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getting to grips with modern navigation

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AIRBUS

FOREWORD

The purpose of this brochure is to provide Airbus aircraft Operators with the agreed interpretations of the currently applicable RNP and RVSM and RNAV regulations.

Should there be any discrepancy between the information provided in this brochure and that published in the applicable AFM, MMEL, FCOM and SB, the information in the latter publications prevails unless otherwise approved by the national operational authorities.

This brochure is designed to provide recommendations which satisfy RNP and RVSM, and RNAV operational and certification requirements, in order for airlines to obtain operational approval from their national operational authorities.

All recommendations conform to current regulatory requirements, and are intended to assist Operators in maximizing the cost effectiveness of their operations.

We encourage you to submit any suggestions concerning this brochure, or any questions concerning the information to:

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1. INTRODUCTION

Traffic density is limited by aircraft vertical and horizontal separations, imposed by current navigation procedures associated with the performance of ground and airborne equipment.

Due to increased traffic in specific areas, airspace is becoming saturated. This necessitates a reduction in aircraft separation while maintaining at least, the equivalent level of safety. Recent navigation systems offer the required navigation performance to achieve this objective, in conjunction with increased routing flexibility.

Aircraft separation reduction with required level of safety requires the aircraft manufacturer, airspace administrators and Operators to demonstrate compliance with new standards referred to as:

Reduced Vertical Separation Minimum (RVSM), and

Required Navigation Performance (RNP).

Another modern navigation trend involves the development of instrument procedures that are not based on conventional radio navaids. This type of navigation is called Area Navigation or RNAV. It can be used enroute, in association with the RNP concept, but also for terminal area navigation and instrument approach procedures. The last chapter of this document mainly addresses RNAV approaches, with and without RNP, although RNP RNAV approaches, will certainly become the standard in the future.

2. REQUIRED NAVIGATION PERFORMANCE

2.1 General Concept

Current navigation procedures are based on the availability of satisfactory ground navigation aids, infrastructures (VOR, DME, NDB...), and aircraft navigation systems, which enable navaid to navaid navigation. Large safety margins mandated with respect to aircraft separation, contribute to airspace saturation in certains areas.
The air navigation structure of existing airways, SID's, STAR's, etc. does not take into account the availability of modern navigation systems, with enhanced performance, nor the availability of glass cockpits, which provide crews with improved awareness when flying such procedures.

The International Civil Aviation Organization (ICAO) has recognized the need to benefit from available RNAV technology to improve existing air navigation systems, in the interest of increasing airspace capacity, and offering such advantages as: Fuel savings, direct tracks, etc. The introduction of RNP and RNAV will enable each country to design and plan routes that are not necessarily located over radio-navaid installations.

To fully benefit from the CNS/ATM (Communication Navigation Surveillance / Air Traffic Management) concept, aircraft will need to attain a certain level of navigation performance in terms of accuracy, availability, integrity, and service continuity.
For additional details, you may refer to our "Getting to Grips with FANS" brochure (STL 94B.0073/99).
"REQUIRED NAVIGATION PERFORMANCE" (RNP) is a navigation element, which is expected to affect currently existing airspace structures and lead to a whole new concept in air navigation.

2.1.1 Definitions

Required Navigation Performance (RNP)

RNP is a statement on navigation performance accuracy, essential to operations within a defined airspace. Note that in addition to accuracy, other requirements, also apply to specific RNP types.

RNP Airspace

Generic terms referring to airspace, route(s), procedures where minimum navigation performance requirements (RNP) have been established. Aircraft must meet or exceed these performance requirements in order to fly in that airspace.

RNP Type

This is a designator, established according to navigational performance accuracy in the horizontal plane, namely lateral and longitudinal position fixing. This designator is indicated by an accuracy value given in nautical miles.

RNP-X

A designator is used to indicate the minimum navigation system requirements needed to operate in an area, on a route, or on a procedure (e.g., RNP-1, RNP-4). The designator invokes all of the navigation system requirements, specified for the considered RNP RNAV type, and is indicated by the value of X (in NM).

2.1.2 Performance Requirements

Navigation Accuracy

Each aircraft operating in RNP airspace shall have a total system navigation position error **equal to, or less than, the RNP value for 95 % of the flight time.** See Figure 1 illustrating the crosstrack error accuracy.

Containment Integrity

The probability that the total system navigation position error in RNP airspace exceeds the specified crosstrack containment limit without annunciation, should be less than 10^{-5} per flight hour. **The crosstrack containment limit is twice the RNP value.**
See Figure 1, illustrating the crosstrack error containment limit.

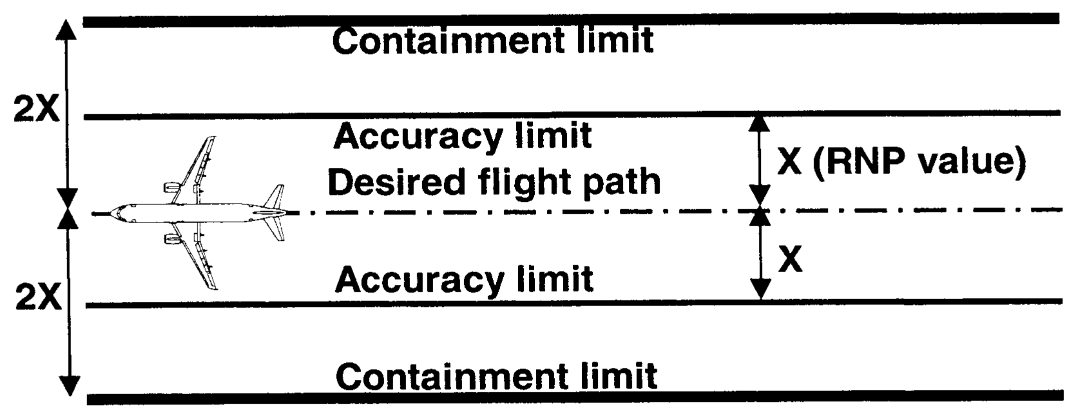


Fig. 1 RNP-X accuracy and containment limit

Containment Continuity

The probability of an annunciated loss of RNP-X capability (true or false annunciation) shall be less than 10^{-4} per flight hour.

2.1.3 Functionality Requirements

In addition to the accuracy, integrity, and continuity requirements, navigation systems must comply with functionality requirements covering:

FMS flight path definition and construction
FMS functions
Navigation database
Navigation display
APs and FDs
etc.

These requirements are published in various documents, the most comprehensive one being the Minimum Aviation System Performance (MASPS reference ED75 or DO236). The purpose of this document is to provide aircraft designers/manufacturers as well as users, with global requirements and minimum navigation performance functions needed when operating in RNP airspace. These requirements are designed to meet the ICAO RGCSP's (Review of the General Concept of Separation Panel) definition of RNP, while providing increased integrity via repeated and predictable navigation. Compliance with these standards is one of the means of ensuring the system will satisfactorily perform its intended functions, under conditions normally encountered in flight operations.

The aviation community, through US RTCA SC 181 and EUROCAE WG13 is currently finalizing the above-noted standard, applicable to the vertical part.

MASPS also requires associated functional features and displays to be available (Direct To, Number of waypoints, F/PLN offset, Navigation Database, messages...).

In addition, Regulatory Authorities have published standards for specific RNP airspaces.

The JAA AMJ 20-X2 (TLG 2) and the JAA TGL 10 provides certification and operational requirements for RNP-5 Basic RNAV and for RNP1 PRNAV within European airspace (refer to Annexes 5.1 and 5.2 at the end), and FAA Order 8400.12A addresses RNP-10 operations in oceanic and remote areas (refer to Annex 5.3 at the end).

To minimize the economic burden on the aviation industry, as well as obtain early benefits from RNP operations, European certification authorities have agreed to define a transition period (1998-2005) during which a large number of transport aircraft (already equipped with appropriate navigation systems), will be recognized as meeting the "reduced functionality" requirements, identified in draft MASPS Appendix D and AMJ 20-X2.

MASPS Appendix D provides RNP airspace operations guidelines in assessing existing RNAV systems during the transition period (1998-2005). At the end of this transition period (≈ 2005), aircraft will have to be fully compliant with MASPS, in order to fly in the dedicated RNP RNAV airspaces. Installation of an appropriate navigation system will therefore, be required to fly designated routes/airspace as per MASPS and its appendix D.

Nevertheless, some navigation equipment may be uncompliant, or may have some limitations. Aircraft with such equipment might, consequently be excluded from the specified RNP airspace, or requested to leave this airspace after a certain flight duration.

2.2 RNP Airspace Environment and Implementation

2.2.1 RNP routes supported by radio navaid coverage

Such airspace is mainly implemented, or will be implemented for enroute navigation over continental areas.
Typical RNP values are RNP-5 and RNP-4, but RNP-2 is considered for US domestic airspace. In Europe, Basic RNAV airspace (RNP-5) was implemented in April 1998. RNP-1 is considered for RNAV SIDs and STARs, but is also planned en route for the future Precision RNAV airspace in Europe (2003).

2.2.2 RNP routes outside radio navaid coverage

This airspace is implemented, or will be implemented, for enroute oceanic navigation or for continental areas outside radio navaid coverage.
Typical RNP values are RNP-10 and RNP-12, but RNP-4 is also envisaged in the future. Other operational constraints may be associated to this type of airspace, such as MNPS North Atlantic airspace.
In particular, the navigation system must be certified as the sole means of navigation with the adequate level of redundancy.
RNP-10 is implemented, for example, in the NOPAC and CEPAC routes, and in the area of the Tasmanian sea area.

2.2.3 RNAV Non Precision Approaches with RNP

RNAV approaches with RNP-0.3 have been published in the USA, and these will undoubtedly become more frequent in the future.
RNAV approaches without GPS are possible, provided the Operator has verified that, for each specific procedure, FMS navigation radio updating will support the required accuracy. It is, nevertheless anticipated that RNAV approaches will more frequently be associated with the GPS.
Throughout the world, there are many airports that are suitable for transport aircraft. Although some of these airports may not have available let down aid, RNAV approach procedures (based on GPS) could be established and published without the need for large investments.

2.3 Aircraft Navigation Svstems

2.3.1 Aircraft Equipment

Airbus models, equipped with RNAV capability, can be divided into three main categories:

A300 B2/B4s with INS, but without GPS.
Other Airbus models with FMS but without GPS PRIMARY.
Airbus models equipped with FMS and GPS PRIMARY.

Aircraft without GPS PRIMARY

For these aircraft, navigation performance depends on radio navaid updating, and on the time since the last radio update or INS/IRS ground alignment. This is based on the assumption that **the ground radio navaid infrastructure supports the level of accuracy.**
Outside radio navaid coverage, navigation performance is determined by the INS/IRS drift rate, which implies **a time limitation in direct relation to the RNP value to be achieved.**

Aircraft with GPS PRIMARY

When GPS PRIMARY is available in flight, onboard **navigation performance exceeds the currently known requirements** for any kind of route, including RNAV approaches.

The availability of GPS PRIMARY, on any given route, is a function of the:

Satellite constellation configuration
Aircraft equipment
Aircraft's geographical position
Required navigation accuracy

Depending on which type of RNP value is envisaged, and which type of navigation mode is available, if GPS PRIMARY is lost, a preflight verification of 100% GPS PRIMARY availability may be required for the planned route.

For example, the navigation system of A300 B2/B4s equipped with GNLU, can either use GPS or radio sensors. When the aircraft is outside radio navaid coverage, GPS becomes the sole means of navigation, therefore 100% GPS availability must be verified prior to the flight (limited "RAIM holes" can be acceptable, refer to Annex 5.3).

For other Airbus models, IRS navigation is available as an ultimate means of navigation. Therefore, a temporary loss of GPS PRIMARY is acceptable, depending on the RNP value desired.

If GPS accuracy is needed for a Non Precision Approach, at destination or at alternate, then GPS availability at the ETA at this airport must be checked prior to departure. (For Litton AIME, this check is unnecessary, if 23 or more satellites are available).

2.3.2 Navigation System Capability

A300 B2/B4s with INS, but without GNLU (FMS+GPS)

The navigation system of these aircraft consists of one, two, or three INS that supply geographical position and navigation data to fly a flight plan entered in the system. Some of these aircraft are equipped with a function to that "automatically" (with manual navaid selection) updates the INS position with radio sensors. This navigation system may be authorized to operate within RNP airspaces **but with time limitations.** Authorization will be given on an individual basis, by the authority in charge of the applicable RNP airspace.
Authorities will consider, for example the applications of A300 B2/B4 Operators that intend to fly within the European Basic RNAV (RNP-5) airspace with INS equipment: The time from INS ground alignment will be limited to 2 hours.

For INS with position radio updates, certified in compliance with AC 90-45A [(1)], the time limitation may be calculated starting from the last radio update, provided the Operator can show the authorities that adequate procedures have been developed and trained.

This navigation system is considered to meet all RNP-10 requirements up to 6.2 flight hours. This time starts when the system is placed in navigation mode, or when the system discontinues radio updating. If the system is updated enroute, the Operator must demonstrate the effect of update accuracy on the time limit, or may use the 1-hour time reduction for radio updates indicated in FAA Order 8400.12A, §12,e.
Authorities in charge of a particular airspace may specify a different time limitation. For example, Australian and New Zealand Authorities consider 4.5 hours, since the last radio update, to be compliant with their RNP-10 requirement (information early 1998).

In reference to FAA Order 8400.12A, aircraft eligibility for RNP-10 is classified in Group 2 paragraph 12.b.(2);(Aircraft with INS, complying with FAR 121 App. G).

[(1)] Not shown by Airbus during Type Certification.

A300-600s and A310s without GPS PRIMARY

The navigation system of these aircraft consists of 2 FMS, 3 IRS, and radio navaid sensors. The FMS uses radio sensors for position updates, or the mixed IRS position, if radio position is lost. This navigation system is certified, in compliance AC 90-45A, as indicated in the AFM. Compliance with this AC is considered to be satisfactory by JAA AMJ 20X-2 for European Basic RNAV (RNP-5).
For these aircraft, **navigation performance is mainly determined by the radio navaid ground infrastructure.**

Within radio navaid coverage, navigation accuracy is a function of the update type (VORDME or DMEDME) and the navaid distance. MASPS (ED75/DO236) indicates that the following minimum RNP values can be achieved with radio updating:

RNP-4 enroute
RNP-2 in terminal area

For aircraft having FMS, with a standard capable of GPS: RNP accuracy criteria are met, provided radio navaid coverage supports it for:

RNP-1 enroute and in terminal area, provided a required accuracy of 1.2NM(1) is manually entered in the CDU.
RNP-0.3 in approach, provided a required accuracy of 0.36NM(1) is manually entered in the CDU.

Note: (1) Radial equivalent to the specified XTK/ATK accuracy

Outside radio navaid coverage (when in IRS ONLY), the RNP-X capability will be maintained during a certain lapse of time, based on the demonstrated IRS drift rate, starting at IRS ground alignment or at the last FMS radio update.
For Basic RNAV RNP-5 in Europe, the acceptable time since the last radio updated will be 2 hours.

This navigation system is considered to meet all RNP-10 requirements up to 6.2 flight hours. This time starts when the IRS are placed in navigation mode, or when the FMS discontinues radio updating. If the FMS is updated enroute, the Operator must demonstrate the effect of update accuracy on the time limit or may use the half hour time reduction for automatic VORDME updates indicated in FAA Order 8400.12A, §12,e.
Authorities in charge of a particular airspace may specify a different time limitation. For example, Australian and New Zealand Authorities consider 4.5 hours since the last radio update, to be compliant with their RNP-10 requirement (information early 1998).

In reference to FAA Order 8400.12A, aircraft eligibility for RNP-10 is classified in Group 2 , paragraph 12.b.(1);(aircraft with FMS and ND).

A319/320/321s, A330s and A340s without GPS PRIMARY

The navigation system of these aircraft consists of 2 FM, 3 IRS and radio navaid sensors. The FM uses radio sensors for position updates or the mixed IRS position, if radio position is lost. This navigation system is certified, in compliance with the TSO C 115, as indicated in the AFM. This navigation system also complies with the JAA AMJ 20-X2 for European Basic RNAV.

For these aircraft, **navigation performance is mainly determined by the radio navaid ground infrastructure**.

Within radio navaid coverage, navigation accuracy is a function of the update type (VORDME or DMEDME) and the navaid distance. MASPS (ED75/D0236) indicates that the following minimum RNP values can be achieved with radio updating:

RNP-4 enroute
RNP-2 in terminal area

For aircraft having FMGC with a standard incapable of GPS: When the FMS estimated position accuracy is higher than the default required accuracy, “HIGH” is indicated on the PROG page, otherwise “LOW” will be displayed.
When HIGH is displayed:

RNP-2.8 accuracy is estimated to be fulfilled enroute
RNP-1.7 accuracy is estimated to be fulfilled in the terminal area
RNP-0.5 accuracy is estimated to be fulfilled in approach with VORDME updating
RNP-0.3 accuracy is estimated to be fulfilled in approach with DMEDME updating

For aircraft having FMGCs, with a standard capable of GPS: RNP accuracy criteria are met, provided radio navaid coverage supports it for:

RNP-1 enroute and in terminal area, provided a required accuracy of 1.2NM(1) is manually entered in the MCDU.
RNP-0.3 in approach, provided a required accuracy of 0.36NM(1) is manually entered in the MCDU.
Note: (1) Radial equivalent to the specified XTK/ATK accuracy. With FMS2 the RNP value can be entered or the system RNP can be used if satisfactory.

Outside radio navaid coverage (when in IRS ONLY), the RNP-X capability will be maintained during a certain lapse of time, based on the demonstrated IRS drift rate, starting at the last IRS ground alignment or FMS radio update.
For Basic RNAV RNP-5 in Europe, the acceptable time since last radio update will be 2 hours.

This navigation system is considered to meet all RNP-10 requirements up to 6.2 flight hours. This time starts when the IRS are placed in navigation mode, or when the FMS discontinues radio updating. If the FMS is updated enroute, the Operator must demonstrate the effect of update accuracy on the time limit or may use the half-hour time reduction for automatic VORDME updates indicated in FAA Order 8400.12A, §12,e.

Authorities in charge of a particular airspace may specify a different time limitation. For example, Australian and New Zealand Authorities consider 4.5 hours, since the last radio update, to be compliant with their RNP-10 requirement (information early 1998).

In reference to FAA Order 8400.12A, aircraft eligibility for RNP-10 is classified in Group 2, paragraph 12.b.(1);(aircraft with FMS and ND).

A300-600s, A310s, A320s, A330s and A340s with GPS PRIMARY

The navigation system of these aircraft consists of 2 FMS, 3 IRS, 2 GPS and radio navaid sensors. The GPS position is primarily used for FM position updates, however if GPS PRIMARY is lost, FM reverts to radio updates or to IRS ONLY navigation when outside radio navaid coverage.
This navigation system is certified in compliance with FAA AC 20-130A and TSO C-129, and meets the requirements of Class C-1, or C3, for navigation enroute, in terminal area and in approach. It also complies with JAA AMJ 20X-2 for European Basic RNAV.

The MASPS (ED75/D0236) performance requirements have proven to be:

When GPS PRIMARY is available:
RNP-0.3 when AP or FD is used in approach.
RNP-1 in terminal area.
RNP-2 enroute.

When GPS PRIMARY is lost within radio navaid coverage:
Refer to the above RNP capability without GPS PRIMARY.

When GPS Primary is lost outside radio navaid coverage:
RNP-X capability will be maintained in IRS ONLY for a certain lapse of time, based on the demonstrated IRS drift rate.

In reference to FAA Order 8400.12A, aircraft eligibility for RNP-10 is classified in Group 1, paragraph 12.a;(aircraft with RNP capability certified in AFM) or Group 2 paragraph 12.b (5)

A300 B2/B4s with GNLU (FMS+GPS)

The navigation system of these aircraft consists of 2 FMS, 2 GPS, and radio navaid sensors. The GPS position is primarily used for FMS position updates, but if GPS PRIMARY is lost, the FMS reverts to radio updates or to dead reckoning (DR) mode when outside radio navaid coverage.
This navigation system is certified in compliance with FAA AC 20-130A, Class C-1, for navigation enroute, in terminal area and for approach. It also complies with JAA AMJ 20X-2 for European Basic RNAV.

The MASPS (ED75/D0236) performance requirements of have proven to be:

When GPS PRIMARY is available:
RNP-0.3, when AP or FD is used in approach.
RNP-1, enroute and in terminal area.

When GPS PRIMARY is lost:
RNP-4, with VOR/DME updating.
RNP-1, with DME/DME updating.

In reference to FAA Order 8400.12A, aircraft eligibility for RNP-10 is classified in Group 1 paragraph 12.a;(aircraft with RNP capability certified in AFM), or Group 2 paragraph 12.b(5).

For operations outside radio navaid coverage, GPS availability must be verified prior to the flight (small RNAIM holes, an acceptable, refer to annex 5.3)

	A300B2/B4 With INS	A310, A300-600 Without GPS	A320,A330, A340 Without GPS	A310, A300-600, A320,A330,A340 With GPS	A300B2/B4 With GNLU (GPS)
FAR 121 App. G	Y	(2)	(2)	(2)	
AC 25-4	Y	(2)	(2)	(2)	
AC 90-45A		Y			
AMJ 20-X2/TGL2		(1)	Y	Y	Y
TGL10			(3)	(3)	
TSO C115			Y	Y	Y
TSO C129A				Y	Y
AC 20-130A				Y	Y
FAA Notice 8110.60					Y
ED75/DO236 App. D			Y	Y	Y

(1) AC 90-45A satisfactory for AMJ 20-X2

(2) (2) Performance criteria in IRS ONLY

(3) With FMS2

Figure 2: Status of Airbus Navigation Systems' Compliance

Navigation System	Eligibility Group FAA 8400.12A	Compliance according to FAA 8400.12A, paragraph
All Airbus models with GPS	Gr. 1 or Gr. 2	§ 12. a. § 12.b(5)
Airbus with FMS and ND Without GPS	Gr. 2	§12.b.(1)
A300 B2/B4 with INS Without GNLU	Gr. 2	§ 12. b. (2)
A300 B2/B4 with GNLU	Gr. 1 or Gr. 2	§ 12. a. (AFM) §12.b.(5)

Figure 3: RNP-10 Navigation System Eligibility

2.3.3 MEL Requirements

MEL requirements are based on the type of RNP airspace.
For airspace within radio navaid coverage, one RNAV system is required, taking into account that conventional navigation from navaid to navaid and radar guidance remain available in case of system failure.
For airspace outside radio navaid coverage, two RNAV systems are required to ensure the appropriate redundancy level.

MEL requirements for European Basic RNAV and for RNP-10 are outlined below, and are compared to the main MMEL navigation requirements. Refer to the approved MMEL for an exhaustive review of the airline's MEL.

MEL Requirements for European Basic RNAV airspace

References: AMJ 20-X2, JAR OPS 1.865, Airbus MMEL

Example: A320, A330,
A340 with or without GPS.

Equipment	AMJ 20X2 Requirements	JAR OPS 1.865 Requirements	MMEL Requirements
FM (lateral guidance)	1	1	1
MCDU	1	1	1
RMP	-	2	2
IRS	1	1	2
VOR receiver	**1**	**2***	As required by the regulation
DME receiver	**1**	**1**	As required by the regulation
EFIS CRT	3	3	3
Flight Plan Data on ND (MAP information)	On **2** ND in ROSE NAV or ARC mode	-	As required by the regulation
VOR data on ND or DDRMI	On **1** ND or **1** DDRMI	On **2** ND in ROSE VOR mode (or **1** ND + **1** DDRMI)	As required by the regulation

Note: The figures in bold are related to requirements that are above the Airbus MMEL, and that need to be taken into account in the airline's MEL.

* 1 VOR, if sub-paragraph (c) (vi) of the JAR OPS 1.865 does not apply.

Example: A310s, A300-600s with or without GPS

Equipment	AMJ 20X2 Requirements	JAR OPS 1.865 Requirements	MMEL Requirements
FMS (lateral guidance)	1*	1	1
CDU	1	1	2
IRS	1	1	2
VOR receiver	**1**	**2****	As required by the regulation
DME receiver	**1**	**1**	As required by the regulation
EFIS CRT	3	3	3
Flight Plan Data on ND (MAP information)	On **2** ND in MAP mode	-	As required by the regulation
VOR data on ND, or on DDRMI	On **1** ND in ARC or ROSE mode (or on **1** DDRMI)	On **2** ND in ARC or ROSE mode (or **1** ND + **1** DDRMI)	As required by the regulation
NAV/VOR/ILS switch	1	2	2

Note: The figures in bold are related to requirements that are above the Airbus MMEL and that need to be taken into account by the airlines' MEL.
* Two FMS may be required, for aircraft without FMS switching.
**1 VOR, if sub-paragraph (c) (vi) of the JAR OPS 1.865 does not apply.

Example: A300 B2/B4s with GNLU

Equipment	AMJ 20X2 Requirements	JAR OPS 1.865 Requirements	MMEL Requirements
FMS/GPS (GNLU) (lateral guidance)	**1**	**1**	As required by the regulation
MCDU	**1**	**1**	As required by the regulation
ND LCD	1	1	1
VOR receiver	**1**	**2***	As required by the regulation
DME receiver	**1**	**1**	As required by the regulation
Flight Plan Data on ND (MAP information)	On **1** ND in MAP mode		As required by the regulation
VOR data	On **1** ND in HSI or ARV mode (or **1** DDRMI)	On 2 ND in HSI or ARV mode (or 1 ND+1 DDRMI)	As required by the regulation
NAV/OR/ILS switch or NAV/RAD switch	1	2	2

Note: The figures in bold are related to requirements that are above the Airbus MMEL, and that need to be taken into account by the airlines' MEL.
* 1 VOR, if sub-paragraph (c) (vi) of the JAR OPS 1.865 does not applies.

MEL Requirements for RNP-10 airspace

Reference: FAA Order 8400.12A, JAR OPS 1.865 and 1.870, A340 MMEL

Example: A340s with GPS PRIMARY

Equipment	FAA Order Requirements	JAR OPS 1 Requirements	MMEL Requirements
FM (lateral guidance)	**2**	1 +1 B/UP NAV*	1 + 1 B/UP NAV*
MCDU	2	2	2 Outside radio cov.
RMP	-	2	2
IRS	2	2	2
VOR receiver	-	**2***	As required by the regulation
DME receiver	-	1	As required by the regulation
GPS receiver	**1**	-	As required by the regulation
EFIS CRT	3	3	3
Flight Plan Data on ND (MAP information)	On **2** ND in ROSE NAV or ARC mode	-	As required by the regulation
VOR data on ND or DDRMI	-	On **2** ND in ROSE VOR mode (or **1** ND+**1** DDRMI)	As required by the regulation

Note: The figures in bold are related to requirements that are above the Airbus MMEL, and that need to be taken into account by the airlines' MEL.

* 1 VOR, if sub-paragraph (d) of the JAR OPS 1.865 applies.
** In B/UP NAV GPS, FMS update is unavailable.

Operators MELs are expected to include the requirements applicable to the areas in which they intend to operate, in accordance with the operational regulations. Refer to ICAO Doc 7030 "Regional Supplementary Procedures" and JAR OPS 1 or FAR 121, or the applicable national regulation.

2.4 RNP Operations

The operational requirements and procedures are determined by the type of RNP route or airspace, and will differ for:

RNP enroute, or terminal area within radio navaid coverage
RNP enroute, in oceanic, or remote areas.
RNAV approach, based on RNP (see chapter 4 below)
SID/STAR, based on RNP.

The level of performance (RNP value) also has an effect on these operational requirements and procedures, and on aircraft equipment (GPS, or no GPS).

2.4.1 RNP-5 (or RNP-4) based on radio navaid infrastructure

It is normally the airspace administration's responsibility to support the required navigation performance by providing the adequate navaid infrastructure. NOTAMs are expected to be published when a navaid failure may affect the navigation performance on a given route.

Operator are responsible for addressing the following steps prior to beginning operations within such an RNP airspace:

Verify aircraft certification status.
Collect adequate flight crew information.
Establish MEL repercussions.
Implement adequate flight crew training and verify Operations Manual repercussions.
Apply for operational approval, if required by national authorities..

Aircraft Certification Status

For all Airbus models, except A300 B2/B4s without GNLU, the AFM has appropriate reference to justify this type of RNP capability.
AMJ 20-X2 has a provision to support the operational approval of INS-equipped aircraft complying with AC 25-4 and AC 90-45A for radio update capability.
As A300 B2/B4s with INS are certified in accordance with AC 25-4 and FAR 121 appendix G, this navigation system is capable of Basic RNAV within European airspace with a time limitation of 2 hours since INS ground alignment. Operators may be authorized benefit from INS radio update capability if they demonstrate compliance with criteria of AC 90-45A.

If an INS radio update is anticipated, Operators may have to establish procedures for:

INS ground alignment (FCOM)
INS radio updates (FCOM)
Frequency of INS radio updates
Navaid selection criteria, etc.

Flight Crew Information

The Operator shall collect, in the national AIP (or AIM), the routes and airspace vertical and lateral limits where RNP capability and procedures are implemented. Also refer to the ICAO Doc 7030 “Regional Supplementary Procedures”, and to the information published by the authority, administering the specific airspace where flights are intended.

Ex: Eurocontrol Standard Document 03-93 for Basic RNAV in Europe.
JCAB AIC Nr 005 for RNP-4 in Japan

Particular contingency procedures, in the event of an RNP-X capability loss, may also be published in the above documents.
In most cases, crew action will be to inform the ATC, which may require the aircraft to leave the RNP airspace or to use routes that are based on conventional radio navigation.
Airlines may have to complement their route manual or operations manual with the above information.
To inform the ATS in advance that the aircraft has the appropriate RNP capability, the letter "R" should be added in Box 10 of the ICAO ATC Flight Plan.

MEL Repercussions

Generally speaking, specific MEL requirements for this kind of RNP airspace are already covered by the basic Airbus MMEL and by general operational requirements like JAR OPS 1.

See the example included in paragraph 2.3.3 above, to review the airline’s MEL.

Flight Crew Training and Operations Manual Complement

Use of the RNAV system (FMS, FMGS, INS) is integrated in the Airbus Type Rating Flight Crew Typerating training course. No additional crew training is required on RNAV systems knowledge and procedures.
The Airbus FCOM provides the necessary RNAV system (FMS, INS, GNLU) description and procedural information.
General RNP procedures are published for:

A310/A300-600:	FCOM, Section 2.18.95.
A320/319/321:	FCOM, Section 2.04.55.
A330/A340:	FCOM, Section 2.04.50.

Additional information, which can be used by airlines to complement the FCOM or Operations Manual, is provided below.

Loss of RNP-X capability

Except for aircraft with GPS PRIMARY, when GPS PRIMARY is available, normal FMS position monitoring with navaid raw data (as described in FCOM) must be observed. Any discrepancy, between the navaid raw data and FMS position, with a magnitude of the order of the RNP-X value, shall be considered as a loss of RNP capability.

Aircraft without GPS:

For the A300-600s and A310s with R/I indication on the CDU, the RNP-X capability should be considered as lost, if the system remains in IRS ONLY navigation for more than the approved time limit (2 hours for Basic RNAV in Europe).
For Airbus models with HIGH/LOW accuracy indication on the (M)CDU, there are distinct FMS standards:

FM standards uncompatible with the GPS installation where the required accuracy is a function of the area of operations:

Enroute:	2.8 NM
Terminal area:	1.7 NM
Approach:	0.5 NM with VOR/DME update
Approach:	0.3 NM with DME/DME update

For these aircraft, when LOW accuracy appears enroute on the (M)CDU, the RNP-5 or RNP-4 capability is not necessarily lost. It means that the Estimated Position Error is larger than 2.8 NM. Nevertheless, we consider that it is conservative and not penalizing to use the appearance of the LOW accuracy message as an indication, requesting navigation accuracy crosscheck with radio navaid raw data. If no raw data is available, the LOW indication or the time in IRS ONLY, remains a valid criteria to determine the loss of RNP capability.

FM standards compatible with the GPS installation, where required accuracy is defaulted as per above, but where an accuracy value equal to the RNP-X can be entered on the (M)CDU. For such aircraft, the RNP-X capability should be considered as lost when LOW accuracy appears on the (M)CDU, with "X" entered as the required navigation accuracy.

FMS2 where defaulted required accuracy is a function of the area of operations:

Enroute	2 NM
Terminal area	1 NM
Approach	0.3 NM if a GPS IAP is selected
	0.5 NM for other cases (can be modified)

Reminder: LOW is displayed on the (M)CDU when the Estimated Position Error (EPE) (95% probability), calculated by the FMS, is larger than the required accuracy.

Aircraft with GPS:

When GPS PRIMARY is available, all RNP requirements are fulfilled up to:

RNP-0.3, when the AP or FD is used in approach
RNP-0.5, when the AP is used, or RNP1 when FD is used in the terminal area
RNP-1, enroute.

When GPS PRIMARY LOST is displayed, RNP capability is maintained in the conditions described above for aircraft without GPS.

(M)CDU Messages such as FMS1/FMS2 POS DIFF, or CHECK A/C POSITION, may also indicate a RNP capability loss, unless the faulty system has been identified and the healthy system is used for navigation and is monitored.

If RNP-X capability is lost, the crew must inform the ATC, who may require the aircraft to leave RNP airspace.
If both FMS' fail including NAV BACK UP for the A330/A340 (or all INS for the A300 B2/B4 without GNLU), RNP and RNAV capability are also lost. The crew must revert to conventional radio navigation and inform the ATC for rerouting or radar assistance.

Conditions to enter RNP airspace

RNP airspace can only be entered if the required equipment is operative.
Only one RNAV system is required to enter RNP airspace within radio navaid coverage, which basically signifies that, for Airbus aircraft the following equipment is operative:

One FMS (or 1 INS)
One (M)CDU
One VOR
One DME
Two NDs with flight plan (or 2 HSI)
Navaid raw data on ND or DDRMI.

The expected RNP-X capability must be available. Verifying that the conditions of RNP capability loss (see above) are not present does this.

Operational Approval

Airline national Authorities may, by regulation, leave up to the airlines to comply with RNP airspace requirements, or may require a documented application for formal operational approval.
If a formal application is required, Authorities may review all RNP-X aspects, including: Aircraft capability, operational documentation amendment, and crew training. RNP operational approval may be provided by including RNAV and RNP Operator's AOC list of Special Authorizations

Airlines are, therefore invited to contact their national Authorities for information on the applicable process.
A300 B2/B4 Operators, (without GNLU) may also have to substantiate the procedures and time limitations for INS use.

2.4.2 PRNAV

Precision RNAV (RNP1) will be implemented within European airspace starting from 2003. The aircraft navigation system will need to comply with JAA TGL 10 (see Annex 5.2).

Compliance with TGL 10 has been demonstrated for FMS2 and is in progress for the legacy FMS.

In the European airspace, the PRNAV will be supported by the ground navaid infrastructure for FMS radio-update. Therefore GPS will not be mandatory.

The operational requirements will be quite similar to the existing European BRNAV. PRNAV capability will be first required to fly new RNAV SID's and STAR's.

RNAV SID's and STAR's procedures are becoming increasingly common, but in general these existing RNAV procedures are not associated with a RNP level.

Therefore all Airbus aircraft with a FMS or the GNLU can fly these RNAV SID's and STAR's.

2.4.3 RNP-10 in oceanic or remote areas

Operators are responsible for addressing the following steps prior to beginning operations within such an RNP airspace:

Verify aircraft certification status.
Collect adequate flight crew information.
Verify that the intended route is possible, if the navigation system is time-limited.
Establish MEL repercussions.
Implement adequate flight crew training and verify Operations' Manual repercussions.
Apply for operational approval, if required by national authorities.

<u>Aircraft Certification Status</u>

Airbus aircraft with GPS PRIMARY

A310s, A300-600s, A319/320/321s, A330s and A340s, equipped with GPS PRIMARY, have an RNP capability statement certified in the AFM.
When GPS PRIMARY is available, the navigation system is capable of RNP-1 enroute without a time limitation.
For these aircraft, if GPS PRIMARY is temporarily lost, IRS navigation is available. The probability of losing GPS PRIMARY long enough to exceed the RNP-10 accuracy requirement is very unlikely. Therefore, for these aircraft, GPS availability does not need to be verified before flight for RNP-10 capability.

A300 B2/B4s equipped with GNLU also have an RNP capability statement certified in the AFM. The GNLU is capable of RNP-1 enroute but, outside radio navaid coverage, it will revert to a dead reckoning (DR) mode, if GPS availability is lost. Therefore, GPS availability must be verified for the intended route before flight. This can be done with an approved GPS availability ground prediction program.

Airbus aircraft without GPS PRIMARY

RNP capability of these Airbus aircraft is not indicated in the AFM. However, they are eligible with reference to the provisions of FAA Order 8400.12A.

Refer to Figures 2 and 3 above, for Navigation System Compliance status and for RNP-10 eligibility as per FAA Order 8400.12A.

The RNP-10 capability of these aircraft is time-limited from the moment of IRS/INS ground alignment or the last radio update, when leaving radio navaid coverage.

This time limitation is based on an assumed 1.6 NM/h drift rate (crosstrack or along track equivalent drift rate) with a 95 % probability of IRS's or INS's installed on Airbus aircraft.

Therefore, a 6.2 hours limitation is normally acceptable for RNP-10, starting from IRS/INS ground alignment.

For FMS-equipped aircraft, it is more advantageous to define a time limitation since the last FMS position radio update. However, in this case, it is necessary to assess the effect of radio update accuracy on the time limit.
Considering that VORDME updating will occur first, and taking into account the time limit reduction of FAA Order 8400.12A §12 (e) the time limit to maintain RNP-10 capability since the last FMS radio update will be 5.7 hours (6.2h-0.5h=5.7h).
For A300 B2/B4s equipped with INS, which have radio update capability, the effect of update accuracy on the time limit is a function of the update procedure.
Using §12 (e) of FAA Order 8400.12A, a 5.2 hours time limit can be proposed. Some Authorities have set this time limit at 4.5 hours.
If INS radio updating is anticipated, Operators may have to establish procedures for:

INS ground alignment (FCOM)
INS radio update (FCOM)
Frequency of INS radio update
Navaid selection criteria, etc

Flight Crew Information

Operators shall collect, in the national AIP (or AIM), the routes and airspace vertical and lateral limits where RNP capability and procedures are implemented. Also refer to the ICAO Doc 7030 “Regional Supplementary Procedures”, and to the information published by the authority, administering the specific airspace where flights are intended.
Particular contingency procedures in the event of an RNP-X capability loss, may also be published in the above documents.
Airlines may have to complement their route or operations’ manuals with the above information.
To inform the ATS in advance that the aircraft has the appropriate RNP capability, the letter "R" should be added in Box 10 of the ICAO ATC Flight Plan.

Determination of the time limitation for aircraft without GPS PRIMARY

If the navigation system has time limitation since the last radio update Operators must define which routes are in compliance with this limitation. For that purpose, the wind enroute shall be taken into consideration.
A calculation can be performed for each flight but the operator may elect to make only one calculation, taking into account the statistical wind on the route with a 75 % probability.

Our suggestion is to determine the length of the flight segment in IRS only, as illustrated in Figure 4.

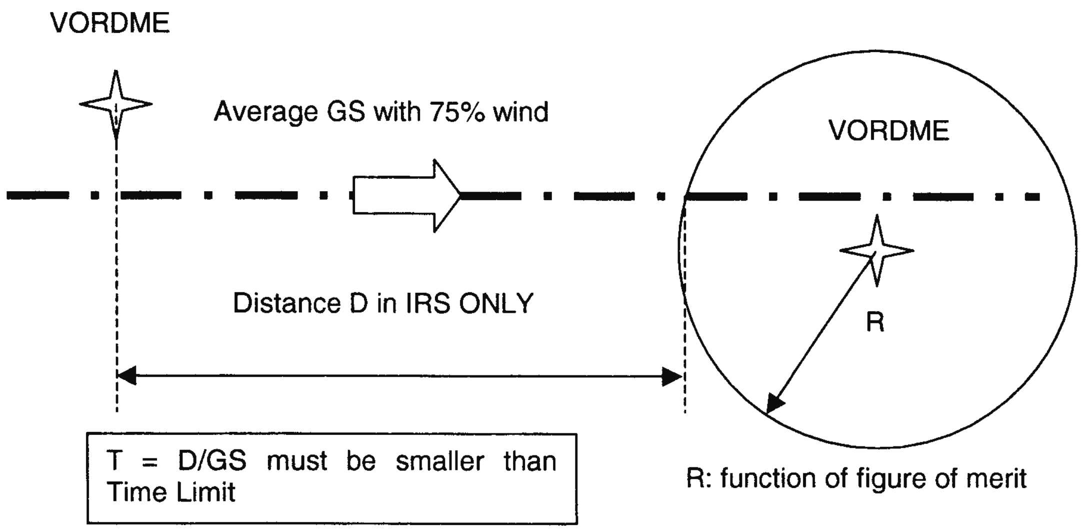


Figure 4 : Estimation of flight length in IRS ONLY navigation

MEL Repercussions

The MEL requirements for operations within oceanic and remote areas impose two navigation systems, which basically means 2 FMS (or 1 FM+1 B/UP NAV for the A330 and A340), 2 (M)CDUs, 2 IRSs, and 2 NDs.
Airlines should review their MEL to include the specific requirement of a particular RNP-10 airspace. Information can be found in the ICAO Doc 7030 of the AIP (AIM) or in the documentation published by Authorities that administer airspace.

