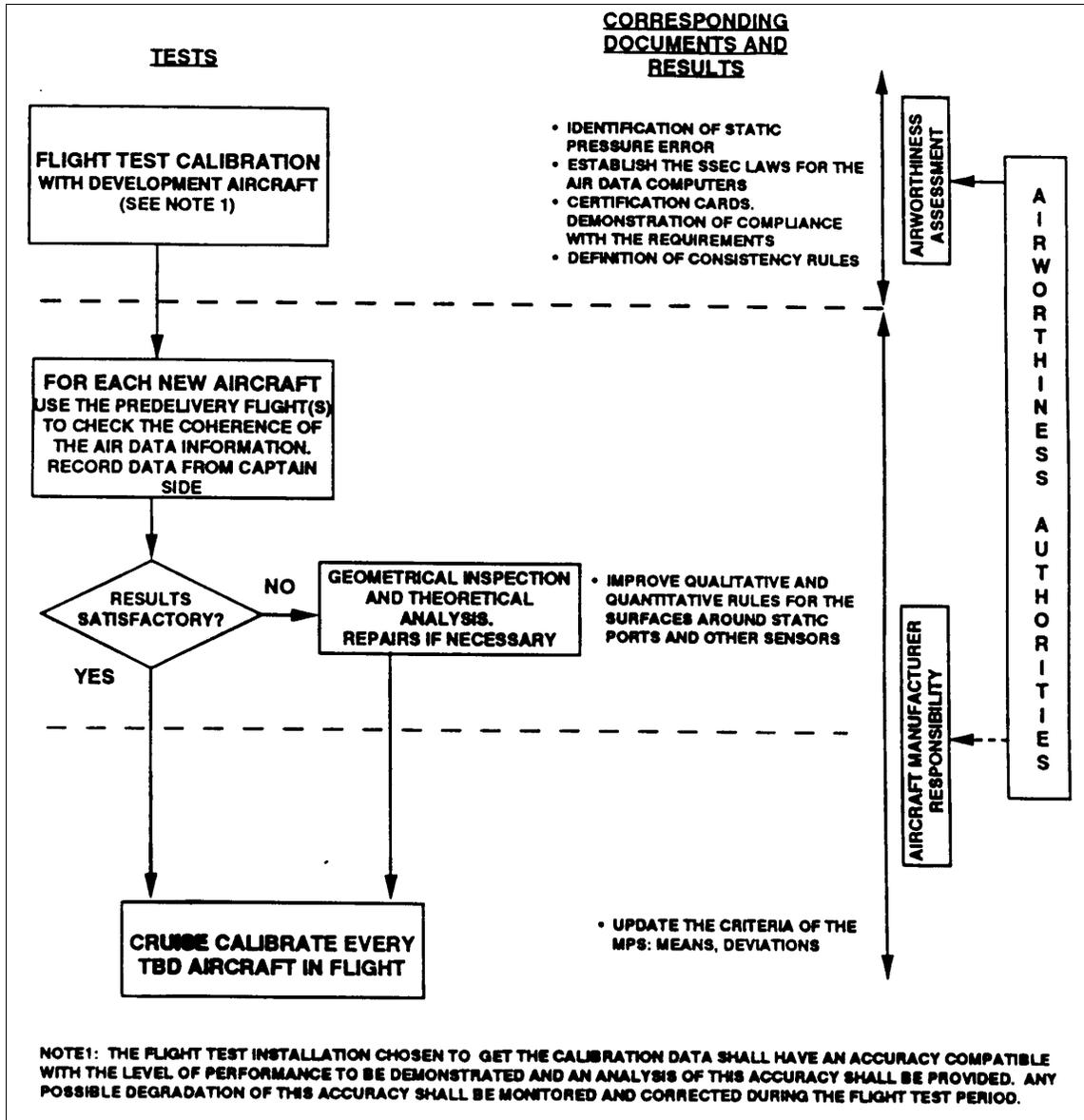
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Appendix 3

