

**Guidance Material for the
Flight Inspection of RNAV
Procedures**

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1 INTRODUCTION

- 1.1 RNAV systems establish the aircraft position using inputs from positioning sensors, such as DME and GNSS, and establish the required track using navigation data, from an onboard navigation database. RNAV procedures which are published in a State AIP define the track to be flown and specify which navigation sensor types may be used. Before an RNAV procedure is published, it must be checked, as part of the safety assurance process, to establish that the track definition is correct, the obstacle clearance is sufficient and the navaid coverage is adequate. Some checks will already have been carried out by the procedure design office, as outlined in the EUROCONTROL Guidance Material for RNAV Procedure Validation, but some can only be carried out by flight inspection with suitably equipped aircraft.

2 OVERVIEW

- 2.1 ICAO Doc 8071, Manual on Testing of Radio Navigation Aids, provides general guidance on the extent of testing and inspection normally carried out to ensure that radio navigation systems meet the SARPs in ICAO Annex 10. It also provides guidance on the flight inspection of instrument flight procedures. There are references to RNAV applications in Volume 1, Chapter 3, Distance Measuring Equipment, in Volume 1, Chapter 8, Flight Inspection of Instrument Flight Procedures and in Volume 2, Chapter 2, GNSS Stand Alone Procedures.
- 2.2 It is anticipated that Doc 8071 will be amended in the course of time to better reflect the requirements for the flight inspection and verification of RNAV procedures. In the meantime, this document is intended to supplement Doc 8071 and provide initial guidance on specific aspects pertaining to RNAV procedures. This material will continue to be revised and amended as more experience is gained.

3 SCOPE

- 3.1 This material is intended to provide guidance for States planning to implement RNAV procedures. It is NOT a specification for any particular flight inspection regime, NOR a requirement for any change to existing flight inspection equipment. States are expected to select the most efficient combination of tools commensurate with the available resources and the inspection task.

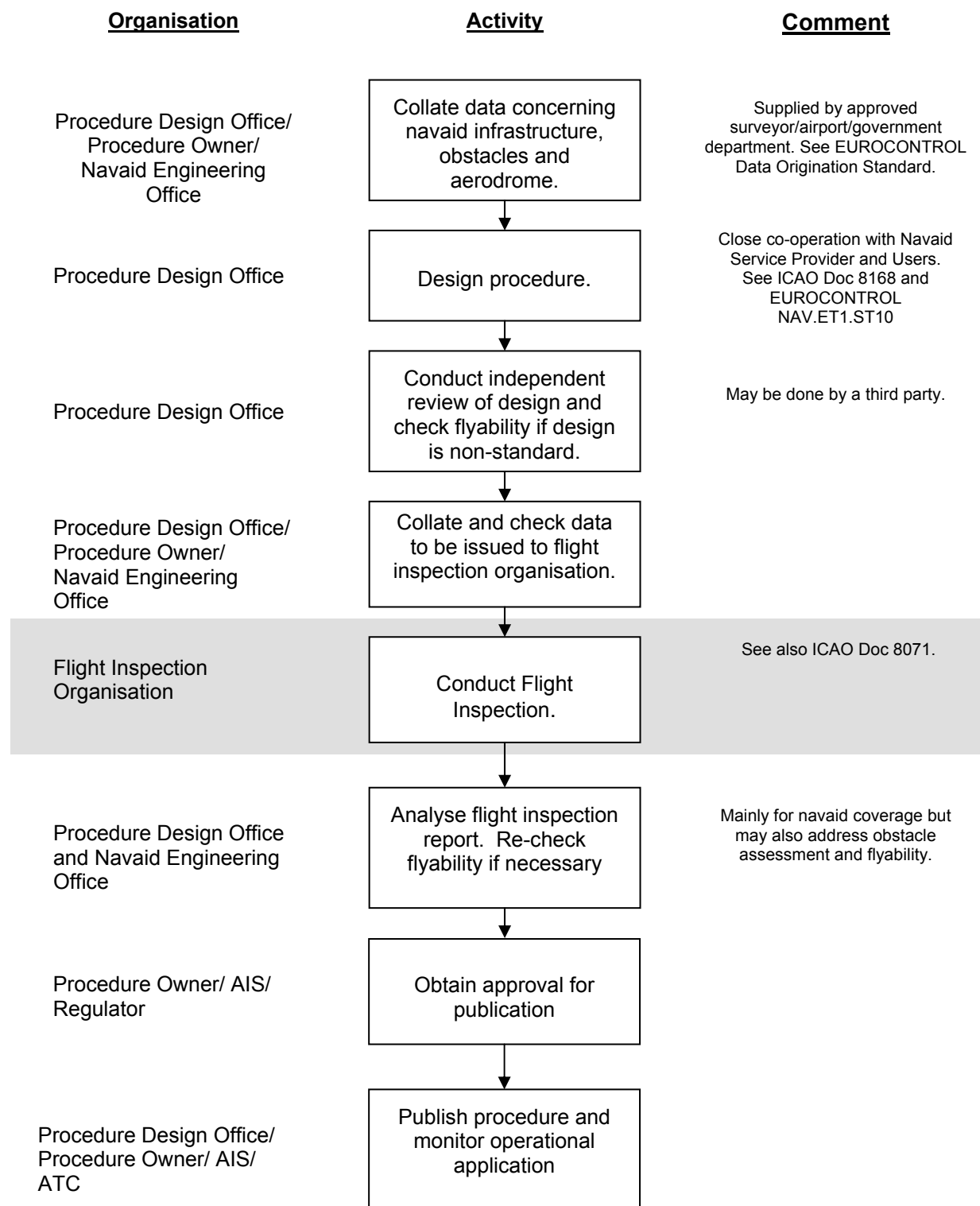
- 3.2 The document is applicable to all RNAV applications currently foreseen in en-route and terminal airspace, including final approach and missed approach¹. The flight inspection of an RNAV procedure primarily checks the coverage and accuracy provided by the navaid infrastructure over the whole procedure and identifies any electromagnetic interference, or other performance anomalies, in the frequency bands associated with that navaid infrastructure. The flight inspection of an RNAV procedure may also be used to verify the obstacle environment within which the procedure is located and the flyability of the procedure. These optional activities are addressed separately in paragraph 5.