See the example in paragraph 2.3.3 above to review the Airline MEL.

Flight Crew Training and Operations Manual Complement

Use of the RNAV system (FMS, FMGS, INS) is integrated in Airbus' Flight Crew Typerating training course. No additional crew training is required on RNAV systems knowledge and procedures.
The Airbus FCOM provides the necessary RNAV system (FMS, INS, GNLU) description and procedural information.
General RNP procedures are published in the FCOM for the:

A310/A300-600:	FCOM, Section 2.18.95.
A320/319/321:	FCOM, Section 2.04.55.
A330/A340:	FCOM, Section 2.04.50.

Additional information, which can be used by airlines to complement the FCOM or Operations Manual data is provided below. Also refer to Appendix 4 of FAA Order 8400.12A, given in the Annexe.

Loss of RNP-X capability

If the aircraft is not in GPS PRIMARY, normal FMS position monitoring with navaid raw data (as described in FCOM) must be observed as long as the aircraft remains within radio navaid coverage.
Any discrepancy, between the navaid raw data and FMS position, with a magnitude of the order of the RNP-X value, shall be considered as a loss of RNP capability.

Aircraft with GPS PRIMARY:

The probability of losing GPS PRIMARY long enough to exceed the RNP-10 accuracy requirement is very unlikely, unless both GPS receivers fail. In that case, the RNP-10 capability will be maintained in IRS ONLY navigation for 6.2 hours since the loss of the second GPS. For the A300 B2/B4s with GNLU, loss of both GPS receivers is equivalent to a loss of RNP-10 capability. Small RAIM holes can be acceptable (see annex 5.3)

If the FM/GPS POSITION DESAGREE message is triggered, the crew shall determine the distance between GPS and FM positions to evaluate the capacity to maintain RNP-10.

Aircraft without GPS PRIMARY:

RNP-10 capability is maintained, as long as flight time in IRS ONLY has not exceeded 5.7 hours (5.2 hours with INS) or a duration acceptable to the Authorities.

For Airbus aircraft, equipped with an FMS standard compatible with GPS installation and with a required accuracy of 10 NM entered in the (M)CDU, the LOW accuracy message may appear before the 5.7 hours since the last radio update has elapsed. This message can be considered as an advisory.
(M)CDU messages like FMS1/FMS2 POS DIFF, may also indicate an RNP capability loss, unless the faulty system has been identified and the healthy system is used.

If RNP-X capability is lost, the crew must inform the ATC, who may require the aircraft to leave RNP airspace.

If both FMS are failed, including NAV BACK UP for the A330/340 (or all INS for the A300 B2/B4 without GNLU), RNP and RNAV capabilities are also lost.

In NAV BACK UP RNP10 is lost 6.2 hours after IRS alignment.

Conditions for entering the RNP airspace

RNP airspace can only be entered only if the required equipment is operative.
In most cases, two navigation systems must be operative before entering RNP-10 airspace, which means:

Two FMS (or 1 FM + 1 B/UP NAV for A330 and A340)
Two (M)CDU
Two IRS
Two ND (or 2 INS and 2 HSI)

The expected RNP-X capability must be available. This is ascertained by verifying that RNP capability loss (see above) conditions are not present.
For aircraft without GPS, the FMS navigation accuracy must be verified before leaving radio navaid coverage

Operational Approval

Airline Airworthiness Authorities may, by regulation, leave it up to the airlines to comply with RNP airspace requirements, or they may require a documented application for formal operational approval.
If a formal application is required, the Authorities may review all RNP aspects including aircraft capability, operational documentation amendment and crew training. RNP operational approval may be achieved by including RNAV and RNP in the Special Authorizations list of the Operator's AOC.

Airlines are therefore invited to contact their national Authorities for information on applicable process.
Airbus aircraft operators without GPS shall also request their national Authorities to provide a time limitation in IRS/INS ONLY navigation.

3. REDUCED VERTICAL SEPARATION MINIMUM

3.1 General Concept

RVSM airspace is defined as an airspace or route where aircraft are vertically separated by 1000 feet (rather than 2000 feet) between FL 290 and FL 410 inclusive.
The objective is to increase the route capacity of saturated airspace, while maintaining (at least) the same level of safety. This can be achieved by imposing strict requirements on equipment and on the training of personnel, flight crews and ATC controllers. As part of the RVSM program, the aircraft "altitude-keeping performance" is monitored, overhead specific ground-based measurement units, to continuously verify that airspace users are effectively applying the approved criteria and that overall safety objectives are maintained.

3.2 RVSM Airspace implementation

The concept was first implemented in the NAT MNPS area and associated airspace, from FL 330 to FL370 inclusive, beginning March 1997, and implemented in January 1998

In 1998, 90% of NAT MNPS operations were conducted with RVSM-approved aircraft, and 75% use FL 330 to 370.
From the outset, the RVSM concept has been validated; the "aircrafts' altitude-keeping performance" is monitored by the Height Monitoring Units (HMU) of Gander and Strumble to ensure that the safety objectives are met.
The NAT RVSM operational experience has revealed some case of:

Spurious TCAS messages
Wake vortex encounters

However the few reported occurrences were considered to be not critical.
The new generation of TCAS solves the TCAS events, and spacing or offset track in specific weather conditions will reduce vortex encounters.

The subsequent RVSM, implementation milestones is the European RVSM like BRNAV, will be applicable within all ECAC (European Civil Aviation Conference) countries but non ECAC adjacent countries are also encouraged to participate in the program. Up to approximately 38 countries are expected to enforce RVSM from FL 290 to FL 410.

3.3 Aircraft Certification Status

3.3.1 Applicable Regulation

The JAA Temporary Guidance Leaflet (TGL) No. 6 (See Annex 5.4) was released for consultation in 1998.
It is entitle: "Guidance Material on the Approval of Aircraft and Operators for Flight in Airspace above Flight Level 290 where a 300M (1000 feet) Vertical Separation Minimum is applied".

This JAA TGL No. 6 replaces the JAA Information Leaflet No. 23, which was applicable at the time of RVSM certification. However aircraft certified in compliance with JAA IL No. 23, or FAA Interim Guidelines 91-RVSM, will not need to be re-investigated. These aircraft satisfy the airworthiness criteria of TGL No 6 and **credit may be taken from the existing approval**.

The changes incurred from JAA IL 23 to JAA TGL No. 6 are, in fact, minor except the introduction of a new appendix dedicated to specific procedures for European RVSM airspace (mainly ATC procedures).

All Airbus aircraft have RVSM capability, also valid for the European RVSM.

3.3.2 Airworthiness Requirements

System Performance:

Aircraft manufacturers must demonstrate that the aircraft mean Altimetry System Error (ASE) is better than 80 feet and that the mean ASE + 3 times its standard deviation, taking into account unit to unit variability and the effect of environmental conditions, does not exceed 200ft.

The AP must be capable of maintaining the selected altitude within 65 feet under non turbulent, no gust conditions. The "soft altitude hold" mode (for Airbus models fitted with this AP/FM mode) still satisfies RVSM requirements.

The minimum required equipment for RVSM is:

Two independent altitude measurement systems
One secondary surveillance radar transponder
One altitude alert system
One automatic altitude control system.

The rate of undetected altimetry system failures must not exceed 10^{-5} per flight hour.

All Airbus models can meet these requirements with the appropriate configuration.

Any Airbus aircraft is considered to be a member of an aircraft group for the purposes of RVSM approval. A modification or SB number formalises the RVSM data package implementation. This modification or SB is required for inclusion of the RVSM capability in the AFM.

In addition, for some Airbus models, a particular equipment standard is required. Refer to SIL 34-064, for more information on this subject.

The RVSM SB consists of a:

Visual check of static sources area and air data probes to verify the absence of impact or excessive skin waviness.
Check, on ground, that altitude readings from all sources(*) are within the tolerances indicated given in the FCOM.
Comparative check, in flight, that altitude readings from all sources(*) at three different Flight Levels.

*"All sources" signifies: ADR 1, 2 and 3 (or ADC 1 and 2) and standby altimeters, as applicable.

If all of the above checks prove to be satisfactory, the aircraft is capable of RVSM, and its AFM can be revised accordingly.
Airbus can deliver new aircraft with the RVSM data package and configuration.

3.3.3 MMEL Requirements

The MMEL for all Airbus models have also been revised to refer to the list of required equipment published in the AFM. Generally speaking, the Airbus MMELs do not include specific RVSM requirements.
Operators have to refer to the AFM in preparing their MEL.

Typically, the list of required equipment is as shown in the following table:

Equipment	Number required	Remarks
ADR or ADC	2	For A319, A320 and A321, ADR1+ADR2 is required
ATC transponder	1	
FCU	1	For altitude selection, Climb, Descent AP mode selection
Auto Pilot	1	
FWC	1	For altitude alert function
PFD or Altimeters	2	

3.4 RVSM Operations

3.4.1 Operational Approval

Operators must obtain operational approval from their national Authorities to operate within RVSM airspace. To do so, applicant must ensure that the following items have been addressed:

Each individual aircraft is certified for RVSM:

The RVSM SB has been successfully implemented.
The Equipment standard is adequate.

The Operational Documentation has been amended:

The Operations Manual includes the necessary information and procedures (FCOM provides the necessary information for all Airbus models).
The Airline MEL has been revised to comply with the AFM list of required equipment.
The route documentation includes the specific requirements of the airspace being flown (For example, refer to ICAO Doc 7030-"Regional Supplementary Procedures").

Flight crews have received adequate instruction, and briefing notes.

The Maintenance program has been reviewed for RVSM, and Maintenance documentation has been amended.

The Airline intends to participate in a monitoring program for the overall altitude keeping performance of a number of aircraft in its fleet. Completion of this program is not a prerequisite for obtaining RVSM operational approval.

This demonstration can be made by flying over specific Height Monitoring Units (HMU), or by using of a GPS Monitoring Unit (GMU) which is an independent height monitoring system taken onboard the aircraft.
Authorities, in charge of RVSM airspace, will analyze HMU or GMU data.
For each Operator, about 60 % of aircraft pertaining to the same group will need to be checked. This percentage can be reduced considerably (10% or 2 aircraft) for aircraft types of the same design, with regards to the altimetry system for which an important number of individual aircraft have been checked, showing a high level of confidence independent of the operator.
For NAT RVSM, 2 HMU are in operation (Strumble in UK and Gander).
For EUR RVSM, 3 new HMU are implemented in central Europe (Geneva, Nattenheim, and Linz), in addition to the HMU of Strumble.
Up to 25 GMUs will be available for Operators that cannot to fly the HMU stations.

3.4.2 RVSM Procedures

RVSM procedures can be divided into two categories:

General procedures valid in any RVSM airspace
Procedures specific to a given airspace.

General RVSM procedures are published in the FCOM for all Airbus models:

A300	FCOM, Section 8.02.16
A300 FFCC	FCOM, Section 2.02.14
A310/A300-600	FCOM, Section 2.18.90
A320/319/321	FCOM, Section 2.04.50
A330/A340	FCOM, Section 2.04.45

A generic summary of these procedures is provided below, for information only.

Preflight:

Check that the aircraft is capable of RVSM.
The aircraft is approved for RVSM (SB implemented).
The required equipment for RVSM is operative (MEL).
No maintenance log entry, concerning defects which may affect RVSM capability. Corrective actions have been taken, if necessary.

Check, on ground, that at least two main altitude indications are within the tolerances indicated in the FCOM.

Review the weather forecast paying particular attention to severe turbulence, which may affect aircraft altitude, in order to maintain the required RVSM performance required RVSM.

Check that the letter “W“ is written in field 10 of the ATC Flight Plan to indicate RVSM capability.

Prior to entry into RVSM airspace:

The required minimum equipment must be operative otherwise, a new clearance to avoid RVSM airspace must be obtained:

Two ADR (or 2 ADC), and two main altitude indications (for A319, A320, A321, ADR 1+2)
One ATC transponder
One AP in ALT and OPEN CLB/DES (or LVL/CH) modes
FCU altitude selection and OPEN CLB/DES (or LVL/CH) selection
One FWC for altitude alert function.

At least two main altimeter indications on the STD setting must be within 200 feet.

If only two ADRs (or 2 ADC) are operative, record significant main and standby altimeter indications for reference, in case of subsequent altimeter failure.

Within RVSM Airspace:

Keep AP in command for cruise and level changes.
When making a level change, monitor AP guidance so as not to overshoot the assigned FL by more than 150 feet.
Approximately every hour, check the altitude indications. At least two main indications should be within 200 feet.

Post flight:

Report any malfunction or deviation in relation to the altitude keeping capability, and any failure of the required RVSM equipment.

Inflight abnormal procedures:

When flying within RVSM airspace, the ATC must be informed in case of:

Failure of both APs.
Loss of altimeter indication redundancy. Only one main indication remains.
Excessive discrepancy of altitude indications without means of determining which indication is valid.
Encounter with severe turbulence
Abnormal situation, preventing the aircraft from maintaining the assigned FL

If one AP is unable to keep the assigned altitude, select the other AP.

Procedures specific to a particular airspace:

The procedures specific to a particular airspace, including contingency procedures, are published for the RVSM NAT MNPS airspace in ICAO Doc 7030, or in the North Atlantic MNPS Airspace Operations Manual (Seventh Edition), and in the JAA IL 23 Appendix 5 (or draft JAA TGL No 6 appendix 7).
The specific procedures for the future European RVSM airspace is published in the ICAO Doc 7030, and in Appendix 6 of the JAA TGL No. 6.

3.4.3 Suspension or Revocation of RVSM Approval

Operators should report height-keeping deviations to the responsible Authority within 72 hours when the deviation exceeds:

A total Vertical Error of 300 feet (for example, measured by an HMU).
An Altimetry System Error of 245 feet.
An Assigned Altitude Deviation of 300 feet.

These errors, caused by equipment failures or operational errors, may lead the responsible Authority to suspend or revoke the Airline's RVSM approval.
It is therefore important for the airline to report any poor height-keeping performance and to indicate which corrective actions have been taken.

4. RNAV INSTRUMENT APPROACH PROCEDURES (RNAV IAP)

4.1 RNAV Introduction

Area Navigation (RNAV) is a navigation method that enables aircraft operations on any desired flight path within station-referenced navigation aids or within capability limits self-contained aids, or a combination of both.

An RNAV system may be used in the horizontal plane, which is known as lateral navigation (LNAV), but may also include functional capabilities for operations in the vertical plane, known as vertical navigation (VNAV).

The RNAV (lateral) has been used for years in oceanic and remote area environment, and more recently, for continental routes in high traffic density environments (Basic RNAV).
RNAV is now also used in Terminal Areas for SID, STARS and Instrument Approach Procedures (IAP) of NPA type.

The term “RNAV IAP” covers different kinds of approaches:

RNAV approach, procedure, designed in overlay to a conventional IAP, based on ground radio navaids.
Stand-alone RNAV approach, not associated with an RNP.
Stand-alone RNAV approach requiring GPS accuracy, sometimes called GPS (stand-alone) approach.
RNAV approach with associated RNP value, with and/or without GPS.

To fly RNAV approaches, aircraft must be equipped with a RNAV system, which is the FMS for Airbus aircraft.

All Airbus aircraft models are capable of flying these types of approaches, with variable conditions, depending of the availability of the GPS PRIMARY function. GPS PRIMARY means GPS with RAIM integrity or the equivalent (Litton AIME).
For A300B2/B4s installation of the GNLU is mandatory.
This document will, for the sake of simplicity, deal mainly with the FMGC standards called “GPS capable” with, or without, GPS and the FMS2 of the FBW Airbus aircraft family.

In the above list, the first kind of IAP is commonly flown with NAV and FINAL APP mode, and with the related radio navaids actively-monitored. This approach technique, already covered in the FCOM, will not be discussed in this document unless the approach can be flown with the reference radio navaids unserviceable, or the onboard equipment inoperative or not installed.

4.2 Types of RNAV Approach Procedures (IAP)

4.2.1 RNAV IAP Requiring VOR DME Radio Updating

The first type of RNAV IAP that were developed and published were intended for navigation systems using a selected nearby VOR with a collocated DME to compute the aircraft position. This type of system was limited to LNAV.

The IAP was made up of waypoints, determined by a radial and a distance to this reference navaid. The approach chart indicated the bearing and distance that had to be checked by the crew at each significant waypoint (IAF, FAF,….) when flying over it.

This type of IAP can be flown with the FMS of Airbus aircraft, provided the approach is properly coded in the navigation database and the reference navaid is selected and monitored. However, for the most part, or at least for airports having large commercial aircraft, this type of IAP is no longer used.

4.2.2 RNAV IAP Requiring FMS and ND Equipment

This type of navigation equipment is called /F or /E “capable” because the letter F or E has to be written in the field relative to the aircraft navigation capability of the FAA flight plan form. Note that the ICAO flight plan form is completely different from the FAA’s one and that /F or /E is either non existent or has no meaning.
For approach, the FMS position is automatically updated with two DME signals or, with one VOR and one collocated DME signal. There is no specific requirement on navigation accuracy (no associated RNP). Sometimes, specific VOR/DME or DME’s may be required to be operative (NOTAM).
The same type of equipment may also be required for RNAV SID and STARS (see paragraph 2.4.2 above).
All Airbus aircraft with FMS or GNLU can fly these type of procedures.
These IAP procedures can be flown with a GPS-updated FMS provided the approach is coded in the WGS 84 coordinate system or equivalent. Otherwise, GPS should be deselected.

4.2.3 RNAV IAP Requiring GPS

These IAP are sometimes published as GPS approaches. They require an FMS equipment with GPS position update and RAIM integrity or equivalent (Litton AIME).

This type of navigation equipment is sometimes called /G, because the letter G has to be written in the field relative to the aircraft navigation capability of the FAA flight plan form.

These approaches are necessarily coded in the WGS 84 coordinate system.
In the US, these IAP will be progressively renamed RNAV approaches.
All Airbus aircraft with the GPS PRIMARY function can fly this kind of IAP.

4.2.4 RNAV IAP with RNP Value (RNP RNAV)

RNP 0.3 is the current navigation accuracy standard in approach. RNP 0.3 means that the aircraft position error must be less than 0.3nm, with a probability of 95%. In the future, lower RNP values will be envisaged, when it can justify lower minima.
Normally, an FMS with GPS updating is required to demonstrate RNP 0.3, but the same RNP value can be achieved by an FMS with DME/DME updating, provided the density of DME ground facilities is sufficient to support it.
If DME coverage is demonstrated to be satisfactory, Authorities may accept RNP 0.3 RNAV approaches without GPS. Specific DME may need to be operative (NOTAM).
All Airbus aircraft with the GPS PRIMARY function can fly this type of IAP.

4.3 Navigation System Capability

4.3.1 Lateral Navigation (LNAV)

GPS PRIMARY unavailable, or GPS deselected or not installed

Airbus models, with FMS standards compatible with GPS, meet the navigation accuracy requirements of TSO C115B.
This TSO defines the required navigation accuracy (RNP) function of the flight phase.
For approach, the TSO C115B RNP is 0.3nm with DME/DME updating or 0.5nm with VOR/DME updating. If the pilot does not manually enter a value in the RNP field of the MCDU, the TSO C115B default values will be used and displayed.
In fact, on the MCDU, the RNP is given as a radial equivalent to the XTK and, ATK values of TSO C115B.
For example, RNP 0.3nm (XTK/ATK) becomes 0.36nm (radial).

The default values displayed on MCDU are the following:

En route:	3.4nm
Terminal:	2.1nm
Approach VORDME:	0.61nm
Approach DMEDME:	0.36nm

For the new generation of FMS standard, called FMS2, the default RNP are:

En route:	2nm
Terminal:	1nm
Approach:	0.3nm (if GPS IAP is selected)
	0.5 nm

In addition, with FMS2 the RNP can be defined in the Navigation Database for a specific procedure.
For both FMS standards, an RNP can be manually entered by the pilot.

In the navigation system, the RNP has no other use than to control the HIGH/LOW navigation accuracy display, which is the result of a comparison with the Estimated Position Error (EPE) calculated by the FMS:

EPE > RNP ⟹ LOW accuracy
EPE < RNP ⟹ HIGH accuracy

A model, based on the FMS position-updating mode calculates the EPE. In the FMS2, this model has been slightly adjusted for DME/DME and VOR/DME updating modes.
This means that, when HIGH accuracy is displayed, the actual position error has a probability to be smaller than the RNP. In other words, the EPE is not an indication of the actual position error and only a comparison with independent raw data (navaid, GPS) can indicate the actual position error.
The LOW accuracy display and the associated NAV ACCUR DOWNGRAD message should, therefore, only be used as indicators requiring actual navigation position confirmation with other means.

Consequently, without the GPS PRIMARY function, navigation system performance is dependent on ground navaid infrastructure.
In particular, DME ground facilities density must be sufficient to support the desired performance.

RNP 0.3 IAP with DME/DME updating can be acceptable, provided the DME coverage has been verified inflight or assessed, making use of a DME coverage model, unless the published approach chart indicates that DME/DME updating is granted.

GPS PRIMARY available

Airbus models with GPS PRIMARY meet the navigation requirements of TSO C129A for class C1, or equivalent, and AC 20-130A.

The RNP definition displayed on the MCDU is identical to the one in the above paragraph.
The EPE, calculated by the FMS, is a function of the figure of merit given by the GPS/GPIRS. It is usually quite small, which means that HIGH accuracy will normally be displayed with the RNP currently used for RNAV IAP.

With the GPS PRIMARY function, the RAIM (Honeywell) or the AIME (Litton) in addition ensures navigation position integrity.

Both the AIME and the RAIM compute a Horizontal Integrity Limit (HIL) with:
- 99.9 % probable maximum error, assuming a satellite failure.
- Guaranteed containment distance, even with undetected satellite failures.
- Compared to an Alarm Limit (AL) function of the area of operation.

In approach, the AL is set to 0.3nm (containment limit) which may support an RNP value of 0.15.

When the accuracy and integrity of the GPS navigation solution is not met, the GPS PRIMARY function is lost and a “GPS PRIMARY LOST” message is displayed.

4.3.2 Vertical Navigation (VNAV)

For the type of vertical navigation considered in this document, the system compares the vertical position (barometric altitude) with a desired vertical profile derived from baro-referenced altitude data associated to waypoints, flight path angles, or defined vertical flight paths.

This type of vertical navigation is called ″BARO VNAV″ to differentiate it from the “GPS- referenced vertical navigation” provided by GLS.

All Airbus FBW aircraft are approved for BARO VNAV use in approach (FINAL APP mode), and have been shown to meet the intent of FAA AC 20-129.

Due to the vertical flight path’s definition, vertical navigation accuracy is influenced by:

The along flight path horizontal position accuracy.
The baro-altitude accuracy, including the effect of low OAT.

4.4 Navigation Database

The use of NAV and FINAL APP modes is authorized provided the IAP to be flown can be extracted from the FMS navigation database.
In paragraph 4.3 above, we addressed navigation system performance in term of position accuracy and position integrity, relative to a flight path defined in the navigation database.
Therefore, overall navigation function integrity must include the integrity of the navigation database. This is particularly true when FINAL APP mode is to be used and when navaid raw data monitoring is unavailable, as may be the case in an RNAV approach.

4.4.1 Navigation Database Validation

Validation must ensure that the IAP is correctly coded, so that the aircraft in FINAL APP mode will fly a constant flight path angle from FAF to the runway with the required obstacle margins.

Operators should make ensure this validation is performed in addition to the navigation database integrity checks normally performed by navigation data providers and FMS manufacturers.

This validation should be complemented by dedicated crew procedures.

Three steps need to be considered:

New RNAV IAP vertical flight path coding should be verified. A list of validated RNAV IAP should be provided to the crew, unless the unvalidated procedures are removed from the navigation database.

Periodic navigation database release should be checked, preferably via automatic means to identify any IAP changes in comparison to the master file of validated procedures. Then, only the modified IAP need be re-validated.

Crew procedures should be complemented with recommendations on:

Approach vertical F-PLN verification with the MCDU and ND.
Restrictions on approach F-PLN modifications.
Monitoring of the remaining raw data.

4.4.2 Initial Approach Procedure Validation

The navigation database can be validated by flying each approach in a simulator or with the aircraft in VMC.

RNAV IAP that are regularly flown in FINAL APP mode can be considered as validated.
Another validation method is to crosscheck it with the navigation database listing obtained from the diskette delivered to the airline prior to its downloading on the aircraft. A dedicated software is necessary to read the navigation database, unless the database is delivered with the appropriate listing.

All IAP for the envisaged destinations should be verified, in comparison to the published approach charts.

The following data shall be verified:

Waypoint identifications
Waypoint coordinates (as necessary)
Distances between waypoints
Approach course
Crossing altitudes
Flight Path Angle(s)
Type of leg termination
No waypoint common to a STAR or VIA and FAF, with different altitude constraints

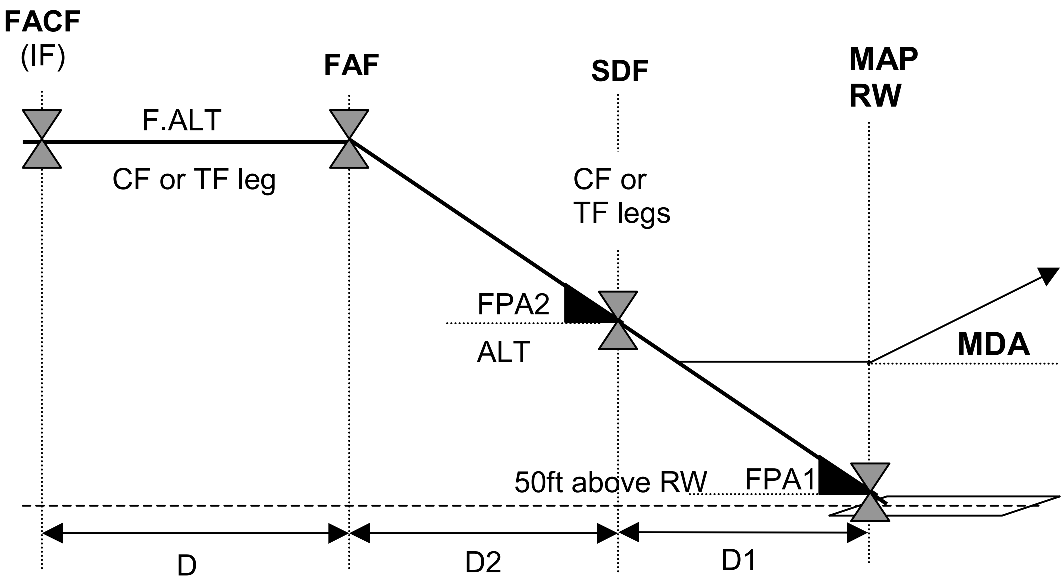
The verification must ensure that the flight path, defined in the navigation database, will clear the minimum altitudes of the official publication.

Taking into consideration the fact that the crew is unauthorized to modify on IAP's altitude constraints, the effect of very low OAT on obstacle clearance may have to be assessed. As appropriate, a minimum OAT below which the use of FINAL APP mode is prohibited should be established and indicated to the crew, unless this information is in the published approach chart.

Verification should also ensure that the information displayed on the MCDU will be sufficient for the pilot to perform a check of the vertical and lateral F-PLN, extracted from the navigation database with the approach chart.

4.4.3 Approach Vertical Coding Requirements

RNAV IAP are generally designed with a FACF, a FAF, and a MAP at the RW.
(With or without SDF)



FACF	= Final Approach Course Fix	SDF	= Step Down Fix
FAF	= Final Approach Fix	MDA	= Minimum Descent Altitude
RW	= Runway Threshold	MAP	= Missed Approach Point
F.ALT	= FAF Altitude feet	ALT	= Altitude crossing feet (if any)
FPA	= Flight Path Angle	D	= Distance NM
CF	= Course to Fix leg	TF	= Track to Fix leg
IF	= Initial Fix (database definition)		

 = Waypoints shown on the MCDU, with associated altitude constraints

RNAV IAP Coding Requirements:

FPA (≠0°) must be coded at MAP and at each SDF between FAF and MAP.
Altitude constraints must be coded at MAP, SDF, and FAF.
Altitude constraints and FPA must match.
AT or ABOVE constraint types can be used for SDF, provided they are compatible with the published IAP.

The MAP of an IAP listed as RNAV in the navigation database must be located at runway threshold (or not more than 0.1 nm before).
The MAP of an IAP listed as GPS in the navigation database can be located at or before the runway threshold.

<u>CAUTION</u>:

FPA=0°, at a MAP located at RW, will lead to an incorrect flight path calculation, and may cause an FMGS reset or a loss of FMGS predictions. Absence of FPA coding will lead to an idle segment.
IAP coded with PI-CF leg (PROC-T) must not be flown in NAV mode (Refer to FCOM Bulletin on use of FINAL APP MODE).

4.5 Flight Crew Procedures

Airlines will need to develop flight crew procedures for RNAV approaches based on the FCOM's 3.03.19 (SOP for NPA), which remains generally applicable.
The following additions need to be considered :

4.5.1 Approach Guidance

RNAV approach must be available in the FMS navigation database.
RNAV approaches will normally be flown, making use of lateral and vertical managed guidance (FINAL APP mode).

The following are cases where lateral managed guidance, associated with vertical selected guidance (NAV/FPA), should be used:

When altitude corrections are necessary due to a very low OAT.
If an incorrect vertical coding has been identified in the navigation database.

RNAV approaches should be flown using the AP or FD.

Use of the AP in command down to MDA/DA is recommended, except in certain failure cases (refer to the FCOM and AFM).

4.5.2 Navigation in Approach

A. Navigation systems without GPS PRIMARY

For RNAV approaches based on specified VORDME, the reference navaid must be operative (NOTAM).
For RNAV approaches based on DME/DME updates, Airlines (as part of their operational approval), or State Authorities should verify adequate navaid coverage. Specified DMEs may be required to be operative (NOTAM).

RNAV approaches with RNP 0.3 based on DME/DME position update may be approved by the Authorities.

RNAV approaches requiring GPS accuracy or IAP published, as “GPS approach” normally cannot be flown without GPS PRIMARY, unless authorized by the Authorities.

An FMS position accuracy check with raw data must be performed prior starting the approach. Refer to the FCOM.

HIGH accuracy with the default RNP, or an appropriate manually-entered (or database) RNP, must be checked prior to starting the approach, and must remain displayed during the approach (except for RNAV approaches with specified reference VORDME, if raw data monitoring confirms correct navigation).

B. Navigation System with GPS PRIMARY

Any type of RNAV approach can be flown with GPS PRIMARY, provided the IAP is published using the WGS 84 or equivalent coordinate system.
Unless an instrument approach procedure, not requiring GPS PRIMARY, is available at destination alternate and if applicable at the required takeoff and enroute alternate, the availability of GPS PRIMARY at the ETA must be verified prior to flight with an approved prediction software.

AIME (Litton) is available worldwide, if 23 (24) GPS satellites or more are operative. As a reference, in the summer of 2001, the satellite constellation had 27 operative satellites.
If the number of GPS satellites is 22 (23) or less, check AIME availability using the approved version of the Litton ground-based AIME prediction software.

In addition, with Honeywell GPS, check RAIM availability using the PREDICTIVE GPS MCDU page or an approved ground-based RAIM prediction software prior starting the approach.

To check GPS availability, it is necessary to know the status of the GPS satellite constellation (NOTAM). NOTAM should also be reviewed to identify any relevant information on local GPS signal perturbation.

No FMS navigation accuracy check with navaid raw data is required prior to starting the approach, provided GPS PRIMARY is displayed on the MCDU.
The RNAV approach should be discontinued if GPS PRIMARY is lost, unless the RNAV approach based on the DME/DME position update is available and approved, and HIGH accuracy is displayed on the MCDU with the default RNP or an appropriate manually – entered RNP (or a database).

4.5.3 Approach F-PLN Verification

Before starting the approach, the crew must check the FMS F-PLN, on the MCDU and ND in PLAN mode with the CSTR displayed, starting from the beginning of the STAR down to the runway and the missed approach procedure, and verify the profile against the published RNAV approach chart.

For the final approach procedure, the crew should check:
That the waypoints are correctly sequenced from the current TO waypoint.
The approach course.
The waypoints and associated altitude constraints.
The distance from FAF to RW.
The approach angle (shown on the MCDU line above related waypoints)
FPA ≠ 0°at the MAP (which must be at runway threshold for RNAV IAP)
FPA ≠0° must be defined at each Step Down Fix
The altitude at the runway threshold.
No procedure turn is part of the procedure (PROC-T indicated on MCDU).

4.5.4 Limitations to Approach F-PLN Modifications

When performing an IAP, using NAV and FINAL APP modes, modifications can be done to active F-PLN extracted from the navigation database, provided the following limitations are observed:

F-PLN modifications:

No lateral F-PLN modification from FACF (inclusive) to RW.
Modification before FACF is permitted, provided the resulting flight path course change will not be so substantial as to prevent the aircraft from being laterally stabilized on the final approach course before reaching the FAF.

No altitude constraint modification from FACF to RW. Even in case of a very low OAT, no altitude correction can be entered by this means. This may require defining a minimum OAT, so that the vertical flight path will clear the obstacles with the required margin. This minimum OAT should be given to the crew, when appropriate. A minimum OAT may be published on the approach chart itself.

When the FAF is the TO waypoint, the FROM waypoint must not be cleared in an attempt to perform a DIR TO/INTERCEPT.

To benefit managed speed and have a correct DECEL point location, it is recommended that Vapp be entered as a SPD CSTR at FAF.

DIR TO:

DIR TO FACF is permitted, provided the resulting flight path course change at FACF will not be substancial as to prevent the aircraft from being laterally stabilized on the final approach course before reaching the FAF.

DIR TO FAF is permitted, provided the resulting flight path course change at FAF is minimal.

DIR TO/INTERCEPT TO FAF is permitted, provided the RADIAL IN corresponding to the final approach course (approach course+180°) is selected and the interception angle is not so large as to prevent the aircraft from being laterally stabilized on the final approach course before reaching the FAF.

Lateral F-PLN interception in HDG/TRK:

The F-PLN must be intercepted before FACF, and the interception angle should not be so large as to prevent the aircraft from being laterally stabilized on the final approach course before reaching the FAF, or

Before FAF, at the latest, provided the interception angle is small.

Caution:
- Before arming NAV, check that the correct "TO" waypoint is displayed on the ND.
- The intercept path in HDG/TRK must not cause premature sequencing of the FAF.
  The FAF should be sequenced in NAV mode, when established on a final approach course.

Vertical F-PLN interception:

Manage the descent so that the vertical F-PLN is intercepted before FAF at the latest.

4.5.5 Approach Monitoring

For the type of RNAV IAP, based on a specified, referenced VORDME, the approach navaid should be tuned, and the associated raw data displayed and actively-monitored to check correct radial and distance from the reference navaid, when flying over the approach waypoints.
For the other RNAV IAP types, based FMS navigation using GPS or DME/DME position updates, no raw data is available for lateral navigation monitoring.

Vertical navigation should be monitored using the distance to waypoints, displayed on the ND and altimeter reading.

When APPR is selected on the FCU, the crew should verify:

Correct FMA display (APP NAV green, FINAL blue).
Correct TO waypoint on the ND.
Correct lateral flight plan and crosstrack error (XTK).
Correct Vertical Flight Path deviation indication (V-DEV).
Blue descent arrow at FAF, and correct F-PLN, including blue track, armed for Missed Approach.
When passing the FAF, the crew should verify:
Correct altitude indication.
Correct FMA display (FINAL APP green).
Correct TO waypoint on ND.
After passing the FAF when stabilized on the final descent, the crew should check:

Correct XTK, V-DEV, and consistent FPV.
Correct altitude versus distance to the runway.

The IAP shall be discontinued, when one of the following warnings occurs:
GPS PRIMARY LOST (if GPS accuracy is required).
NAV ACCUR DOWNGRAD (without GPS PRIMARY).
FM/GPS POS DISAGREE (if GPS installed and not deselected).

Crew Reporting

The crew must report any lateral or vertical NAV guidance anomaly to the Flight Operations. The report must be fully documented for further investigation and corrective actions:
Approach designation and airport.
A/C type, MSN, GW, wind/temp.
Navigation database cycle.
Pilot selections, FMA, ND, MCDU displays.
Description of anomaly, flight path.
DFDR/QAR reading.

4.6 Operational Approval

Operational approval may be required by the national Authorities in order to perform RNAV approaches.
For Operators flying under FAA regulation, authorization will be indicated in the Operational Specifications.

This operational approval may be generic for any type of RNAV IAP, or specific for designated approach procedures, depending on the type of airborne navigation equipment.
Typically, when the aircraft is equipped with GPS PRIMARY, a generic approval should be obtained for any type of RNAV IAP published in the WGS 84 coordinate system. Conversely, RNP 0.3 RNAV approach procedures based on DME/DME position updates,should be the subject of an operational approval for each individual approach, unless specifically granted on the published approach chart.

4.6.1 Navigation System Capability

The certified capability and the approved FMGS modes of operations are given in the AFM.
All Airbus aircraft models have RNAV approach capability, as indicated in Chapter 2 above, for each type of RNAV IAP.
Airbus aircraft with GPS PRIMARY have a statement in the AFM on RNP capability.
For aircraft without GPS PRIMARY, there is no such statement in the AFM as the RNP concept did not exist at the time of certification. However, RNP 0.3 capability is usually accepted when the DME/DME position can be ensured during the whole procedure.

Approach Minima

Weather minima need to be established-based on :

Published approach minima according to:

JAR OPS
TERPS
ICAO

Minima-acceptable to the national Authorities or in compliance with national regulations.

The aircraft certified capability:
For conventional NPA procedures, usually no limitation is given in the AFM as the published MDH for this kind of approach is sufficiently high. However, for Airbus aircraft with GPS PRIMARY, the certified capability is indicated: minimum MDH of 250 feet.

Minima are normally expressed in terms of horizontal visibility, or RVR and MDA(H), as with any conventional NPA.
The FAA supports the use of the DA(H) concept, rather than MDA(H), when VNAV guidance is available. It is also supported by Airbus.

The new RNAV TERPS format gives different minima for LNAV/VNAV and for LNAV only.

For Airbus aircraft, LNAV/VNAV is when the FINAL APP mode is used, while LNAV only is when NAV and FPA modes are used.

The minima are expressed as:

DA(H) and RVR (or visibility) for LNAV/VNAV.
MDA(H) and RVR (or visibility) for LNAV only.

In addition, the new TERPS format indicates:

The minimum OAT to use Baro-VNAV.

If RNP 0.3 is authorized with DME/DME updating and as appropriate the ground navaids which must be operative.
IAP published today as GPS approach will be progressively renamed by the FAA as RNAV (GPS) IAP.

Dispatch Requirements

Two FMGCs must be operative, unless the missed approach procedure can be performed with radio navaid raw data or radar, and another approach procedure, based on the availability of radio navaid raw data navigation at destination or at the destination alternate.

Training and Documentation

The Airbus aircraft RNAV system is the FMGS. Flight crews are extensively trained to use this system from their first typerating course, and from routine use of the system. Therefore, no specific training is required to use the FMGS for RNAV approaches, unless the airline's policy is to fly conventional NPA with selected FMGS modes only. In such a case, some refresher training, on the procedures for using NAV and FINAL APP modes in approach, can be accomplished during a recurrent training session.

The FCOM’s give the necessary system description information, and the corresponding procedures for using the RNAV system.
Airlines need to establish RNAV approach procedures, based on the FCOM SOP for NPA, and derived from Chapter 5 of this document.
Flight crews need a general RNAV IAP briefing, which can be developed from this document.

5. ANNEXES

FOR RNP OPERATIONS:

5.1 JAA TGL2 (AMJ 20-X2)
5.2 JAA TGL 10
5.3 Extract of FAA Order 8400.12A

FOR RVSM OPERATIONS:

5.4 Extract of the JAA TGL N°6

ANNEX 5.1

JAA TGL2 (AMJ 20-X2)

JAA Administrative & Guidance Material
Section One: General Part 3: Temporary Guidance Leaflets

LEAFLET NO 2 rev. 1: AMJ 20X2 - JAA GUIDANCE MATERIAL ON AIRWORTHINESS APPROVAL AND OPERATIONAL CRITERIA FOR THE USE OF NAVIGATION SYSTEMS IN EUROPEAN AIRSPACE DESIGNATED FOR BASIC RNAV OPERATIONS

This revision to the Temporary Guidance Leaflet No. 2 supersedes the previous version published by the JAA in July 1996, and contains:

> AMJ 20X2 - JAA Guidance Material on Airworthiness Approval and Operational Criteria for the use of Navigation Systems in European airspace designated for Basic RNAV Operations. This Leaflet presents revised guidance material relative to the implementation of Basic RNAV operations within European designated Airspace, from January 1998. This Leaflet has been co-ordinated with EUROCONTROL.

This Leaflet will be amended, as required.