APPENDIX 3: ESTABLISHING AND MONITORING STATIC SOURCE ERRORS

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APPENDIX 3: ESTABLISHING AND MONITORING STATIC SOURCE ERRORS

Figure 3-3 Process for Showing Initial and Continued Compliance of Airframe Static Pressure Systems for In-Service and New Model Aircraft



APPENDIX 4. TRAINING PROGRAMS AND OPERATING PRACTICES AND PROCEDURES

1. Introduction. The following items (detailed in paragraphs 2 through 7) should be standardized and incorporated into training programs and operating practices and procedures. Certain items may already be adequately standardized in existing operator programs and procedures. New technologies may also eliminate the need for certain crew actions. If this is the case, then the intent of this guidance can be considered to be met.

Note. The document has been written for use by a wide variety of operator types (FAA Part 91 to Part 121) and therefore, certain items have been included for purposes of clarity and completeness.

2. Flight Planning. During flight planning, the flightcrew and dispatchers, if applicable, should pay particular attention to conditions which may affect operation in RVSM airspace. These include, but may not be limited to:

a. verifying that the aircraft is approved for RVSM operations.

* b. annotating the flight plan to be filed with the Air Traffic Service Provider to show that the aircraft and operator are approved for RVSM operations. Block 3 of the FAA Flight Plan (Aircraft Type/Special Equipment) or block 10 (Equipment) of the ICAO flight plan should be annotated with the letter "W" to show RVSM approval. For the FAA Flight plan, other letters may be applicable in the future. If so, they will be announced in NOTAMS, the Aeronautical Information Manual and on the RVSM Documentation Webpage.

c. reported and forecast weather conditions on the route of flight;

d. minimum equipment requirements pertaining to height-keeping systems; and

e. If required for the specific aircraft group; accounting for any aircraft operating restrictions related to RVSM airworthiness approval. (See paragraph 7c(4)(iii)).

3. Preflight procedures at the aircraft for each flight. The following actions should be accomplished during preflight:

a. Review maintenance logs and forms to ascertain the condition of equipment required for flight in the RVSM airspace. Ensure that maintenance action has been taken to correct defects to required equipment;

b. During the external inspection of aircraft, particular attention should be paid to the condition of static sources and the condition of the fuselage skin in the vicinity of each static source and any other component that affects altimetry system accuracy (this check may be

APPENDIX 4. TRAINING PROGRAMS AND OPERATING PRACTICES AND PROCEDURES

accomplished by a qualified and authorized person other than the pilot, e.g., a flight engineer or maintenance personnel);

c. Before takeoff, the aircraft altimeters should be set to the local altimeter (QNH) setting and should display a known elevation (e.g., field elevation) within the limits specified in aircraft operating manuals. The difference between the known elevation and the elevation displayed on the altimeters should not exceed 75 ft. The two primary altimeters should also agree within limits specified by the aircraft operating manual. An alternative procedure using QFE may also be used;

d. Before take-off, equipment required for flight in RVSM airspace should be operational, and indications of malfunction should be resolved.

*4. Procedures prior to RVSM airspace entry. The following equipment should be operating normally at entry into RVSM airspace:

- a. Two primary altitude measurement systems.
- b. One automatic altitude-control system.
- c. One altitude-alerting device.

d. Should any of the required equipment fail prior to the aircraft entering RVSM airspace, the pilot should request a new clearance so as to avoid flight in this airspace;

Note. Operating Transponder. The operator should ascertain the requirement for an operational transponder in each RVSM area where operations are intended. The operator should also ascertain the transponder requirements for transition areas adjacent to RVSM airspace. Appendix 5, paragraph 9 discusses transponder failure for RVSM transition areas.

5. In-flight Procedures. The following policies should be incorporated into flight crew training and procedures:

a. Flight crews should comply with aircraft operating restrictions (if required for the specific aircraft group) related to RVSM airworthiness approval. (See paragraph 7c(4)(iii)).