4 FLIGHT INSPECTION PROCESS

4.1 WORK PROCESS

- 4.1.1 An example of the relationship that Flight Inspection has within the procedure design and publication process is illustrated in the figure below.

¹ This includes RNP 1, P-RNAV, B-RNAV and RNP 0.3, RNAV_(VOR/DME), RNAV_(DME/DME) and RNAV_(GNSS) approach applications



4.2 NAVAID INFRASTRUCTURE ASSESSMENT

- 4.2.1 Navaid infrastructure assessment in the context of this document is considered to be a measurement of the coverage, accuracy and suitability of signals received from one, or a number of navigation aids, necessary for the RNAV procedure to be flown. Note that, as far as GNSS signals are concerned, they should be monitored and recorded by ground-based stations and the infrastructure assessment can be conducted on an area basis rather than for individual procedures.
- 4.2.2 Prior to commencing the procedure design, the anticipated coverage from the available navaids is analysed by the navaid engineer and the procedure designer using appropriate tools². The design should therefore have taken account of the available infrastructure as well as the obstacle limitations, the ATS requirements and the RNAV system requirements. It is the responsibility of the procedure owner to use the results of the flight inspection to confirm that the infrastructure assumptions along the nominal track, made during the design phase, are valid. This can include an assessment of procedure continuity and critical navaids.
- 4.2.3 The flight inspection is required to measure the actual coverage and accuracy provided by the specified navaid types along the entire instrument flight procedure. The output from the coverage analysis that was conducted by/for the procedure designer should be made available to the flight inspection team, together with any supporting data and design assumptions, for use in planning the flight inspection. The procedure owner should also identify any alternate routes published on the chart as 'at ATC discretion'. Such routes should also be reviewed to determine if it is necessary for them to be included in the flight inspection.
- 4.2.4 The flight inspection aircraft should fly the proposed RNAV procedure following the ground track defined by the procedure designer.³ One way in which this can be achieved is by using an RNAV system and an ARINC 424 compatible navigation database containing the procedures to be checked.⁴ The RNAV system and the database may be part of the flight inspection system or the aircraft navigation system. In cases where the nominal track passes close to the edge of the predicted coverage of a specific navaid it may be necessary to fly an additional off-set track .