PREAMBLE

JAA Temporary Guidance Leaflet No. 2 was first published in July 1996, containing Advisory Material for the Airworthiness Approval of Navigation Systems for use in European Airspace designated for Basic RNAV operations. This material was developed by EUROCAE WG-13 and was commonly referenced as AMJ 20X2. Initially, the JAA intended to produce AMJ 20X2 as part of a series of interpretative/ explanatory material and acceptable means of compliance relative to aircraft in general, and applicable to more than one JAR. However, due to difficulties in formalising the AMJ-20-Series concept, this AMJ was published as Temporary Guidance Material, so as to provide timely information for the impending implementation date for Basic RNAV operations.

This revision 1 to the Leaflet contains both airworthiness and operational guidance material including specific guidance on the approval and use of stand-alone GPS equipment for the purposes of conducting Basic RNAV operations. Due to the projected withdrawal of its ground stations, Omega is no longer considered as being able to support Basic RNAV operations. The inclusion of AMJ 20X2 in the title has been retained so as to avoid amendment to the EUROCONTROL Standard and Aeronautical Information Circulars published by national authorities.

Publication of the text as Temporary Guidance Material does not change the status of the document as described in its "Purpose" below.

1. PURPOSE

This document provides guidance material for airworthiness approval and operational criteria for the use of navigation systems in European airspace designated for Basic RNAV operations. The document establishes an acceptable means, but not the only means, that can be used in the airworthiness approval process, and provides guidelines for operators where GPS stand-alone equipment is used as the means for Basic RNAV operations. The document is in accordance with the April 1990 directive issued by the Transport Ministers of ECAC member states and with regard to the Basic RNAV operations as defined within the EUROCONTROL Standard 003-93 Edition 1 and satisfies the intent of ICAO Doc. 9613-AN/937 Manual on Required Navigation Performance (RNP) First Edition - 1994. It is consistent also with Regional Supplementary Procedures contained within ICAO Doc 7030.

2. SCOPE

This document provides guidance related to navigation systems intended to be used for Basic RNAV operations and considers existing airworthiness approval standards as providing acceptable means of compliance. The content is limited to general certification considerations including navigation performance, integrity, functional requirements and system limitations.

Compliance with the guidance in this Leaflet does not constitute an operational approval/authorisation to conduct Basic RNAV operations. Aircraft operators should apply to their Authority for such an approval/authorisation.

ICAO RNP-4 criteria are outside the scope of this Leaflet, but it is expected that navigation systems based on position updating from traditional radio aids and approved for Basic RNAV operations in accordance with this Leaflet will have an RNP-4 capability.

Related requirements

JAR/FAR 25.1301, 25.1307, 25.1309, 25.1321, 25.1322, 25.1431

JAR/FAR 23.1301, 23.1309, 23.1311, 23.1321, 23.1322, 23.1431

JAR/FAR 27.1301, 27.1309, 27.1321, 27.1322

JAR/FAR 29.1301, 29.1309, 29.1321, 29.1322, 29.1431

JAR-OPS 1.243, 1.845, 1.865, as amended by NPA-OPS-7

JAR-OPS 3.243, 3.845, 3.865 as amended by NPA-OPS-8

National operating requirements

ATC Documents

EUROCONTROL Standard Document 003-93 Edition 1

ICAO Doc. 9613-AN/937 - Manual on Required Navigation Performance (RNP) First Edition - 1994

Related navigation documents

<u>JAA Advisory Material</u>

AMJ 25-11 Electronic Display Systems

TGL No. 3 JAA Interim Guidance Material on Airworthiness Approval and Operational Criteria for the use of the NAVSTAR Global Positioning System (GPS)

<u>FAA Advisory Circulars</u>

AC 20-121 A Airworthiness Approval of LORAN C for use in the U.S. National Airspace System

AC 20-130() Airworthiness Approval of Multi-sensor Navigation Systems for use in the U.S. National Airspace System

AC 20-138 Airworthiness Approval of NAVSTAR Global Positioning System (GPS) for use as a VFR and IFR Supplemental Navigation System

AC 25-4Inertial Navigation Systems (INS)

AC 25-15 Approval of FMS in Transport Category Airplanes

AC 90-45 A Approval of Area Navigation Systems for use in the U S. National Airspace System

JTSOs/TSOs

JTSO-2C115/ TSO-C115()	Airborne Area Navigation Equipment Using Multi Sensor Inputs
TSO-C129()	Airborne Supplemental Navigation Equipment Using the Global Positioning System (GPS)

EUROCAE/RTCA documents

ED-27	Minimum Operational Performance Requirements (MOPR) for Airborne Area Navigation Systems, based on VOR and DME as sensors
ED-28	Minimum Performance Specification (MPS) for Airborne Area Navigation Computing Equipment based on VOR and DME as sensors
ED-39	MOPR for Airborne Area Navigation Systems, based on two DME as sensors
ED-40	MPS for Airborne Computing Equipment for Area Navigation System using two DME as sensors.
ED-58	Minimum Operational Performance Specification (MOPS) for Area Navigation Equipment using Multi-Sensor Inputs
ED-72()	MOPS for Airborne GPS Receiving Equipment
DO-180()	Minimum Operational Performance Standards (MOPS) for Airborne Area Navigation Equipment Using a Single Collocated VOR/DME Sensor Input
DO-187	MOPS for Airborne Area Navigation Equipment Using Multi Sensor Inputs
DO-200	Preparation, Verification and Distribution of User-Selectable Navigation Data Bases
DO-201	User Recommendations for Aeronautical Information Services
DO-208	MOPS for Airborne Supplemental Navigation Equipment Using Global Positioning System (GPS)

3. SYSTEMS CAPABILITY

Area navigation (RNAV) is a method which permits aircraft navigation along any desired flight path within the coverage of either station referenced navigation aids or within the limits of the capability of self-contained aids, or a combination of both methods.

In general terms, RNAV equipment operates by automatically determining aircraft position from one, or a combination, of the following together with the means to establish and follow a desired path:

VOR/DME

DME/DME

INS* or IRS

LORAN C*

GPS*

Notes: 1. Equipment marked with an asterisk *, is subject to the limitations contained in paragraph 4.4.2.
2. Due to the projected withdrawal of its ground stations, Omega is no longer considered as being able to support Basic RNAV operations.

4. AIRWORTHINESS APPROVAL

4.1 Criteria For Basic RNAV System

4.1.1 Accuracy

The navigation performance of aircraft approved for Basic RNAV operations within European airspace requires a track keeping accuracy equal to or better than +/- 5 NM for 95% of the flight time. This value includes signal source error, airborne receiver error, display system error and flight technical error.

This navigation performance assumes the necessary coverage provided by satellite or ground based navigation aids is available for the intended route to be flown.

4.1.2 Availability and Integrity

Guidance for assessment of the effects associated with the loss of navigation function or erroneous display of related information is given in AMJ 25-11 paragraph 4 a (3)(viii).

The minimum level of availability and integrity required for Basic RNAV systems for use in designated European airspace can be met by a single installed system comprising one or more sensors, RNAV computer, control display unit and navigation display(s) (e.g. ND, HSI or CDI) provided that the system is monitored by the flight crew and that in the event of a system failure the aircraft retains the capability to navigate relative to ground based navigation aids (e.g. VOR, DME and NDB).

4.2 Functional Criteria

4.2.1 Required Functions

The following system functions are the minimum required to conduct Basic RNAV operations.

(a) Continuous indication of aircraft position relative to track to be displayed to the pilot flying on a navigation display situated in his primary field of view

In addition where the minimum flight crew is two pilots, indication of aircraft position relative to track to be displayed to the pilot not flying on a navigation display situated in his primary field of view

(b) Display of distance and bearing to the active (To) waypoint

(c) Display of ground speed or time to the active (To) waypoint

(d) Storage of waypoints; minimum of 4

(e) Appropriate failure indication of the RNAV system, including the sensors.

4.2.2 Recommended Functions

In addition to the requirements of paragraph 4.2.1, the following system functions and equipment characteristics are recommended:

(a) Autopilot and/or Flight Director coupling

(b) Present position in terms of latitude and longitude

(c) "Direct To" function

(d) Indication of navigation accuracy (e.g. quality factor)

(e) Automatic channel selection of radio navigation aids

(f) Navigation data base

(g) Automatic leg sequencing and associated turn anticipation

4.3 Aircraft Flight Manual - MMEL (Master Minimum Equipment List)

The basis for certification should be stated in the Aircraft Flight Manual (AFM), together with any RNAV system limitations. The AFM may also provide the appropriate RNAV system operating and abnormal procedures applicable to the equipment installed, including, where applicable, reference to required modes and systems configuration necessary to support an RNP capability.

The (Master) Minimum Equipment List MMEL/MEL should identify the minimum equipment necessary to satisfy the Basic RNAV criteria defined in paragraphs 4.1 and 4.2.

4.4. Basic RNAV Systems - Acceptable Means Of Compliance

4.4.1 Acceptable Means of Compliance

Navigation systems which are installed on aircraft in accordance with the advisory material contained within FAA AC 90-45A, AC 20-130(), AC 20-138 or AC 25-15, are acceptable for Basic RNAV operations. Where reference is made in the AFM to either the above advisory material or the specific levels of available navigation performance (RNP), no further compliance statements will be required.

Compliance may be based also on the lateral navigation standards defined in JTSO-2C115, TSO-C115(), TSO-C129(), ED-27/28, ED-39/40, DO-187/ED-58 or DO-180(). However, qualification of the equipment to these standards, in itself, is not considered as sufficient for the airworthiness approval.

4.4.2 Limitations on the Use of Navigation Systems

The following navigation systems, although offering an RNAV capability, have limitations for their use in Basic RNAV operations.

4.4.2.1 INS

INS without a function for automatic radio updating of aircraft position and approved in accordance with AC 25-4, when complying with the functional criteria of paragraph 4.2.1, may be used only for a maximum of 2 hours from the last alignment/position update performed on the ground. Consideration may be given to specific INS configurations (e.g. triple mix) where either equipment or aircraft manufacturer's data, justifies extended use from the last on-ground position update.

INS with automatic radio updating of aircraft position, including those systems where manual selection of radio channels is performed in accordance with flight crew procedures, should be approved in accordance with AC 90-45A or equivalent material.

4.4.2.2 LORAN C

No JAA advisory material currently exists for operational or airworthiness approval of LORAN C system within European airspace. Where LORAN C coverage within European Airspace permits use on certain Basic RNAV routes, AC 20-121A may be adopted as a compliance basis.

4.4.2.3 GPS

The use of GPS to perform Basic RNAV operations is limited to equipment approved to TSO-C129 () and which include the minimum system functions specified in paragraph 4.2.1. Integrity should be provided by Receiver Autonomous Integrity Monitoring (RAIM) or an equivalent means within a multi-sensor navigation system. The equipment should be approved in accordance with the JAA TGL No. 3. In addition, GPS stand-alone equipment should include the following functions:

(a) Pseudorange step detection

(b) Health word checking.

These two additional functions are required to be implemented in accordance with FAA TSO-C129a criteria.

Traditional navigation equipment (e.g. VOR, DME and ADF) will need to be installed and be serviceable, so as to provide an alternative means of navigation.

Note: Where GPS stand-alone equipment provides the only RNAV capability installed onboard the aircraft, this equipment, on its own, may be incompatible with a future airspace infrastructure such as Precision RNAV routes, terminal procedures, and where implementation of an augmented satellite navigation system will allow, the decommissioning of traditional ground based radio navigation aids.

5. OPERATIONAL CRITERIA FOR USE OF GPS STAND-ALONE EQUIPMENT

5.1 General Criteria

GPS stand-alone equipment approved in accordance with the guidance provided in this Leaflet, may be used for the purposes of conducting Basic RNAV operations, subject to the operational limitations contained herein. Such equipment should be operated in accordance with procedures acceptable to the Authority. The flight crew should receive appropriate training for use of the GPS stand-alone equipment for the normal and abnormal operating procedures detailed in paragraphs 5.2 and 5.3.

5.2 Normal Procedures

The procedures for the use of navigational equipment on Basic RNAV routes should include the following:

(a) During the pre-flight planning phase, given a GPS constellation of 23 satellites or less (22 or less for GPS stand-alone equipment that incorporate pressure altitude aiding), the availability of GPS integrity (RAIM) should be confirmed for the intended flight (route and time). This should be obtained from a prediction program either ground-based, or provided as an equipment function (see Annex 1), or from an alternative method that is acceptable to the Authority.
Dispatch should not be made in the event of predicted continuous loss of RAIM of more than 5 minutes for any part of the intended flight.

(b) Where a navigation data base is installed, the data base validity (current AIRAC cycle) should be checked before the flight;

(c) Traditional navigation equipment (e.g. VOR, DME and ADF) should be selected to available aids so as to allow immediate cross-checking or reversion in the event of loss of GPS navigation capability.

5.3 Abnormal Procedures in the event of loss of GPS navigation capability

The operating procedures should identify the flight crew actions required in the event of the GPS stand-alone equipment indicating a loss of the integrity monitoring detection (RAIM) function or exceedance of integrity alarm limit (erroneous position). The operating procedures should include the following:

(a) In the event of loss of the RAIM detection function, the GPS stand-alone equipment may continue to be used for navigation. The flight crew should attempt to cross-check the aircraft position, where possible with VOR, DME and NDB information, to confirm an acceptable level of navigation performance. Otherwise, the flight crew should revert to an alternative means of navigation.

(b) In the event of exceedance of the alarm limit, the flight crew should revert to an alternative means of navigation.

ANNEX 1

GPS Integrity Monitoring (RAIM) Prediction Program

Where a GPS Integrity Monitoring (RAIM) Prediction Program is used as a means of compliance with paragraph 5.2(a) of this document, it should meet the following criteria:

1. The program should provide prediction of availability of the integrity monitoring (RAIM) function of the GPS equipment, suitable for conducting Basic RNAV operations in designated European airspace.

2. The prediction program software should be developed in accordance with at least RTCA DO 178B/EUROCAE 12B, level D guidelines.

3. The program should use either a RAIM algorithm identical to that used in the airborne equipment, or an algorithm based on assumptions for RAIM prediction that give a more conservative result.

4. The program should calculate RAIM availability based on a satellite mask angle of not less than 5 degrees, except where use of a lower mask angle has been demonstrated to be acceptable to the Authority.

5. The program should have the capability to manually designate GPS satellites which have been notified as being out of service for the intended flight.

6. The program should allow the user to select:

   a) the intended route and declared alternates

   b) the time and duration of the intended flight

ANNEX 5.2

JAA TGL10

LEAFLET NO 10: AIRWORTHINESS AND OPERATIONAL APPROVAL FOR PRECISION RNAV OPERATIONS IN DESIGNATED EUROPEAN AIRSPACE

This leaflet provides guidance material for the approval of aircraft and operations in the European region where Precision Area Navigation (P-RNAV) is required. It relates to the implementation of area navigation within the context of the European Air Traffic Management Programme (EATMP) and should be read in conjunction with EUROCONTROL document 003-93(), Area Navigation Equipment: Operational Requirements and Functional Requirements.

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PREAMBLE

As a further development of the concept of area navigation within the European region, Precision Area Navigation (P-RNAV) is to be implemented in terminal airspace as an interim step to obtain increased operating capacity together with environmental benefits arising from route flexibility.

In accordance with the EUROCONTROL Navigation Strategy, the carriage of RNAV equipment capable of precision navigation will be optional enabling the initial application of P-RNAV in terminal airspace for suitably equipped aircraft. The P-RNAV application addresses a navigation performance for track keeping accuracy but does not satisfy all aspects of the Required Navigation Performance (RNP) concept promulgated by ICAO in documents 9613 and 9650. P-RNAV is expected to be progressively replaced by RNP-RNAV operations from about 2005.

This leaflet provides guidance material for the airworthiness approval of area navigation systems and their use for P-RNAV operations. The guidance is consistent with EUROCONTROL publications dealing with related operational and functional requirements, and with the design of terminal airspace procedures for DME/DME and GNSS based area navigation.

1 PURPOSE

The guidance material of this leaflet does not constitute a regulation but, when followed in its entirety, does establish an acceptable means that can be used to obtain airworthiness approval of a P-RNAV system, and to obtain the necessary operational approval for its use in designated European airspace. An applicant may elect to use an alternative means of compliance. However, that means of compliance must meet the objectives of this leaflet and be acceptable to the responsible authority. Compliance with this leaflet is not mandatory hence use of the terms *shall* and *must* apply only to an applicant who elects to comply with this leaflet as the means to obtain airworthiness and operational approval.

This leaflet may be amended periodically and will be replaced in due course by appropriate JAR Requirements, Advisory or Interpretative and Explanatory Material.

2 SCOPE

2.1 The guidance material includes airworthiness and operational approval criteria related to P-RNAV systems intended to be used under Instrument Flight Rules, including Instrument Meteorological Conditions, in designated European airspace. It addresses general certification considerations including functional requirements, accuracy, integrity, continuity of function, and system limitations together with operational considerations.

2.2 The guidance material is applicable to P-RNAV operations in terminal airspace and, where implemented by states, to en-route navigation. For the purposes of this leaflet, P-RNAV procedures are expected to apply to operations including departures, arrivals, and approaches up to the point of the Final Approach Waypoint (FAWP). For the immediate future, holding patterns are expected to be flown with conventional procedures. For P-RNAV operations in terminal airspace, obstacle clearance protection, up to the FAWP, will assume that aircraft comply with the P-RNAV accuracy requirements. It should be noted, however, that the navigational accuracy required for the final flight phase of the intermediate segment will be influenced by the transition to, and requirements of the subsequent flight phase.

2.3 The final approach, i.e. from the FAWP down to the runway threshold, together with the associated missed approach, will be addressed in a future leaflet. Similarly, a future leaflet will address the application of the concepts of RNP-RNAV.

2.4 The P-RNAV application addresses a navigation performance for track keeping accuracy but does not satisfy all aspects of the Required Navigation Performance concept promulgated by ICAO in documents 9613 and 9650.

2.5 This leaflet discusses operational aspects of vertical navigation but does not give certification criteria for such systems as vertical navigation capability is not mandated for P-RNAV.

2.6 Section 3.2 of this leaflet refers to documents which contribute to the understanding of the P-RNAV concept and which may support an application for approval. However, it is important that an applicant evaluates his aircraft system and proposed operational procedures against the criteria of this leaflet. Unless stated to the contrary in this leaflet, systems and procedures previously approved as compliant with earlier area navigation guidance material will need to be re-evaluated to identify where additional approval effort , if any, is needed.

2.7 Compliance with this leaflet provides a basis for, but by itself does not constitute, an operational approval to conduct P-RNAV operations. Aircraft operators should apply to their national authority for such an approval.

2.8 A glossary of terms and acronyms used in this leaflet is given in Annex A.

3 REFERENCE DOCUMENTS

3.1 Related Requirements

JAR/FAR 25.1301, 25.1307, 25.1309, 25.1316, 25.1321, 25.1322, 25.1329, 25.1431, 25.1335 25.1581.
JAR/FAR 23.1301, 23.1309, 23.1311, 23.1321, 23.1322, 23.1329, 23.1335, 23.1431, 23.1581.
JAR/FAR 27.1301, 27.1309, 27.1321, 27.1322, 27.1329, 27.1335, 27.1581.
JAR/FAR 29.1301, 29.1309, 29.1321, 29.1322, 29.1329, 29.1335, 29.1431, 29.1581.
Appendices A to JAR 27 and JAR 29: Instructions for Continued Airworthiness.
JAR-OPS 1.243, 1.420, 1.845, 1.865, as amended by NPA-OPS-7 and NPA -OPS - 15.
JAR-OPS 3.243, 3.845, 3.865 as amended by NPA-OPS-8.
National operating regulations.

3.2 Related Guidance Material

3.2.1 ICAO

Doc 8168-OPS/611	Aircraft Operations (PANS OPS).

3.2.2 JAA

AMJ 25-11	Electronic Display Systems.
JAA Leaflet No 2 Rev 1	JAA Guidance Material on Airworthiness Approval and Operational Criteria for the use of Navigation Systems in European Airspace Designated for Basic RNAV Operations.
JAA Leaflet No 3 Rev 1	Interim Guidance Material on Airworthiness Approval and Operational Criteria for the use of the Navstar Global Positioning System (GPS).
JAA Leaflet No 9	Recognition of EUROCAE Document ED-76 (RTCA DO-200A): Standards for Processing Aeronautical Data.

3.2.3 EUROCONTROL

NAV.ET1.ST16-001 ()	Navigation Strategy for ECAC.
NAV.ET1.ST10 ()	Guidance Material for the Design of Terminal Procedures for DME/DME and GNSS Area Navigation.
Document 003-93 ()	Area Navigation Equipment: Operational Requirements and Functional Requirements.

3.2.4 FAA

AC 25-11	Electronic Display Systems.
AC 90-45A	Approval of Area Navigation Systems for Use in US. National Airspace System.
AC 20-130()	Airworthiness Approval of Navigation or Flight Management Systems Integrating Multiple Navigation Sensors.
AC 20-138	Airworthiness Approval of NAVSTAR Global Positioning System (GPS) for use as a VFR and IFR Supplemental Navigation System.
AC 25-4	Inertial Navigation Systems (INS).
AC 25-15	Approval of Flight Management Systems in Transport Category Airplanes.
AC 90-94	Guidelines for Using GPS Equipment for IFR En-route & Terminal Operations & for Non Precision Instrument Approaches.

3.2.5 Technical Standard Orders

JTSO-2C115() / TSO-C115()	Airborne Area Navigation Equipment Using Multi-sensor Inputs.
JTSO-C129a / TSO-C129a	Airborne Supplemental Navigation Equipment Using the Global Positioning System (GPS)
FAA TSO-C145	Airborne Navigation Sensors Using the Global Positioning System (GPS) Augmented by the Wide Area Augmentation System (WAAS).
FAA TSO-C146	Stand-Alone Airborne Navigation Equipment Using the Global Positioning System (GPS) Augmented by the Wide Area Augmentation System (WAAS).

3.2.6 EUROCAE / RTCA and ARINC

ED-75A / DO-236A	Minimum Aviation System Performance Standards: Required Navigation Performance for Area Navigation.
ED-76 / DO-200A	Standards for Processing Aeronautical Data.
ED-77 / DO-201A	Standards for Aeronautical Information.
DO-229B	Minimum Operational Performance Standards for Global Positioning System/Wide Area Augmentation System Airborne equipment.
ARINC 424	Navigation System Data Base.

4 ASSUMPTIONS

Applicants should note that this guidance material is based on the following assumptions concerning the measures taken by the responsible airspace authorities to safeguard P-RNAV operations in the European region:

(a) All terminal P-RNAV procedures:

(1) are consistent with the relevant parts of ICAO Doc 8168 PANS OPS ;

(2) are designed following the guidelines of EUROCONTROL document NAV.ET1.ST10 ‘Guidance Material for the Design of Procedures for DME/DME and GNSS Area Navigation’, as amended, or equivalent material;

(3) take account of the functional and performance capabilities of RNAV systems and their safety levels as detailed in this leaflet;

Note: Particular attention should be given to the constraints implied by the certification objectives of paragraph 6.

(4) take account of the lack of a mandate for vertical navigation by ensuring that traditional means of vertical navigation can continue to be used; and

(5) support integrity checking by the flight crew by including, on the charts, fix data (e.g. range and bearing to navigational aids) from selected waypoints.

(b) All routes/procedures are based upon WGS 84 co-ordinates.

(c) The design of a procedure and the supporting navigation infrastructure (including consideration for the need of redundant aids) have been assessed and validated to the satisfaction of the responsible airspace authority demonstrating aircraft compatibility and adequate performance for the entire procedure. This assessment includes flight checking where appropriate.

(d) If the procedure allows a choice of navigation infrastructure, e.g. DME/DME, VOR/DME or GNSS, the obstacle clearance assessment has been based upon the infrastructure giving the poorest precision.

(e) The required navigation aids critical to the operation of a specific procedure, if any, i.e. those which must be available for the required performance, are identified in the AIP and on the relevant charts. Navigation aids that must be excluded from the operation of a specific procedure, if any, are identified in the AIP and on the relevant charts.
Note: This may include required VOR/DME beacons.

(f) Barometric altitude compensation for temperature effects is accounted for in accordance with current approved operating practices. (Temperature compensation is not addressed as a special P-RNAV consideration in this leaflet).

(g) The supporting navigation infrastructure, including the GNSS space segment, is monitored and maintained and timely warnings (NOTAM) are issued for non-availability of a P-RNAV procedure, if navigational aids, identified in the AIP as critical for a specific P-RNAV procedure, are not available.

(h) For procedures which allow aircraft to rely only on GNSS, (see paragraph 5.1), the acceptability of the risk of loss of P-RNAV capability for multiple aircraft due to satellite failure or RAIM holes, has been considered by the responsible airspace authority. Similarly, the risk is considered where a single DME supports multiple P-RNAV procedures.

(i) The particular hazards of a terminal area and the feasibility of contingency procedures following loss of P-RNAV capability are assessed and, where considered necessary, a requirement for the carriage of dual P-RNAV systems is identified in the AIP for specific terminal P-RNAV procedures, e.g. procedures effective below the applicable minimum obstacle clearance altitude, or where radar performance is inadequate for the purposes of supporting P-RNAV.
Note: Airspace authorities may need to amend their national legal code to establish the power to require that P-RNAV or dual P-RNAV systems be carried in airspace notified for the purposes of these requirements.

(j) Where reliance is placed on the use of radar to assist contingency procedures, its performance has been shown to be adequate for that purpose, and the requirement for a radar service is identified in the AIP.

(k) RT phraseology appropriate to P-RNAV operations has been promulgated.

(l) Navigation aids, including TACAN, not compliant with ICAO Annex 10, are excluded from the AIP.

5 SYSTEM DESCRIPTION

5.1 Lateral Navigation

5.1.1 For lateral navigation, the RNAV equipment enables the aircraft to be navigated in accordance with appropriate routing instructions along a path defined by waypoints held in an on-board navigation database.

5.1.2 For the purposes of this leaflet, P-RNAV operations are based upon the use of RNAV equipment that automatically determines aircraft position in the horizontal plane using inputs from the following types of positioning sensor (in no specific order of priority):

(a) Distance Measuring Equipment giving measurements from two or more ground stations (DME/DME).
(b) Very high frequency Omni-directional Radio range with a co-located DME (VOR/DME) where it is identified as meeting the requirements of the procedure.
(c) Global Navigation Satellite System (GNSS).
(d) Inertial Navigation System (INS) or Inertial Reference System (IRS), with automatic updating from suitable radio based navigation equipment.

Notes: (1) LORAN-C is not an acceptable navigation sensor for terminal airspace operations.
(2) TACAN beacons may be included in the on-board navigation database and used to supplement DME provided they meet ICAO Annex 10 Standards and are listed in the AIP.
(3) The term GNSS refers to the US Department of Defence Global Positioning System (GPS) with barometric altitude augmentation and Receiver Autonomous Integrity Monitoring (RAIM), or to a GPS with Aircraft Based Augmentation System (ABAS), or Space Based Augmentation System (SBAS), e.g. EGNOS. See also JAA TGL 3 rev 1, Appendix A, paragraphs 2.4 and 2.5.
(4) Limitations for the use of inertial data, as the means of determining aircraft position during short periods of loss of radio updating, are discussed in further detail in paragraph 8.4.

5.1.3 Navigation parameters, such as distance and bearing to a waypoint, are computed from the aircraft position and the location of the waypoint. Guidance, referenced to the path between two waypoints, is then output to navigation displays and guidance systems to enable the desired path to be followed.

5.2 Vertical Navigation

Although this leaflet does not set criteria for the approval of vertical navigation systems, a brief description is included in Annex D to aid understanding of the overall navigation function and the relationship of VNAV to this guidance material.

6 AIRWORTHINESS CERTIFICATION OBJECTIVES FOR P-RNAV SYSTEMS

The following performance certification criteria are defined for the airborne systems on the basis that the *Assumptions* of Section 4 are valid.

6.1 Accuracy

During operations on routes or in areas notified exclusively for P-RNAV equipped aircraft, the lateral track keeping accuracy of the on-board P-RNAV system shall be equal to or better than +/- 1 NM for 95% of the flight time.

Notes: (1) The track keeping accuracy is dependent on the navigation system error (a combination of path definition error, position estimation error and display error) and Flight Technical Error (FTE). It corresponds to the accuracy component of RNP-1 and RNP-1 RNAV. Further explanation may be found in documents ED-75A / DO-236A.

(2) For the purposes of obstacle clearance, a FTE of ± 0.5NM is assumed for the departure (except at the departure end of the runway where, in accordance with PANS-OPS Doc 8168, Volume II, Part II, 7.3.2 and 8.1, a value of ±0.1NM is assumed), ±1NM for the initial and intermediate segments, and 2NM for en-route.

(3) The objective behind this chosen level of performance is to enable RNAV systems based on DME/DME, as currently installed in many aircraft, to be used in terminal airspace on P-RNAV procedures designed according to the published criteria without further evaluation of system accuracy.

(4) Provided that the assumption of paragraph 4(c) has been shown to be valid in respect of typical DME performance, then, for RNAV systems that have been declared (e.g. in the Aircraft Flight Manual) to be compliant with the 2D navigation accuracy criteria of FAA AC 90-45A, AC 20-130(), FAA TSO-C115(), or JAA JTSO-2C115(), the intent of this paragraph is considered as satisfied and no further accuracy demonstration is required. However, such a Flight Manual statement, by itself, does not constitute an airworthiness approval for P-RNAV and compliance with all other criteria of this leaflet will need to be shown.

6.2 Integrity

With respect to the airborne system, the probability of displaying hazardously misleading navigational or positional information simultaneously to both pilots shall be Remote.

Notes:

(1) In the context of P-RNAV operations in the terminal area, *hazardous* should be interpreted as involving misleading information without a timely warning and which, in the absence of other cues, is unlikely to be detected by the flight crew.

(2) An airborne safety objective of *Remote* is an alleviation to the current guidelines of paragraph 4.a.(3)(viii) of AMJ 25-11, which specifies *Extremely Remote* for the departure, arrival and approach phases of flight. This alleviation recognises that the PANS-OPS procedure design, and PANS-RAC air traffic separation criteria, account for and accommodate these type of aircraft and their system integrity in current airspace. Furthermore, conservative safety margins are used in the design of P-RNAV procedures such that the risks are not increased above those currently experienced.

(3) A safety objective of *Extremely Remote* will continue to be applicable to a precision approach on the final segment i.e. from the FAWP down to the runway.

(4) Systems approved for RNP operations have capabilities exceeding that required for P-RNAV operations. These systems provide higher navigation integrity through implementation of containment and by giving the flight crew better awareness of accuracy through the availability of estimated position uncertainty.

(5) Probability terms are defined in JAA AMJ 25.1309.

6.3 Continuity of Function

With respect to the airborne systems, it shall be shown that:

(a) The probability of loss of all navigation information is Remote.

(b) The probability of non-restorable loss of all navigation and communication functions is Extremely Improbable.

Notes:

(1) In addition to the equipment required by JAR-OPS 1, Sub-part L for IFR flight (or equivalent national requirements), at least one area navigation system is required.

(2) Probability terms are defined in JAA AMJ 25.1309.

7 FUNCTIONAL CRITERIA

7.1 Required Functions

Table 1 lists and describes the minimum system functions required for P-RNAV operations.

Item	Functional Description

Item	Functional Description
1	Display elements, e.g. CDI, (E)HSI, each with a lateral deviation display, To/From flag, and failure indicator, for use as primary flight instruments for navigation of the aircraft, for manoeuvre anticipation, and for failure/status/integrity indication, visible to the pilot and located in the primary field of view when looking forward along the flight path. The course selector of the deviation display shall be automatically slaved to the RNAV computed path. The deviation display shall have a full-scale deflection suitable for the phase of flight and based on the required track keeping accuracy. Scaling may be set automatically by default logic or to a value obtained from a navigation database. The full-scale deflection value must be known or made available for display to the flight crew. For P-RNAV operations, a value of ±1 NM is acceptable. An acceptable alternative is a navigation map display, readily visible to the flight crew, with appropriate map scales and giving equivalent functionality to the lateral deviation display, except that scaling may be set manually by the pilot. Note: JAA JTSO-C129a, for GPS equipment, prescribes scaling values of 5.0 NM for en-route, 1.0 NM for terminal airspace, and 0.3 NM for a non-precision approach.
2	Capability to continuously display to the pilot flying, on the primary flight instruments for navigation of the aircraft, the RNAV computed desired path (DTK) and aircraft position relative to the path.
3	Where the minimum flight crew is two pilots, means for the pilot not flying to verify the desired path and the aircraft position relative to the path.
4	A navigation database, containing current navigation data officially promulgated for civil aviation, which can be updated in accordance with the AIRAC cycle and from which terminal airspace procedures can be retrieved and loaded into the RNAV system. The resolution to which the data is stored must be sufficient to achieve the required track keeping accuracy. The database must be protected against flight crew modification of the stored data. Note: When a procedure is loaded from the database, the RNAV system is required to fly it as published. This does not preclude the flight crew from having the means to modify a procedure or route already loaded into the RNAV system as permitted by Section 10. However, the procedure stored in the database must not be modified and must remain intact within the database for future use and reference.
5	Means to display the validity period of the navigation database to the flight crew.
6	Means to retrieve and display data stored in the navigation database relating to individual waypoints and navigation aids, to enable the flight crew to verify the procedure to be flown.
7	Capacity to load from the database into the RNAV system the whole terminal procedure(s) to be flown.
8	Display of the active navigation sensor type, either in the pilot's primary field of view, or on a readily accessible page on an MCDU together with a means of determining navigation system performance.
9	Display of the identification of the active (To) waypoint, either in the pilot's primary field of view, or on a readily accessible page on an MCDU, readily visible to the flight crew.
10	Display of distance and bearing to the active (To) waypoint in the pilot's primary field of view. Where impracticable, the data may be displayed on a readily accessible page on an MCDU, readily visible to the flight crew.
11	Display of ground speed or time to the active (To) waypoint, either in the pilot's primary field of view, or on a readily accessible page on a MCDU, readily visible to the flight crew.

Item	Functional Description
12	Where the MCDU is to be used to support the accuracy checks of Section 10, display of lateral deviation with a resolution of 0.1NM.
13	Automatic tuning of VOR and DME navigation aids used for position updating together with the capability to inhibit individual navigation aids from the automatic selection process. Note: Further guidance may be found in ED-75A/DO-236A, Section 3.7.3.1.
14	Capability for the P-RNAV system to perform automatic selection (or de-selection) of navigation sources, a reasonableness check, an integrity check, and a manual override or deselect. Further guidance may be found in ED-75A/DO-236A, Section 3.7.3.1.
15	Capability for the “Direct to” function.
16	Capability for automatic leg sequencing with display of sequencing to the flight crew.
17	Capability to execute database procedures including fly-over and fly-by turns.
18	Capability to execute leg transitions and maintain tracks consistent with the following ARINC 424 path terminators, or their equivalent: Initial Fix (IF), Track between Two Fixes (TF), Course to a Fix (CF) Course from a Fix to an Altitude (FA), Direct to a Fix (DF) Note: Path terminators are defined in ARINC Specification 424, and their application is described in more detail in documents EUROCAE ED-75A/ RTCA DO-236A, ED-77/ DO-201A, and EUROCONTROL document NAV.ET1.ST10.
19	Indication of the RNAV system failure, including the associated sensors, in the pilot’s primary field of view.
20	For multi-sensor systems, automatic reversion to an alternate RNAV sensor if the primary RNAV sensor fails. Note: This does not preclude means for manual navigation source selection.
21	Alternative means of displaying navigation information, sufficient to perform the checking procedures of Section 10.

Table 1: Required Functions

7.2 Recommended Functions

Table 2 lists and describes system functions recommended for P-RNAV operations.

Item	Functional Description

Item	Functional Description
1	Capability to fly a path parallel to, but offset left or right from, the original active route. The system should provide for entry of an offset distance of at least 20 NM in increments of 1 NM. Operation in offset mode should be clearly indicated to the flight crew. When in offset mode, the system should provide reference parameters (e.g. cross-track deviation, distance-to-go) relative to the offset path and offset reference points. An offset should not be propagated through route discontinuities, unreasonable path geometry, or beyond the initial approach waypoint. Prior to the end of the offset path, indication should be provided to the flight crew, to allow sufficient time to return to the original active route. Once a parallel offset is activated, it should remain active for all route segments of the flight plan until either it is removed automatically, until the flight crew enter a Direct-To routing, or until flight crew (manual) cancellation. Note: The purpose of this function is to enable offsets for tactical operations authorised by ATC (e.g. weather avoidance). It is not intended to be used for strategic offsets which will be promulgated and coded in the navigation database as separate parallel routes.
2	Coupling to the flight director and /or automatic pilot from the RNAV system with unambiguous mode indication. (See also paragraph 8.1.1 (e)).
3	Capability for vertical navigation based upon barometric inputs. (See Annex D).
4	For an RNAV system using DME/DME updating, supported by IRS, means for automatic runway position update at the start of the take-off run including means to enter a distance offset for situations where the published threshold and the actual start of the take of run differ (i.e. take-off shift).
5	Display of the navigation mode in the pilot's primary field of view.
6	Capability to execute leg transitions and maintain tracks consistent with the following ARINC 424 path terminators, or equivalent: Holding Pattern to a Manual Termination (HM) Holding Pattern to an Altitude (HA) Holding Pattern to a Fix (HF) Constant Radius to a Fix (RF). Notes: (1) Path terminators are defined in ARINC Specification 424, and their application is described in more detail in documents EUROCAE ED-75A/ RTCA DO-236A, ED-77/ DO-201A, and EUROCONTROL document NAV.ET1.ST10. (2) The RF leg type is unique to RNP-RNAV systems whereas the other types may exist in non-RNP systems.

Table 2: Recommended Functions

8 ACCEPTABLE MEANS OF AIRWORTHINESS COMPLIANCE

8.1 General

Where practicable, to get a concurrent process that ensures the operational evaluation rationale is based on the certification rationale for the particular equipment installation, the airworthiness assessment of this Section should be performed in conjunction with the operational evaluation of Section 10, taking account of the proposed normal and contingency procedures. The following compliance guidelines assume that the aircraft is equipped in accordance with JAR-OPS 1 Sub-part L for IFR flight, or equivalent national requirements.

8.1.1 New or Modified Installations

In demonstrating compliance with this leaflet, the following specific points should be noted:

(a) The applicant will need to submit, to the responsible authority, a compliance statement which shows how the criteria of this leaflet have been satisfied. The statement should be based on a plan, agreed by the responsible authority at an early stage of the implementation programme. The plan should identify the certification data to be submitted which should include, as appropriate, a system description together with evidence resulting from the activities defined in the following paragraphs.

(b) Compliance with the airworthiness requirements for intended function and safety may be demonstrated by equipment qualification, system safety analysis, confirmation of appropriate software design assurance level (i.e. consistent with paragraph 6.2), performance analyses, and a combination of ground and flight tests. To support the approval application, design data will need to be submitted showing that the objectives and criteria of Sections 6 and 7 of this leaflet have been satisfied.

(c) Use of the RNAV systems and the manner of presentation of lateral and vertical guidance information on the flight deck must be evaluated to show that the risk of flight crew error has been minimised. In particular, during the transition to the final approach, the display of ILS information simultaneously with RNAV information to a flight crew member will need careful consideration.

(d) Equipment failure scenarios involving conventional navigation sensors and the RNAV system(s) must be evaluated to demonstrate that adequate alternative means of navigation are available following failure of the RNAV system, and that reversionary switching arrangements, e.g. VOR#2 on HSI#1, do not lead to misleading or unsafe display configurations. The evaluation must consider also the probability of failures within the switching arrangements

(e) The coupling arrangements for the RNAV system to flight director/automatic pilot must be evaluated to show compatibility and that operating modes, including RNAV system failures modes, are clearly and unambiguously indicated to the flight crew.

(f) To comply with Section 7, Table 1, item 18, and Table 7.2, item 6 (if applicable), the execution of all leg types (in particular when intercepting a CF leg) must be shown to be possible without the need for manual intervention, i.e. without disengaging the RNAV mode, and then a manual course selection. This does not preclude means for manual intervention when needed.

8.1.2 Existing Installations

The applicant will need to submit, to the responsible authority, a compliance statement which shows how the criteria of this leaflet have been satisfied for existing installations. Compliance may be established by inspection of the installed system to confirm the availability of required features and functionality. The performance and integrity criteria of Section 6 may be confirmed by reference to statements in the Aircraft Flight Manual or to other applicable approvals and supporting certification data. In the absence of such evidence, supplementary analyses and/or tests may be required. Paragraph 9.3 addresses Aircraft Flight Manual changes that might be necessary.

8.2 Database Integrity

The navigation database updating process shall comply with EUROCAE ED-76 / RTCA DO--200A, or equivalent approved procedures (see paragraph10.6).

8.3 Use of GPS Equipment

8.3.1 The use of GPS to perform P-RNAV operations is limited to equipment approved under FAA TSO-C145 and TSO-146, and JTSO-C129a/ TSO-C129 (), in the equipment classes: A1, B1, C1, B3 and C3, and which support the minimum required system functions specified in Section 7, Table 1 of this leaflet. Receiver Autonomous Integrity Monitoring (RAIM), or an equivalent means of integrity monitoring as part of a multi-sensor navigation system, must be provided.