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

APPENDIX 4. TRAINING PROGRAMS AND OPERATING PRACTICES AND PROCEDURES

c. In level cruise it is essential that the aircraft is flown at the CFL. This requires that particular care is taken to ensure that ATC clearances are fully understood and followed. Except in contingency or emergency situations, the aircraft should not intentionally depart from CFL without a positive clearance from ATC;

d. During cleared transition between levels, the aircraft should not be allowed to overshoot or undershoot the cleared flight level by more than 150 ft (45 m);

Note. It is recommended that the level off be accomplished using the altitude capture feature of the automatic altitude-control system, if installed.

e. An automatic altitude-control system 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;

f. The altitude-alerting system should be operational;

g. At intervals of approximately one hour, cross-checks between the primary altimeters and the stand-by altimeter should be made. A minimum of two primary altimeters should agree within 200 ft (60 m) or a lesser value if specified in the aircraft operating manual. (Failure to meet this condition will require that the altimetry system be reported as defective and notified to ATC). The difference between the primary and stand-by altimeters should be noted for use in contingency situations.

(1) The normal pilot scan of cockpit instruments should suffice for altimeter crosschecking on most flights.

* (2) At least the initial altimeter cross-check should be recorded. On Class II navigation legs this should be in the vicinity of the point where Class II navigation is begun (e.g., on coast out). The readings of the primary and standby altimeters should be recorded and available for use in contingency situations. (Class II navigation is defined in FAA Order 8400.10).

Note. Future systems may make use of automatic altimeter comparators in lieu of cross-checks by the crew.

h. Normally, the altimetry system being used to control the aircraft should be selected to provide the input to the altitude-reporting transponder transmitting information to ATC.

APPENDIX 4. TRAINING PROGRAMS AND OPERATING PRACTICES AND PROCEDURES

i. If the pilot is notified by ATC of an AAD error which exceeds 300 ft (90 m) then the pilot should take action to return to CFL as quickly as possible.

* j. Contingency procedures after entering RVSM airspace. The pilot should notify ATC of contingencies (aircraft system failures, weather conditions) which affect the ability to maintain the CFL and co-ordinate a plan of action. "Area of Operations Specific Information" on the RVSM Documentation Webpage contains contingency procedures for individual areas including the domestic United States. 91-RVSM Appendix 5 contains detailed guidance for contingency procedures for oceanic airspace.

6 Post Flight.

a. In making maintenance log book entries against malfunctions in height-keeping systems, the pilot should provide sufficient detail to enable maintenance to effectively troubleshoot and repair the system. The pilot should detail the actual defect and the crew action taken to try to isolate and rectify the fault. The following information should be noted when appropriate:

(1) Primary and standby altimeter readings.

(2) Altitude selector setting.

(3) Subscale setting on altimeter.

(4) Autopilot used to control the airplane and any differences when the alternate system was selected.

(5) Differences in altimeter readings if alternate static ports selected.

(6) Use of air data computer selector for fault diagnosis procedure.

(7) Transponder selected to provide altitude information to ATC and any difference if alternate transponder or altitude source is manually selected.

7. Special Emphasis Items: Flightcrew Training. The following items should also be included in flightcrew training programs:

* a. Area of Operations Specific Policy and Procedures Including Standard ATC Phraseology. See Area of Operations Specific Information on the RVSM Documentation Webpage for RVSM operational policy and procedures for individual areas of operation including the domestic United States;

APPENDIX 4. TRAINING PROGRAMS AND OPERATING PRACTICES AND PROCEDURES

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 SSEC/PEC through the use of correction cards;

d. problems of visual perception of other aircraft at 1,000 ft (300 m) planned separation during night conditions, when encountering local phenomena such as 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. operational procedures and operating characteristics related to TCAS (ACAS) operation in an RVSM operation. See "TCAS Documents" under "Documents Applicable to All RVSM Approvals" on the RVSM Documentation Webpage;

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

h. Aircraft operating restrictions (if required for the specific aircraft group) related to RVSM airworthiness approval. (See paragraph 7c(4)(iii));

* i. Use of track offset procedures in oceanic airspace to mitigate the effect of wake turbulence and to mitigate the effect of operational errors. See Area of Operations Specific Information on the RVSM Documentation Webpage for information on the application of lateral offsets in individual areas of operation.