² Details of such software packages are provided at Annex C.

³ As detailed in EUROCONTROL NAV.ET1.ST10 - Guidance Material for the Design of Terminal Procedures for Area Navigation.

⁴ The prescribed ground track is defined by waypoint location, waypoint type, path terminator and, where appropriate, speed constraint, altitude constraint and course. If a flyability assessment is also required, it is important that the data displayed to the flight inspector accurately reflects that which will subsequently be displayed to pilots.

4.3 DME

4.3.1 In the case of procedures based upon DME/DME positioning, an assessment should be made of the impact on the navigation solution of all the DME signals, received along the prescribed track⁵.

4.3.2 The flight inspection should establish, for each route flown:

- a) Whether the DMEs identified by the procedure designer provide coverage and the required accuracy over the route, in accordance with ICAO SARPS (as detailed in Annex 10 Vol1 Chap 3 and Doc 8071 Chap 3⁶);
- b) Whether any additional DMEs, not identified by the procedure designer, could contribute to the navigation solution and, if possible, what coverage and accuracy is achieved.
- c) Whether there is any electromagnetic interference or other perturbation that has a deleterious effect on the received signals including any unlocks or multipath.

4.3.3 The data gathered during the flight inspection, detailed in paragraph 4.3.2 above, should be used to support the subsequent analysis necessary to establish:

- a) Whether the maximum Position Estimation Error (PEE) achieved using these DMEs is acceptable for all points along the route. For example, for P-RNAV, the 1σ PEE is 0.3NM and, for RNP 0.3 RNAV, the 1σ PEE is 0.09NM.⁷
- b) Whether any DME is critical to ensure adequate coverage⁸;

⁵ Additional tools will be required in addition to existing flight inspection equipment to support these requirements. See section 8.

⁶ Field density >89 dBW/m² and signal in space accuracy ≤ 0.1 NM (See ICAO Annex 10 Vol 1 Section 3.5.3.1.3.3 Note 1) In order to assess DMEs with coverage near the lower field strength limit, the measurement accuracies of existing flight inspection systems may have to be re-evaluated to take account of actual receiver and installed antenna performance.

⁷ Based upon guidance in EUROCAE ED 75/RTCA DO 236: 'Minimum Aviation System Performance Standards: Required Navigation Performance for Area Navigation'. – see extracts at Annex B. (*Editor's note: The guidance provided by ED75/DO 236 is currently under review and the 1σ PEE values may increase as a result*)

⁸ In this context, if the PEE at any point on the procedure can only be achieved using specific DMEs, then those DMEs are considered to be critical to the procedure. If the PEE can be achieved using a range of DMEs, then the individual DME stations are not critical. The Flight Inspection is only required to identify, or confirm, and report those DMEs that meet these criticality criteria.

- 4.3.4 Where an additional DME station has been installed, or brought back into service after significant modification, to support RNAV operations, or where a DOC has been increased to support RNAV applications, that station may require a standard commissioning check prior to inspecting any RNAV procedure likely to be affected by that station.

4.4 GNSS

- 4.4.1 In the case of GNSS, the orbiting constellation provides a continually changing set of point sources and, for this reason, flight inspection cannot generate any meaningful assessment of positioning accuracy or coverage for a specific procedure. The primary role of flight inspection is to establish whether there is any electromagnetic interference or other distortions, e.g multipath, that has a deleterious effect on the received satellite signals⁹.

5 OPTIONAL ACTIVITIES

5.1 OVERVIEW

- 5.1.1 The flight inspection of an RNAV procedure may also be used to verify:

- a) The obstacle environment within which the procedure is located.
- b) The flyability of the procedure.

5.2 OBSTACLE ASSESSMENT

- 5.2.1 Within ECAC, procedure design should normally be based upon recently surveyed obstacle data (including photogrammetric survey), high integrity terrain databases and current topographic charts. The flight inspection can aid the safety assurance process by reporting any possible additional significant obstacles that may have been erected, or existing obstacles that may be charted with grossly incorrect heights, along the designated track, within the pilot's primary field of view.