8.3.2 To complete the compliance statement of paragraph 8.1.1(a) for JTSO-C129a/TSO-C129() equipment, the criteria of JAA Guidance Leaflet No.3, revision 1, paragraph 5.4, needs to be taken into consideration when stand-alone GPS equipment is the only installed means of meeting the P-RNAV criteria.

8.3.3 GPS with the capability for satellite Fault Detection and Exclusion (FDE) is recommended to improve Continuity of Function.

8.4 Use of Inertial Data

In the event of unavailability or loss of radio sensor derived automatic position updating, it is permissible to use, for a short period of time, data from an inertial system as the only means of positioning. For such operations, in the absence of a position integrity indication, the applicant must establish how long the aircraft can maintain the required accuracy using only inertial data. Both take-off and terminal area operations will need to be considered and may need to be addressed in the contingency procedures. The limits may be based on an acceptable drift rate model as agreed by the responsible aircraft operations authority .

8.5 Intermixing of Equipment

Installation of area navigation systems with different crew interfaces can be very confusing and can lead to problems when they have conflicting methods of operation and conflicting display formats. There can be problems even when intermixing different versions of the same equipment. For approach operations, intermixing of RNAV equipment is not permitted. As a minimum, consideration must be given to the following potential incompatibilities particularly where the flight deck architecture includes cross coupling capabilities (e.g. GNSS-2 switched to drive the number 1 displays).

(a) Data entry: The two systems must have consistent methods of data entry, and similar pilot procedures for accomplishing common tasks. Any differences should be evaluated for pilot workload. If the wrong procedures are used, (for example, the data entry procedures for the offside system are used by mistake for the onside), there must be no misleading information and it must be easy to identify and recover from the mistake.

(b) CDI scaling: Sensitivity must be consistent or annunciated.

(c) Display symbology and mode annunciation: There must be no conflicting symbols or annunciation (e.g., a common symbol used for two different purposes), and differences should be specifically evaluated to evaluate the potential confusion they may cause.

(d) Mode logic: The modes internal to the equipment and their interface to the rest of the aircraft must be consistent.

(e) Equipment failure: The effect of failure of one unit must not result in misleading information.

(f) Displayed data: The display of primary navigation parameters must use consistent units and a consistent notation. Any inconsistency in the display of the primary information will not be approved.

(g) Database differences: Due to the inherent data conflict, differences in the area navigation database will not be permitted.

9 AIRCRAFT FLIGHT MANUAL

9.1 For new or modified aircraft, the Aircraft Flight Manual (AFM) or the Pilot's Operating Handbook (POH), whichever is applicable, should provide at least the following information. This limited set assumes that a detailed description of the installed system and related operating instructions and procedures are available in other approved operating or training manuals.

(a) A statement which identifies the equipment and aircraft build or modification standard certificated for P-RNAV operations or having RNP-1 or better capability.

9.2 In the absence of suitable material in other approved operating or training manuals, appropriate amendments or supplements to cover P-RNAV operations will need to be provided for the following sections of the Flight Manual, or the Pilot's Operating Handbook, whichever is applicable:

- Limitations
- Normal Procedures
- Abnormal Procedures
- Emergency Procedures
- Performance

9.3 For existing aircraft already equipped with an RNAV system but where the Flight Manual or Pilot's Operating Handbook does not define, or is unclear about, the system capability, the aircraft operator may adopt, as an alternative to Change Sheets or Supplements produced by the aircraft constructor, one of the following options, subject to agreement of the responsible authority:

(a) Submit a compliance statement as discussed in 8.1.2 together with a proposed Supplement, devised by the operator, in accordance with the guidelines of 9.1, and in a format using the template given in Annex E; or

(b) Submit a compliance statement as discussed in 8.1.2 together with a proposed Operational Specification that includes information equivalent to that normally contained in a Flight Manual.

9.4 Systems approved for RNP operations have capabilities exceeding that required for P-RNAV operations. These systems provide higher navigation integrity through implementation of containment integrity and by giving the flight crew better awareness of accuracy through the availability of estimated position uncertainty. Therefore, reference in the AFM to specific RNP(s) of the system may then be used in determining compatibility of the RNAV capability with the performance required for specific flight operations.

10 OPERATIONAL CRITERIA

10.1 General

10.1.1 An operational evaluation based on the criteria /rationale of paragraphs 8.1.1(c) to (f), or paragraph 8.1.2, as applicable, will need to be made to confirm the adequacy of the operator's normal and contingency procedures for the particular equipment installation.

10.1.2 The following guidelines may be used by the operator to develop operating procedures that are appropriate to the aircraft installation and to the environment within which the aircraft will be operated. It should be noted that airworthiness approval alone does not authorise flight in airspace, along routes, or for terminal area procedures for which P-RNAV approval is required. Operational approval will be stated in the applicable Air Operator Certificate, or issued in accordance with national procedures, as appropriate.

10.2 Normal Procedures

10.2.1 Pre-flight Planning

10.2.1.1 During the pre-flight planning phase, the availability of the navigation infrastructure, required for the intended operation, including any non-RNAV contingencies, must be confirmed for the period of intended operation. Availability of the onboard navigation equipment necessary for the route to be flown must be confirmed. The onboard navigation database must be appropriate for the region of intended operation and must include the navigation aids, waypoints, and coded terminal airspace procedures for the departure, arrival and alternate airfields.

10.2.1.2 Where the responsible airspace authority has specified in the AIP that dual P-RNAV systems are required for specific terminal P-RNAV procedure, the availability of dual P-RNAV systems must be confirmed. This typically will apply where procedures are effective below the applicable minimum obstacle clearance altitude or where radar coverage is inadequate for the purposes of supporting P-RNAV. This will also take into account the particular hazards of a terminal area and the feasibility of contingency procedures following loss of P-RNAV capability.

10.2.1.3 If a stand-alone GPS is to be used for P-RNAV, the availability of RAIM must be confirmed with account taken of the latest information from the US Coastguard giving details of satellite non-availability.
Note: RAIM prediction may be a function of the equipment provided that satellite non-availability data can be entered. In the absence of such a function, an airspace service provider may offer an approved RAIM availability service to users.

10.2.2 Departure

10.2.2.1 At system initialisation, the flight crew must confirm that the navigation database is current and verify that the aircraft position has been entered correctly. The active flight plan should be checked by comparing the charts, SID or other applicable documents, with the map display (if applicable) and the MCDU. This includes confirmation of the waypoint sequence, reasonableness of track angles and distances, any altitude or speed constraints, and, where possible, which waypoints are fly-by and which are fly-over. If required by a procedure, a check will need to be made to confirm that updating will use a specific navigation aid(s), or to confirm exclusion of a specific navigation aid. A procedure shall not be used if doubt exists as to the validity of the procedure in the navigation database

Note: As a minimum, the departure checks could be a simple inspection of a suitable map display that achieves the objectives of this paragraph.

10.2.2.2 The creation of new waypoints by manual entry into the RNAV system by the flight crew is not permitted as it would invalidate the affected P-RNAV procedure. Route modifications in the terminal area may take the form of radar headings or 'direct to' clearances and the flight crew must be capable of reacting in a timely fashion. This may include the insertion in the flight plan of waypoints loaded from the database.

10.2.2.3 Prior to commencing take off, the flight crew must verify that the RNAV system is available and operating correctly and, where applicable, the correct airport and runway data have been loaded.

10.2.2.4 Unless automatic updating of the actual departure point is provided, the flight crew must ensure initialisation on the runway either by means of a manual runway threshold or intersection update, as applicable. This is to preclude any inappropriate or inadvertent position shift after take-off. Where GNSS is used, the signal must be acquired before the take-off roll commences and GNSS position may be used in place of the runway update.

10.2.2.5 During the procedure and where feasible, flight progress should be monitored for navigational reasonableness, by cross-checks, with conventional navigation aids using the primary displays in conjunction with the MCDU. Where applicable and when used, the flight crew procedures will need to include monitoring to verify automatic updating of the inertial systems to ensure the period without updating does not exceed the permitted limit. (See paragraph 8.4).

10.2.2.6 Where the initialisation of paragraph 10.2.2.4 is not achieved, the departure should be flown by conventional navigation means. A transition to the P-RNAV structure should be made at the point where the aircraft has entered DME/DME coverage and has had sufficient time to achieve an adequate input.

Note: If a procedure is designed to be started conventionally, then the latest point of transition to the P-RNAV structure will be marked on the charts. If a pilot elects to start a P-RNAV procedure using conventional methods, there will not be any indication on the charts of the transition point to the P-RNAV structure.

10.2.3 Arrival

10.2.3.1 Prior to the arrival phase, the flight crew should verify that the correct terminal procedure has been loaded. The active flight plan should be checked by comparing the charts with the map display (if applicable) and the MCDU. This includes confirmation of the waypoint sequence, reasonableness of track angles and distances, any altitude or speed constraints, and, where possible, which waypoints are fly-by and which are fly-over. If required by a procedure, a check will need to be made to confirm that updating will exclude a particular navigation aid. A procedure shall not be used if doubt exists as to the validity of the procedure in the navigation database.

Note: As a minimum, the arrival checks could be a simple inspection of a suitable map display that achieves the objectives of this paragraph.

10.2.3.2 The creation of new waypoints by manual entry into the RNAV system by the flight crew would invalidate the P-RNAV procedure and is not permitted.

10.2.3.3 Where the contingency to revert to a conventional arrival procedure is required, the flight crew must make the necessary preparation.

10.2.3.4 During the procedure and where feasible, flight progress should be monitored for navigational reasonableness by cross-checks with conventional navigation aids using the primary displays in conjunction with the MCDU. In particular, for a VOR/DME RNAV procedure, the reference VOR/DME used for the construction of the procedure must be displayed and checked by the flight crew. For RNAV systems without GNSS updating, a navigation reasonableness check is required during the descent phase before reaching the Initial Approach Waypoint (IAWP). For GNSS based systems, absence of an integrity alarm is considered sufficient. If the check fails, a conventional procedure must then be flown.

Notes:
(1) For example, where feasible, display bearing/range to a VOR/DME from the RNAV system and compare the result with the RMI read-out (selected to same VOR/DME).
(2) For some systems the accuracy may be derived from the navigation mode or accuracy mode.
(3) Where the MCDU shows only integers and is unable to display errors with sufficient resolution for P-RNAV accuracy checks, an alternative means of checking will need to be followed.

10.2.3.5 Route modifications in the terminal area may take the form of radar headings or 'direct to' clearances and the flight crew must be capable of reacting in a timely fashion. This may include the insertion of tactical waypoints loaded from the database. Manual entry or modification by the flight crew of the loaded procedure, using temporary waypoints or fixes not provided in the database, is not permitted.

10.2.3.6 Although a particular method is not mandated, any published altitude and speed constraints must be observed.

Note: Annex D provides further information on vertical navigation.

10.3 Contingency Procedures

10.3.1 Contingency procedures will need to be developed by the operator to address Cautions and Warnings for the following conditions:

(a) Failure of the RNAV system components including those affecting flight technical error (e.g. failures of the flight director or automatic pilot).
(b) Multiple system failures.
(c) Failure of the navigation sensors.
(d) Coasting on inertial sensors beyond a specified time limit.

10.3.2 The flight crew must notify ATC of any problem with the RNAV system that results in the loss of the required navigation capability, together with the proposed course of action.

10.3.3 In the event of communications failure, the flight crew should continue with the RNAV procedure in accordance with the published lost communication procedure.

10.3.4 In the event of loss of P-RNAV capability, the flight crew should invoke contingency procedures and navigate using an alternative means of navigation which may include the use of an inertial system. The alternative means need not be an RNAV system.

10.4 Incident Reporting

Significant incidents associated with the operation of the aircraft which affect or could affect the safety of RNAV operations, need to be reported in accordance with JAR-OPS 1.420. Specific examples may include:

(a) Aircraft system malfunctions during P-RNAV operations which lead to:
   - (i) Navigation errors (e.g. map shifts) not associated with transitions from an inertial navigation mode to radio navigation mode.
   - (ii) Significant navigation errors attributed to incorrect data or a navigation database coding error.
   - (iii) Unexpected deviations in lateral or vertical flight path not caused by pilot input.
   - (iv) Significant misleading information without a failure warning.
   - (v) Total loss or multiple navigation equipment failure.

(b) Problems with ground navigational facilities leading to significant navigation errors not associated with transitions from an inertial navigation mode to radio navigation mode.

10.5 Flight Crew Training

All flight crews must receive appropriate training, briefings and guidance material in the operation of RNAV-based departure and arrival procedures. This should cover the normal and contingency procedures identified in paragraphs 10.2 (Normal Procedures) and 10.3 (Contingency Procedures). Wherever practicable, standard training events (simulator checks/proficiency checks) should include departures and arrivals using the RNAV-based procedures. The operator must ensure that the Training Manual contains appropriate material to support P-RNAV operations. As a minimum, the items listed in Table 3 should be addressed in the Training Manual.

Subject
Theory of RNAV, including the differences between B-RNAV, P-RNAV and RNP-RNAV.
Limitations of RNAV
Charting, database and avionics issues including: Waypoint naming concepts. RNAV Path terminator concepts and especially: Use of the 'CF' path terminator. Use of the 'TF' path terminator. Fly-by and fly-over waypoints.

Use of the RNAV equipment including, where appropriate: Retrieving a procedure from the database. Verification and sensor management. Tactically modifying the flight plan. Addressing discontinuities. Entering associated data such as: Wind. Altitude/Speed constraints. Vertical Profile/Vertical Speed. Flying the procedure. Use of Lateral Navigation Mode and associated lateral control techniques. Use of Vertical Navigation Mode and associated vertical control techniques. Use of automatic pilot, flight director and auto-throttle at different stages of the procedure.
RT phraseology for RNAV
The implications for RNAV operations of system malfunctions which are not RNAV related (e.g. hydraulic failure or engine failure).

Table 3: RNAV Training Items

10.6 Database Integrity

10.6.1 The navigation database should be obtained from an approved supplier who has complied with EUROCAE/RTCA document ED-76/DO-200A, Standards for Processing Aeronautical Data.

10.6.2 Until such approved suppliers become available, prior to the effective date of the navigation database, as a minimum, the operator must implement navigation database integrity checks using appropriate software tools or approved manual procedures to verify data relating to waypoints below the applicable minimum obstacle clearance altitude. Such checks are in addition to any checks previously performed by the Aeronautical Information Services, unapproved navigation database suppliers, or navigation equipment manufacturers. The integrity checks need to identify any discrepancies between the navigation database and the published charts/procedures. Integrity checks may be performed by an approved third party.

10.6.3 Discrepancies that invalidate a procedure must be reported to the navigation database supplier and affected procedures must be prohibited by a operator's notice to its flight crew.

10.6.4 Aircraft operators should consider the need to continue their own database checks even for products obtained from approved suppliers.
Note: See JAR-OPS 1.035 Quality Systems

10.6.5 To aid database integrity checking, a suitable tool having functionality as defined in Annex B may be used.

10.7 Flight Operations Documentation

10.7.1 The aircraft Operations Manual (e.g. Aircraft or Flight Crew Operating Manuals (A/FCOM)) and check lists must be revised to take account of the information specified in

9.1, 9.2 and 9.3, and the operating procedures detailed in paragraphs 10.2 (Normal Procedures) and 10.3 (Contingency Procedures). The operator must make timely amendments to his Operations Manual to reflect relevant P-RNAV procedures and database checking strategies. Manuals and checklists need to be submitted for review by the responsible authority as part of the approval process.

10.7.2 The aircraft operator should propose an amendment to the Minimum Equipment List (MEL) appropriate to P-RNAV operations.

11 AVAILABILITY OF DOCUMENTS

Copies of EUROCONTROL documents may be requested from EUROCONTROL, Documentation Centre, GS4, Rue de la Fusee, 96, B-1130 Brussels, Belgium; (Fax: 32 2 729 9109). Web site www.ecacnav.com.

Copies of EUROCAE documents may be purchased from EUROCAE, 17 rue Hamelin, 75783 PARIS Cedex 16, France, (Fax : 33 1 45 05 72 30). Web site: www.eurocae.org.

Copies of FAA documents may be obtained from Superintendent of Documents, Government Printing Office, Washington, DC 20402-9325, USA.

Copies of RTCA documents may be obtained from RTCA Inc., 1140 Connecticut Avenue, N.W., Suite 1020, Washington, DC 20036-4001, USA., (Tel: 1 202 833 9339). Web site www.rtca.org.

Copies of ARINC documents may be obtained from Aeronautical Radio Inc., 2551 Riva Road, Annapolis, Maryland 24101-7465, USA. (web site http: // www.arinc.com).

Copies of JAA documents are available from JAA's publisher Information Handling Services (IHS). Information on prices, where and how to order, is available on the JAA web site (www.jaa.nl) and on the IHS web sites www.global.ihs.com and www.avdataworks.com.

Copies of ICAO documents may be purchased from Document Sales Unit, International Civil Aviation Organisation, 999 University Street, Montreal, Quebec, Canada H3C 5H7, (Fax: 1 514 954 6769, or e-mail: sales_unit@icao.org) or through national agencies.

ANNEX A GLOSSARY

The following are definitions of key terms used in the context of area navigation. For the purposes of P-RNAV, these definitions have been adapted from those given in corresponding ICAO, EUROCAE and RTCA documents.

Area Navigation (RNAV). A method of navigation which permits aircraft operation on any desired flight path.

Accuracy. The degree of conformance between the estimated, measured, or desired position and/or the velocity of a platform at a given time, and its true position or velocity. Navigation performance accuracy is usually presented as a statistical measure of system error and is specified as predictable, repeatable and relative.

Availability. An indication of the ability of the system to provide usable service within the specified coverage area and is defined as the portion of time during which the system is to be used for navigation during which reliable navigation information is presented to the crew, automatic pilot, or other system managing the flight of the aircraft.

Continuity of Function. The capability of the total system (comprising all elements necessary to maintain aircraft position within the defined airspace) to perform its function without non-scheduled interruptions during the intended operation.

Integrity. The ability of a system to provide timely warnings to users when the system should not be used for navigation.

Receiver Autonomous Integrity Monitoring (RAIM). A technique whereby a GNSS receiver / processor determines the integrity of the GNSS navigation signals using only GNSS signals or GNSS signals augmented with altitude. This determination is achieved by a consistency check among redundant pseudo-range measurements. At least one satellite in addition to those required for navigation must be in view for the receiver to perform the RAIM function (FAA AC 20-138, AC 90-94).

Vertical Navigation. A method of navigation which permits aircraft operation on a vertical flight profile using altimetry sources, external flight path references, or a combination of these.

The following acronyms are used in the document:

ADF	Automatic Direction Finding
AFM	Aircraft Flight Manual
AIP	Aeronautical Information Publication
AIRAC	Aeronautical Information Regulation and Control
AIS	Aeronautical Information Service
ATC	Air Traffic Control
B-RNAV	Basic RNAV
CDI	Course Deviation Indicator
CF	Course to a Fix
CG	Centre of Gravity
CNF	Computer Navigation Fix
DF	Direct to a Fix
DME	Distance Measuring Equipment
DTK	Desired Track
EGNOS	European Geo-stationary Navigation Overlay System
(E)HSI	(Electronic) Horizontal Situation Indicator

FA	Course from a Fix to an Altitude
FACF	Final Approach Course Fix
FAWP	Final Approach Waypoint
FDE	Fault Detection and Exclusion
FMS	Flight Management System
FTE	Flight Technical Error
GPS	Global Positioning System
GNSS	Global Navigation Satellite System
HA	Holding Pattern to an Altitude
HF	Holding Pattern to a Fix
HM	Holding Pattern to a Manual Termination
ICAO	International Civil Aviation Organisation
IF	Initial Fix
IFR	Instrument Flight Rules
ILS	Instrument Landing System
INS	Inertial Navigation System
IRS	Inertial Reference System
MASPS	Minimum Aviation System Performance Standards
MCDU	Multi-function Control Display Unit
MEL	Minimum Equipment List
MLS	Microwave Landing System
NDB	Non Directional Beacon
NM	Nautical Mile
NOTAM	Notice to Airmen
P-RNAV	Precision RNAV
RAIM	Receiver Autonomous Integrity Monitoring
RF	Radius to a Fix
RMI	Radio Magnetic Indicator
RNAV	Area Navigation
RNP	Required Navigation Performance
RTA	Required Time of Arrival
SID	Standard Instrument Departure
STAR	Standard Arrival Route
TF	Track between Two Fixes
VOR	VHF Omni-directional Range
WGS	World Geodetic System

ANNEX B SPECIFICATION FOR A DATABASE INTEGRITY CHECK TOOL

A database integrity check tool is a software tool which enables an aircraft operator to conduct independent checks on specific data areas in a navigation database to ensure that integrity is maintained. These checks can be delegated to a service organisation. The software tool does not have to be qualified in accordance with EUROCAE ED-12B/ RTCA DO-178B.

The tool should include the following functionality:

(a) Allow a user to specify the data areas to be checked and the critical data items to be monitored.

(b) Detect any changes in monitored data items.

(c) Generate reports listing all identified changes.

(d) Provide a full data history to support configuration control.

(e) Maintain non editable log-files of all online actions.

(f) Provide analyses of database quality and changes in quality levels by tracking of rates of discovered errors.

(g) Provide a flexible data input interface to enable database integrity checks for a variety of database providers.

ANNEX C EVOLUTION FROM CONVENTIONAL TERMINAL AIRSPACE PROCEDURES TO RNP-RNAV

There are a number of steps envisaged in the transition from today's conventional terminal airspace procedures to future RNP-RNAV procedures:

(a) Conventional Procedure

A conventional procedure design (VOR radials, NDB bearings and DME fixes/arcs, ILS, MLS). Flown with conventional means (VOR, DME, ADF, ILS and MLS).

(b) Conventional Procedure flown by an RNAV system coded to ARINC 424

A conventional procedure design but stored in a navigation database using the full set of ARINC 424 Path Terminators (currently 23 different leg types).

(c) Conventional Procedure meeting RNAV criteria

A conventional procedure designed specifically to meet RNAV criteria using sensors such as VOR/DME, DME/DME and GNSS. This procedure is published as a conventional procedure and may reference VOR radials, NDB bearings and DME fixes. However, it will have associated waypoints to define the RNAV path. This removes the ambiguity/approximations found in conventional procedures of paragraph (b), when flown using RNAV systems and ensures repeatability of the intended path over the ground.

Note: This is the first step towards achieving predictable track-keeping resulting from consistent and correct coding in the navigation databases, published waypoints and the application of fly-by turns. This can be used as a learning period for designers, chart and AIS providers, introducing as it does the concepts of path terminators, procedure validation, database issues, charting and publication issues.

(d) RNAV Procedure (Not RNP)

A procedure designed specifically for RNAV using sensors such as DME/DME, GNSS and VOR/DME. Use is made of waypoints located according to minimum distance requirements as laid down in PANS-OPS. This procedure is identified as an RNAV procedure and the sensor used for the design must be published. The procedure is intended for Precision RNAV or RNP-RNAV certified system.

(e) RNP-RNAV Procedure

A procedure designed according to RNP-RNAV criteria. This procedure is identified as RNP-RNAV and may be used for all applicable sensors, and is protected as such. The procedure is intended for RNP-RNAV certified systems.

The conventional procedure of paragraph (a) was originally designed for hand-flown operations and does not always lend itself to the use of RNAV systems. Navigation database providers have had to interpret the procedure specification using the leg types available in the full ARINC 424 tool kit. This has resulted in the need for additional fixes (Computer Navigation Fixes (CNF)) to be defined in order to construct a best fit to the procedure path. In general, these aspects are transparent to ATC, but can result in path deviations under given conditions of aircraft type, configuration (weight, CG), FMS manufacturer, and wind. The RNAV system, whilst commanding path steering, may be restricted by built-in bank angle or performance limits. The consequence of such limits may be a path deviation which may be recovered automatically or may require pilot intervention.

At all times, the conventional procedure, be it coded according to ARINC 424 or not, may be monitored by the flight crew against raw radio aid data, and the integrity of the navigation database is not really an issue. From the aircraft perspective, the safety of flight envelope is maintained, although separation from obstacles or other traffic may be lost. Hence, the major concern with these types of procedures is their compatibility with the RNAV system and how well the procedure can be flown under all conditions for all aircraft types. It would be preferable for conventional procedures to be designed to take into account the limitations and constraints of the RNAV system.

When P-RNAV is subsequently mandated, the underlying conventional procedure may be withdrawn leaving a stand-alone RNAV procedure.

The RNP-RNAV procedures of paragraph (e) are expected to be introduced initially to take advantage of the reduced obstacle clearance requirements associated with RNP<1 instrument procedures and RNP MASPS compliant systems. They are expected to replace all RNAV procedures.

ANNEX D VERTICAL NAVIGATION

(a) Although this leaflet does not set criteria for approval of vertical navigation systems, the following provides a brief description to aid understanding of the overall navigation function and the relationship of VNAV to this the guidance material. The flight crew must clearly understand the application of vertical navigation mode and/or speed management, as appropriate, particularly in the context of a continuous descent profile.

(b) For vertical navigation, the system compares the determined vertical position (barometric altitude) with a desired vertical profile derived from altitude data, a vertical angle, or a vertical flight profile, applicable to that route or procedure and selected from an on-board navigation database. The desired vertical profile to be followed and the difference between it and the determined vertical position are then output to the following types of system to enable the profile to be followed:

- Vertical Profile Deviation Indicator
- Vertical Profile Display.
- Automatic Thrust System.
- Flight Director.
- Automatic pilot.

(c) Some systems may provide the capability to determine optimised climb and descent profiles based on aircraft performance characteristics (including engine performance), aircraft weight, aircraft speed, prevailing meteorological conditions, operator cost constraints, and published altitude and speed constraints associated with a particular arrival/approach/departure procedure.

(d) A VNAV capability is optional for P-RNAV. It should be possible to fly a published descent profile conventionally manually, given adequate flight deck information and with appropriate crew training.

(e) Unless a published VNAV procedure is being flown, the vertical profile between two altitude constraints is always at the pilot's discretion. However, the flight crew should aim, wherever possible, to adhere to the optimum vertical profile. Crews should recognise that there are a number of methods by which adherence to the path can be achieved. Where a VNAV procedure is published, the flight crew are required to fly in accordance with the published constraints.

(f) Use of GNSS is only considered as a sensor for the purposes of lateral navigation and its use for vertical navigation is not addressed by this leaflet.

(g) Further description of VNAV functionality and performance requirements, and their relationship with RNP-RNAV, may be found in EUROCAE/RTCA documents ED-75A/DO-236A.

Annex E Flight Manual Change Sheet Template

(Aircraft Type) Aircraft Flight Manual *[or POH if applicable]*
Document Reference *(1234)*

(Name Of Organisation)

CHANGE SHEET NO. : *(…)*   ISSUE : *(…)*

Aircraft Serial No: *(…)*   **Registration Mark: *(…)***

COMPLIANCE WITH AREA NAVIGATION CRITERIA
Modification Number : *(abc, if applicable)*

ADDITIONAL LIMITATIONS AND INFORMATION FOR CERTIFICATION

The limitations and information contained herein either supplement or, in the case of conflict, override those in the flight manual.

LIMITATIONS

1 Area Navigation System *(xyz system)* has satisfied only the requirements defined in [delete or add as applicable]:

(a) **P-RNAV** JAA Temporary Guidance Material, Leaflet No. (*this leaflet*)**:** Airworthiness and Operational Approval for Precision RNAV Operations in Designated European Airspace.

(b) **B-RNAV** JAA Temporary Guidance Material, Leaflet No. No. 2 Rev. 1**:** JAA Guidance Material On Airworthiness Approval And Operational Criteria For The Use Of Navigation Systems In European Airspace Designated For Basic RNAV Operations.

(c) **GNSS** JAA Temporary Guidance Material, Leaflet No. 3 Rev. 1**:** JAA Interim Guidance Material On Airworthiness Approval And Operational Criteria For The Use Of the NAVSTAR Global Positioning System (GPS).

(d) **OCEANIC/REMOTE** FAA Notice N8110.60**:** GPS As A Primary Means Of Navigation For Oceanic/Remote Operations.

2 The *(xyz system)* is not approved for [delete as applicable] :

(a) RNAV instrument approach operations;

(b) Non Precision instrument approach operations;

(c) Vertical Navigation;

(d) Specific Modes *(define as applicable).*

To be inserted in the flight manual facing Section (....), Page (....), and the revisions record sheet amended accordingly.

Page 1 of   **Authority Approval**

Signature: **Date:**

NOTES ON THE PRODUCTION OF FLIGHT MANUAL CHANGE SHEET

(a) The supplement/change sheet should be written to fit the size and style of the Flight Manual supplied by the aircraft constructor and to which it refers, preferably without resorting to photo-reduction.

(b) A company logo can be included if desired.

(c) Each change sheet must be uniquely identifiable within a referenced Flight Manual.

(d) A log of change sheets should be provided for inclusion in the front of the manual.

(e) Aircraft identification (Registration etc.) should be added to the copy which goes in the aircraft copy of the Flight Manual. Where several aircraft on the same Flight Manual document have the same equipment, copies of the same change sheet may be issued to each aircraft.

(f) In addition to the Limitations specified on the template and In the absence of suitable material in other approved operating or training manuals, appropriate amendments or supplements to cover P-RNAV operations will need to be provided for the following sections of the Flight Manual, or the Pilot's Operating Handbook, whichever is applicable:

- Normal Procedures
- Abnormal Procedures
- Emergency Procedures
- Performance

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ANNEX 5.3

Extract of FAA ORDER 8400.12A

ORDER

U.S. DEPARTMENT OF TRANSPORTATION
FEDERAL AVIATION ADMINISTRATION

8400.12A

2/9/98

SUBJ: REQUIRED NAVIGATION PERFORMANCE 10 (RNP-10) OPERATIONAL APPROVAL

1. PURPOSE. The purpose of this Order is to provide policy and direction for obtaining operational approval of Required Navigation Performance 10 (RNP-10) capability. Guidance on airworthiness, continuing airworthiness, and RNP-10 operational approval are provided. The order enables an applicant to be approved as capable of meeting the NAVIGATION ELEMENT requirements when RNP-10 is specified. The order does not address communications or surveillance requirements that may be specified to operate on a particular route or in a particular area. Those requirements are specified in other documents such as Aeronautical Information Publications (AIP) and the International Civil Aviation Organization (ICAO) Regional Supplementary Procedures Document (DOC 7030).

2. DISTRIBUTION. This order is distributed to the director level in Washington headquarters and the Centers; to all regional administrators; to the branch level in the Flight Standards Service, and Aircraft Certification Service; to the branch level in the regional Flight Standards divisions, and Aircraft Certification directorates; to all regional International Aviation Officers; to all Flight Standards, Aircraft Certification, and International Aviation field offices.

3. CANCELLATION. FAA Order 8400.12, dated January 24, 1997, is canceled.

4. BACKGROUND.

a. States and operators are beginning implementation of RNP as part of a worldwide ICAO effort to implement the Future Air Navigation Systems (FANS), Communication/Navigation/Surveillance (CNS) and Air Traffic Management (ATM) concept. To support this effort, the Informal Pacific Air Traffic Service Coordination Group (IPACG) has developed plans to implement 50 Nautical Mile (NM) lateral separation on the North Pacific (NOPAC) and Central East Pacific (CEPAC) routes based on approval of an RNP-10 capability for the total route of the flight. In accordance with ICAO coordinated regional agreements, operators will be required to obtain approval to the RNP-10 criteria, or equivalent criteria developed by the operator's state of registry. This performance capability requirement is similar to the existing Minimum Navigation Performance Specification (MNPS) over the Atlantic.

b. Following the implementation of 50 NM lateral separation based upon an RNP-10 capability, additional separation reductions based on more stringent parameters will be implemented. The implementation of more stringent RNP capability, as well as other CNS elements, is part of a worldwide ICAO coordinated effort to improve ATM and CNS services. This first step is necessary to provide early benefits to users in terms of efficient use of airspace, more optimum routings, reduced delay, increased traffic flow capacity, increased flexibility, reduced costs, appropriately adjusted aircraft to aircraft separation standards and increased safety.

5. RELATED PUBLICATIONS.

a. FAA Documents.

(1) 14 CFR Part 121, Appendix G.

(2) Advisory Circular (AC) 20-130, Airworthiness Approval of Navigation or Flight Management Systems Integrating Multiple Navigation Sensors, latest edition.

(3) AC 20-138, Airworthiness Approval of Global Positioning System (GPS) Navigation Equipment for Use as a VFR and IFR Supplemental Navigation System, latest edition.

(4) FAA Order 7110.82, Monitoring of Navigation/Altitude Performance in Oceanic Airspace, latest edition.

(5) FAA Order 8400.10, Air Transportation Operations Inspector's Handbook.

(6) FAA Order 8700.1, General Aviation Operations Inspector's Handbook.

(7) Handbook Bulletin for Air Transportation (HBAT) 95-09, Guidelines for Operational Approval of Global Positioning System [GPS] to Provide the Primary Means of Class II Navigation in Oceanic and Remote Areas of Operation.

b. Other Documents.

(1) Copies of the following may be obtained from Document Sales Unit, ICAO, 999 University Street, Montreal, Quebec, Canada H3C 5H7:

(a) Manual on Required Navigation Performance (RNP), ICAO DOC 9613-AN/937.

(b) Asia Pacific Guidance Material for RNAV Operations.

(2) Copies of the following may be purchased from NOAA, N/ACC3, Distribution Division, Riverdale, MD 20737:

(a) United States Government Flight Information Publication - Chart Supplement - Alaska.

(b) United States Government Flight Information Publication - Chart Supplement - Pacific.

(3) Copies of Minimum Aviation System Performance Standards (MASPS): Required Navigation Performance for Area Navigation, RTCA, may be purchased from RTCA, Inc., 1140 Connecticut Avenue, NW., Suite 1020, Washington, DC 20036.

(4) Copies of Aeronautical Information Manual (AIM) may be purchased from the U.S. Government Printing Office, P.O. Box 371954, Pittsburgh, PA 15250-7954.

6. APPLICABILITY.

a. This guidance applies to all operators conducting operations under Title 14 of the Code of Federal Regulations (14 CFR) parts 91, 121, 125, and 135.

b. The requirements are consistent with 14 CFR part 91, sections 91.703(a)(1) and (a)(2), which require each certificate holder, operating a civil aircraft of U.S. registry outside of the United States, to comply with ICAO, Annex 2, when over the high seas, and to comply with the regulations of a foreign country when operating within that country's airspace.

7. OPERATIONAL APPROVAL.

a. General. To obtain operational approval, aircraft eligibility must be determined, appropriate flightcrew procedures for the navigation systems to be used must be identified by the applicant (e.g., Class II Nav procedures); and database use and operating procedures must be evaluated, if applicable. Then appropriate operations specifications or a letter of authorization (LOA) may be issued, as applicable to the operator.

b Approved Aircraft/System List. The Federal Aviation Administration (FAA) Technical Programs Division, AFS-400, will maintain a list of aircraft/navigation systems that have received approval. This list will be maintained for informational, statistical, and training purposes. The list IS NOT USED as a means of determining qualifications for approval, but may serve as a guideline to field offices and operators to note those aircraft and navigation systems which have been approved.

8. OPERATIONAL APPROVAL PROCESS. RNP-10 requires that each individual aircraft must be determined to be qualified, and the individual operator must be approved by appropriate FAA offices before the operator conducts flight in RNP-10 airspace. This Order provides guidance for the approval of operators for flight in airspace where RNP-10 is applied, and provides guidance on aircraft certification where RNP-10 eligibility cannot otherwise be determined, or where the operator chooses to lengthen RNP-10 approval time limits. The following paragraphs provide application guidelines for operators desiring to obtain RNP-10 operational approvals. Appendix 5 is a combined operator's and inspector's Job Aid that provides a concise summary of the steps required to complete the approval process.

a. Preapplication Meeting. Each individual operator should schedule a preapplication meeting with either the certificate holding district office (CHDO) or the Flight Standards district office (FSDO). The intent of this meeting is to inform the operator of FAA expectations in regard to approval to operate in an RNP-10 airspace for a specified length of time; to discuss the contents of the operator's application; for the FAA to review and evaluate the application; and to discuss conditions for removal of the operational approval.

b. Operators seeking RNP-10 operational approval should contact FAA offices as follows:

(1) Parts 121, 125, and 135 Operators. These operators should notify the Certificate Management Office (CMO) or CHDO which holds its operating certificate of its intent to request approval for RNP-10 operations. RNP-10 authorizations for air carriers will be addressed through issuance of approved operations specifications. The operations specifications will identify any conditions or limitations necessary (e.g., navigation systems or procedures required, time limits, routes or areas authorized). A sample letter of request for an air carrier to obtain RNP-10 operational approval is provided in Appendix 3, figure 1.

(2) Part 91 Operators. These operators should contact their local FSDO to start the process for RNP-10 authorization. Operators under part 91 will receive an LOA, which authorizes RNP-10 operations. The LOA will identify any conditions or limitations necessary (e.g., navigation systems or procedures required, time limits, routes or areas authorized). A sample letter of request for a general aviation operator to obtain RNP operational approval and the resulting LOA are provided in Appendix 3, figure 2.

c. Determining Eligibility and Approval of Aircraft for RNP-10. Many aircraft and navigation system types currently in use in oceanic or remote area operations will qualify for RNP-10 based on one or more provisions of existing certification criteria. Thus, additional aircraft certification action may not be necessary for the majority of RNP-10 approvals. In these instances, additional aircraft certification will only be necessary if the operator chooses to claim additional performance beyond that originally certified or stated in the Airplane Flight Manual (AFM) and if the operator cannot demonstrate the desired performance through data collection.

9. APPLICATION.

a. Contents of Operator's RNP-10 Application.

(1) Eligibility Airworthiness Documents. Sufficient documentation should be available to establish that the aircraft has an appropriate AFM, AFM Supplement (AFMS), if applicable, and is otherwise suitably qualified to fly the intended routes (e.g., long-range navigation, communication).

(2) Description of Aircraft Equipment. The applicant should provide a configuration list which details pertinent components and equipment to be used for long range navigation and RNP-10 operations.

(3) RNP-10 Time Limit for Inertial Navigation Systems (INS) or Inertial Reference Units (IRU) (if applicable). The RNP-10 time limit for which the applicant's INS or IRU system have been approved should be provided (see paragraph 12). In addition, the applicant should consider the effect of headwinds in the area of operations in which RNP-10 operations are intended to be carried out (see paragraph 15).

(4) Operational Training Programs and Operating Practices and Procedures.

(a) Air carrier operators should submit training syllabi and other appropriate material to the FAA to show that the operational practices and procedures and training items related to RNP-10 operations are incorporated in various training programs where applicable (e.g., initial, upgrade, recurrent). Training for other personnel should be included where appropriate (e.g., dispatchers, maintenance). 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 before entry into an RNP-10 route or airspace; inflight, contingency and flightcrew qualification procedures.

(b) Part 91 operators should confirm that they will operate using the practices and procedures identified in Appendix 4.

(5) Operational Manuals and Checklists.

(a) Part 121, 125, 135 Operators. The appropriate manuals and checklists should be revised to include information/guidance on standard operating procedures detailed in Appendix 4. Appropriate manuals should include navigation equipment operating instructions and any procedures established to operate in a specific area of operations (e.g., contingency procedures). Manuals and checklists should be submitted for review as part of the application process.

(b) Part 91 Operators. An airplane Flight Manual and required supplements for the airplane seeking approval should be submitted with the approval package, if one is required for that airplane.

(6) Past Performance. An operating history for the operator should be included in the application. The applicant should address any events or incidents related to Class II Navigation Errors for that operator

(e.g., Overseas Navigation Error Reports) which have been rectified by changes in training, procedures, maintenance, or the aircraft/navigation system that are to be used.)

(7) Minimum Equipment List (MEL). Any MEL revisions necessary to address the RNP-10 provisions of this guidance (e.g., if approval is based on Triple-Mix, then the MEL must reflect that three navigation units must be operating).

(8) Maintenance. The operator should submit a maintenance program for approval in accordance with paragraphs 13 and 14 at the time the operator applies for operational approval.

b. Evaluation of Application. Conditions for Removal of Authorization. and Error Reports.

(1) FAA Review and Evaluation of Applications. 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. When all the airworthiness and operational requirements of the application are met, the FAA district office will issue the appropriate operations specifications or LOA for approval to operate in RNP-10 airspace, for a specific time period.

(2) Investigation of Navigation Errors. Demonstrated navigation accuracy provides the basis for determining the lateral spacing and separation necessary for traffic operating on a given route. Accordingly, lateral and longitudinal navigation errors are investigated to prevent their reoccurrence. Radar observations of each aircraft's proximity to the centerline and altitude before coming into coverage of short-range navaids at the end of the oceanic route segment are typically noted by Air Traffic Service (ATS) facilities. If an observation indicates that an aircraft was not within an established limit, the reason(s) for the apparent deviation from centerline or altitude may need to be determined and steps taken to prevent a recurrence.

(3) Removal of RNP-10 Authorization. Oceanic Navigation Error Reports (ONER) and Oceanic Altitude Deviation Reports (OADR), for example, are established in FAA Order 7110.82, latest edition and in FAA Order 8700.1, chapter 223. When appropriate, the FAA may consider these reports in determining remedial action. Repeated ONER or OADR occurrences attributed to a specific piece of navigation equipment, may result in withdrawal of operations specifications or rescinding an LOA, for use of that equipment. Information that indicates the potential for repeated errors may require a modification of an operator's training program. Information that attributes multiple errors to a particular pilot crew may necessitate remedial qualifications or airmen certification review.