APPENDIX 5. SPECIFIC PROCEDURES FOR OCEANIC AIRSPACE

1. INTRODUCTION

* a. RVSM was initially implemented in North Atlantic Minimum Navigation Performance Specification (NAT MNPS) airspace in March 1997. The guidance that follows has been applied in the NAT region since that time. It is also applied to RVSM operations in the Pacific, West Atlantic and other oceanic airspace.

b. This appendix contains information on procedures which are unique to oceanic RVSM airspace where direct voice communications between pilots and air traffic controllers is not available. Contingency procedures contained in regional supplementary procedures and guidance which is specifically related to RVSM are presented in this appendix. Contingencies which relate to lateral as well as vertical navigation are also discussed.

2. GENERAL INFORMATION: AIRSPACE DIMENSIONS

a. NAT MNPS AIRSPACE.

(1) When RVSM was implemented in NAT MNPS airspace, NAT MNPS approval expanded to encompass demonstration of special qualification for both lateral navigation and height-keeping performance.

(2) NAT MNPS airspace now has a ceiling of FL 420 and a floor of FL 285. As of October 1998, 1,000 ft (300 m) vertical separation is applied between aircraft operating between FL 310 and FL 390 (inclusive). At a future date, planning calls for RVSM to be expanded to apply in NAT MNPS between FL 290 and FL 410 (inclusive).

* b. RVSM IN OTHER OCEANIC AIRSPACE. The FAA RVSM Homepage ({ HYPERLINK "<http://www.faa.gov/ats/ato/rvsm1.htm>" }) provides a chart showing oceanic and continental airspace in the world where RVSM has been implemented.

3. INTENDED USE OF THIS MATERIAL.

a. Paragraph 4, Basic Concepts For Contingencies. This paragraph is intended to provide an overview of contingency procedures. It is intended to orient the pilot's thinking to the concepts involved and aid in understanding the specific guidance detailed in paragraph 5 and 6. This material should be included in training programs and appropriate flight crew manuals.

b. Paragraph 5, Guidance To The Pilot In the Event of Equipment Failures or Encounters With Turbulence After Entering RVSM Airspace. This paragraph details summary guidance on specific actions for the pilot to take to mitigate the potential for

APPENDIX 5. SPECIFIC PROCEDURES FOR OCEANIC AIRSPACE

conflict with other aircraft in the situations listed. It should be reviewed in conjunction with Paragraph 6 which provides additional technical and operational detail. The pilot actions in Paragraph 5 should be considered **required pilot knowledge** and should be included in training/qualification programs and appropriate flight crew manuals.

c. Paragraph 6, Expanded RVSM Equipment Failure and Turbulence Scenarios. This paragraph reviews the situations discussed in Paragraph 5 in greater detail. The material may be used in training programs as an operator deems appropriate.

d. Paragraph 7, Contingency Procedures published in ICAO Document 7030, Regional Supplementary Procedures. This paragraph lists the “Special Procedures for In-flight Contingencies” published for various ICAO regions in the Doc 7030. These procedures should be considered **required pilot knowledge**. The material may be condensed for ease of presentation and should be included in training/qualification programs and appropriate flight crew manuals.

e. Paragraph 8, Wake Turbulence Procedures. Paragraph 8 discusses published procedures for the pilot to follow in the event that wake turbulence is encountered. These procedures should be considered **required pilot knowledge**.

f. Paragraph 9, RVSM Transition Areas. Paragraph 9 highlights the necessity for pilots to be informed on policy and procedures established for operation in RVSM transition areas. This information should be addressed in training programs and manuals.

4. **BASIC CONCEPTS FOR CONTINGENCIES.**

a. General. The in-flight contingency procedures for the NAT, published in Doc 7030, were revised to provide for RVSM implementation in NAT MNPS airspace. Specifically, NAT Regional Supplementary Procedures, Paragraph 5.0 was revised to account for RVSM operations. NATSPG developed draft Paragraph 5.0 revisions which were endorsed by the Limited NAT Regional Air Navigation Meeting in November 1992. They were made effective at the start of operational trials in March 1997. (Aircraft were separated vertically above FL 290 by 1,000 ft (300 m) in the NAT for the first time when operational trials were begun). The NAT Operations Manual was also revised with this material prior to the start of operational trials.

b. The basic concepts for contingencies described in this paragraph have been developed from the specific guidance contained in Doc 7030 paragraphs published for individual ICAO regions entitled “Special Procedures for In-flight Contingencies”. Contingency procedures become complicated when specific situations are detailed. However, if the details are examined in the context of certain basic concepts, then they are more easily understood. Reviewing these concepts should serve to aid pilots' understanding of the specific contingency procedures detailed in the Doc 7030 paragraphs.

APPENDIX 5. SPECIFIC PROCEDURES FOR OCEANIC AIRSPACE

c. The basic concepts for contingencies are:

(1). Guidance for contingency procedures should not be interpreted in any way which prejudices the final authority and responsibility of the pilot in command for the safe operation of the aircraft.

(2). If the pilot is unsure of the vertical or lateral position of the aircraft or the aircraft deviates from its assigned altitude or track for cause without prior ATC clearance, then the pilot must take action to mitigate the potential for collision with aircraft on adjacent routes or flight levels.

(i) In this situation, the pilot should alert adjacent aircraft by making maximum use of aircraft lighting and broadcasting position, flight level, and intentions on 121.5 MHz (as a back-up, the appropriate VHF inter-pilot air-to-air frequency may be used);

(3) Unless the nature of the contingency dictates otherwise, the pilot should advise ATC as soon as possible of a contingency situation and if possible, request an ATC clearance before deviating from the assigned route or flight level.

(4) If a revised ATC clearance cannot be obtained in a timely manner and action is required to avoid potential conflict with other aircraft, then the aircraft should be flown at an altitude and/or on a track where other aircraft are least likely to be encountered:

(i) This can be accomplished by offsetting from routes or altitudes normally flown in the airspace. The Doc 7030 paragraphs entitled "Special Procedures for In-flight Contingencies" provide recommendations on the order of preference for the following pilot actions:

(A) The pilot may offset half the lateral distance between routes or tracks.

(B) The pilot may offset half the vertical distance between altitudes normally flown.

(C) The pilot may also consider descending below FL 285 or climbing above FL 410. (The vast majority of oceanic traffic has been found to operate between FL 290 and 410. Flight above FL 410 or below FL 285 may limit exposure to conflict with other aircraft).

(5). When executing a contingency maneuver the pilot should:

(i) Watch for conflicting traffic both visually and by reference to ACAS, if equipped.

APPENDIX 5. SPECIFIC PROCEDURES FOR OCEANIC AIRSPACE

(ii) Continue to alert other aircraft using 121.5 MHz (as a back-up, the VHF inter-pilot air-to-air frequency may be used) and aircraft lights.

(iii) Continue to fly offset tracks or altitudes until an ATC clearance is obtained.

(iv) Obtain an ATC clearance as soon as possible.

5. GUIDANCE TO THE PILOT (INCLUDING EXPECTED ATC ACTIONS) IN THE EVENT OF EQUIPMENT FAILURES OR ENCOUNTERS WITH TURBULENCE AFTER ENTRY INTO RVSM AIRSPACE. In addition to emergency conditions that require immediate descent, such as loss of thrust or pressurization, ATC should be made aware of the less explicit conditions that may make it impossible for an aircraft to maintain its CFL appropriate to RVSM. Controllers should react to such conditions but these actions cannot be specified, as they will be dynamically affected by the real-time situation.

a. Objective of the Guidance Material. The following material is provided with the purpose of giving the pilot guidance on actions to take under certain conditions of equipment failure and encounters with turbulence. It also describes the expected ATC controller actions in these situations. 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 maintain the assigned FL and route while the pilot and controller take precautionary action to protect separation. For extreme cases of equipment failure, however, the guidance recognizes that the safest course of action may be for the aircraft to depart from the cleared FL or route by obtaining a revised ATC clearance or if unable to obtain prior ATC clearance, executing the established Doc 7030 contingency maneuvers for the area of operation.