10. RNP-10 REQUIREMENTS.

a. All aircraft operating in RNP-10 airspace shall have a 95% cross-track error of less than 10 NM. This includes positioning error, flight technical error (FTE), path definition error and display error. All aircraft shall also have a 95% along-track positioning error of less than 10 NM.

NOTE: For RNP-10 approval, navigation positioning error is considered the dominant contributor to cross-track and along-track error. Flight technical error, path definition error, and display error are considered to be insignificant for the purposes of RNP-10 approval. (RNP-10 is intended for oceanic and remote areas where aircraft separation minima, on the order of 50 NM, are applied.)

b. When using the method of Appendix 1 for approval, these error types are included but for the data collection method described in Appendix 6, they are not included since the Appendix 6 method is more conservative. The Appendix 6 method uses radial error instead of cross track and along track error.

(1) Flight Technical Error (FTE) The accuracy with which the aircraft is controlled as measured by the indicated aircraft position, with respect to the indicated command or desired position is the FTE. It does not include blunder errors.

(2) Path Definition. This is the difference between the ***defined path*** and *the* ***desired path*** at a specific point and time.

(3) Display Errors (Display System Error). These errors may include error components contributed by any input, output or signal conversion equipment used by the display as it presents either aircraft position or guidance commands (e.g., course deviation or command heading) and by any course definition entry device employed. For systems in which charts are incorporated as integral parts of the display, the display system error necessarily includes charting errors to the extent that they actually result in errors in controlling the position of the aircraft relative to a desired path over the ground. To be consistent, in the case of symbolic displays not employing integral charts, any errors in way-point definition, directly attributable to errors in the reference chart used in determining way-point positions, should be included as a component of this error. This type of error is virtually impossible to handle and in general practice, highly accurate, published way-point locations are used to the greatest extent possible in setting up such systems to avoid such errors and reduce workload.

(4) Navigation System Error (NSE). This is the root sum square of the ground station error contribution, the airborne receiver error and the display system contribution.

(5) Total System Error (TSE). This is system use error. $TSE = \sqrt{(NSE)^2 + (FTE)^2}$

(6) Position Estimation. This is the difference between true position and estimated position.

c. Satisfying requirements for an RNP-10 operation in oceanic and remote areas also necessitates that an operation identified in those parts of 14 CFR relevant to the type of operation conducted must also be satisfied, including at least dual carriage of navigation systems of integrity such that the navigation system does not provide misleading information.

11. AIRCRAFT GROUPS (FLEETS OF AIRCRAFT].

a. Definition of Aircraft Group For aircraft to be considered as members of a group for purposes of RNP-10 approval, they should satisfy the following conditions:

(1) Aircraft should have been manufactured to a nominally identical design and approved by the same Type Certificate (TC), TC amendment, or supplemental TC (STC), 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 when INS/IRU is used to meet RNP-10 navigation requirements.

(2) The navigation system installed on each aircraft to meet the minimum RNP-10 approval should be manufactured to the manufacturer's same specifications and have the same part numbers.

(3) Where approval is sought for an aircraft group, the data package must contain the following information:

(a) A list of the aircraft group to which the data package applies.

(b) A list of the routes to be flown and the maximum estimated time in navigation from alignment to the time in which the flight will leave Class II Navigation airspace.

(c) The compliance procedures to be used to ensure that all aircraft submitted for approval meet RNP-10 navigation capabilities for the RNP-10 approved time duration.

(d) The engineering data to be used to ensure continued in-service RNP-10 capability for the RNP-10 approved time duration.

NOTE: Aircraft which have INS/IRU's which are of a different manufacturer or part number may be considered part of the group, if it is demonstrated that this navigation equipment provides equivalent navigation performance.

b. Definition of a Nongroup Aircraft. An aircraft for which the operator applies for approval on the characteristics of the unique airframe and navigation system used rather than on a group basis. For nongroup aircraft where airworthiness approval has been based on data collection, the continuing integrity and accuracy of the navigation system shall be demonstrated by the same amount of data collection as is required for group aircraft.

NOTE: Data collected by one or more operators may be used as the basis for approval by another operator and may reduce the number of trials required to obtain approval. Appendix 6 describes a sample data collection procedure and provides sample forms to be used to collect the data.

12. DETERMINING AIRCRAFT ELIGIBILITY.

NOTE : The following groupings are different than the groupings discussed in paragraph 11, above, the groupings below are eligibility groups. These groups were established for the convenience of discussion and do not have a precise definition . The definitions in this order only aid in determining the approval method that may be used to approve specific aircraft and navigation systems. Neither Omega or Doppler systems can be approved for RNP-10.

a. Aircraft Eligibility through RNP Certification (Eligibility Group 1). Group 1 aircraft are those that have obtained formal certification and approval of RNP integration in the aircraft.

(1) RNP compliance is documented in the AFM, and is typically not limited to RNP-10. The AFM will address RNP levels that have been demonstrated and any related provisions applicable to its use (e.g., navaid sensor requirements). Operational approval of Group 1 aircraft will be based upon the performance stated in the AFM.

(2) An airworthiness approval specifically addressing RNP-10 performance may be obtained. Example wording that will be used in AFMs when RNP-10 approvals are granted by Aircraft Certification offices for a change in the INS/IRU certified performance is:

"The XXX navigation system has been demonstrated to meet criteria of FAA Order 8400.12A, as amended, as a primary means of navigation for flights up to XXX hours in duration without updating. The determination of flight duration starts when the system is placed in the navigation mode.

For flights which include airborne updating of navigation position, the operator must address the effect that updating has on position accuracy, and any associated time limits for RNP operations, pertinent to the updating navaid facilities use, and the area, routes, or procedures to be flown.

Demonstration of performance in accordance with provisions of FAA Order 8400.12A, does not constitute approval to conduct RNP operations."

NOTE: The above wording in an AFM is based upon performance approval by Aircraft Certification, it is only one element of the approval process. Aircraft which have had this wording entered into their flight manual will be eligible for approval through issuance of operation specifications or an LOA if all other criteria are met. The XXX hours specified in the AFM does not include updating. When the operator proposes a credit for updating, the proposal must address the effect the updating has on position accuracy, and any associated time limits for RNP operations pertinent to the updating navaid facilities use, and the area, roots, or procedures to be flown.

b. Aircraft Eligibility Through Prior Navigation System Certification (Eligibility Group 2) 2 aircraft are those that can equate their certified level of performance, under previous standards; to the RNP-10 criteria. The standards listed in subparagraphs (1) to (5), below, can be used to qualify an aircraft under Group 2. Other standards may also be used if they are sufficient to ensure that the RNP-10 requirements are met. If other standards are to be used, the FSDO or CMO should consult with AFS-400 to determine the appropriate operational approval and limitations. As new standards are used for the basis of RNP-10, this Order will be revised to reflect the new standards.

(1) Aircraft which Qualify for the /E Suffix as Defined in the Aeronautical Information Manual (AIM) Aircraft equipped with Inertial Navigation Systems (INS), Inertial Reference Units (IRU), Radio Navigation Positioning Updating, and Electronic Map Displays, that qualify for the /E equipment suffix as defined in the AIM, are considered to meet all of the RNP-10 requirements for up to 6.2 hours of flight time. This time starts when the system is placed in the navigation mode. If systems are updated en route, the 6.2 hour RNP-10 time limit must be adjusted after the update to account for the accuracy of the update (see paragraph 12e below for adjustment factors for systems that are updated en route).

NOTE: The consideration to use 6.2 hours of flight time is based on an Inertial System with a 95% Radial Position Error Rate (circular error rate) of 2.0 NM/hr which is statistically equivalent to individual 95% cross-track and 95% along -track position error rates (orthogonal error rates) of 1.6015 NM/hr each, and 95% cross-track and 95% along -track position error limits of 10 NM each (e.g., 10 NM/1.6015 NM/hr = 6.2 hrs).

(2) Aircraft Equipped with INS's or IRU's that have been Approved in Accordance with 14 CFR Part 121, Appendix G Inertial systems approved in accordance with part 121, appendix G, are considered to meet RNP-10 requirements for up to 6.2 hours of flight time. This time starts when the system is placed

in the navigation mode. If systems are updated en route, the 6.2 hours RNP-10 time limit must be adjusted to account for the accuracy of the update. INS accuracy, reliability, training, and maintenance issues that are required by section 121.355, appendix G, are considered to be applicable to an RNP-10 authorization, including any associated Class II Navigation procedures. Except as authorized by the Administrator in accordance with section 121.351(c) at least dual equipage of eligible INS systems is required.

(3) Aircraft Equipped with INS's or IRU's Approved for Australian RNAV Operations. Aircraft equipped with dual INS's or IRU's approved for MNPS operations or RNAV operations in Australia can be considered to meet RNP-10 requirements for up to 6.2 hours after the system is placed in the navigation mode.

NOTE: Paragraph 12d provides information on acceptable procedures for operators that desire to increase the 6.2 hours of flight time specified.

(4) Aircraft Equipped with Global Positioning Systems (GPS) Approved to Primary Means of Navigation Standards. Aircraft approved to use GPS as a primary means of navigation for oceanic and remote operations in accordance with the appropriate FAA documents, or equivalent, are considered to meet the RNP-10 requirements without time limitations. The AFM(s) should indicate if a particular GPS installation meets the appropriate FAA documents requirements. As specified in the appropriate FAA documents, at least dual GPS equipment is required, and an approved dispatch fault detection and exclusion (FDE) availability prediction program must be used. The maximum allowable time for which FDE capability is projected to be unavailable is 34 minutes. The maximum outage time should be included as a condition of the RNP-10 approval. (See FAA Handbook Bulletin [HBB] for Air Transportation [HBAT], number HBAT 95-09, Guidelines for Operational Approval of Global Positioning System [GPS] to Provide the Primary Means of Class II Navigation in Oceanic and Remote Areas of Operation)

NOTE: If predictions indicate that the maximum FDE outage for the intended RNP-10 operation cannot be met, then the operation must be rescheduled when FDE is available, or RNP-10 must be predicated on an alternate means of navigation.

(5) Multisensor Systems Integrating GPS (with GPS Integrity Provided by Receiver Autonomous Integrity Monitoring (RAIM)) Multisensor systems integrating GPS with RAIM or FDE that are approved using the guidance of AC 20-130A, Airworthiness Approval of Navigation or Flight Management Systems Integrating Multiple Navigation Sensors, or equivalent, can be considered to meet RNP-10 requirements without time limitations. In this case, the INS or IRU must be approved in accordance with part 121, appendix G.

c. Aircraft Eligibility Through Data Collection (Eligibility Group 3). A data collection program should address appropriate navigation accuracy requirements for RNP-10. The data collection must ensure that the applicant demonstrates to the FAA that the aircraft and navigation system provides the flightcrew with navigation situational awareness relative to the intended RNP-10 route. The data collection must also ensure that a clear understanding of the status of the navigation system is provided, and that failure indications and procedures are consistent with maintaining the required navigation performance. Two types of data collection are described in this order, a sequential and a periodic data collection method.

(1) The sequential method is a data collection program meeting provisions of Appendix 1. This method allows the operator to collect data and plot it against the Pass-Fail graphs to determine if the operator's system will meet RNP-10 requirements for the length of time needed by the operator.

(2) The periodic method of data collection employs the use of a hand-held GPS receiver as a base line for collected INS data, which is described in Appendix 6, (Periodic Method). The collected data is then analyzed as described in Appendix 6 to determine if the system is capable of maintaining RNP-10 for the length of flight desired by the operator.

d. Obtaining Approval for an Extended Time Limit for INS or IRU Systems. The baseline RNP-10 time limit for INS and IRU systems after the system is placed in the navigation mode is 6.2 hours, as detailed in paragraphs 12b(1)(2) and (3). This time limit may be extended by one of the following methods:

(1) An extended time limit may be established when RNP is integrated into the aircraft navigation system through a formal certification process (as described in paragraph 12a).

(2) When an INS or IRU has been approved using an existing approval standard (as detailed in paragraphs 12b(1)(2) and (3)), an extended time limit may be established by an applicant presenting justifying data to the appropriate Aircraft Certification Office. Group approvals will be granted by aircraft certification with appropriate restrictions if the collected data indicates that approval is merited.

(3) An applicant may establish an extended time limit by showing that the carriage of multiple navigation sensors, that mix or average navigation position error, justifies such an extension (e.g., triple mixed INS's). If the applicant uses a time limit based on mixing, then the availability of the mixing capability is required for 14 CFR parts 121, 125, and 135 dispatch or for part 91 takeoff for flight on RNP-10 routes. If the mixing or averaging function is not available at dispatch, then the applicant must use a time limit that does not depend on mixing. The extended time limit must be validated by a data collection program and analysis as specified in paragraph 12d(4).

(4) When an INS or IRU has been approved using an existing approval standard, operators can establish an extended time limit by conducting a data collection program in accordance with the guidance provided in Appendix 1 or Appendix 6.

e. Effect of En route Updates. Operators may extend their RNP-10 navigation capability time by updating. Approvals for various updating procedures are based upon the baseline for which they have been approved minus the time factors shown below:

(1) Automatic updating using DME/DME = Baseline minus 0.3 hours (e.g., an aircraft that has been approved for 6.2 hours can gain 5.9 hours following an automatic DME/DME update).

(2) Automatic updating using DME/VOR = Baseline minus 0.5 hours.

(3) Manual updating using a method similar to that contained in Appendix 7 or approved by AFS-400 = Baseline minus one hour.

f Conditions under which Automatic Radio Position Updating may be considered as Acceptable for Flight in Airspace where RNP-10 is Required. Automatic updating is considered to be any updating procedure that does not require crews to manually insert coordinates. Automatic updating may be considered acceptable for operations in airspace where RNP-10 is applied provided that:

(1) Procedures for automatic updating are included in an operator's training program.

(2) Crews are knowledgeable of the updating procedures and of the effect of the update on the navigation solution.

(3) An acceptable procedure for automatic updating may be used as the basis for an RNP-10 approval for an extended time as indicated by data presented to the POI or ASI. This data must present a clear indication of the accuracy of the update and the effect of the update on the navigation capabilities for the remainder of the flight.

g. Conditions under which Manual Radio Position Updating may be Considered as Acceptable for Flight in Airspace where RNP-10 is Required. If manual updating is not specifically approved, manual position updates are not permitted in RNP-10 operations. Manual radio updating may be considered acceptable for operations in airspace where RNP-10 is applied provided that:

(1) Procedures for manual updating are reviewed by AFS-400 on a case-by-case basis. An acceptable procedure for manual updating is described in Appendix 7 and may be used as the basis for an RNP-10 approval for an extended time when supported by acceptable data.

(2) The operator shows that updating procedures and training contain measures for cross checking to prevent blunder errors and that the crew qualification curriculum is found to provide effective pilot training.

(3) The operator provides data that establishes the accuracy with which the aircraft navigation system can be updated using manual procedures and representative navigation aids. Data should be provided that shows the update accuracy achieved in in-service operations. This factor must be considered when establishing the RNP-10 time limit for INS's or IRU's. (See paragraph 12e.)

13. MEL. If RNP-10 operational approval is granted on the basis of a specific operational procedure (such as credit for Triple-Mix), operators should make MEL adjustments specifying the required dispatch conditions through their CHDO.

14. CONTINUING AIRWORTHINESS (MAINTENANCE REQUIREMENTS). Aircraft in Group 1, Group 2, and Group 3 should have an established maintenance program for the individual navigation systems. For others installing navigation systems, the operator will submit those changes appropriate to their existing maintenance manual for review and acceptability.

15. OPERATIONAL REQUIREMENTS.

a. Navigational Performance. All aircraft shall meet a track keeping accuracy equal to or better than ± 10 NM for 95% of the flight time in RNP-10 airspace. All aircraft shall meet along - track positioning accuracy of ± 10 NM for 95% of the flight time in RNP-10 airspace.

b. Navigation Equipage. All aircraft RNP-10 operation in oceanic and remote areas except as authorized by the Administrator in accordance with section 121.351 (c), shall have at least dual carriage of navigation systems of integrity such that the navigation system does not provide misleading information.

c. Flight Plan Designation. Operators should use the appropriate FAA or ICAO flight plan designation specified for the RNP-10 route flown. The letter "R" should be placed in Block 10 of the ICAO flight plan to indicate that the pilot has reviewed the planned route of flight to determine RNP-10 requirements and the aircraft and operator have been approved by the FAA to operate in areas or on routes where RNP-10 is a requirement for operation.

NOTE: **The letter that indicates RNP approval has not yet been established for FAA flight plans.**

d. Availability of NAVAIDS. At dispatch or during flight planning, the operator should ensure that adequate navigation aids are available en route to enable the aircraft to navigate to RNP-10.

e. Route Evaluation for RNP-10 Time Limits for Aircraft Equipped with only INS's or IRU's. As d&ailed in paragraph 12e, Effects of En route Updates, an RNP-10 Time Limit must be established for aircraft equipped only with INS's or IRU's to meet the RNP-10 accuracy requirement. When planning operations in areas where RNP-10 is applied, the operator must evaluate its intended route(s) of flight in relation to the RNP-10 time limit. In making this evaluation, the operator must consider the effect of headwinds. The operator may choose to make this evaluation on a one time basis (75% probability wind components) or on a per flight basis.

(1) Route Evaluation. The operator must establish its capability to satisfy the RNP-10 time limit established for dispatch or departure into RNP-10 airspace.

(2) Start Point for Calculation. The calculation should start at the point where the system is placed in the navigation mode or the point where it is expected to be updated.

(3) Stop Point for Calculation. The stop point may be one of the following:

(a) the point at which the aircraft will begin to navigate by reference to ICAO Standard Navaids (VOR, DME, NDB) and/or comes under radar surveillance from ATC; or

(b) the point at which the navigation system is expected to be updated.

(4) Sources of Wind Component Data. The headwind component to be considered for the route may be obtained from any source found acceptable to the FAA. Acceptable sources for wind data include: National Weather Service, Bracknell, industry sources such as Boeing Winds on World Air Routes, and historical airline data supplied by the operator.

(5) One Time Calculation Based on 75% Probability Wind Components. Certain sources of wind data establish the probability of experiencing a given wind component on routes between city pairs on an annual basis. If an operator chooses to make a one time calculation of RNP-10 time limit compliance, it may use the annual 75% probability level to calculate the effect of headwinds (this level has been found to be a reasonable estimation of wind components).

(6) Calculation of Time Limit For Each Specific Fight. The operator may choose to evaluate each individual flight using flight planned winds to determine if the aircraft will comply with the specified time

limit. If it is determined that the time limit will be exceeded, then the aircraft must fly an alternate route or delay the flight until the time limit can be met. This evaluation should be considered a flight planning or dispatch task.

16. DISCUSSION OF CERTIFICATION ACTIONS RELATED TO RNP-10.

a. The operator may elect to certify the aircraft navigation performance to a new standard to take advantage of the aircraft capability. The aircraft may obtain credit for improved performance through operational data collection, in which case certification is not necessary. The following paragraphs provide guidelines for different types of navigation systems. The applicant must propose an acceptable means of compliance for any systems not identified below.

(1) Aircraft Incorporating INS. For aircraft with INS certified under part 121, appendix G, additional certification is only necessary for operators who choose to certify INS accuracy to better than 2 NM per hour radial error.

(a) The certification of INS performance must address all issues associated with maintaining the required accuracy including, accuracy and reliability, acceptance test procedures, maintenance procedures, and training programs.

(b) The applicant should identify the standard against which INS performance is to be demonstrated. This standard may be a regulatory (i.e., appendix G), industry, or applicant unique specification. A statement should be added to the AFM identifying the accuracy standard used for certification. (See paragraph 12a(2).)

(2) Aircraft Incorporating GPS. AC 20-138 provides an acceptable means of compliance for aircraft that use GPS, but do not integrate the GPS with other sensors. AC 20-130A, describes an acceptable means of compliance for multi-sensor navigation systems that incorporate GPS. Aircraft which intend to use GPS as the only navigation system in RNP-10 airspace (e.g., no IRS or INS), must also comply with the requirements of the appropriate FAA documents, except for specific GPS requirements described in this Order.

b. The equipment configuration used to demonstrate the required accuracy must be identical to the configuration which is specified in the MEL.

c. The equipment configuration used to demonstrate the required accuracy must be supportable in RNP-10 oceanic and remote airspace. For example, the statistical benefit of estimating position using INS position data filtered with DME data, will not be considered.

Thomas E. Stuckey
Acting Director, Flight Standards Service

APPENDIX 1. AIRCRAFT ELIGIBILITY THROUGH DATA COLLECTION

1. GENERAL.

a. This appendix offers broad guidance to principal operation inspectors (POI) in the use of a statistical procedure to determine whether aircraft should be approved for flight in RNP-10 airspace. Inspectors are to consider each application on its own merit, and should weigh such factors as the operator's experience, crew training procedures, the airspace in which error data are accumulated (e.g., NOPAC, CEPAC, NAS, MNPS), and the age of the data. Inspectors may request a review of the data by FAA navigation specialists or by AFS-400.

b. RNP-10 approvals will be issued for specific combinations of aircraft and navigation system. If the navigation system which is a candidate for RNP-10 approval is an INS, IRS, or any other system whose accuracy decreases with increasing flight time, the approval must be limited to the number of hours during which the aircraft can be expected to satisfy both the lateral ("cross-track") and longitudinal ("along-track") accuracy criteria of RNP-10.

c. This appendix describes statistical tests that use data gathered from repeated flights. Invoking standard statistical terminology, the appendix refers to a flight trial. This means for example an aircraft with three INS's could provide three data points (trials per flight). In each trial the operator measures two errors:

(1) the longitudinal position-determination error of the candidate navigation system; and

(2) the lateral deviation of the candidate aircraft from its planned route center line.

The longitudinal position-determination error measured in the i^{th} trial is called a_i ; the lateral deviation measured in the i^{th} trial is called c_i. In order for the statistical test to be valid, the data gathered in each trial must be independent of those gathered in any other trial. In other words, the outcome of each trial must not influence the outcome of any subsequent trial. Data will typically be gathered after an aircraft has flown for at least as long as the time for which operational approval is being requested, while being guided solely by the navigation system which is a candidate for RNP-1 0 approval.

d. An operator requesting RNP-10 approval for a candidate aircraft and navigation system must inform the FAA of the flights during which it plans to collect error data. The operator should collect data on every eligible flight until the statistical procedure described in this appendix indicates that the data collection should cease. The operator must use all valid data, and, in particular, may not ignore data that show large errors while submitting only those that show small errors.

2. DATA COLLECTION GUIDELINES.

a. Operators using the methods described in this appendix are to collect position estimates and use those estimates to compute the lateral and longitudinal errors of their aircraft. If a combination of aircraft and navigation system is a candidate for RNP-10 approval for a stated number of hours h, the data must be collected at least h hours after that navigation system was last updated or initialized. Furthermore, the data must be collected after the aircraft has been guided solely by that navigation system for a period long enough to eliminate the effects of prior guidance by any other navigation system that the aircraft may have used during its flight.

b. In order to determine the lateral and longitudinal error data, the operator must simultaneously obtain position estimates from:

(1) the navigation system which is a candidate for RNP-10 approval (the candidate system); and

(2) a reference system, which must be highly accurate in the area where the position is estimated. (The estimate from the reference system is taken to represent the aircraft's actual position.)

The candidate-system position and the reference-system position must be measured simultaneously, at a time when the aircraft has been flying along a straight segment of its planned route for several minutes, and is expected to continue flying along that segment for several more minutes. The operator must ensure that the aircraft's actual position at the time of the measurement is due to guidance derived solely from the candidate system. In particular, the operator must ensure that no other navigation system (especially the reference system) contributed, to any significant extent, to the aircraft's position at the time of the measurement.

c. The operator is responsible for establishing that reference-system positions are accurate. The operator may wish to consider the following in selecting reference systems:

(1) DME/DME positions taken within 200 NM of both DME stations, derived automatically and displayed on systems such as Flight Management Computers.

(2) GPS derived positions.

(3) VOR/DME positions taken within 25 NM of the navigation aid.

NOTE: Operators considering the use of these systems are reminded that many of them are installed so that their outputs are automatically used to guide the aircraft. If any system other than the candidate system has significant influence on the aircraft's position at the time when position estimates are obtained, the test of the candidate system will not be valid.

d. The positions simultaneously reported by the candidate system and the reference system must both be expressed (or re-expressed) in terms of the same coordinate system. The longitudinal error a_i is the distance between the position reported by the reference system and the position reported by the candidate system, measured alone a line parallel to the planned route of flight. (Thus, if the two reported positions are connected by a vector, and the vector is resolved into a component parallel to the route and a component perpendicular to the route, a_i is the magnitude of the component parallel to the route). The lateral deviation c_i is the distance between the planned route of flight and the position reported by the reference system (Note that the position reported by the candidate system has no role in determining the value of c_i.). The distances a_i and c_i must be absolute distances expressed in NM, i.e., expressed as non-negative numbers. In particular, longitudinal errors in opposite directions do not offset each other; nor do lateral deviations to the left and right offset each other.

e. Suppose for example, that an operator wishes to obtain RNP-10 approval of an airplane equipped with an INS, and that the RNP-10 time limit being sought for the INS is 6 hours. Suppose also, that the airplane can very accurately determine its position when it is in airspace with multiple DME coverage, and that it usually enters a large block of such airspace 5½ hours after the last use of another navigation system or signal to adjust its INS output. On each occasion when:

(1) the airplane is flying in an area of multiple DME coverage;

(2) at least 6 hours have passed since the last adjustment of INS output; and

(3) the airplane has been flying straight for several minutes, and is expected to continue flying straight for several more minutes; the crew records: (1) the time; (2) the desired track (or just the "from" and "to" waypoints); (3) the position reported by the INS; and (4) the position reported by the multiple-DME system. The operator later computes the longitudinal error a_i and the lateral deviation c_i.

f. The following is a non-technical summary of the steps used in collecting, plotting, and analyzing data collected for the purpose of using the pass-fail graphs in this appendix. The data collected indicates the difference between the aircraft's navigation system and a highly accurate reference system. The position determined from the reference system is the aircraft's actual position. The point at which this data should be taken is when first leaving Class II Navigation at the designation end of the flight.

(1) Operator collects the following independent data on each eligible flight:

(a) on the desired flightpath, the last waypoint (last waypoint passed) and the to waypoint (these points should be taken from the flight plan),

(b) the reference system (e.g., DME/DME) computed aircraft position

(c) aircraft guidance system (e.g., INS) computed aircraft position for each system
NOTE: (b) and (c) measurements should be taken simultaneously.

(2) The data must be taken tier the guidance system (candidate navigation system) has been operating without any external update for a time at least as long as the time limit being requested.

(3) The data gathered in subparagraph (1), above, is now used to calculate:

(a) cross track error (lateral deviation c_i)

(b) along track error (longitudinal deviation a_i)
NOTE: a_i in (b), above, is considered to represent along track error.

(4) <u>Cross Track Error (c_i)</u>. Calculate the perpendicular distance from the reference system computed aircraft position to the desired flightpath (the desired flightpath is a great circle line between the last waypoint and the to waypoint).

(5) <u>Along Track Error (a_i)</u>. Calculate the distance between the reference system computed aircraft position and the guidance system (INS, etc.) computed aircraft position along a line parallel to the desired flightpath.

(6) <u>Cross Track Pass/Fail.</u> Following the first flight, errors are summed (e.g., if the error was 2 NM on the first flight and 3 NM on the second flight then the cumulative error would equal 5. The cumulative error is the value of the ordinate (y coordinate in a Cartesian coordinate system) and the number of trials is the value of the abscissa (x coordinate in a Cartesian coordinate system). The intersection of these two is then plotted on figure 1. The cross track RNP-10 requirements are passed when the plots of the cumulative errors fall below the lower pass line or fail if they go above the upper fail line.

(7) <u>Alone Track Pass/Fail.</u> Following each flight, the errors are squared and following the first flight, the errors squared are summed (e.g., if the error was 2 NM on the first flight and 3 NM on the second flight then

the cumulative squared errors would equal 4 + 9 = 13. The cumulative error squared is the value of the ordinate (y coordinate in a Cartesian coordinate system) and the number of trials is the value of the abscissa (x coordinate in a Cartesian coordinate system). The intersection of these two values is then plotted on figure 2. The along track RNP-10 requirements are passed when the plots of the cumulative errors squared fall below the lower pass line or fail if they pass above the upper fail line.

g. Operators planning to use their aircraft in a particular route system should gather error data from flights through that system (e.g., NOPAC, CEPAC). If operations are planned for an area other than the one in which data are collected, the operator should show that navigational performance will not be degraded there.

h. The operator should develop a standard form on which to document each flight. It should include:

(1) Date
(2) Departure airport
(3) Destination airport
(4) Aircraft type, series and registration number
(5) Make and model of the candidate navigation system
(6) Type of reference system used (e.g., VOR/DME, DME/DME)
(7) Time at which the candidate system is placed in navigation mode
(8) Times (if any) at which the candidate system is updated while en route
(9) Time at which positions are recorded from the candidate system and the reference system
(10) Reference system position coordinates
(11) Candidate system position coordinates
(12) Desired track, or waypoints passed immediately before and after the recorded positions

After the flight the operator computes the lateral deviation c_i and the longitudinal error a_i, as indicated above.

3. STATISTICAL PROCEDURES.

a. Background. Sequential sampling procedures are used to determine whether a candidate aircraft and navigation system should receive RNP-10 approval. After each trial the operator recomputes certain statistics and compares them to numbers indicated below. The comparison will infer one of three possible results:

(1) the candidate aircraft and navigation system satisfy the RNP-10 performance requirements, and the statistical test is terminated; or

(2) the candidate aircraft and navigation system do not satisfy the RNP-10 performance requirements, and the statistical test is terminated; or

(3) the operator needs to perform another trial (i.e., gather more data) and continue the statistical test, as it cannot yet reach a decision with the required level of confidence.

b. A sequential sampling procedure typically requires fewer trials than does a statistical test that has a fixed number of trials and has the same probability of making the correct decision. In general, the better an aircraft navigates, the fewer trials it will need to pass the test, i.e., to demonstrate RNP-10 compliance. However, for the FAA to have sufficiently high confidence in the test results, even an aircraft that navigates perfectly will need to perform at least 13 trials in order to demonstrate that it meets the RNP-10 lateral containment criterion, and at least 19 trials to demonstrate that it meets the RNP-10 longitudinal accuracy criterion. An aircraft that navigates poorly will need relatively few trials before failing the test. The test has been designed so that the average number of trials needed for it to reach a decision is approximately 100.

c. Test of Lateral Conformance. To establish whether or not the navigation system meets the RNP-10 lateral containment criterion, the operator may use the mathematical process described in this paragraph, or use the graph shown in figure 1 and described in paragraph 3e. After conducting at least 13 trials, the operator should add together all of the lateral deviations obtained up to that point. Suppose, in particular, that n trials have been conducted. If the sum of lateral deviations does not exceed $2.968n - 37.853$, the candidate aircraft and navigation system have demonstrated compliance with the RNP-10 lateral containment criterion, and the operator should stop computing lateral deviation data. If the sum of the lateral deviations equals or exceeds $2.968n + 37.853$, the candidate aircraft and navigation system have demonstrated that they do not meet the RNP-10 lateral containment criterion, and the operator should stop computing lateral deviation data. If the sum of the lateral deviations is between $2.968n - 37.853$ and $2.968n + 37.853$, the test cannot yet yield a decision. The operator must perform another trial to obtain an additional lateral deviation. This new lateral deviation is added to the sum obtained previously, and the new sum is then compared to $2.968(n+1) - 37.853$ and $2.968(n+1) + 37.853$.

d. In other words, let $S_{c,n} = c_1 + c_2 + \ldots + c_n$ be the sum of (the absolute values of) the lateral deviations obtained in the first n trials. If $S_{c,n} \leq 2.968n - 37.853$, the aircraft and its navigation system pass the lateral conformance test. If $S_{c,n} \geq 2.968n + 37.853$, the aircraft. and its navigation system fail the lateral conformance test. If $2.968n - 37.853 < S_{c,n} < 2.968n + 37.853$, the operator must:

(1) perform another trial to obtain c_{n+1};

(2) compute $S_{c,n+1} = c_1 + c_2 + \ldots + c_n + c_{n+1}$ $(= S_{c,n} + c_{n+1})$;

(3) compare $S_{c,n+1}$ to $2.968(n+1) - 37.853$ and to $2.968(n+1) + 37.853$; and

(4) determine whether the candidate aircraft and navigation system pass the test or fail the test, or whether an $(n + 2)^{th}$ trial is needed.

e. Figure 1 illustrates these rules for the lateral conformance test. The operator may wish to plot points on figure 1 as lateral deviation data are collected. The abscissa (horizontal component) of each plotted point is n, the number of trials completed; and the ordinate (vertical component) of each point is $S_{c,n}$, the sum of the (absolute values of the) lateral deviations observed in the n trials. The test ends as soon 'as a point falls into the lower right region or the upper left region of the graph. If a point is plotted in the lower right region, the candidate aircraft and navigation system have shown that they satisfy the RNP-10 lateral containment criterion. If a point is plotted in the upper left region the candidate aircraft and navigation system have demonstrated that they do not meet the criterion. Whenever a point is plotted in the middle region, the operator needs to accumulate more data.

f. In the event that the tests of $S_{c,n}$ do not yield a decision on *the* aircraft's lateral performance after 200 trials, the operator should perform the following computations:

(1) Compute the quantity $D_1 = c_1^2 + c_2^2 + \ldots + c_{200}^2$

(2) Compute the quantity $D_2 = \frac{S_{c,200}^2}{200} = \frac{(c_1 + c_2 + \ldots + c_{200})^2}{200}$

(3) Compute the quantity $D_c^2 = \frac{D_1 - D_2}{200}$

If D_c^2 does not exceed 18.649, the aircraft and navigation system satisfy the RNP-10 lateral containment criterion. If D_c^2 does exceed 18.649, the aircraft and navigation system do not meet the criterion, and do not qualify for RNP-10 approval.

g. Test of Longitudinal Accuracy To establish whether or not the navigation system can meet the RNP-10 longitudinal accuracy criterion the operator may use the mathematical process described in paragraphs 3h and 3i, or use the graph provided in figure 2, as described in paragraph 3j.

h. After conducting at least 19 trials, the operator should add together the squares of all the longitudinal errors obtained up to that point. Suppose, for example, that n trials have been conducted. If the sum of the squares of the longitudinal errors does not exceed $22.018n - 397.667$, the aircraft and navigation system have demonstrated compliance with the RNP-10 longitudinal accuracy requirement, and the operator should stop computing longitudinal error data. If the sum of the squares of the longitudinal errors exceeds $22.018n + 397.667$, the aircraft and navigation system have demonstrated that they do not meet the RNP-10 longitudinal accuracy requirement, and the operator should stop computing longitudinal error data. If the sum of the squares of the longitudinal errors is between $22.018n - 397.667$ and $22.018n + 397.667$, the test cannot yield a decision. The operator must perform another trial to obtain an additional longitudinal error. The square of this new longitudinal error is added to the sum obtained previously, and the new sum is then compared to $22.018(n+1) - 397.667$ and to $22.018(n+1) + 397.667$.

i. In other words, let $S_{a,n} = a_1^2 + a_2^2 + \ldots + a_n^2$ be the sum of the squares of the longitudinal errors obtained in the first n trials. If $S_{a,n} \leq 22.018n - 397.667$, the aircraft and its navigation system pass the longitudinal accuracy test. If $S_{a,n} \geq 22.018n + 397.667$, the aircraft and its navigation system fail the longitudinal accuracy test. If $22.018n - 397.667 < S_{a,n} < 22.018n + 397.667$, the operator must:

(1) perform another trial to obtain another longitudinal error a_{n+1};

(2) compute $S_{a,n+1} = a_1^2 + a_2^2 + \ldots + a_n^2 + a_{n+1}^2 \ (= S_{a,n} + a_{n+1}^2)$;

(3) compare $S_{a,n+1}$ to $22.018(n+1) - 397.667$ and to $22.018(n+1) + 397.667$; and

(4) determine whether the candidate aircraft and navigation system pass the test or fail the test, or whether an $(n + 2)^{th}$ trial is needed.

j. Figure 2 illustrates the rules for the sequential test of longitudinal accuracy. The operator may wish to plot points on figure 2 as longitudinal error data are collected. The abscissa (horizontal component) of a plotted point is n, the number of trials completed; and the ordinate (vertical component) of a point is $S_{a,n}$, the sum of the squares of the longitudinal errors observed in the n trials. The test ends as soon as a point falls into the lower right region or the upper left region of the graph. If a point is plotted in the lower right region, the candidate aircraft and navigation system have shown that they satisfy the RNP-10 longitudinal accuracy criterion. If a point is plotted in the upper left region, the aircraft and navigation system have demonstrated that they do not meet that criterion. Whenever a point is plotted in the middle region, the operator needs to accumulate more data.

k. In the event that the sequential sampling procedure described above does not yield a decision on the aircraft's longitudinal performance after 200 trials, the operator should perform the following computations:

(1) Compute the quantity $D_3 = \dfrac{(a_1 + a_2 + \ldots + a_{200})^2}{200}$

(2) Compute the quantity $D_a^2 = \dfrac{S_{a,200} - D_3}{200}$

If D_a^2 does not exceed 21.784, the aircraft and navigation system satisfy the RNP-10 longitudinal accuracy criterion. If D_a^2 does exceed 21.784, the aircraft and navigation system do not meet the criterion, and do not qualify for RNP-10 approval.

Figure 1: Acceptance, Rejection, and Continuation Regions for Sequential Test of Lateral Conformance

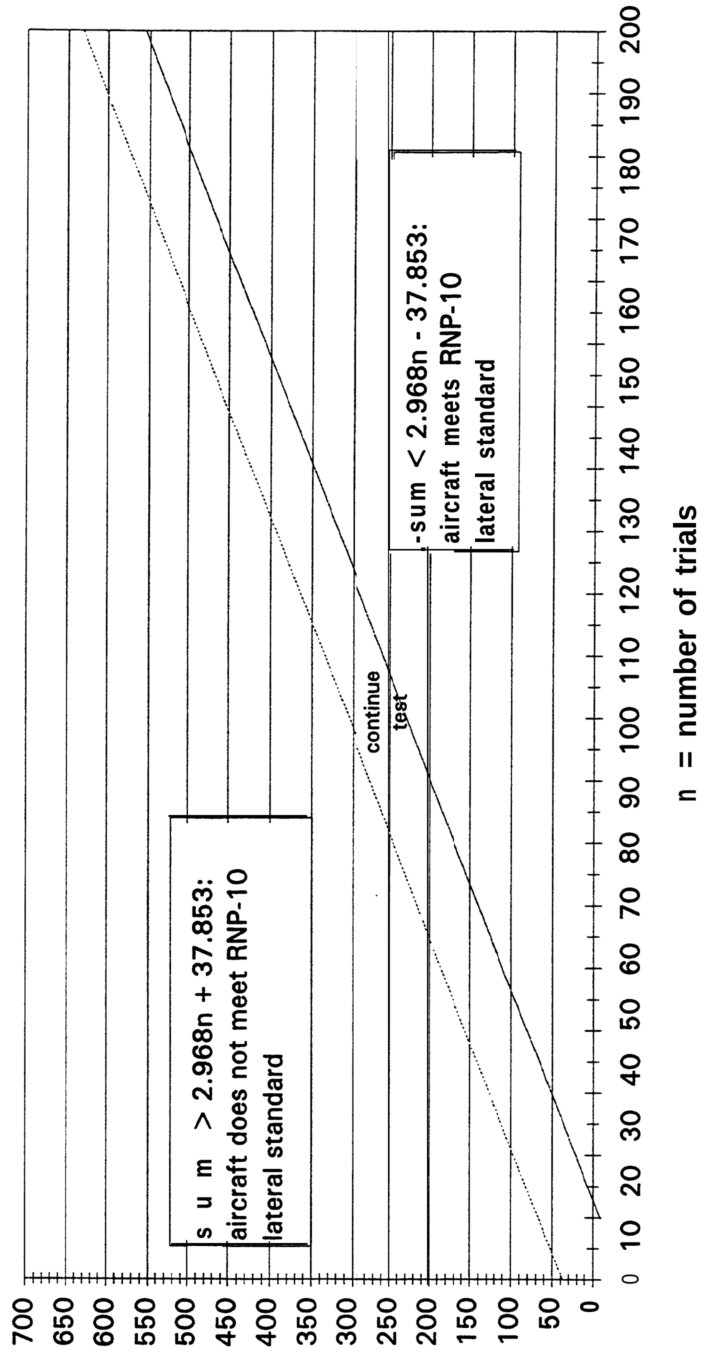
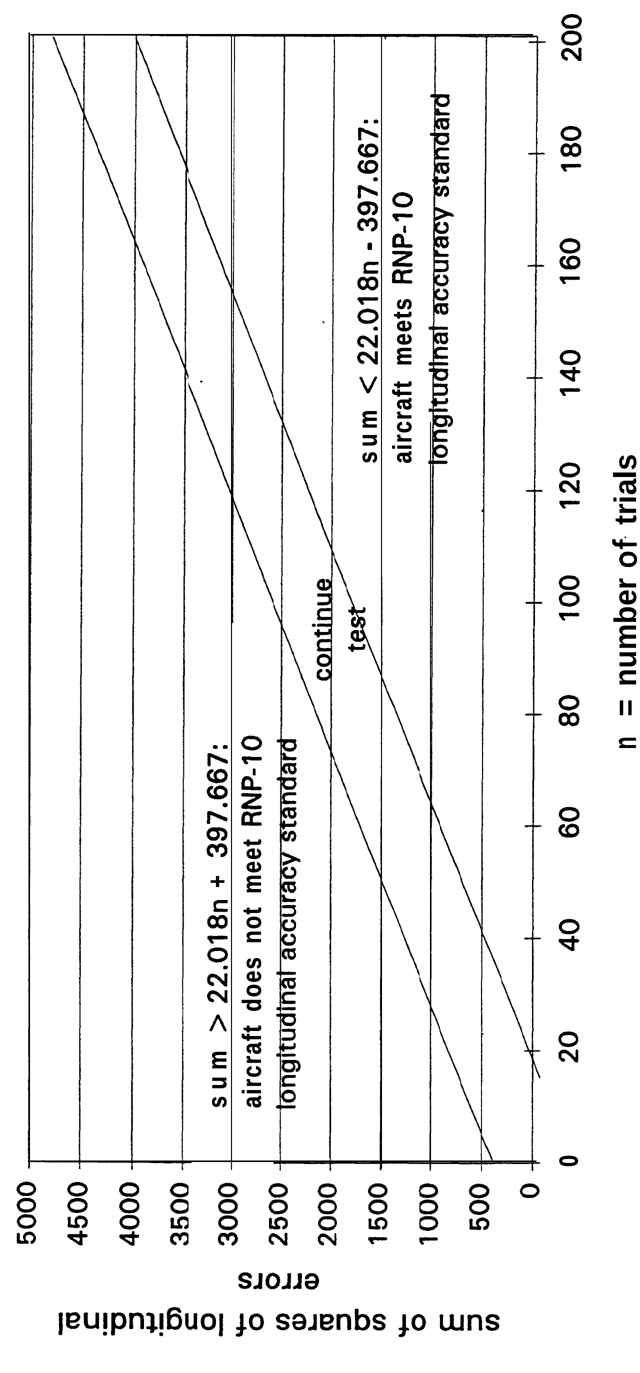


Figure 2: Acceptance, Rejection and Continuation Regions for Sequential Test of Longitudinal Accuracy



APPENDIX 2. CERTIFICATION OF IRU PERFORMANCE

1 GUIDELINES AND ASSUMPTIONS. IRU's that meet the current requirements of part 121, appendix G, meet all of the RNP-10 requirements for up to 6.2 hours of flight time without radio position updating. IRU accuracy, reliability, training, and maintenance issues that are required by appendix G, are part of the aircraft certification. However, IRU manufacturers believe that the actual performance of some types of IRU's exceeds the current appendix G requirements. A methodology for analyzing IRU performance, combined with requirements to update IRU manufacturer's Specification Control Drawings (SCD), Acceptance Test Procedures (ATP), and airline IRU maintenance /removal criteria is described in the following paragraph.