Note: Paragraph 6 provides an expanded description of the scenarios detailed below.

b. CONTINGENCY SCENARIOS. The following paragraphs summarize pilot actions to mitigate the potential for conflict with other aircraft in certain contingency situations. They should be reviewed in conjunction with the expanded contingency scenarios detailed in Paragraph 6 which contain additional technical and operational detail.

APPENDIX 5. SPECIFIC PROCEDURES FOR OCEANIC AIRSPACE

Scenario 1: The pilot is: 1) unsure of the vertical position of the aircraft due to the loss or degradation of all primary altimetry systems, or 2) unsure of the capability to maintain CFL due to turbulence or loss of all automatic altitude control systems.

The Pilot should:	ATC can be expected to:
Maintain CFL while evaluating the situation;	
Watch for conflicting traffic both visually and by reference to ACAS, if equipped;	
If considered necessary, alert nearby aircraft by <ol style="list-style-type: none"> 1) making maximum use of exterior lights; 2) 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 situation and intended course of action. Possible courses of action include:	Obtain the pilot's intentions and pass essential traffic information.
<ol style="list-style-type: none"> 1) maintaining the CFL and route provided that ATC can provide lateral, longitudinal or conventional vertical separation. 	<ol style="list-style-type: none"> 1) If the pilot intends to continue in RVSM airspace, assess 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.
<ol style="list-style-type: none"> 2) requesting ATC clearance to climb above or descend below RVSM airspace if the aircraft cannot maintain CFL and ATC cannot establish adequate separation from other aircraft. 	<ol style="list-style-type: none"> 2) If the pilot requests clearance to exit RVSM airspace, accommodate expeditiously, if possible.
<ol style="list-style-type: none"> 3) 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. 	<ol style="list-style-type: none"> 3) 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.
	<ol style="list-style-type: none"> 4) Notify adjoining ATC facilities/sectors of the situation.

Scenario 2: There is a failure or loss of accuracy of one primary altimetry system (e.g., greater than 200 foot difference between primary altimeters)

The Pilot should
Cross check standby altimeter, confirm the accuracy of a primary altimeter system and notify ATC of the loss of redundancy. If unable to confirm primary altimeter system accuracy, follow pilot actions listed in the preceding scenario.

APPENDIX 5. SPECIFIC PROCEDURES FOR OCEANIC AIRSPACE

6. EXPANDED EQUIPMENT FAILURE AND TURBULENCE ENCOUNTER SCENARIOS.

Operators may consider this material for use in training programs.

Scenario 1: All automatic altitude control systems fail (e.g., Automatic Altitude Hold).

The Pilot should	ATC can be expected to
Initially	
Maintain CFL	
Evaluate the aircraft's capability to maintain altitude through manual control.	
Subsequently	
Watch for conflicting traffic both visually and by reference to TCAS, if equipped.	
If considered necessary, alert nearby aircraft by 1) making maximum use of exterior lights; 2) 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 and intended course of action. Possible courses of action include:	
1) maintaining the CFL and route, provided that the aircraft can maintain level.	1) If the pilot intends to continue in RVSM airspace, assess 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.
2) 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.	2) If the pilot requests clearance to exit RVSM airspace, accommodate expeditiously, if possible.
3) 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.	3) 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.
	4) Notify adjoining ATC facilities/sectors of the situation.

APPENDIX 5. SPECIFIC PROCEDURES FOR OCEANIC AIRSPACE

Scenario 2: Loss of redundancy in primary altimetry systems

The Pilot should	ATC can be expected to
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

Scenario 3: All primary altimetry systems are considered unreliable or fail

The Pilot should	ATC can be expected to
Maintain CFL by reference to the standby altimeter (if the aircraft is so equipped).	
Alert nearby aircraft by <ol style="list-style-type: none"> 1) making maximum use of exterior lights; 2) 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. Possible courses of action include:	Obtain pilot's intentions, and pass essential traffic information.
1) maintaining CFL and route provided that ATC can provide lateral, longitudinal or conventional vertical separation.	1) If the pilot intends to continue in RVSM airspace, assess 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.
2) requesting ATC clearance to climb above or descend below RVSM airspace if ATC cannot establish adequate separation from other aircraft.	2) If the pilot requests clearance to exit RVSM airspace, accommodate expeditiously, if possible.
3) executing the Doc 7030 contingency maneuver to offset from the assigned track and FL, if ATC clearance cannot be obtained.	3) 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.
	4) Notify adjoining ATC facilities/sectors of the situation.

APPENDIX 5. SPECIFIC PROCEDURES FOR OCEANIC AIRSPACE

Scenario 4: The primary altimeters diverge by more than 200ft (60m)

The Pilot should
Attempt to determine the defective system through established trouble-shooting procedures and/or comparing the primary altimeter display to the standby altimeter (as corrected by the correction cards, if required).
If the defective system can be determined, couple the functioning altimeter system to the altitude keeping device.
If the defective system cannot be determined, follow the guidance in Scenario 3 for failure or unreliable altimeter indications of all primary altimeters.

Scenario 5: Turbulence (greater than moderate) which the pilot believes will impact the aircraft's capability to maintain flight level.

The Pilot should	ATC can be expected to
Watch for conflicting traffic both visually and by reference to TCAS, if equipped.	
If considered necessary, alert nearby aircraft by: <ul style="list-style-type: none"> 1) making maximum use of exterior lights; 2) 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 intended course of action as soon as possible. Possible courses of action include:	
1) maintaining CFL and route provided ATC can provide lateral, longitudinal or conventional vertical separation.	1) Assess 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.
2) requesting flight level change, if necessary.	2) If unable to provide adequate separation, advise the pilot of essential traffic information and request pilot's intentions.
3) 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.	3) Notify other aircraft in the vicinity and monitor the situation
	4) Notify adjoining ATC facilities/sectors of the situation.

APPENDIX 5. SPECIFIC PROCEDURES FOR OCEANIC AIRSPACE

7. SPECIAL PROCEDURES FOR IN-FLIGHT CONTINGENCIES PUBLISHED FOR INDIVIDUAL ICAO REGIONS IN DOC 7030.

a. The Doc 7030 should be considered the source document for specific contingency procedures applicable to individual ICAO regions. Doc 7030 should always be consulted before training material or manuals are developed.

b. In-flight contingency procedures applicable to Pacific oceanic operations are published in paragraph 4.0 of the Regional Supplementary Procedures for the Pacific and the Middle East/Asia (Mid/Asia).

c) In-flight contingency procedures applicable to NAT oceanic operations are published in paragraph 5.0 of NAT Regional Supplementary Procedures.

*8. WAKE TURBULENCE PROCEDURES.

* a. The ATS authorities developed pilot and ATC procedures for aircraft experiencing wake turbulence. These procedures provide for the contingency use of a 2 NM lateral offset to avoid exposure to wake turbulence. The procedures have been published in State NOTAMS, AIPs, and Regional Supplementary Procedures. They are also posted in the Area of Operations Specific Information section of the RVSM Documentation Webpage. These procedures should be incorporated in pilot training programs and manuals.

* b. ATS authorities are developing procedures to enable pilots to fly lateral offsets on oceanic tracks of up to 2 NM as a standard operating procedure rather than on a contingency basis. The intent is to provide procedures that can be used to mitigate the effects of wake turbulence and also to provide a margin of safety when non-normal events such as operational errors occur. See the Area of Operations Specific section of the RVSM Documentation Webpage to determine if the new lateral offset procedures are applied in an individual airspace.

9. TRANSPONDER FAILURE AND RVSM TRANSITION AREAS. The specific actions that ATC will take in the event of transponder failure in RVSM transition areas will be determined by the provider States. (Transition areas are planned to be established between airspaces where different vertical separation standards are applied).