2. CERTIFICATION GUIDELINES.

a. IRU Accuracy and Reliability. IRU accuracy and reliability must be analyzed in conjunction with the flight management system interface. An analysis performed on a specific manufacturer's aircraft model is not necessarily applicable to other aircraft operating the same equipment. However, other aircraft may be analyzed using the same or equivalent methodology as proposed herein.

(1) The Radial Navigation Error Distribution for IRU's is Modeled by a Rayleigh Distribution. The 95% statistic of radial position error will be used when demonstrating compliance. It is assumed that cross-track and along-track errors are Gaussian, independent, and have equal variances.

(2) The Radial Position Error will be Evaluated for the Range of the Independent Time Variable (time in navigation), as certified for the IRU navigation maximum time (e.g., 18 hours).

(3) Time-Dependent Position Error Data will be Presented. Other non-inertial error sources will not be considered as part of the IRU certification (i.e., flight technical error). Therefore, the maximum time duration of flight operations in RNP-10 airspace will be evaluated and determined as part of the operational approval.

(4) The Assessment of Navigation Performance may Employ System Analysis. IRU Error Modeling (Covariance Analysis). and System Simulation. Analytical findings may be validated with empirical data from laboratory testing and aircraft flight testing, as applicable.

b. When credit is required for IRU performance that is superior to the original certification, the existing IRU specification control drawings for the IRU Type Designs should be revised to account for the new tighter tolerance system error budgets. If it has been determined that all IRU's for a given part number meet the minimum requirements of the new performance standard, then the IRU part number may remain the same. When only some of the IRU's for a given part number meet the minimum requirements of the new performance standard, then screening is required and part number updates will be required to identify the IRU's which are compliant to the new performance standard.

c. The AFM or AFM Supplement (AFMS) must be modified to reflect the certification of IRU's to tighter accuracy requirements, consistent with AC 25-4, Inertial Navigation System (INS), paragraph 5b(4). The AFM should provide sufficient time-dependent information so that the maximum time in RNP-10 airspace can be assessed as part of the operational approval.

d. In addition, production and field acceptance test procedures will require an update by the supplier, to ensure that the installed IRU meets the tighter accuracy tolerance required.

e. Operator maintenance procedures will require updating to ensure appropriate monitoring of IRU performance to the new requirements contained in this Order, and replacement of IRU's on aircraft that do not meet the navigation performance of this new criteria.

f. Procedures for flight operations should be identified and applied to ensure IRU alignment before extended range flights and time-in-navigation for the intended time duration of flight in RNP-10 airspace.

APPENDIX 3. DOCUMENTATION REQUIRED TO COMPLETE THE APPROVAL PROCESS

FIGURE 1. SAMPLE LETTER OF REQUEST BY AN AIR CARRIER TO OBTAIN RNP-10 OPERATIONAL APPROVAL

SUBJECT: Request for Required Navigation Performance (RNP) - 10 Approval

TO: Appropriate POI

[*Insert Airline Name]* request that Operations Specifications approval be issued to conduct en route operations on RNP *[insert number]* of *[insert number]* hours between updates on designated routes.

The following *[Insert Airline Name]* aircraft meet the requirements and capabilities as defined/specified in Federal Aviation Administration Order *[insert the number of this Order]*, dated ***[insert the date of this** Order]* for a RNP-10 qualification.

AIRCRAFT TYPE/SERIES	RNP-10 TIME LIMIT *	**NAVIGATION** EQUIPMENT	COMMUNICATIONS **EQUIPMENT**
B-747-400 Name and		List Nav Equip by Name and Type/Manuf/Model	List Corn Equip by Type/Manuf/Model
B-737-500 Name and		List Nav Equip by Name and Type/Manuf/Model	List Corn Equip by Type/Manuf/Model
MD-11 Name and		List Nav Equip by Name and Type/Manuf/Model	List Corn Equip by Type/Manuf/Model

Note: The above listed aircraft are samples only.

Training of flightcrews have been accomplished in accordance with applicable FAA regulations and guidance material.

* If unlimited time is requested, state: "Unl."

Sincerely,

[insert typed name and signature]

[insert title]

APPENDIX 3. DOCUMENTATION REQUIRED TO COMPLETE THE APPROVAL PROCESS

FIGURE 2. SAMPLE LETTER OF REQUEST BY A GENERAL AVIATION OPERATOR TO OBTAIN RNP-10 OPERATIONAL APPROVAL

SUBJECT: Request for a Letter of Authorization (LOA) to conduct Required Navigation Performance (RNP)

TO: Appropriate Flight Standards District Office (FSDO)

Operators must submit requests by letter with a separate page containing the "Format for an LOA to Operate at RNP-10" as shown on the following page.

LOA's

Aviation safety inspectors (ASI) can administratively issue an LOA to any general aviation operator that has an aircraft-navigation system meeting the requirements of this Order. The procedure for the issuance of the LOA is identical to the procedure contained in FAA Order 8700.1, chapter 222, with the exception that the format for the LOA has been modified to meet the specific requirements of an RNP approval. The format to be used is contained on the following page and may be copied or retyped at the convenience of the operator. If the LOA is retyped, inspectors will ensure that every item appearing in the sample, is included in the operator's version.

APPENDIX 3. DOCUMENTATION REQUIRED TO COMPLETE THE APPROVAL PROCESS

FORMAT FOR AN LOA TO OPERATE AT RNP-10

This letter constitutes approval for the named aircraft to operate or to conduct oceanic/remote area flight on routes specified as RNP-10 routes at the level indicated by the authorized operator or crew listed under the conditions and limitations below.

Aircraft make and model ______________________ N-Number __________________________
Aircraft serial number ________________________ Aircraft color ________________________

NAVIGATION EQUIPMENT

TYPE/MANUFACTURER/MODEL	PART NUMBER	DATE INSTALLED	RNP-10 TIME LIMIT

COMMUNICATION EQUIPMENT

TYPE/MANUFACTURER/MODEL	PART NUMBER	DATE INSTALLED

Aircraft base of operations (city, state, zip) ______________________________
Name of aircraft owner/operator ______________________________
Crew training conducted by ______________________________
Print name of person responsible for crew operations or agent for service (must be a U.S. citizen)

____
Signature of person responsible for crew operations or agent for service

____
Street address (cannot be a Post Office box)

____
City, state, and zip code ______________________________

FOR FAA USE ONLY (To be completed by issuing office)

This approval is for: RNP-10 under the conditions typed on the back of this authorization.
Authorization Number ______________________________
Aircraft limitations (if applicable) ______________________________
Program Tracking and Reporting Subsystem (PTRS) tracking number ______________________________
Date of Issuance ______________ Expiration Date ________________

This authorization is subject to the conditions that all operations conducted on an oceanic RNP route are in accordance with the flight rules contained in International Civil Aviation Organization (ICAO), Annex 2, and that all operations outside of the United States comply with section 91.703, and Annex 2. The person responsible for crew operations or agent for service must accept responsibility for complying with the stated regulations by signing this document. This document is considered invalid until signed. If the person signing this document relinquishes responsibility, changes mailing address, or the aircraft changes ownership or base of operation, this letter becomes invalid and the signee should immediately notify the issuing office of the change. LOA's can be renewed via letter or fax request submitted at least 30 days before the expiration date, if no changes have been made. If any changes have been made, application for a new LOA must be made in the same manner as that required for the initial LOA.

____
Office Manager's Signature

APPENDIX 3. DOCUMENTATION REQUIRED TO COMPLETE THE APPROVAL PROCESS INFORMATION TO BE INSERTED ON THE BACK OF THE LOA

PRE-FLIGHT SPECIAL REQUIREMENTS: ***Note: Operators should list any procedures that are utilized which are pertinent to the accuracy and time limit of the navigation capability*** **(e.g., an approved Fault Detection and Exclusion (FDE) program is required if GPS is to be used - if utilizing a procedure detailed in an another FAA document, that document may be referenced and a copy attached to the application).**

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OTHER INFORMATION AS DEEMED NECESSARY BY THE ISSUING FLIGHT STANDARDS DISTRICT OFFICE:

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APPENDIX 3. DOCUMENTATION REQUIRED TO COMPLETE THE APPROVAL PROCESS

FORMAT FOR LETTER TO RENEW LOA

FROM: *[person or department requesting LOA]*
[company name (if applicable)]
[street address] (P.O. Box not acceptable)
[city, state, zip code]

TO: Federal Aviation Administration (FAA)
Flight Standards District Office
[street address]
[city, state, zip]

Dear Inspector:

Enclosed is a copy of our LOA, which is due to expire within the next 60 days, and a completed form requesting a new LOA for operations in Minimum Navigation Performance Specification and/or Reduced Vertical Separation Minimum airspace.

I/we further certify that all authorized crews are qualified to operate in oceanic areas.

Sincerely,

[person's signature responsible for crew operations or agent for service]
[typed name of person responsible for crew operations or agent for service]
[title]
[date]

NOTE: The letter should be sent to the office that issued expired LOA.

APPENDIX 4. TRAINING PROGRAMS AND OPERATING PRACTICES AND PROCEDURES

1. INTRODUCTION. The following items (detailed in paragraphs 2 through 5) 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 found to be the case, then the intent of this appendix can be considered to be met.

2. FLIGHT PLANNING. During flight planning, the flightcrew should pay particular attentions to conditions which may affect operations in RNP-10 airspace (or on RNP-10 routes). These include, but may not be limited to:

a. verifying that the aircraft is approved for RNP-10 operations;

b. that the RNP-10 time limit has been accounted for (see paragraph 15);

c. verify that the letter "R" is annotated in Block 10 (Equipment) of the ICAO Flight Plan;

d. the requirements for GPS, such as FDE, if appropriate for the operation; and

e. if required for a specific navigation system, accounting for any operating restriction related to RNP-10 approval.

3. PREFLIGHT PROCEDURES AT THE AIRCRAFT FOR EACH FLIGHT. The following actions should be completed during preflight:

a. Review maintenance logs and forms to ascertain the conditions of equipment required for flight in RNP-10 airspace or on an RNP-10 route. Ensure the 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 navigation antenna and the condition of the fuselage skin in the vicinity of each of these antenna (this check may be accomplished by a qualified and authorized person other than the pilot, e.g., a flight engineer or maintenance personnel).

c. Emergency procedures for operations in RNP-10 airspace or on RNP-10 routes are no different than normal oceanic emergency procedures with one exception, crews must be able to recognize and ATC advised when the aircraft is no longer able to navigate to its RNP-10 approval capability.

4. EN ROUTE.

a. At least, two Long Range Navigation systems capable of navigating to the RNP should be operational at the oceanic entry point. If this is not the case, then the pilot should consider an alternate routing which does not require that equipment or diverting for repairs.

b. Before entering oceanic airspace, the aircraft's position should be checked as accurately as possible by using external navigation aids (navaids). This may require distance measuring equipment DME/DME and/or DME/VHF omnidirectional (VOR) checks to determine navigation system errors through displayed and actual positions. If the system is updated , the proper procedures should be followed with the aid of a prepared checklist.

c. Operator in-flight operating drills shall include mandatory cross checking procedures to identify navigation errors in sufficient time to prevent aircraft from inadvertent deviation from ATC cleared routes.

d. Crews shall advise ATC of any deterioration or failure of the navigation equipment below the navigation performance requirements or of any deviations required for a contingency procedure.

5. FLIGHTCREW KNOWLEDGE.

a. Commercial Operators should ensure that crews have been trained to ensure that they are knowledgeable of the topics contained in this order, limits of their RNP-10 navigation capabilities, effects of updating and RNP- 10 contingency procedures.

b. Part 9 1 operators should show the FAA that pilots are knowledgeable on RNP-10 operations. The intent is for an applicant for RNP-10 authorization to show the FAA that crew members are knowledgeable on the material contained in this order. FAA Order 8700.1, General Aviation Inspector's Handbook, Chapter 222, addresses training for part 91 operators. It states that specific training is not required by 14 CFR or by Annex 2 to the ICAO Rules of the Air and gives inspectors latitude in determining pilot qualifications. It further states that on the LOA, the statement, "Crew training conducted by" can be completed with an entry of: none, self, company training or the name of a commercial training course. Training "acceptable" to the FAA is not a prerequisite for issuing an RNP-10 authorization. It is also not a requirement that a part 9 1 operator provide a certificate of training that says it is FAA approved. What can be considered as acceptable for an operator to show that crews have adequate knowledge of the RNP- 10 operating practices and procedures contained in this order is:

(1) FAA inspectors can accept training center certificates without further evaluation;

(2) FAA inspectors may elect to evaluate a training course before accepting a training center certificate from a specific center;

(3) FAA inspectors may accept a statement in the operator's application for an RNP-10 LOA that the operator has and will ensure that crews are knowledgeable of RNP-10 operating practices and procedures contained in this order; and

(4) FAA inspectors may accept a statement by the operator that it has conducted or will conduct an in-house RNP-10 training program.

APPENDIX 5. CHECKLIST AND JOB AID FOR THE RNP-10 APPROVAL APPLICATION PROCESS

OPERATOR FUNCTIONS:

1 OPERATOR PREPARES AN APPLICATION PACKAGE AS DESCRIBED IN PARAGRAPH 9 OF THIS ORDER.

2. OPERATOR SELF-EXAMINATION. It is advisable that operators become familiar with paragraphs 8 and 9 of this order before contacting the FAA. These sections provide the criteria for approvals by placing aircraft/navigation systems in groups. A knowledge of these sections provides the operator with an indication of how much time might be required in obtaining an approval. Group I approvals are administrative and can be granted as quickly as district office work loads will permit. Group II approvals may be made quite rapidly or may take longer depending upon the aircraft/navigation system configurations. Group III approvals will usually involve an extended time for evaluation and an approval may or may not be granted.

3. OPERATOR SCHEDULES A PREAPPLICATION MEETING. The operator schedules a preapplication meeting with either CHDO for commercial operators, or FSDO for general aviation.

4. OPERATOR SUBMITS A FORMAL APPLICATION FOR APPROVAL. The operator submits a formal application for approval in accordance with the FAA expectations discussed in the preapplication meeting. The formal application should be made in writing in a manner similar to those shown in appendix 3.

- Figure 1 for Air Carriers
- Figure 2 for General Aviation

5. OPERATOR TRAINS CREW. An RNP-10 airspace or an RNP-10 route is a special airspace. There are no legal requirements for general aviation operators to have specific training for RNP-10 operations; however, ICAO Rules demand that States ensure that the crew members are qualified to operate in special airspace. Thus, general aviation operators will be required to satisfy the Administrator that they are qualified.

6. OPERATORS RECEIVE OPERATION SPECIFICATIONS OR AN LOA. The operators receive operation specifications for an LOA to operate in an RNP-10 airspace or on an RNP-10 route.

7. CREWS ARE AUTHORIZED TO PERFORM RNP-10 OPERATIONS. Crews are authorized to perform RNP-10 operations for the time authorized within the parameters established for their navigation system configuration.

INSPECTOR FUNCTIONS:

See Job Aid on the next page.

INSPECTOR'S JOB AID

PTRS CODE	APPLICANT______________________________	Para & Pg	INSP INIT.	DATE
	1. Inspector familiarization with the approval process	Para 8 Pg 3		
1366	**2. Set up applicant meeting date**	Para 8a Pg 3		
1366	**3. Application meeting:** **Inspector____________________** Applicant orientation to FAA Order 8400.12A Check of Documentation -RNP time requested for specific route system or area of operation -Airworthiness documentation -Current Operation Specifications, if applicable -Current Letter of Authorization, if applicable -Copy of pertinent sections of the Airplane Flight Manual -List of number and type of Long Range Navigation Units (e.g., 3- Litton 92, INS) -Description of Long Range Navigation System integration. -Description of updating procedures, if used -Review of training program -RNP-10 Operations Issues -RNP- 10 Contingency Procedures -Updating Procedures and Implications of the Update on the Navigation Solution (if updating is planned)	Para 8a Pg 3		
	3. Evaluate Operator's Long Range Navigation System - Determine Eligibility Group Choose one of the following as a means by which approval will be accomplished: -The operator has an Airplane Flight Manual (AFM) entry or other documentation from an FAA Aircraft Certification office granting certification approval for RNP-10 or better for a specific time period (eligibility group 1) -Plan on approving the operator for unlimited RNP- 10 navigation if either one or both of the required Long Range Navigation Systems is a GPS and the unit(s) are integral to the primary steering instrument of the mandatory flightcrew. GPS approval guidance is contained in HBAT 95-09 and FAA Notice 8110.60 -Approve the operator for the RNP value and time specified in the AFM -Approve the operator for RNP-10 for 6.2 hours based upon the "/E" suffix as defined in the AIM and qualifications that meet	Para 12 Pg 7 Para 12a Pg 8		

INSPECTOR'S JOB AID (Continued)

PTRS CODE		Para & Pg	INSP INIT	DATE
	3. Evaluate Operator% Long Range Navigation System (continued) Title 14 CFR Part 12 1, Appendix G (eligibility group 2) ask operator if approval of additional time will be needed - if yes, then a discussion of one of the extended time procedures will be required	Para 12b Pg 8		
	-Require that operational navigation performance data be presented (eligibility group 3)	Para 12c Pg 9		
	-Determine if the operator has updating procedures. If yes, then the procedures for its use must be contained in the training curriculum and crews must be knowledgeable in its use and its effect on the navigation solution. If no, then;	para 121d and 12e Pg 10		
	-Advise operator that a data collection program based on one of the following will be required prior to granting approval (eligibility group 3)	Appendix 1		
	-Sequential sampling based on Appendix 1 of FAA Order 8400.12A	Appendix 6		
	-Periodic data collection based upon a portable GPS being used for a base-line (see Appendix 6) or data collection based upon the radial error determined from destination gate positions			
	4. Data Analysis Meeting -Check all data required and discussed at the application meeting -Be especially aware that the documentation is consistent with the equipment actually installed in the aircraft Check training curriculum or in the case of general aviation operators, the knowledge of the person endorsing the crew knowledge section of the LOA	Appendices 1 and 6		
	-If data collection was required, examine it closely. If any doubt exist as to the validity or integrity of the data, contact one of the navigation specialists or AFS-400 at Washington headquarters	Appendix 4		

INSPECTOR'S JOB AID (Continued)

1442	**5. Issue operation specifications or an LOA* to the operator.**			
1442	**6. Complete a Program Tracking and Reporting System (PTRS) report noting the issuance of the RNP-10 authorization for a specified time** -The National Use Field is a 9 space Alpha Numeric Field. The following entry must be made in the field: **"RNP-10"** followed by 3 spaces.			

** Note FAA Order 8700.1, chapter 222, Guidance for the Issuance of a Letter of Authorization, provides the AS' with details relative to the issuance of an LOA.*

APPENDIX 6. A SAMPLE DATA COLLECTION PROCESS (PERIODIC METHOD)

1. INTRODUCTION.

a. This section describes data collection procedures that have been approved by AFS-400 on the basis of analysis of the data and multiple validation flights. There are two methods in which data may be collected. One procedure is based upon the use of a handheld Global Positioning System (GPS) as a baseline for the correct position determination with the GPS readings and the data collection being taken by a non-essential flightcrew member. Only authorized flightcrews may operate the navigation system. Although no technical specifications are stated for the GPS unit used, it behooves operators to use the best quality unit that is practical. Poorer quality units might malfunction or provide erroneous data that will distort or negate the data collected **and** make the process excessively expensive. The second method uses a single, un-updated gate position as a data point and performing the calculations at the end of this appendix to determine an RNP-10 limit.

b. It is possible to evaluate triple-mix, individual units or both using this data collection procedure, the data collection forms are designed for this purpose. Operators desiring to use gate position only, do not need to use the data pages but can go directly to the destination data page and record the gate position data and time since last update.

2. GENERAL INSTRUCTIONS.

a. GPS Updating. Pilots are requested not to update the INS to a GPS position. Doing so would invalidate the data collected.

b. Data Recording. When recording data, all times are Universal Coordinated Time (UTC). Circle latitude and longitude senses (N or S, E or W). Please record any additional information that could be helpful in analyzing recorded data.

c. Page Heading. Complete all sections of the heading ON EACH PAGE. This is important in the event that pages become separated and get mixed with data from other flights.

d. INS Initialization. (Page 1 of DATA PAGES following this section.)

(1) Record any unusual movement of the airplane during INS initialization before NAV mode selected, such as wind gusts, or an airplane service vehicle bumping the airplane, or settling during fueling.

(2) If there was any unusual movement during INS alignment, record INS track (TK / GS) after NAV mode is selected.

(3) Record the published gate coordinates and/or GPS position where the INS is initialized.

(4) Was triple-mix selected? Check yes or no.

(5) Check if updating is by radio navigation of position, yes or no.

e. Times. (Page 1 of DATA PAGES following this section.)

(1) Before departure, record the time the pilots are observed putting the INS NAV mode selectors in NAV.

(2) Record OFF time.

(3) Record the time leaving class II navigation when radar contact is first established.

(4) Record IN (at the gate) time.

f. Destination Gate Positions. (Pages 4 and 5 of the DATA PAGES following this section.)

(1) Request that pilots not remove INS updates until INS updated / triple-mix positions are recorded at the gate.

(2) Record the destination gate number, published position, the number of GPS SV's (Satellite Vehicles) in view, GPS DOP and EPE values, and GPS position.

(3) Record INS updated / triple-mix positions.

(4) Remove INS updates.

(5) Record INS un-updated positions and INS distances from the gate position.

(6) INS data should be recorded in the Maintenance Log as usual.

g. 1/2 Hourly Position Readings. (Page 2 and beyond of data pages following this section.)

(1) Once each 30 minutes after takeoff (ACARS OFF time), plus or minus 5 minutes, record GPS and INS positions. Do not record data during climb or descent, during pilot INS Waypoint Change procedures or at other times when pilots obviously are busy with other tasks, such as ATC or cabin communications.

(2) Record the desired track (DSRTK/STS) of steering INS.

(3) Record the last and next waypoints lat/long and name.

(4) Freeze the GPS and INS positions simultaneously.

(5) Record GPS position.

(6) Record INS updated / triple-mix positions (HOLD and POS selected).

(7) Record the INS un-updated (Inertial) positions. (HOLD and WAY PT, thumbwheel other than 0 selected).

(8) Release the frozen INS and GPS positions.

h. En Route INS Updates. Use this section only if manual updating is being evaluated.
NOTE: There is no data sheet example for radio navigation updates.

(1) Record the identifier of the navaid over which updating is accomplished and the navaid coordinates.

(2) Record the number of GPS satellites in view and the GPS PDOP value.

(3) Record the time when INS coordinates are frozen before the en route update is accomplished.

(4) After INS positions are frozen and BEFORE AN UPDATED POSITION IS ENTERED.

(5) Record the INS updated / triple-mix positions and INS un-updated positions.

(6) Record the GPS position.

i. Radio Navigation INS Updates. Use this section only if manual updating is being evaluated (e.g., ground based radio navigation positions are used for INS updates); record:
NOTE: There is no data sheet example for radio navigation updates.

(1) Navaid identifiers.

(2) Aircraft position derived from ground navaids (update position).

(3) Time of update.

(4) INS position before update.

(5) GPS position.

DATA PAGES

Flight No. ______ UTC Departure Date _________ Departure Airport ______________________________

Aircraft Type. ________ Registration No. N____________ Arrival Airport _________ Captain ______________

INS INITIALIZATION

Were there any unusual motion events during alignment? Yes ________ No ________
If yes, INS Track (TK / GS)

If yes, provide a brief description of the event(s): ____

____

____

INS initialization coordinates (published or GPS): N / S

E / W

Triple-mix selected? Yes ________ No ________

Radio navigation updating? Yes ________ No ________

TIMES

	Z	OFF
	Z	Time NAV mode selected
hrs.	mins.	Time in NAV mode before takeoff
	Z	Time entering Class II nav airspace
	Z	Approx time leaving Class II nav airspace
	Z	Time NAV mod selected
hrs.	mins.	Approx time in NAV mode before leaving Class II airspace
	Z	IN
	Z	Time NAV mode selected
hrs.	mins.	Total time in NAV mode

DATA PAGES

Flight No. _______ UTC Departure Date __________ Departure Apt ________________________________

Plane No. ________ Registration No. N____________ Arrival Apt _________ Captain ________________

DATA POINT 1		**Z**		**Altitude**	
GPS	No. of SV	DOP		EPE	
GPS Position	N/S			E/W	
Triple-Mix Positions				Un-Updated Positions	
		INS 1			
		INS 2			
		INS 3			
LAST WAYPOINT		NAME		N/S E/W	
NEXT WAYPOINT		NAME		N/S E/W	

DATA POINT 2		**Z**		**Altitude**	
GPS	No. of SV	DOP		EPE	
GPS Position	N/S			E/W	
Triple-Mix Positions				Un-Updated Positions	
		INS 1			
		INS 2			
		INS 3			
LAST WAYPOINT		NAME		N/S E/W	
NEXT WAYPOINT		NAME		N/S E/W	

DATA PAGES

Flight No. _______ UTC Departure Date __________ Departure Airport ________________________________

Aircraft Type. ________ Registration No. N____________ Arrival Airport _________ Captain ______________

DATA POINT 3	Z		Altitude	
GPS	No. of SV	DOP	EPE	
GPS Position	N/S		E/W	

Triple-Mix Positions		Un-Updated Positions	
	INS 1		
	INS 2		
	INS 3		
LAST WAYPOINT	NAME	N/S E/W	
NEXT WAYPOINT	NAME	N/S E/W	

DATA POINT 4	Z		Altitude	
GPS	No. of SV	DOP	EPE	
GPS Position	N/S		E/W	

Triple-Mix Positions		Un-Updated Positions	
	INS 1		
	INS 2		
	INS 3		
LAST WAYPOINT	NAME	N/S E/W	
NEXT WAYPOINT	NAME	N/S E/W	

DATA PAGES

Flight No. _______ UTC Departure Date __________ Departure Apt ________________________________

Plane No. ________ Registration No. N____________ Arrival Apt _________ Captain ________________

NOTE: Copy previous pages for use in collecting data points in excess of 4 as needed to collect data for the total flight hours. Use the procedures following the destination data pages to analyze the data.

<u>COMPLETE DESTINATION DATA ON NEXT PAGE</u>

DATA PAGES

Flight No. _______ UTC Departure Date __________ Departure Airport ________________________________

Aircraft Type. ______ Registration No. N____________ Arrival Airport _________ Captain ______________

DESTINATION GPS / INS POSITIONS

Please do not remove INS updates **until** up-dated / triple-mix positions are recorded at the gate.

Destination Gate No.

PUBLISHED POSITION --------> N/S E/W

GPS	No. of SV	DOP	EPE
GPS Position	N/S	E/W	
Triple-Mix Position	Un-Updated Positions	Distance	

Name of person recording data (Please print): ________________________________

Position: ______________________ Company Location: ______________________

Telephone No. (Business and home): ________________________________

3. RNP-10 DATA REDUCTION TECHNIQUES FOR PERIODIC IN-FLIGHT. METHOD OF DATA COLLECTED.

a. Collect reference data (GPS) and INS/IRU data at least every 30 minutes after reaching initial cruise altitude. (Lat, Long, Height and time at the same time for each system.)

b. Determine North-South and East-West error in NM. (Difference between GPS and INS/IRU position translated into NM.)

c. Graph position error (using GPS as reference) vs. time for each flight.

d. Since the actual time of measurement and the test time interval will vary, establish on each flight chart (plot) an equally spaced interval.

e. At each time interval, calculate the radial position error for each flight. (This requires interpolation of the North-South, East-West data from the graphs.)

f. This radial error is the data used to determine the 95 percentile level of error. "The 95 percentile error level of error" is used here to mean that it is 95 % probable that the error in a given flight will fall below this level or that the level will be below this level in 95% of flights if the number of flights is very large.

g. After collecting the data for all flights, calculate the root-mean-square (RMS) and Geometric Mean (GM) of the radial errors For each elapsed time point. Also determine the ratio of GM/RMS for each elapsed time point.

$$RMS = \left(\frac{1}{n} \sum_{i=1}^{i=n} r_i^2 \right)^{1/2}$$

$$GM = \left(\prod_{i=1}^{i=n} r_i \right)^{1/n}$$

where:

r = radial error at elapsed time point

n = number of observations of radial error at equally spaced time intervals

h. Using the P=95 curve from the figure 1 on page 10, find the value of $r_{(P)}$/RMS for the calculated value of GM/RMS. Multiply this $r_{(P)}$/RMS factor by the value of RMS to determine an estimate of the 95th percentile value of radial error at this elapsed time point.

i. Repeat the above procedure for each elapsed time point. Graph $r_{(95)}$ values of radial error (in NM) vs. elapsed time since entering the NAVIGATE mode.

j. Pass-Fail Criteria. The elapsed time when radial error $r_{(95)}$ exceeds 10 NM defines maximum flight time wherein the navigation system meets RNP-10 criteria.

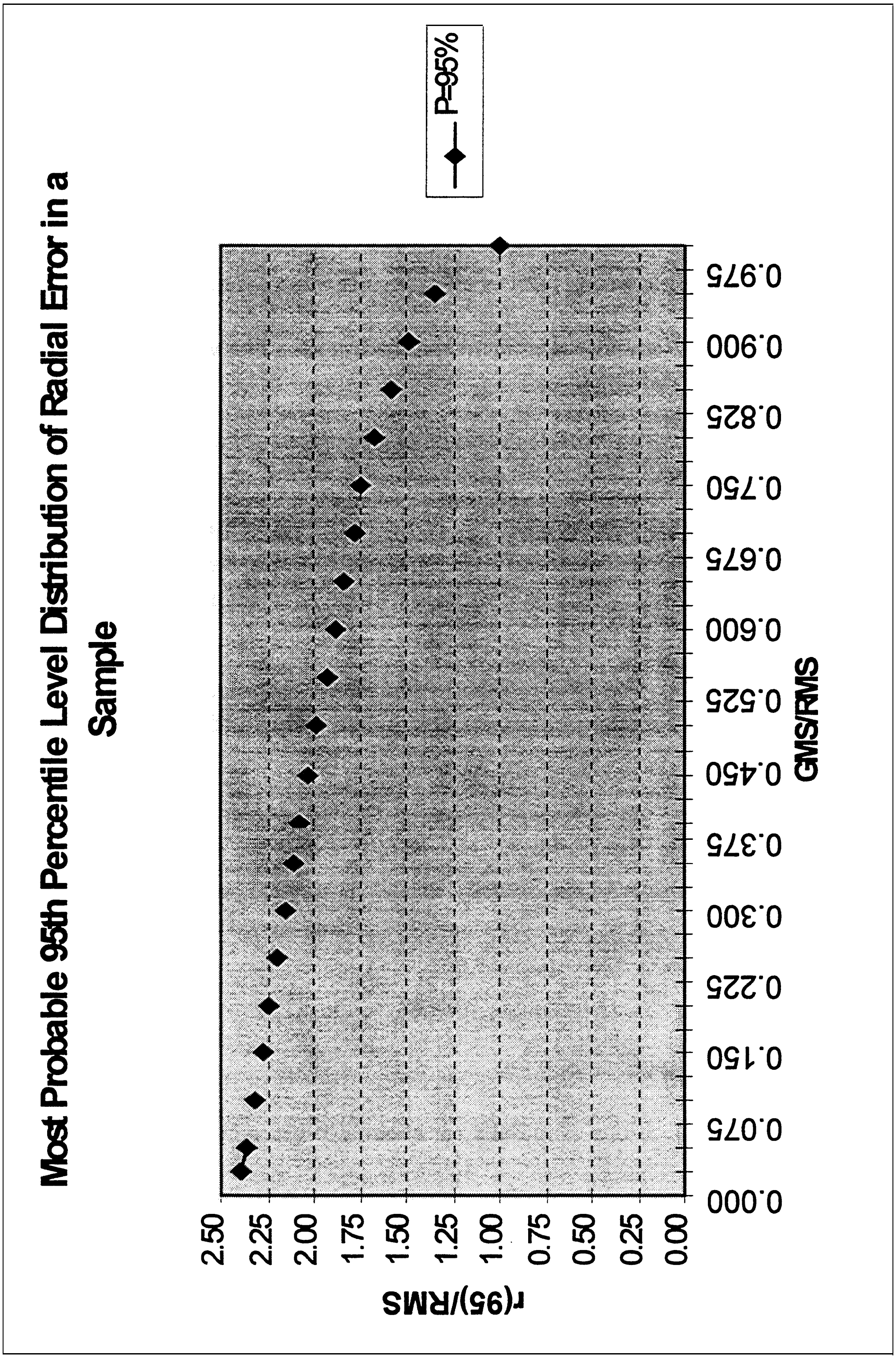
Most Probable 95th Percentile Level Distribution of Radial Error in a Sample
P=95%
r(95)/RMS
2.50
2.25
2.00
1.75
1.50
1.25
1.00
0.75
0.50
0.25
0.00
0.000
0.075
0.150
0.225
0.300
0.375
0.450
0.525
0.600
0.675
0.750
0.825
0.900
0.975
GMS/RMS

Figure 1

4. PERIODIC METHOD EXAMPLE. For an example, a 6 flight data set is used (in actual practice a much larger data set should be used to provide confidence). For simplicity of illustration, this example uses only the Triple-Mix positions after 10 hours in nav (the time was an arbitrary selection to illustrate the means of calculation). Data for individual navigation units is not included in this example; if they had been used, they would be calculated in exactly the same manner that the Triple-Mix data is calculated in the example. If an operator decided to use gate position, only Figure 2 should be used.

Symbols Used in figures below:

r = radial error

r^2 = square of the radial error

IIr = product of radial errors

Σ = Sum

Σr^2 = Sum of the squares of the radial errors

Figure 1. Table of Radial Errors "r" (Use for airborne data collection)

Flight	radial errors = r	r^2
1	6.5	42.25
2	5.5	30.25
3	12.7	161.22
4	14.0	196.00
5	7.2	51.84
6	7.0	49.00

The product **(II)** of radial errors (column 2) = 320,360

The sum of the radial errors squared (Σr^2) (column 3) = 530.63

Calculations:

$$\text{RMS} = \left(\frac{1}{n}\sum_{i=1}^{i=n} r_i^{\,2}\right)^{1/2} = (1/6\ (530.63))^{1/2} = 9.40$$

$$\text{GM} = \left(\prod_{i=1}^{i=n} r_i\right)^{1/n} = (320.36)^{1/6} = 8.27$$

RATIO = GM/RMS = 8.27/9.40 = 0.88

Find this value (0.88) on the abscissa of the "Most Probable Graph" and intersect it with the 95% curve to find $r_{(95)}$ /RMS (on the ordinate of the graph)

thus $r_{(95)}$ /RMS = 1.47 (for this example)

The ordinate is defined as $r_{(95)}$ /RMS

where $r_{(95)}$ = 95 percentile of error

Now $r_{(95)}$ for the data in the example is determined from the following:

$r_{(95)}$ = Ordinate value (for the data) x RMS = 1.47 x 9.40 = 13.8 NM

These results indicate:

The 95 percentile level of error at 10 hours is 13.8 NM which is greater than the required 10 NM and the system would not qualify for RNP-10 for 10 hours based on the data presented.

For guidance on gate position data collection, go to next page.

Figure 2. Table of Radial Errors (Use for gate position data)

Note: No data is provided for this method. Calculations would be made identical to the procedure used in Figure **1.**

Time is critical with this set of data and it should be noted that the credited time is that of the smallest time value in the data set.

Flight	Times since last update	Radial Error at Gate = r	r^2

(1) The product (II) of radial errors (column 3) = ______________

(2) The n^{th} route of II = ________________ = GM

(3) The sum of the radial errors squared (Σr^2) (column 4) = ________________

(4) The square route of $\left(\frac{1}{n} \sum r_i^{\ 2}\right)$ = ________________ = RMS

After calculating (2) and (4) use figure 1 on page 10 to determine $r_{(95)}$. Multiply this factor by the RMS to determine the drift in NM. If this value is less than 10 NM then the navigation system can be approved for RNP-10 for the time in nav of this flight. Note that this is the data for one flight only, data **must** be collected in the same manner and in an equal time length for a minimum of 20 flights.

APPENDIX 7. AN APPROVED MANUAL UPDATING PROCEDURE

Manual Updating for RNP-10 Operations

1. INTRODUCTION. In order to facilitate RNP-10 operations for airborne navigation systems that are unable to achieve RNP-10 performance for greater than 6.2 hours, the following methods of manual position updating are suggested as a means to extend the 6.2 hours. Manual position updating is defined to mean a technique where the crew uses one of the techniques, described below, to adjust their INS output to compensate for the detected error. The detected error is the difference between the radio navigation position and the INS/IRU position with the radio navigation position being considered the correct position.

Two techniques using VOR/DME or TACAN and one technique using a Global Positioning System are possible means of manual updating. The first is a position update based on crossing a fix along a route defined by a bearing and distance from/to a VOR/DME or TACAN facility. The second is based on a route that flies over a VOR/DME or TACAN facility. The third is similar to the first but uses a TSO C-129 GPS receiver with an approved installation for the update in place of a navigation aid. In each of the three methods, a log (the plotting chart used in each of the procedures is an acceptable log if all required data is entered on the chart) of the procedure must be made of the data and maintained by the operator for a period of 30 days. The conditions under which either method may be used are as follows:

a. Class II Inertial Navigation Systems meeting 14 CFR, part 121, appendix G requirements or the criteria established in Advisory Circular 25-4, Inertial Navigation Systems (INS).

b. For the first and second methods the minimum distance from the reference VOR/DME facility must be at least 50 nautical miles.

c. Both the VOR and DME functions of the reference facility must be operational prior to dispatch release and during the intended updating operation unless the GPS procedures is used as a reference.

d. The flightcrew must have in its possession a plotting chart with the information specified in this Appendix.

2. MANDATORY DATA REQUIRED TO ACCOMPANY ALL OF THE UPDATING METHODS (Required for Each Flight along with Copy of the Plotting Chart).

INS INITIALIZATION

Were there any unusual motion events during alignment? Yes ________ No ________
If yes, INS Track (TK / GS)

If yes, provide a brief description of the event(s): ____

____

INS initialization coordinates (published or GPS): N/S E/E

Triple-mix selected? Yes ________ No ________

Radio navigation updating? Yes __________ No ________

TIMES

PRIOR TO TAKEOFF

__________________Z OFF

__________________Z Time NAV mode selected

__________________hrs. ___mins Time in NAV mode before takeoff

FLIGHT PHASE

__________________Z Approx time leaving Class II nav airspace

__________________Z Time NAV mod selected

__________________hrs. ___mins Approx time in NAV mode before leaving Class II airspace

ARRIVAL PHASE

___________________Z IN

___________________Z Time NAV mode selected

___________________hrs __mins Total time in NAV mode

3. TRAINING.

a. Commercial operators intending on using manual updating procedures must ensure that every flightcrew using the procedures is trained in the updating procedures. The operator should be able to demonstrate that it has a reliable method of having its crews perform the update, and can be approved by the operator's POI to determine if the method is acceptable. Training manuals must be updated to include the procedures and will be evaluated by the POI as a part of the approval process.

b. General aviation operators intending on using manual updating procedures must provide evidence to the approving office that crews using the procedures are capable of maintaining the same standards as commercial operators.

4. METHOD 1: MANUAL UPDATING BASED ON CROSSING A FIX ALONG A ROUTE.

a. Using Method 1, the update is performed when crossing over a fix that is defined by a crossing radial and distance from a VOR/DME or TACAN facility. To accomplish this update, the crossing radial must be at or near perpendicular to the route. The minimum DME /TACAN distance used to define the fix location shall be at least 50 NM.

b. The flightcrew should tune in the reference VOR/DME or TACAN facility and pre-select the appropriate bearing on one CDI. As the CDI centers, the flightcrew will note the distance from the VOR/DME or TACAN facility and mark it on the plotting chart. The flightcrew will also note the inertial positions of each of the operating INS. The crew will then compare the inertial position against the derived position. The crew then may use the derived position (expressed in lat/long) to update the inertial position. If interpolation is necessary, round up. This procedure would provide a means to re-start the RNP-10 clock for an additional predetermined time.

c. To accomplish this manual update, the flightcrew should have a plotting chart that displays the route fix and DME fixes of one-mile increments located along a line that is perpendicular or near perpendicular to the route along the axis of the VOR/TACAN radial used to define the fix. Each fix should be displayed in both DME distance and latitude/longitude coordinates.

d. Put two fixes along the route, one on either side of the "update," fix and note the coordinates on the plotting chart. Crews should then use these fixes to validate the position update. This is similar to the method used for updating when flying on a route that passes over a VOR/DME or TACAN facility. It is imperative for crews to remember that these additional fixes are to be used for verification only, not as an update fix. They do, however, provide a means of verification of the update.

NOTE: This type of manual updating would be applicable when operating along several of the routes that pass in the vicinity of SHEMYA VOR such as R220, W460, R-341, A-590, A-342, R-451 and R-336.

5. METHOD 2: MANUAL UPDATING WHEN FLYING A ROUTE THAT IS DEFINED BY A VOR/DME OR TACAN FACILITY.

a. The accuracy of a manual update when over flying a VOR/DME or TACAN facility is questionable due to the "cone of confusion" that exists overhead the facility and varies as a function of the altitude of the aircraft. To increase the accuracy of a manual update in this situation, it is recommended that a plotting chart be created that has fixes depicted along the route at a minimum distance of 50 NM, but not more than 60 NM from the VOR/DME or TACAN. These fixes should display the bearing and distance and the latitude/longitude coordinates expressed to a tenth of a degree. The specified distances will account for slant range error and radial width.

b. In this situation, the suggested procedure would be for the flightcrew to discontinue INS navigation when receiving the VOR/DME or TACAN signal and attempt to align the aircraft exactly on the desired radial to or from the station. When passing over the specified fix, the crew will compare each of the INS positions with the reference lat/long position of the fix. The manual update should be attempted if the along track position error is greater than 1 NM. After the manual update is completed, the crew should continue to navigate by the VOR radial to the next designated fix and compare the coordinates to verify that the update was successful.

c. As minimum requirements for use of these procedures, the crew must have on board the appropriate plotting charts with the specified information, and the operator must demonstrate that its crews know how to use the charts and procedures.

d. These procedures should be based on the assumption that triple mix position fixing is not used, and each inertial must be updated accordingly. The crew must notify ATC anytime it becomes aware that the aircraft can no longer maintain RNP-10 performance based on evaluation of the position checks.

6. METHOD 3: USING AN IFR APPROVED GPS INSTALLATION AS AN UPDATING REFERENCE.

a. Using Method 3, the update is performed by comparing the INS position to the GPS position at a chosen way point.

b. Prior to departure the mandatory data must be logged.

c. Updating

(1) Record the time when INS coordinates are frozen before the en route update is accomplished and the flight level.

(2) Record the number of GPS SV's (Satellite Vehicles) locked on and the GPS DOP and Estimated Position Error (EPE) values.

(3) Record the desired track (DSRTK / STS) of the steering INS.

(4) Freeze the GPS and INS positions simultaneously.

(5) From the data determine the approximate amount of drift per hour flown, make appropriate corrections and continue to navigate.

(6) If data indicates that RNP-10 capability is impossible to maintain, Air Traffic must be notified as soon as flight conditions will permit.

d. Completion of Class II Navigation and Post Flight: This step is important in that it verifies the accuracy of the updating process and will warn operators if their is an equipment or procedural problem that might effect future flights. Additionally, this information can be used in a response to an Overseas Navigation Error Report (ONER).

(1) Record the time leaving Class II Navigation when radar contact is first established or when first within 150 NM of a VOR navaid, Record IN time.

(2) Destination Gate Positions: Do not remove INS updates until updated INS is recorded at the gate.

(3) Record the destination gate number, the number of GPS SV's (Satellite Vehicles) in view and the GPS DOP and EPE values.

(4) Record updated INS positions.

(5) Remove INS updates.

(6) Record INS un-updated positions and INS distances from the gate position.

(7) Record GPS position. If GPS position is unavailable, record the gate position (FOM airport 10-7 page or airport plan view).

(8) INS data should be recorded in the Maintenance Log as usual.

(9) Release the frozen INS positions.

Appendix 8

INDEX

INDEX (continued)

Appendices

ANNEX 5.4

EXTRACT OF THE JAA TGL°6

LEAFLET NO 6: Revision 1 GUIDANCE MATERIAL ON THE APPROVAL OF AIRCRAFT AND OPERATORS FOR FLIGHT IN AIRSPACE ABOVE FLIGHT LEVEL 290 WHERE A 300M (1,000 FT) VERTICAL SEPARATION MINIMUM IS APPLIED

This Temporary Guidance Leaflet No. 6 cancels and supersedes JAA Information Leaflet No. 23, dated April 1994. The leaflet provides guidance material for the approval of aircraft and operations in airspace where the vertical separation minimum above FL 290 is 300m (1,000 ft) (RVSM Operations).
Revision 1 of this TGL deletes from this document the specific procedures for RVSM operations in Europe and for the North Atlantic, and refers for guidance on operational matters to the EUROCONTROL ATC Manual for RVSM in Europe and to the applicable ICAO material for the North Atlantic and other regions.

LIST OF CONTENTS

PREAMBLE

In 1994, the original version of this text was adopted as JAA Interim Policy and published in JAA Information Leaflet No. 23. The intention is to include this information in a proposed new JAA publication containing interpretative and explanatory material with acceptable means of compliance applicable to aircraft in general. The new publication is not yet established, therefore, the information, now revised, is being published in this Temporary Guidance Leaflet.

The revised material of this leaflet is derived directly from IL 23. The material has been updated to reflect the current status of RVSM operations in general, and to add guidance concerning the application of RVSM within designated airspace in the EUR region (referred to as European RVSM airspace) as defined in ICAO Doc 7030/4. The opportunity has been taken also to make a number of editorial corrections and clarifications of the original text. These revisions include:

- updates to the Background section;
- addition of a list of abbreviations;
- where appropriate, substitution of the mandatory terms "shall" and "must" with "should" consistent with the document's status as guidance material. Where criteria is stated reflecting mandatory requirements of ICAO or other regulatory material, the expression "will need to" is used;
- adoption of the generic term "responsible authority" to replace the various terms previously used to denote the organisations or persons, empowered under national laws, to be responsible for airworthiness certification, operational or maintenance approvals;
- substitution of the previously used terms "acquired altitude" and "commanded altitude" with the term "selected altitude" to represent the altitude/flight level the aircraft is required to keep irrespective of the method used by the pilot to select it;
- deletion of text which is no longer relevant;
- clarification and expansion of the guidance material dealing with the RVSM approval procedure;
- re-numbering of some paragraphs to improve the logical structure;

The units of measurement now used in this document are in accordance with the International System of Units (SI) specified in Annex 5 to the Convention on International Civil Aviation. Non-SI units are shown in parentheses following the base units. Where two sets of units are quoted, it should not be assumed that the pairs of values are equal and interchangeable. It may be inferred, however, that an equivalent level of safety is achieved when either set of units is used exclusively.

Revision marks in the left hand margin show the differences between this Revision and the first issue of TGL No. 6.

It is not intended that aircraft which have received airworthiness approval in compliance with JAA Information Leaflet No. 23, or the equivalent FAA Interim Guidelines 91-RVSM, should be re-investigated. It is accepted that these aircraft satisfy the airworthiness criteria of this TGL No. 6.

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1. PURPOSE

This document provides a Minimum Aircraft Systems Performance Specification (MASPS) for altimetry to support the use of a 300m (1,000 ft) vertical separation above FL 290. It establishes an acceptable means, but not the only means, that can be used in the approval of aircraft and operators to conduct flights in airspace or on routes where Reduced Vertical Separation Minimum (RVSM) is applied. The document contains guidance on airworthiness, continued airworthiness, and operational practices and procedures for RVSM airspace. RVSM airspace is any airspace or route between FL 290 and FL 410 inclusive where aircraft are separated vertically by 300m (1,000 ft).

2. RELATED REGULATIONS

National regulations relating to the granting of an Air Operator's Certificate (AOC), approval for flight in RVSM airspace, testing and inspection of altimeter systems, and maintenance procedures.

Note: National Regulations will be replaced by the appropriate JARs, when implemented. The following regulations are included in JAR OPS 1 for Commercial Air Transportation:

JAR-OPS 1.240	Routes and Areas of Operation.
JAR-OPS 1.241	Operations in Defined Airspace with RVSM.
JAR-OPS 1.872	Equipment for Operations in Defined Airspace with RVSM

3. RELATED READING MATERIAL

International Civil Aviation Organisation (ICAO) Document 9574, Manual on the Implementation of a 300m (1,000 ft) Vertical Separation Minimum Between FL 290 - FL 410 Inclusive.

ICAO Document NAT/DOC/001, the Consolidated Guidance Material North Atlantic Region.

ICAO Document: Guidance Material on the Implementation and Application of a 300m (1,000 ft) Vertical Minimum.

ICAO Document 9536,Review of the General Concept of Separation (RGCSP).

ICAO Document 7030/4, Regional Supplementary Procedures.

EUROCONTROL Document ASM.ET1.ST.5000. Manual for Reduced Vertical Separation (RVSM) in Europe.

4. BACKGROUND

4.1 In 1982, under the overall guidance of the ICAO Review of the General Concept of Separation Panel (RGCSP), several States initiated a series of comprehensive work programmes to examine the feasibility of reducing the vertical separation minimum above FL 290 from 600m (2,000 ft) to 300m (1,000 ft). Studies were made by member states of EUROCONTROL (France, Germany, the Kingdom of the Netherlands, and the United Kingdom - in an extensive co-operative venture which was co-ordinated by the EUROCONTROL Agency), Canada, Japan, the former Union of the Soviet Socialist Republics (USSR), and the United States of America (USA).

4.2 The primary objectives of these studies was to decide whether a global implementation of the Reduced Vertical Separation Minimum (RVSM) :

a) would satisfy predetermined safety standards;
b) would be technically and operationally feasible, and
c) would provide a positive Benefit to Cost ratio.

4.3 These studies employed quantitative methods of risk assessment to support operational decisions concerning the feasibility of reducing the vertical separation minimum. The risk assessment consisted of two elements. First, risk estimation which concerns the development and use of methods and techniques with which the actual level of risk of an activity can be estimated; and second, risk evaluation which concerns the level of risk considered to be the maximum tolerable value for a safe system. The level of risk that is deemed acceptable is termed the Target Level of Safety (TLS). The basis of the process of risk estimation was the determination of the accuracy of height keeping performance of the aircraft population operating at/above FL 290. This was achieved through the use of high precision radar to determine the actual geometric height of aircraft in straight and level flight. This height was then compared with the geometric height of the flight level to which the aircraft had been assigned to determine the total vertical error (TVE) of the aircraft in question. Given this knowledge, it was possible to estimate the risk of collision solely as a consequence of vertical navigation errors of aircraft to which procedural vertical separation had been correctly applied. The RGCSP then employed an assessment TLS (2.5×10^{-9} fatal accidents per aircraft flight hour) to assess the technical feasibility of a 300m (1,000 ft) vertical separation minimum above FL 290 and also for developing aircraft height keeping capability requirements for operating with a 300m (1,000 ft) vertical separation minimum.

4.4 Using the assessment TLS of 2.5×10^{-9} fatal accidents per aircraft flight hour, the RGCSP concluded that a 300 m (1,000 ft) vertical separation minimum above FL 290 was technically feasible without imposing unreasonably demanding technical requirements on the equipment and that it would provide significant benefits in terms of economy and en-route airspace capacity. The technical feasibility referred to the fundamental capability of aircraft height keeping systems, which could be built, maintained, and operated in such a way that the expected, or typical, height keeping performance would be consistent with the safe implementation and use of a 300 m (1,000 ft) vertical separation minimum above FL 290. In reaching this conclusion on technical feasibility, the panel identified the need to establish:

(a) airworthiness performance requirements in the form of a comprehensive Minimum Aircraft Systems Performance Specification (MASPS) for all aircraft which would be operated in RVSM airspace;
(b) new operational procedures; and
(c) a comprehensive means of monitoring for safe operation.

4.5 In the USA, RTCA Special Committee 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 programmes in the US from 1982 to 1987.

4.6 In Europe, EUROCAE Working Group WG 30 was established in 1987 to prepare an altimetry specification appropriate for 300m (1,000 ft) vertical separation above FL 290. Draft specification documents produced in WG-30 formed a major input to the technical documentation on altimetry requirements developed by the ICAO North Atlantic System Planning Group/Vertical Studies Implementation Group.

4.7 The second major report published by RGCSP on RVSM was the Report of RGCSP/7 (Montreal, 30 October - 20 November 1990). This report provided the draft "Manual on Implementation of a 300m (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.

4.8 ICAO Doc 9574 provides guidance on RVSM implementation planning, airworthiness requirements, flight crew procedures, ATC considerations and system performance monitoring. This material was the basis of two MASPS documents which were issued for the application of RVSM in the Minimum Navigation Performance Specification (MNPS) Airspace of the North Atlantic (NAT) Region :

(a) JAA Information Leaflet No. 23: "Interim Guidance Material On The Approval Of Operators/ Aircraft For RVSM Operations", and
(b) FAA Document 91-RVSM: "Interim Guidance for Approval of Operations/ Aircraft for RVSM Operations".

Note: This Temporary Guidance Leaflet No. 6 replaces JAA Information Leaflet No. 23.

4.9 Appendix 5 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.

5. DEFINITIONS AND ABBREVIATIONS

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.

Altimetry System Error (ASE) The difference between the pressure altitude displayed to the flight crew when referenced to the International Standard Atmosphere ground pressure setting (1013.2 hPa /29.92 in.Hg) and free stream pressure altitude.

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

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

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.

Basic RVSM Envelope The range of Mach numbers and gross weights within the altitude ranges FL 290 to FL 410 (or maximum attainable altitude) where an aircraft can reasonably expect to operate most frequently.

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.

General Air Traffic (GAT) Flights conducted in accordance with the rules and provisions of ICAO.

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

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

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.

Operational Air Traffic (OAT) Flights which do not comply with the provisions stated for GAT and for which rules and procedures have been specified by appropriate authorities.

RVSM Approval The approval that is issued by the appropriate authority of the State in which the Operator is registered.

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

State Aircraft Aircraft used in military, customs and police services shall be deemed to be State aircraft

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

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

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

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

Abbreviation	Meaning
AAD	Assigned Altitude Deviation
ADC	Air Data Computer
AOA	Angle of Attack
AOC	Air Operator's Certificate
ASE	Altimetry System Error
ATS	Air Traffic Service
GAT	General Air Traffic
δ	Atmospheric Pressure Ratio
Hp	Pressure Altitude
hPa	Hecto-Pascals
in.Hg	Inches of Mercury
M	Mach number
MASPS	Minimum Aircraft System Performance Specification
MEL	Minimum Equipment List
MMEL	Master Minimum Equipment List
Mmo	Maximum Operating Limit Mach
MNPS	Minimum Navigation Performance Specification
NAT	North Atlantic
NOTAM	Notice to Airmen
OAT	Operational Air Traffic
OTS	Organised Track Structure
QFE	Atmospheric pressure at aerodrome elevation (or at runway threshold)
QNH	Altimeter sub-scale setting to obtain elevation when on ground
RTF	Radio Telephony
SSE	Static Source Error
SSEC	Static Source Error Correction
TVE	Total Vertical Error
VMO	Maximum Operating Limit Velocity
W	Weight

6. THE APPROVAL PROCESS

6.1 General

Airspace where RVSM is applied should be considered special qualification airspace. The specific aircraft type or types that the operator intends to use will need to be approved by the responsible authority before the operator conducts flight in RVSM airspace. In addition, where operations in specified airspace require approval in accordance with an ICAO Regional Navigation Agreement, an operational approval will be needed. This document provides guidance for the approval of specific aircraft type or types, and for operational approval.

6.2 Approval of Aircraft

6.2.1 Each aircraft type that an operator intends to use in RVSM airspace should have received RVSM airworthiness approval from the responsible authority, in accordance with paragraph 9, prior to approval being granted for RVSM operations, including the approval of continued airworthiness programmes. Paragraph 9 provides guidance for the approval of newly built aircraft and for aircraft that have already entered service. Paragraph 10 contains guidance on the continued airworthiness (maintenance and repair) programmes for all RVSM operations.

6.2.2 It is accepted that aircraft which have been approved in compliance with JAA Information Leaflet No. 23 or FAA Interim Guidelines 91-RVSM satisfy the airworthiness criteria of this TGL No. 6.

Note: Operators are advised to check existing approvals and the Aircraft Flight Manual for redundant regional constraints.

6.3 Operational Approval

For certain airspace, as defined by ICAO Regional Navigation Agreements, operators are required to hold State approval to operate in that airspace, which may or may not include RVSM. Paragraph 11 contains guidance on operational procedures that an operator may need to adopt for such airspace where RVSM is applied including advice on the operational material that may need to be submitted for review by the responsible authority.

7. RVSM PERFORMANCE

7.1 General

The objectives set out by the RGCSP have been translated into airworthiness standards by assessment of the characteristics of altimetry system error (ASE) and automatic altitude control.

7.2 RVSM Flight Envelopes

For the purposes of RVSM approval, the aircraft flight envelope may be considered as two parts; the Basic RVSM flight planning envelope and the Full RVSM flight envelope (referred to as the Basic envelope and the Full envelope respectively), as defined in paragraph 5 and explained in 9.4. For the Full envelope, a larger ASE is allowed.

7.3 Altimetry System Error

7.3.1 To evaluate a system against the ASE performance statements established by RGCSP (see Appendix 5, paragraph 2), it is necessary to quantify the mean and three standard deviation values for ASE, expressed as ASE_{mean} and ASE_{3SD}. To do this, it is necessary to take into account the different ways in which variations in ASE can arise. The factors that affect ASE are:

(a) Unit to unit variability of avionics equipment.

(b) Effect of environmental operating conditions on avionics equipment.

(c) Airframe to airframe variability of static source error.

(d) Effect of flight operating conditions on static source error.

7.3.2 Assessment of ASE, whether based on measured or predicted data will need to consider sub-paragraphs (a) to (d) of 7.3.1. The effect of item (d) as a variable can be eliminated by evaluating ASE at the most adverse flight condition in an RVSM flight envelope.

7.3.3 The criteria to be met for the Basic envelope are:

(a) At the point in the envelope where the mean ASE reaches its largest absolute value that value should not exceed 25 m (80 ft);

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

7.3.4 The criteria to be met for the Full envelope are:

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

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

(c) If necessary, for the purpose of achieving RVSM approval for a group of aircraft (see 9.3), an operating limitation may be established to restrict aircraft from conducting RVSM operations in parts of the Full envelope where the absolute value of mean ASE exceeds 37 m (120 ft) and/or the absolute value of mean ASE plus three standard deviations of ASE exceed 75 m (245 ft). When such a limitation is established, it should be identified in the data submitted to support the approval application, and documented in appropriate aircraft operating manuals. However, visual or aural warning/indication associated with such a limitation need not be provided in the aircraft.

7.3.5 Aircraft types for which an application for a Type Certificate is made after 1 January 1997, should meet the criteria established for the Basic envelope in the Full RVSM envelope.

7.3.6 The standard for aircraft submitted for approval as non-group aircraft, as defined in sub-paragraph 9.3.2, is as follows:

(a) For all conditions in the Basic envelope:

- **|** Residual static source error + worst case avionics **|** ≤ 50 m (160 ft)

(b) For all conditions in the Full envelope:

- **|** Residual static source error + worst case avionics **|** ≤ 60 m (200 ft)

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

<u>7.4 Altitude Keeping</u>

An automatic altitude control system is required capable of controlling altitude within ±20 m (±65 ft) about the selected altitude, when the aircraft is operated in straight and level flight under non-turbulent non-gust conditions.

Note: Automatic altitude control systems with flight management system/ performance management system inputs allowing variations up to ±40 m (±130 ft) under non-turbulent, non-gust conditions, installed in aircraft types for which an application for Type Certificate was made prior to January 1, 1997, need not be replaced or modified.

8. AIRCRAFT SYSTEMS

8.1 Equipment for RVSM Operations

The minimum equipment fit is:

8.1.1 Two independent altitude measurement systems. Each system will need to be composed of the following elements:

(a) Cross-coupled static source/system, with ice protection if located in areas subject to ice accretion;

(b) Equipment for measuring static pressure sensed by the static source, converting it to pressure altitude and displaying the pressure altitude to the flight crew:

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

(d) Static source error correction (SSEC), if needed to meet the performance criteria of sub-paragraphs 7.3.3, 7.3.4 or 7.3.6, as appropriate; and

(e) Signals referenced to a pilot selected altitude for automatic control and alerting. These signals will need to be derived from an altitude measurement system meeting the criteria of this document, and, in all cases, enabling the criteria of sub-paragraphs 8.2.6 and 8.3 to be met.

8.1.2 One secondary surveillance radar transponder with an altitude reporting system that can be connected to the altitude measurement system in use for altitude keeping.

8.1.3 An altitude alerting system.

8.1.4 An automatic altitude control system.

8.2. Altimetry

8.2.1 *System Composition* 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:

(a) Airframe plus static sources.

(b) Avionics equipment and/or instruments.

8.2.2 *Altimetry System Outputs* The following altimetry system outputs are significant for RVSM operations:

(a) Pressure altitude (Baro-corrected) for display.

(b) Pressure altitude reporting data.

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

8.2.3 *Altimetry System Accuracy* The total system accuracy will need to satisfy the criteria of sub-paragraphs 7.3.3, 7.3.4 or 7.3.6 as appropriate.

8.2.4 *Static Source Error Correction* If the design and characteristics of the aircraft and its altimetry system are such that the criteria of sub-paragraphs 7.3.3, 7.3.4 or 7.3.6 are not satisfied by the location and geometry of the static sources alone, then suitable SSEC will need to be applied automatically within the avionics equipment of the altimetry system. The design aim for static source error correction, whether applied by aerodynamic/ geometric means or within the avionics equipment, should be to produce a minimum residual static source error, but in all cases it should lead to compliance with the criteria of sub-paragraphs 7.3.3, 7.3.4 or 7.3.6, as appropriate.

8.2.5 *Altitude Reporting Capability* The aircraft altimetry system will need to provide an output to the aircraft transponder as required by applicable operating regulations.

8.2.6 *Altitude Control Output*

(a) The altimetry system will need to provide a signal that can be used by an automatic altitude control system to control the aircraft to a selected altitude. The signal may be used either directly, or combined with other sensor signals. If SSEC is necessary to satisfy the criteria of sub-paragraph 7.3.3, 7.3.4 or 7.3.6, then an equivalent SSEC may be applied to the altitude control signal. The signal may be an altitude deviation signal, relative to the selected altitude, or a suitable absolute altitude signal.

(b) Whatever the system architecture and SSEC system, the difference between the signal output to the altitude control system and the altitude displayed to the flight crew will need to be kept to the minimum.

8.2.7 *Altimetry System Integrity* The RVSM approval process will need to verify that the predicted rate of occurrence of undetected failure of the altimetry system 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 value. Other failures or failure combinations need not be considered.

8.3 Altitude Alerting

The altitude deviation system will need to signal an alert when the altitude displayed to the flight crew deviates from selected altitude by more than a nominal threshold value. For aircraft for which an application for a Type Certificate is made before 1 January 1997, the nominal threshold value will need to be not greater than ±90 m (±300 ft). For aircraft for which an application for a Type Certificate is made on or after 1 January 1997, the value will need to be not greater than ±60 m (±200 ft). The overall equipment tolerance in implementing these nominal values will need to be not greater than ±15 m (±50 ft).

8.4 Automatic Altitude Control System

8.4.1 As a minimum, a single automatic altitude control system with an altitude keeping performance complying with sub-paragraph 7.4, will need to be installed.

8.4.2 Where an altitude select/acquire function is provided, the altitude select/acquire control panel will need to be configured such that an error of no more than ±8 m (±25 ft) exists between the value selected by, and displayed to, the flight crew, and the corresponding output to the control system.

8.5 System Limitations

8.5.1 The Aircraft Flight Manual should include a statement of compliance against this TGL (or equivalent guidance material) quoting the applicable Service Bulletin or build standard of the aircraft. In addition the following statement should be included:-

“Airworthiness Approval alone does not authorise flight into airspace for which an RVSM Operational Approval is required by an ICAO Regional Navigation Agreement.”

8.5.2 Non-compliant aspects of the installed systems and any other limitations will need to be identified in the approved Aircraft Flight Manual amendment or supplement, and in the applicable and approved Operations Manual.

For example:-

Non -compliant altimeter systems, e.g. standby altimeter;
Non-Compliant modes of the automatic pilot, e.g. altitude hold, vnav, altitude select;
Weight Limit;
Mach Limit;
Altitude Limit.

9. AIRWORTHINESS APPROVAL

9.1 General

9.1.1 Obtaining RVSM airworthiness approval is a two step process which may involve more than one authority.

9.1.2 For the first step:

- in the case of a newly built aircraft, the aircraft constructor develops and submits to the responsible authority of the state of manufacture, the performance and analytical data that supports RVSM airworthiness approval of a defined build standard. The data will be supplemented with maintenance and repair manuals giving associated continued airworthiness instructions. Compliance with RVSM criteria will be stated in the Aircraft Flight Manual including reference to the applicable build standard, related conditions and limitations. Approval by the responsible authority, and, where applicable, validation of that approval by other authorities, indicates acceptance of newly built aircraft, conforming to that type and build standard, as complying with the RVSM airworthiness criteria.

- in the case of an aircraft already in service, the aircraft constructor (or an approved design organisation), submits to the responsible authority, either in the state of manufacture or the state in which the aircraft is registered, the performance and analytical data that supports RVSM airworthiness approval of a defined build standard. The data will be supplemented with a Service Bulletin, or its equivalent, that identifies the work to be done to achieve the build standard, continued airworthiness instructions, and an amendment to the Aircraft Flight Manual stating related conditions and limitations. Approval by the responsible authority, and, where applicable, validation of that approval by other authorities, indicates acceptance of that aircraft type and build standard as complying with the RVSM airworthiness criteria.

9.1.3 The combination of performance and analytical data, Service Bulletin(s) or equivalent, continued airworthiness instructions, and the approved amendment or supplement to the Aircraft Flight Manual is known as the RVSM approval data package.

9.1.4 For the second step, an aircraft operator may apply to the responsible authority of the state in which the aircraft is registered, for airworthiness approval of specific aircraft. The application will need to be supported by evidence confirming that the specific aircraft has been inspected and, where necessary, modified in accordance with applicable Service Bulletins, and is of a type and build standard that meets the RVSM airworthiness criteria. The operator will need to confirm also that the continued airworthiness instructions are available and that the approved Flight Manual amendment or supplement (see paragraph 8.5) has been incorporated. Approval by the authority indicates that the aircraft is eligible for RVSM operations. The authority will notify the designated monitoring cell accordingly.

For RVSM airspace for which an operational approval is prescribed, airworthiness approval alone does not authorise flight in that airspace.

9.2 Contents of the RVSM Approval Data Package

As a minimum, the data package will need to consist of the following items:

(a) A statement of the aircraft group or non-group aircraft and applicable build standard to which the data package applies.

(b) A definition of the applicable flight envelope(s).

(c) Data showing compliance with the performance criteria of paragraphs 7 and 8.

(d) The procedures to be used to ensure that all aircraft submitted for airworthiness approval comply with RVSM criteria. These procedures will include the references of applicable Service Bulletins and the applicable approved Aircraft Flight Manual amendment or supplement.

(e) The maintenance instructions that ensure continued airworthiness for RVSM approval.

The items listed in 9.2 are explained further in the following sub-paragraphs.

9.3 Aircraft Groupings

9.3.1 For aircraft to be considered as members of a group for the purposes of RVSM approval, the following conditions should be satisfied:

(a) Aircraft should have been constructed to a nominally identical design and be approved on the same Type Certificate (TC), TC amendment, or Supplemental TC, as applicable.

Note: For derivative aircraft it may be possible to use the data from the parent configuration to minimise the amount of additional data required to show compliance. The extent of additional data required will depend on the nature of the differences between the parent aircraft and the derivative aircraft.

(b) The static system of each aircraft should be nominally identical. The SSE corrections should be the same for all aircraft of the group.

(c) The avionics units installed on each aircraft to meet the minimum RVSM equipment criteria of sub-paragraph 8.1 should comply with the manufacturer's same specification and have the same part number.

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

9.3.2 If an airframe does not meet the conditions of sub-paragraphs 9.3.1(a) to (c) to qualify as a member of a group, or is presented as an individual airframe for approval, then it will need to be considered as a non-group aircraft for the purposes of RVSM approval.

9.4 Flight Envelopes

The RVSM operational flight envelope, as defined in paragraph 5, is the Mach number, W/δ, and altitude ranges over which an aircraft can be operated in cruising flight within the RVSM airspace. Appendix 1 gives an explanation of W/δ. The RVSM operational flight envelope for any aircraft may be divided into two parts as explained below:

9.4.1 *Full RVSM Flight Envelope* The Full 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 to be considered.

TABLE 1 - FULL RVSM ENVELOPE BOUNDARIES

	Lower Boundary is defined by	**Upper Boundary is defined by**
Level	• FL 290	The lower of : • FL 410 • Aircraft maximum certified altitude • Altitude limited by: cruise thrust; buffet; other aircraft flight limitations
Mach or Speed	The lower of : • Maximum endurance (holding speed) • Manoeuvre speed	The lower of : • M_{MO}/V_{MO} • Speed limited by cruise thrust; buffet; other aircraft flight limitations
Gross Weight	• The lowest gross weight compatible with operations in RVSM airspace	• The highest gross weight compatible with operations in RVSM airspace

9.4.2 *Basic RVSM Flight Planning Envelope* The boundaries for the Basic envelope are the same as those for the Full envelope except for the upper Mach boundary.

9.4.3 For the Basic 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 aircraft constructor or the approved design organisation. The boundary may be equal to the upper Mach/airspeed boundary defined for the Full envelope or a lower value. This lower value should not be less than the Long Range Cruise Mach Number plus 0.04 Mach, unless limited by available cruise thrust, buffet, or other flight limitations.

9.5 Performance Data

The data package should contain data sufficient to show compliance with the accuracy criteria set by paragraph 7.

9.5.1 *General* 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 envelopes. In the case of group aircraft approval, the worst flight condition may be different for each of the criterion of sub-paragraph 7.3.3 and 7.3.4. Each should be evaluated.

9.5.2 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 be performed only when appropriate ground checks have been completed. Uncertainties in application of the method will need to be assessed and taken into account in the data package.

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

(b) Trailing cone.

(c) Pacer aircraft.

(d) Any other method acceptable to the responsible authority.

Note: When using pacer aircraft, the pacer aircraft will need to be calibrated directly to a known standard. It is not acceptable to calibrate a pacer aircraft by another pacer aircraft.

9.5.3 *Altimetry System Error Budget* It is implicit in the intent of sub-paragraph 7.3, for group aircraft approvals and for non-group approvals, that a trade-off may be made between the various error sources which contribute to ASE. This document does not specify separate limits for the various error sources that contribute to the mean and variable components of ASE as long as the overall ASE accuracy criteria of sub-paragraph 7.3 are met. For example, in the case of an aircraft 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 that includes all significant error sources. This is discussed in more detail in the following sections. Altimetry system error sources are discussed in Appendix 2.

9.5.4 *Avionic Equipment* Avionic equipment should be identified by function and part number. A demonstration will need to show that the avionic equipment can meet the criteria established by the error budget when the equipment is operated in the environmental conditions expected to be met during RVSM operations.

9.5.5 *Groups of Aircraft* Where approval is sought for an aircraft group, the associated data package will need to show that the criteria of sub-paragraph 7.3.3 and 7.3.4 are met. Because of the statistical nature of these criteria, 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 changes in the mean and variability based on geometric inspections and bench test, or any other method acceptable to the responsible authority. In the case of derivative aircraft it may be possible to use data from the parent as part of the data base. This may be applicable to 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 three standard deviations. 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 airframe 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 that could be used to provide this substantiation is provided in Appendix 3, figure 3-2.

(d) An error budget should be established to ensure that the criteria of sub-paragraphs 7.3.3 and 7.3.4 are met. As noted in 9.5.1, the worst condition experienced in flight may differ for each criterion and therefore the component error values may also differ.

(e) In showing compliance with the overall criteria, the component error sources should be combined appropriately. 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 that are independent of each other are combined by rss.

(f) The methodology described above for group approval is statistical. This is the result of the statistical nature of the risk analysis and the resulting statements of Appendix 5 sub-paragraphs 5(a) and 5(b). In the context of a statistical method, the statements of Appendix 5, sub-paragraph 5(c) need further explanation. This item states that 'each individual aircraft in the group shall be built to have an ASE contained within ±60m (±200 ft)'. 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 ±60m (200 ft). Such an interpretation would be unduly onerous considering that the risk analysis allows for a small proportion of aircraft to exceed 60m (200 ft). However, it is accepted that if any aircraft is identified as having an error exceeding ±60m (±200 ft) then it should receive corrective action.

9.5.6 *Non-group Aircraft* When an aircraft is submitted for approval as a non-group aircraft, as explained in sub-paragraph 9.3.2, the data should be sufficient to show that the criteria of sub-paragraph 7.3.6 are met. The data package should specify how the ASE budget has been allocated between residual SSE and avionics error. The operator and responsible authority should agree on what data is needed to satisfy approval criteria. The following data should be established:

(a) Precision flight test calibration of the aircraft to establish its ASE or SSE over the RVSM envelope. Flight calibration should be performed at points in the flight envelope(s) as agreed by the responsible authority. One of the methods listed in sub-paragraphs 9.5.2 (a) to (d) 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 responsible 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, identifying the largest allowable errors.

Using the foregoing, compliance with the criteria of sub-paragraph 7.3.6 should be demonstrated. If, subsequent to aircraft approval for RVSM operation, avionic units that 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.

9.6 Compliance Procedures

The data package will need to define the procedures, inspections and tests, and the limits that will be used to ensure 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 sub-paragraph 9.5.3. The budget allowances will be established by the data package and include a methodology that allows for tracking the mean and standard deviation for new build aircraft. Limits will need to be defined for each potential source of error. A discussion of error sources is provided in Appendix 2. Examples of procedures are presented in Appendix 3. Where an operating limitation has been applied, the package should contain the data and information necessary to document and establish that limitation.

9.7 Continued Airworthiness

9.7.1 The following items should be reviewed and updated as applicable to RVSM:

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

(b) The Master Minimum Equipment List (MMEL).

9.7.2 The data package should include details of any special procedures that are not covered in sub-paragraph 9.7.1, but may be needed to ensure continued compliance with RVSM approval criteria. Examples follow:

(a) For non-group aircraft, where airworthiness approval has been based on flight test, the continuing integrity and accuracy of the altimetry system will need to be demonstrated by ground and flight tests of the aircraft and its altimetry system at periods to be agreed with the responsible authority. However, alleviation of the flight test requirement may be given if it can be demonstrated that the relationship between any subsequent airframe/system degradation and its effects on altimetry system accuracy is understood and that it can be compensated or corrected.

(b) In-flight defect reporting procedures should be defined to aid 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.

<u>9.8 Post Approval Modification</u>

Any variation/modification from the initial installation that affects RVSM approval should referred to the aircraft constructor or approved design organisation, and accepted by the responsible authority.

10. CONTINUED AIRWORTHINESS (MAINTENANCE PROCEDURES)

<u>10.1 General</u>

(a) The integrity of the design features necessary to ensure that altimetry systems continue to meet RVSM approval criteria should be verified by scheduled tests and inspections in conjunction with an approved maintenance programme. The operator should review its maintenance procedures and address all aspects of continued airworthiness that may be relevant.

(b) Adequate maintenance facilities will need to be available to enable compliance with the RVSM maintenance procedures.

<u>10.2 Maintenance Programmes</u>

Each operator requesting RVSM operational approval should establish RVSM maintenance and inspection practices acceptable to, and as required by, the responsible authority, that include any required maintenance specified in the data package (sub-paragraph 9.2). Operators of aircraft subject to maintenance programme approval will need to incorporate these practices in their maintenance programme.

<u>10.3 Maintenance Documents</u>

The following items should be reviewed, as appropriate:

(a) Maintenance Manuals.

(b) Structural Repair Manuals.

(c) Standard Practices Manuals.

(d) Illustrated Parts Catalogues.

(e) Maintenance Schedule.

(f) MMEL.

10.4 Maintenance Practices

If the operator is subject to an approved maintenance programme, that programme should include, for each aircraft type, the maintenance practices stated in the applicable aircraft and component manufacturers' maintenance manuals. In addition, for all aircraft, including those not subject to an approved maintenance programme, attention should be given to the following items:

(a) All RVSM equipment should be maintained in accordance with the component manufacturers' maintenance instructions and the performance criteria of the RVSM approval data package.

(b) Any modification or design change which in any way affects the initial RVSM approval, should be subject to a design review acceptable to the responsible authority.

(c) Any repairs, not covered by approved maintenance documents, that may affect the integrity of the continuing RVSM approval, e.g. those affecting the alignment of pitot/static probes, repairs to dents or deformation around static plates, should be subject to a design review acceptable to the responsible authority.

(d) Built-in Test Equipment (BITE) testing should not be used for system calibration unless it is shown to be acceptable by the aircraft constructor or an approved design organisation, and with the agreement of the responsible authority.

(e) An appropriate system leak check (or visual inspection where permitted) should be accomplished following reconnection of a quick-disconnect static line.

(f) Airframe and static systems should be maintained in accordance with the aircraft constructor's inspection standards and procedures.

(g) 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 will need to be made, as specified by the aircraft constructor, to ensure adherence to RVSM tolerances. These checks should be performed following repairs, or alterations having an effect on airframe surface and airflow.

(h) The maintenance and inspection programme for the autopilot will need to 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.

(i) Whenever the performance of installed equipment has been demonstrated to be satisfactory for RVSM approval, the associated maintenance practices should be verified to be consistent with continued RVSM approval. Examples of equipment to be considered are:

    (i) Altitude alerting.

    (ii) Automatic altitude control system.

    (iii) Secondary surveillance radar altitude reporting equipment.

    (iv) Altimetry systems.

10.4.1 *Action for Non-compliant Aircraft* Those aircraft positively identified as exhibiting height keeping performance errors that require investigation, as discussed in sub-paragraph 11.7, should not be operated in RVSM airspace until the following actions have been taken:

(a) The failure or malfunction is confirmed and isolated; and,

(b) Corrective action is taken as necessary to comply with sub-paragraph 9.5.5 (f) and verified to support RVSM approval.

10.4.2 *Maintenance Training* New training may be necessary to support RVSM approval. Areas that may need to be highlighted for initial and recurrent training of relevant personnel are:

(a) Aircraft geometric inspection techniques.

(b) Test equipment calibration and use of that equipment.

(c) Any special instructions or procedures introduced for RVSM approval.

10.4.3 *Test Equipment*

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

(b) Test equipment should be calibrated at periodic intervals as agreed by the responsible authority using reference standards whose calibration is certified as being traceable to national standards acceptable to that authority. The approved maintenance programme should include an effective quality control programme with attention to the following:

(i) Definition of required test equipment accuracy.