APPENDIX 6. REVIEW OF ICAO DOCUMENT 9574
HEIGHT-KEEPING PARAMETERS

1. ICAO Doc. 9574, Manual on the Implementation of a 300m (1,000 ft) Vertical Separation Minimum Between FL 290 - FL 410 Inclusive, covers the overall analysis of factors for achieving an acceptable level of safety in a given airspace system. The major factors are: passing frequency, lateral navigation accuracy, and vertical overlap probability. Vertical overlap probability is a consequence of errors in adhering accurately to assigned flight level, and this is the only factor addressed in the present document.

2. In ICAO Doc. 9574, Section 2.1.1.3, the vertical overlap probability requirement was restated as the aggregate of height keeping errors of individual aircraft, which must lie within the total vertical error (TVE) distribution expressed as the simultaneous satisfaction of the following four requirements:

a. the proportion of height keeping errors beyond 300 feet (90 m) in magnitude must be less than 2.0×10^{-3} ;

b. the proportion of height keeping errors beyond 500 feet (150 m) in magnitude must be less than 3.5×10^{-6} ;

c. the proportion of height keeping errors beyond 650 feet (200 m) in magnitude must be less than 1.6×10^{-7} ; and

d. the proportion of height keeping errors between 950 feet (290 m) and 1,050 feet (320 m) in magnitude must be less than 1.7×10^{-8} .

3. The following characteristics presented in ICAO Doc. 9574 were developed in accordance with the conclusions of ICAO Doc. 9536, to satisfy the distributional limits in paragraph 2a, and to result in aircraft airworthiness having negligible effect on meeting the requirements in paragraphs 2b, 2c, and 2d. They are applicable statistically to individual groups of nominally identical aircraft operating in the airspace. These characteristics 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 following characteristics are the basis for development of this document:

a. "The mean altimetry system error (ASE) of the group shall not exceed ± 80 feet (± 25 m);

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 245 feet (75 m); and

c. Errors in altitude keeping shall be symmetric about a mean of 0 feet (0 m) and shall have a standard deviation not greater than 43 feet (13 m) and should be such that the

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HEIGHT-KEEPING PARAMETERS

error frequency decreases with increasing error magnitude at a rate which is at least exponential."

4. ICAO Doc. 9574 recognized that specialist study groups would develop the detailed specifications to ensure that the TVE objectives can be met over the full operational envelope in RVSM airspace for each aircraft group. In determining the breakdown of tolerances between the elements of the system, it was considered to be necessary to set system tolerances at levels which recognize that the overall objectives must be met operationally by aircraft and equipment subject to normal production variability, including that of the airframe static source error, and normal in-service degradation. It was also recognized that it would be necessary to develop specifications and procedures covering the means for ensuring that in-service degradation is controlled at an acceptable level.

5. On the basis of studies reported in ICAO Doc. 9536, Volume 2; ICAO Doc. 9574 recommended that the required margin between operational performance and design capability should be achieved by ensuring that the performance requirements are developed to fulfill the following requirements, where the narrower tolerance in paragraph 5b is specifically intended to allow for some degradation with increasing age:

- a. "the mean uncorrected residual position error (static source error) of the group shall not exceed ± 80 feet (± 25 m);
- 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 200 feet (60 m);
- c. each individual aircraft in the group shall be built to have ASE contained within ± 200 feet (± 60 m); and
- d. an automatic altitude control system shall be required and will be capable of controlling altitude within a tolerance band of ± 50 feet (± 15 m) about commanded altitude when operated in the altitude hold mode in straight and level flight under nonturbulent, nongust conditions."

6. These standards provide the basis for the separate performance aspects of airframe, altimetry, altimetry equipment and automatic altitude control system. It is important to recognize that the limits are based on studies (Doc. 9536, Volume 2) which showed that ASE tends to follow a normal distribution about a characteristic mean value for the aircraft group. The document should, therefore, provide controls which will preclude the possibility that individual aircraft approvals could create clusters operating with a mean significantly beyond 80 ft (25 m) in magnitude, such as could arise where elements of the altimetry system generate bias errors additional to the mean corrected static source error.

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