(ii) Regular calibrations of test equipment traceable to a master standard. Determination of the calibration interval should be a function of the stability of the test equipment. The calibration interval should be established using historical data so that degradation is small in relation to the required accuracy.

(iii) Regular audits of calibration facilities both in-house and outside.

(iv) Adherence to approved maintenance practices.

(v) Procedures for controlling operator errors and unusual environmental conditions which may affect calibration accuracy.

11. OPERATIONAL APPROVAL

11.1 Purpose and Organisation

Paragraph 6 gives an overview of the RVSM approval processes. For airspace where operational approval is required, this paragraph describes steps to be followed and gives detailed guidance on the required operational practices and procedures. Appendices 4 and 5 are related to this paragraph and contain essential information for operational programmes.

11.2 RVSM Operations

Approval will be required for each aircraft group and each aircraft to be used for RVSM operations. Approval will be required for each operator and the responsible authority will need to be satisfied that

(a) each aircraft holds airworthiness approval according to paragraph 9;
(b) each operator has continued airworthiness programmes (maintenance procedures) according to paragraph 10;

(c) where necessary, operating procedures unique to the airspace have been incorporated in operations manuals including any limitations identified in paragraph 8.5.

(d) high levels of aircraft height keeping performance can be maintained.

<u>11.3 Content of Operator RVSM Application</u>

The following material should be made available to the responsible authority, in sufficient time to permit evaluation, before the intended start of RVSM operations.

(a) *Airworthiness Documents* Documentation that shows that the aircraft has RVSM airworthiness approval. This should include an Approved Flight Manual amendment or supplement.

(b) *Description of Aircraft Equipment* A description of the aircraft appropriate to operations in an RVSM environment.

(c) *Training Programmes and Operating Practices and Procedures* Holders of Air Operators Certificates (AOC) may need to submit training syllabi for initial, and where appropriate, recurrent training programmes together with other appropriate material to the responsible authority. The material will need to show that the operating practices, procedures and training items, related to RVSM operations in airspace that requires State operational approval, are incorporated. Non-AOC operators will need to comply with local procedures to satisfy the responsible authority that their knowledge of RVSM operating practices and procedures is equivalent to that set for AOC Holders, sufficient to permit them to conduct RVSM operations. Guidance on the content of training programmes and operating practices and procedures is given in Appendix 4. In broad terms, this covers flight planning, pre-flight procedures, aircraft procedures before RVSM airspace entry, in-flight procedures, and flight crew training procedures. The procedures used within airspace of the EUR region and the procedures unique to the North Atlantic Airspace for which specific State operational approval is required are stated in Doc 7030/4.

(d) *Operations Manuals and Checklists* The appropriate manuals and checklists should be revised to include information/guidance on standard operating procedures as detailed in Appendix 4. Manuals should include a statement of the airspeeds, altitudes and weights considered in RVSM aircraft approval; including identification of any operating limitations or conditions established for that aircraft group. Manuals and checklists may need to be submitted for review by the authority as part of the application process.

(e) *Past Performance* Relevant operating history, where available, should be included in the application. The applicant should show that changes needed in training, operating or maintenance practices to improve poor height keeping performance, have been made.

(f) *Minimum Equipment List* Where applicable, a minimum equipment list (MEL), adapted from the master minimum equipment list (MMEL) and relevant operational regulations, should include items pertinent to operating in RVSM airspace.

(g) *Maintenance* When application is made for operational approval, the operator should establish a maintenance programme acceptable to the responsible authority, as detailed in paragraph 10.

(h) *Plan for Participation in Verification/Monitoring Programmes* The operator should establish a plan acceptable to the responsible authority, for participation in any applicable verification/ monitoring programme (See 11.6). This plan will need to include, as a minimum, a check on a sample of the operator's fleet by an independent height monitoring system.

11.4 Demonstration Flight(s)

The content of the RVSM application may be sufficient to verify the aircraft performance and procedures. However, the final step of the approval process may require a demonstration flight. The responsible authority may appoint an inspector for a flight in RVSM airspace to verify that all relevant procedures are applied effectively. If the performance is satisfactory, operation in RVSM airspace may be permitted.

11.5 Form of Approval Documents

(a) *Holders of an Air Operator's Certificate* Approval to operate in designated RVSM airspace areas will be granted by an Approval issued by the responsible authority in accordance with JAR OPS 1, or in compliance with national regulations where operational approval is required by an ICAO Regional Agreement. Each aircraft group for which the operator is granted approval will be listed in the Approval.

(b) *Non AOC Holders* These operators will be issued with an Approval as required by national regulations or with JAR OPS 2 when this JAR is published. These approvals will be valid for a period specified in national regulations, typically 2 years, and may require renewal.

Note: Subject to compliance with applicable criteria, an RVSM Approval combining the airworthiness approval of sub-paragraph 9.1.4 and the operational approval of paragraph 11.2 may be available from some authorities.

11.6 Airspace Monitoring

For airspace where a numerical Target Level of Safety is prescribed, monitoring of aircraft height keeping performance in the airspace by an independent height monitoring system is necessary to verify that the prescribed level of safety is being achieved. However, an independent monitoring check of an aircraft is not a prerequisite for the grant of an RVSM approval.

11.7 Suspension, Revocation and Reinstatement of RVSM Approval

The incidence of height keeping errors that can be tolerated in an RVSM environment is small. It is expected of each operator to take immediate action to rectify the conditions that cause an error. The operator should report an occurrence involving poor height keeping to the responsible authority within 72 hours. The report should include an initial analysis of causal factors and measures taken to prevent repeat occurrences. The need for follow up reports will be determined by the responsible authority. Occurrences that should be reported and investigated are errors of:

(a) TVE equal to or greater than ±90 m (±300 ft),

(b) ASE equal to or greater than ±75 m (±245 ft), and

(c) Assigned altitude deviation equal to or greater than ±90 m (±300 ft).

11.7.1 *Height keeping Errors* Height keeping errors fall into two broad categories:

- errors caused by malfunction of aircraft equipment; and
- operational errors.

11.7.2 An operator that consistently experiences errors in either category will have approval for RVSM operations suspended or revoked. If a problem is identified which is related to one specific aircraft type, then RVSM approval may be suspended or revoked for that specific type within that operator's fleet.

Note: The tolerable level of collision risk in the airspace would be exceeded if an operator consistently experienced errors.

11.7.3 *Operators Actions* The operator should make an effective, timely response to each height keeping error. The responsible authority may consider suspending or revoking RVSM approval if the operator's responses to height keeping errors are not effective or timely. The responsible authority will consider the operator's past performance record in determining the action to be taken.

11.7.4 *Reinstatement of Approval The* operator will need to satisfy the responsible authority that the causes of height keeping errors are understood and have been eliminated and that the operator's RVSM programmes and procedures are effective. At its discretion and to restore confidence, the authority may require an independent height monitoring check of affected aircraft to be performed.

12. AVAILABILITY OF DOCUMENTS

12.1 Copies of EUROCONTROL documents may be requested from EUROCONTROL Documentation Centre, GS4, Rue de la Fusee, 96, B-1130 Brussels, Belgium: (Fax: 32 2 729 9109), and on the internet at < http://www.eur-rvsm.com >.

12.2 Copies of FAA documents mat be obtained from Superintendent of Documents, Government Printing Office, Washington DC 20402-9325, USA.

12.3 Copies of ARINC documents may be obtained from Aeronautical radio Inc., 2551 Riva Road, Annapolis, Maryland 24101-7465, USA.

12.4 Copies of RTCA documents may be obtained from RTCA Inc.,1140 Connecticut Avenue, N.W., Suite1020, Washington, DC 20036-4001, USA,. (Tel: 1 202 833 9339).

12.5 Information for obtaining ICAO and JAA documents should be requested from the applicant's national authority. (Information for obtaining the North Atlantic MNPS Airspace Operational Manual may be found in UK CAA AIC 149/1998).

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APPENDIX 1 - EXPLANATION OF W/δ

1 Sub-paragraph 9.4 describes the range of flight conditions over which conformity with the ASE criteria should 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 versus 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 the 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.

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

δ = ambient pressure at flight altitude divided by sea level standard pressure of 1013.25 hPa
W/δ = Weight over Atmospheric Pressure Ratio
C_L = Lift Coefficient
M = Mach Number
S_{REF} = Reference Wing Area

4 As a result, the RVSM flight envelope(s) 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.

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APPENDIX 2 - ALTIMETRY SYSTEM ERROR COMPONENTS

1. INTRODUCTION

Sub-paragraph 9.5.3 states that an error budget should be established and presented in the approval data package. The error budget is discussed in some detail in subsequent paragraphs for group and non-group aircraft. The purpose of this appendix is to provide guidance to help ensure that all the potential error sources are identified and included in the error budget for each particular model.

2. OBJECTIVE OF ASE BUDGET

2.1 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 criteria. 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 criteria.

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

2.3 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

<u>3.1 Breakdown</u>

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 that can occur, although different system architectures may combine the components in slightly different ways.

(a) The 'Actual Altitude' is the pressure altitude corresponding to the undisturbed ambient pressure.

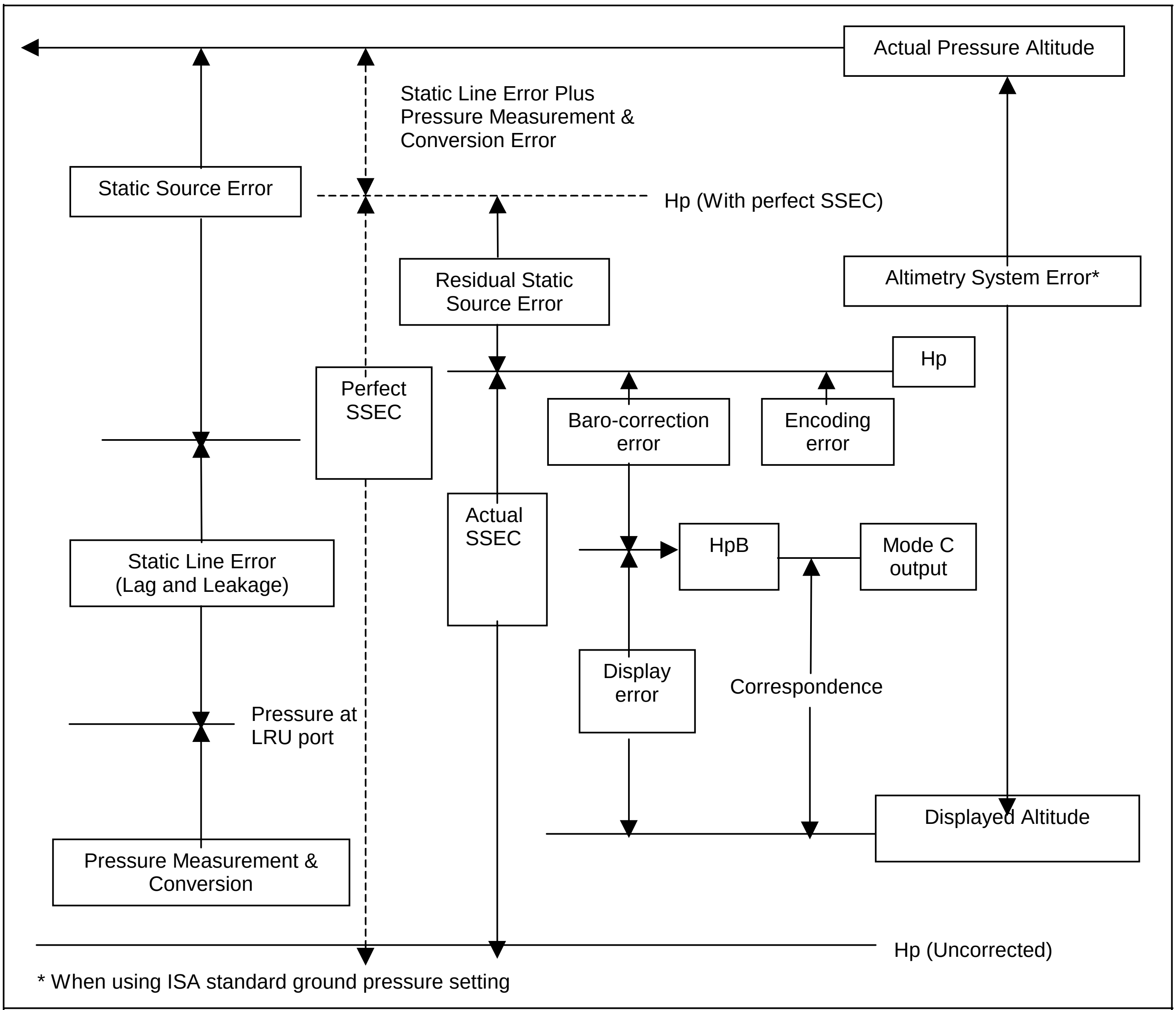
(b) 'Static Source Error' is the difference between the undisturbed ambient pressure and the pressure within the static port, at the input end of the static pressure line.

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

(d) 'Pressure Measurement and Conversion Error' is the error associated with the processes of sensing 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 (Hp) was calculated.

(e) 'Perfect SSEC' would be that correction that compensated exactly for the SSE actually present at any time. If such a correction could be applied, then the resulting value of Hp 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.

FIGURE 2-1 ALTIMETRY SYSTEM ERRORS



(f) '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 Hp will therefore differ from actual pressure altitude by the sum of static line error, pressure measurement and conversion error, and residual SSE.

(g) Between Hp 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 that 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 that can be switched to operate the display directly from the Hp signal can eliminate baro-correction error where standard ground pressure setting is used, as in RVSM operations.

<u>3.2 Components</u>

The altimetry system errors presented in Figure 2-1 and described in 3.1 are discussed below in greater detail.

3.2.1 *Static Source Error* The component parts of SSE are presented in Table 2-1, with the factors that control their magnitude.

(a) 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 that are functions of Mach. It includes the effect of any aerodynamic compensation that may have been incorporated in the design. Once determined, the reference SSE is fixed for the single aircraft or group, although it may be revised when considering subsequent data.

(b) The test techniques used to derive the reference SSE will have some measurement of 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.

(c) 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.

3.2.2 *Residual Static Source Error*

(a) The components and factors are presented in Table 2-1. 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 that would correct the reference value exactly, components 2(a), (b) and (c) from Table 2-2.

(b) There will generally be a difference between the SSEC that would exactly compensate the reference SSE, and the SSEC that 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 that cause a particular set of avionics to apply an actual SSEC that differs from its design value.

(c) 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.

(d) Factors that create variability of SSE relative to the reference characteristic should be accounted for twice. First, as noted for the SSE itself in Table 2-2, and secondly for its effect on the corruption of SSEC as in factor 2(a)(i) of Table 2-2. Similarly the static pressure measurement error should be accounted for in two separate ways. The main effect will be by way of the 'pressure measurement and conversion' component, but a secondary effect will be by way of factor 2(a)(ii) of Table 2-2.

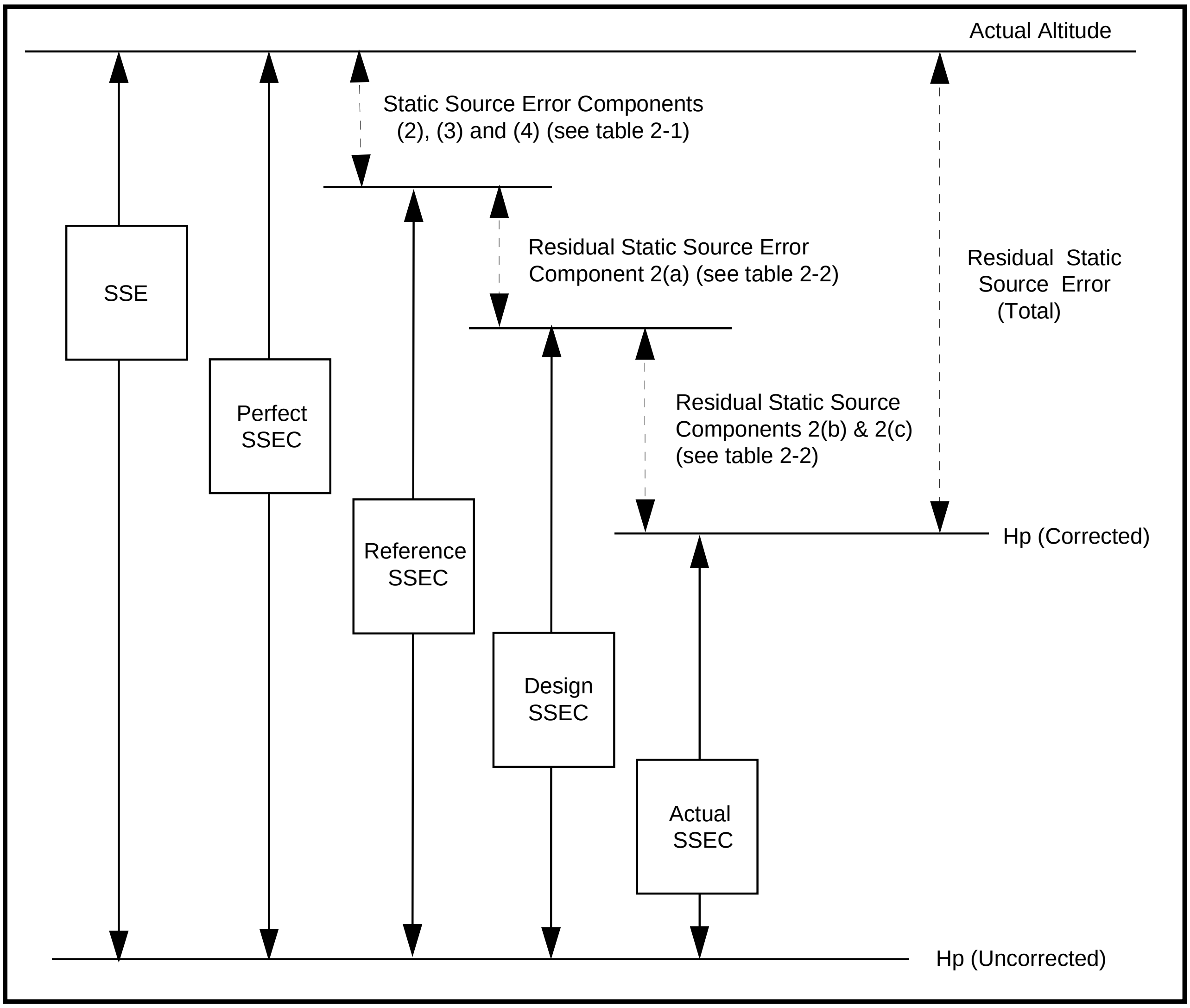
TABLE 2-1 STATIC SOURCE ERROR
(Cause: Aerodynamic Disturbance to Free-Stream Conditions)

Factors	Error Components
Airframe Effects Operating Condition (Speed, altitude, angle of attack, sideslip) Geometry: Size and 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.	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.
Probe/Port Effects Operating Condition (Speed, altitude, angle of attack, sideslip) 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 PLUS (2) Source of input data for SSEC function (a) Where SSEC is a function of Mach: (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: (i) geometric effects on alpha: -sensor tolerances; -installation tolerances; -local surface variations. (ii) measurement error: -angle transducer accuracy. (3) Implementation of SSEC function (a) Calculation of SSEC from input data; (b) Combination of SSEC with uncorrected height.	1) Error Components (*2*), (*3*), and (*4*) from table 2-1 PLUS 2(a) Approximation in fitting design SSEC to flight calibration reference SSE. 2(b) Effect of production variability (sensors and avionics) on achieving design SSEC. 2(c) Effect of operating environment (sensors and avionics) on achieving design SSEC.

FIGURE 2-2 SSE/SSEC RELATIONSHIPS FOR ASE WHERE STATIC LINE, PRESSURE MEASUREMENT AND CONVERSION ERRORS ARE ZERO



3.2.3 *Static Line Error* Static line errors arise from leaks and pneumatic lags. In level cruise these can be made negligible for a system that is correctly designed and correctly installed.

3.2.4 *Pressure Measurement and Conversion Error*

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

(b) The error components are:

(i) calibration uncertainty;

(ii) nominal design performance;

(iii) unit to unit manufacturing variations; and

(iv) effect of operating environment.

(c) 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.

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

3.2.5 *Baro-Setting Error* This is the difference between the value displayed and the value applied within the system. For RVSM operation the value displayed should always be the International Standard Atmosphere ground pressure, but setting mistakes, although part of TVE, are not components of ASE.

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

(i) resolution of setting knob/display;

(ii) sensing of displayed value; and

(iii) application of sensed value.

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

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

3.2.6 *Display Error* The cause is imperfect conversion from altitude signal to display.

The components are:

(a) conversion of display input signal;

(b) graticule/format accuracy, and

(c) readability.

3.2.7 In self-sensing altimeters the first of these would normally be separate from the pressure measurement and conversion error.

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APPENDIX 3 - ESTABLISHING AND MONITORING STATIC SOURCE ERRORS

1. INTRODUCTION

The data package is discussed in sub-paragraph 9.2. It is stated, in sub-paragraph 9.5.5 (c) that the methodology used to establish the static source error should be substantiated. It is further stated in sub-paragraph 9.6 that procedures be established to ensure conformity of newly manufactured aeroplanes. There may be many ways of satisfying these objectives; two examples are discussed below.

2. EXAMPLE 1

2.1 One process for showing compliance with RVSM criteria is shown in Figure 3-1. Figure 3-1 illustrates those 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 criteria. 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 aircraft constructor and agreed to by the responsible authority. The data generated by 'N' inspections and 'M' flight calibrations can be used to track the mean and three standard deviation values to ensure continued compliance of the model with the criteria 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.

2.2 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 aeroplanes 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.

2.3 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

3.1 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 criteria. 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 for consistency in cruise conditions and every Mth aircraft should be calibrated, where M is determined by the manufacturer and agreed to by the responsible authority. The data generated by the M flight calibrations should be used to track the mean and three standard deviation values to ensure continued compliance of the group with the criteria of paragraph 7.

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FIGURE 3-1 PROCESS FOR SHOWING INITIAL AND CONTINUED COMPLIANCE OF AIRFRAME STATIC PRESSURE SYSTEMS

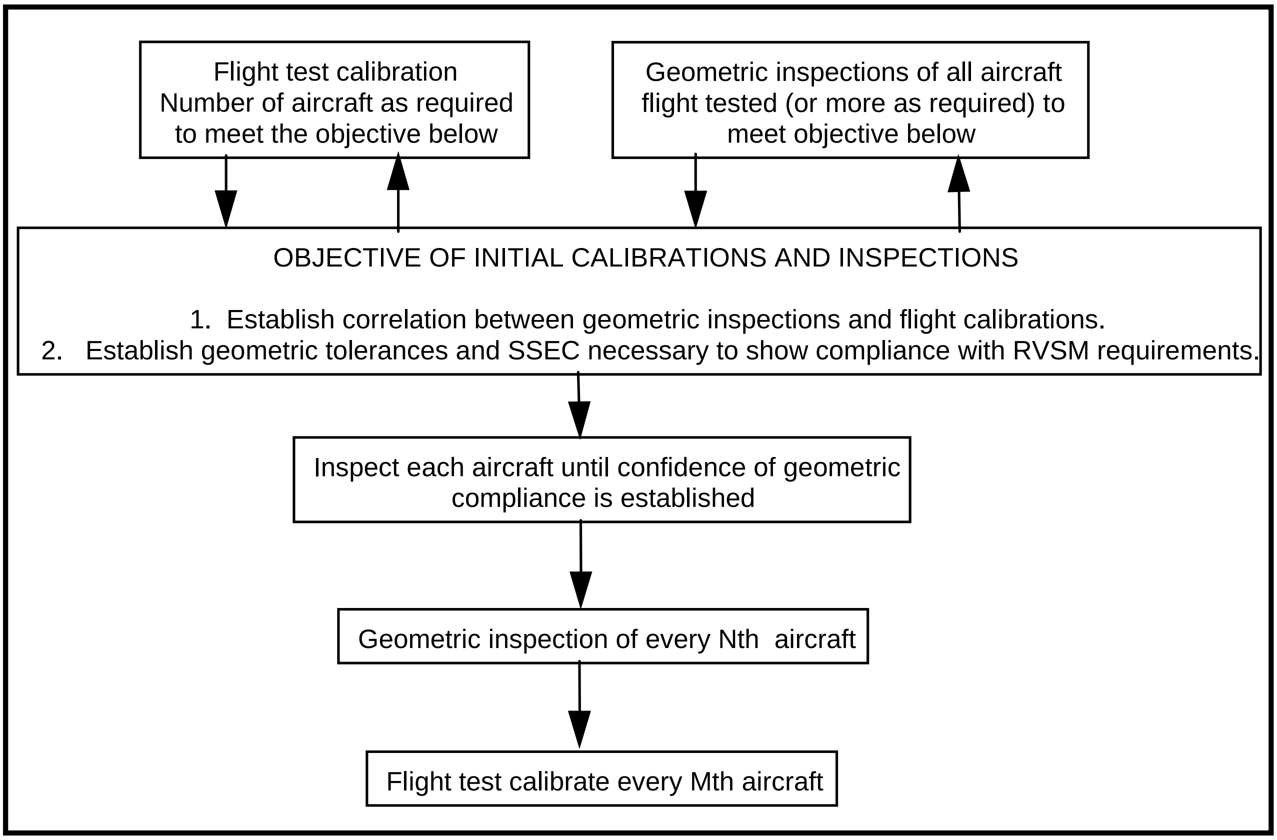


FIGURE 3-2 COMPLIANCE DEMONSTRATION GROUND - TO FLIGHT TEST CORRELATION PROCESS EXAMPLE

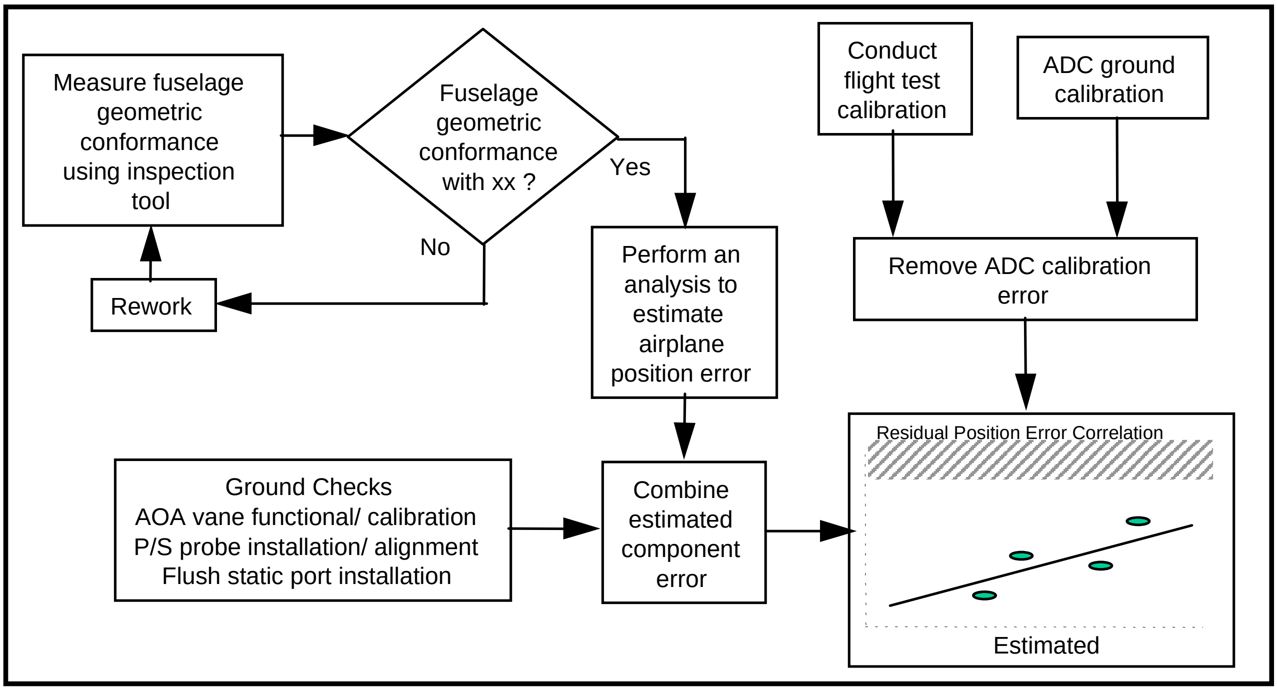
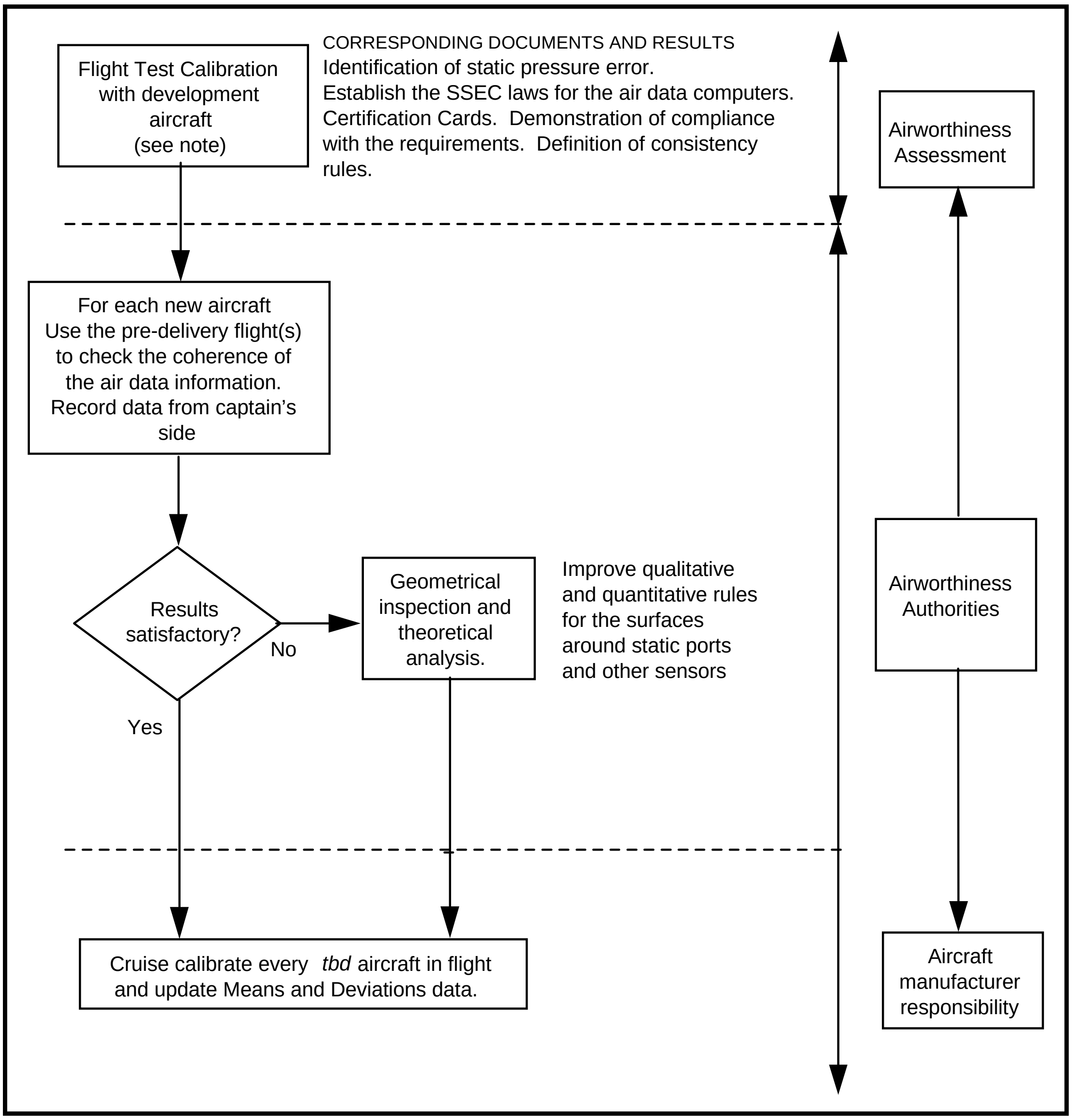


FIGURE 3-3 PROCESS FOR SHOWING INITIAL AND CONTINUED COMPLIANCE OF AIRFRAME STATIC PRESSURE SYSTEMS FOR NEW MODEL AIRCRAFT.



Note : The flight test installation chosen to get the calibration data will need to have an accuracy compatible with the level of performance to be demonstrated and an analysis of this accuracy will need to be provided. Any possible degradation of this accuracy will need to be monitored and corrected during the flight test period.

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APPENDIX 4 TRAINING PROGRAMMES AND OPERATING PRACTICES AND PROCEDURES

1. INTRODUCTION

Flight crews will need to have an awareness of the criteria for operating in RVSM airspace and be trained accordingly. The items detailed in paragraphs 2 to 6 of this appendix should be standardised and incorporated into training programmes and operating practices and procedures. Certain items may already be adequately standardised in existing procedures. New technology may also remove the need for certain actions required of the flight crew. If this is so, then the intent of this guidance can be considered to be met.

Note: This document is written for all users of RVSM airspace, and as such is designed to present all required actions. It is recognised that some material may not be necessary for larger public transport operators.

2. FLIGHT PLANNING

During flight planning the flight crew should pay particular attention to conditions that may affect operation in RVSM airspace.

These include, but may not be limited to:

(a) verifying that the airframe is approved for RVSM operations;

(b) reported and forecast weather on the route of flight;

(c) minimum equipment requirements pertaining to height keeping and alerting systems; and

(d) any airframe or operating restriction related to RVSM approval.

3. PRE-FLIGHT PROCEDURES AT THE AIRCRAFT FOR EACH FLIGHT

The following actions should be accomplished during the pre-flight procedure:

(a) review technical logs and forms to determine 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 near each static source and any other component that affects altimetry system accuracy. This check may be accomplished by a qualified and authorised person other than the pilot (e.g. a flight engineer or ground engineer);

(c) before takeoff, the aircraft altimeters should be set to the QNH of the airfield and should display a known altitude, within the limits specified in the aircraft operating manuals. The two primary altimeters should also agree within limits specified by the aircraft operating manual. An alternative procedure using QFE may also be used. Any required functioning checks of altitude indicating systems should be performed.

Note. The maximum value for these checks cited in operating manuals should not exceed 23m (75ft).

(d) before take-off, equipment required for flight in RVSM airspace should be operative, and any 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.

Note: Dual equipment requirements for altitude-control systems will be established by regional agreement after an evaluation of criteria such as mean time between failures, length of flight segments and availability of direct pilot-controller communications and radar surveillance.

(d) Operating Transponder. An operating transponder may not be required for entry into all designated RVSM airspace. The operator should determine the requirement for an operational transponder in each RVSM area where operations are intended. The operator should also determine the transponder requirements for transition areas next to RVSM airspace.

Note: Should any of the required equipment fail prior to the aircraft entering RVSM airspace, the pilot should request a new clearance to avoid entering this airspace;

5. IN-FLIGHT PROCEDURES

5.1 The following practices should be incorporated into flight crew training and procedures:

(a) Flight crews will need to comply with any aircraft operating restrictions, if required for the specific aircraft group, e.g. limits on indicated Mach number, given in the RVSM airworthiness approval.

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

(c) In level cruise it is essential that the aircraft is flown at the cleared flight level. This requires that particular care is taken to ensure that ATC clearances are fully understood and followed. The aircraft should not intentionally depart from cleared flight level without a positive clearance from ATC unless the crew are conducting contingency or emergency manoeuvres;

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

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 re-trim 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. Following loss of the automatic height keeping function, any consequential restrictions will need to be observed.

(f) Ensure that the altitude-alerting system is operative;

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

   (i) The usual scan of flight deck instruments should suffice for altimeter cross-checking on most flights.

   (ii) Before entering RVSM airspace, the initial altimeter cross check of primary and standby altimeters should be recorded
   Note: Some systems may make use of automatic altimeter comparators.

(h) In normal operations, the altimetry system being used to control the aircraft should be selected for the input to the altitude reporting transponder transmitting information to ATC.

(i) If the pilot is advised in real time that the aircraft has been identified by a height-monitoring system as exhibiting a TVE greater than ±90 m (±300 ft) and/or an ASE greater than ±75 m (±245 ft) then the pilot should follow established regional procedures to protect the safe operation of the aircraft. This assumes that the monitoring system will identify the TVE or ASE within the set limits for accuracy.

(j) If the pilot is notified by ATC of an assigned altitude deviation which exceeds ±90 m (±300 ft) then the pilot should take action to return to cleared flight level as quickly as possible.

5.2 Contingency procedures after entering RVSM airspace are:

5.2.1 The pilot should notify ATC of contingencies (equipment failures, weather) which affect the ability to maintain the cleared flight level, and co-ordinate a plan of action appropriate to the airspace concerned. Detailed guidance on contingency procedures are contained in the relevant publications dealing with the airspace. Refer to Appendix 4, Paragraph 8 of this document.

5.2.2 Examples of equipment failures which should be notified to ATC are:

(a) failure of all automatic altitude-control systems aboard the aircraft;

(b) loss of redundancy of altimetry systems;

(c) loss of thrust on an engine necessitating descent; or

(d) any other equipment failure affecting the ability to maintain cleared flight level;

5.2.3 The pilot should notify ATC when encountering greater than moderate turbulence.

5.2.4 If unable to notify ATC and obtain an ATC clearance prior to deviating from the cleared flight level, the pilot should follow any established contingency procedures and obtain ATC clearance as soon as possible.

6. POST FLIGHT

6.1 In making technical log 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.

6.2 The following information should be recorded when appropriate:

(a) Primary and standby altimeter readings.

(b) Altitude selector setting.

(c) Subscale setting on altimeter.

(d) Autopilot used to control the aeroplane and any differences when an alternative autopilot system was selected.

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

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

(g) The transponder selected to provide altitude information to ATC and any difference noted when an alternative transponder was selected.

7. SPECIAL EMPHASIS ITEMS: FLIGHT CREW TRAINING

7.1 The following items should also be included in flight crew training programmes:

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

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

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

Note: Such correction data will need to be readily available on the flight deck.

(d) problems of visual perception of other aircraft at 300m (1,000 ft) planned separation during darkness, when encountering local phenomena such as northern lights, for opposite and same direction traffic, and during turns; and

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

(f) relationship between the aircraft's altimetry, automatic altitude control and transponder systems in normal and abnormal conditions;

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

8. SPECIFIC REGIONAL OPERATIONAL PROCEDURES

8.1 The areas of applicability (by Flight Information Region) of RVSM airspace in identified ICAO regions is contained in the relevant sections of ICAO Document 7030/4. In addition these sections contain operational and contingency procedures unique to the regional airspace concerned, specific flight planning requirements, and the approval requirements for aircraft in the designated region.

8.2 For the North Atlantic Minimum Navigation Performance Specification (MNPS) airspace, where RVSM have been in operation since 1997, further guidance (principally for State Approval Agencies) is contained in ICAO Document NAT 001 T13/5NB.5 with comprehensive operational guidance (aimed specifically at aircraft operators) in the North Atlantic MNPS Airspace Operational Manual.

8.3 Comprehensive guidance on operational matters for European RVSM Airspace is contained in EUROCONTROL Document ASM ET1.ST.5000 entitled “The ATC Manual for a Reduced Vertical Separation (RVSM) in Europe” with further material included in the relevant State Aeronautical Publications.

8.4 During the life of this document, it is expected that additional ICAO regions or parts of regions may introduce RVSM into their airspace. For example, plans are well in hand to introduce RVSM into parts of the Pacific region. The area of applicability and associated procedures will be published in Document 7030/4 where reference will be made to additional material as necessary.

APPENDIX 5 - REVIEW OF ICAO DOCUMENT 9574 - HEIGHT KEEPING PARAMETERS

1. ICAO Document 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 the assigned flight level, and this is the only factor covered in this document.

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

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

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

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

(d) the proportion of height keeping errors between 290 m (950 ft) and 320 m (1,050 ft) 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. They are applicable statistically to individual groups of nominally identical aircraft operating in the airspace. These characteristics describe the performance that the groups need to be capable of achieving in service, exclusive of human factors errors and extreme environmental influences, if the airspace system TVE criteria 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 ±25m (±80 ft); and

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

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

4. ICAO Doc. 9574 recognises 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 necessary to set system tolerances at levels that recognise 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 recognised 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 criteria are developed to fulfil the following, where the narrower tolerance in sub-paragraph 5 (b) 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 ±25 m (±80 ft); and

(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 60 m (200 ft); and

(c) each individual aircraft in the group shall be built to have ASE contained within ±60 m (±200 ft); and

(d) an automatic altitude control system shall be required and will be capable of controlling altitude within a tolerance band of ±15 m (±50 ft) about selected altitude when operated in the altitude hold mode in straight and level flight under non-turbulent, non-gust 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 recognise that the limits are based on studies (Doc. 9536, Volume 2), which show that ASE tends to follow a normal distribution about a characteristic mean value for the aircraft group and that the in-service performances of the separate groups aggregate together to give an overall performance spread which is distributed about the population mean TVE that is nominally zero. Consequently, controls should be provided which will preclude the possibility that individual aircraft approvals could create clusters operating with a mean significantly beyond 25 m (80 ft) 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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