⁹ See ICAO Annex 10 Vol I App B Section 3.7, and EUROCAE ED-114, 'Minimum Operational Performance Specification for Global Navigation Satellite Ground Based Augmentation System Ground Equipment to Support Category I Operations', and RTCA DO235, 'Assessment of Radio Frequency Interference Relevant to the GNSS'. Particular attention should be paid to harmonics on or within 10 MHz of GPS L1 (1575.42 MHz). If interference is suspected, the geographical extent along the procedure should be established using spectrum, time domain and signal/noise ratio analysis. The Flight Inspection is only required to identify and report anomalous effects.

5.3 FLYABILITY CHECK

5.3.1 A flight inspection procedure may include a check of the flyability of the design. Assessment of flyability covers all aspects of the instrument flight procedure including:

- a) **Aircraft manoeuvring in context of safe operating practices for the category of aircraft.** If the RNAV procedure has been designed according to the PANS-OPS RNAV criteria and has passed the ARINC 424 coding checks then it should be flyable by most, if not all, aircraft. Indeed, the majority of RNAV approach procedures are expected to follow a standard, tried and trusted 'T' or 'Y' layouts which should be flyable by all aircraft. However, when the design encroaches on the limits of the criteria by using, for example: leg lengths that are shorter than recommended, turn angles that are greater than 120°, climb gradients that are greater than 7%, initial fly-by waypoints on SIDs within 3NM of the DER, descent gradients that are steeper than 3.5° or ILS interceptions that are greater than 45°; then it is recommended that particular attention is paid to the flyability check, especially on the initial legs in SIDs and missed approaches, the final approach segment and the final legs of STAR/Transitions.
- a) **Cockpit workload.** The pilot should confirm that the procedure is unambiguous and easily comprehensible both on chart and in the FMS. The procedure should be able to be executed with minimum input and without additional actions required of the cockpit crew. It should be easy to follow and monitor, with minimum head-down time. This is achieved in a clear, uncluttered layout, with the number of waypoints kept to a minimum.
- b) **Charting aspects.** The procedure should be depicted correctly on all corresponding chart material and the presentation on the chart and the FMS must coincide. All waypoints tracks and distances must be depicted correctly and all values (co-ordinates etc) must equate. All relevant information must be presented in a clear, unambiguous and uncluttered fashion.
- c) **Navigation database aspects.** Database integrity checks do not constitute part of the formal flight inspection process. However, as part of the standard pre-flight checks, the accuracy of the waypoint co-ordinates, the bearings and distances displayed for each leg, the altitude and speed constraints, and the depicted track should be compared with the chart or related documentation. Any discrepancies should be reported back to the organisation responsible for the procedure and to the navigation data provider

- 5.3.2 In many instances, the flyability check involves a subjective assessment by the pilot, taking account of the aircraft types that are expected to use the procedure. The flight inspection aircraft cannot replicate the performance of all the aircraft types that will be expected to use the procedure, but can be used to identify gross flyability errors. It is not possible for a flight inspection to meet the ultimate goal of the flyability check for RNAV procedures, which is to establish that the procedure is flyable by the anticipated range of aircraft types in all appropriate weight configurations and in all extremes of weather. Thus an empty aircraft departing on a cold day with a strong headwind, or crosswind, should be able to fly the procedure just as well as a fully laden aircraft departing on a still hot day. Similarly, an aircraft arriving on a cold day, using anti-icing, with a tailwind should be able to fly the procedure just as well as on a hot day with a strong crosswind/headwind. While an experienced flight inspection crew can use techniques to mimic many characteristics of larger aircraft, they cannot cover all aspects and additional checks may be carried out using simulation software. The assessment is provided in a commentary in the flight inspection report.
- 5.3.3 Where a flight inspection is required to address flyability aspects, the procedure designer should identify which procedures, or parts of a procedure, should be reviewed by the flight inspector from a flyability perspective.
- 5.3.4 The verification of the flyability of an RNAV procedure can include independent assessments by procedure designers and other experts using specialist software, full flight simulators or even trial flights conducted by flight inspection aircraft.

6 OBTAINING A FLIGHT INSPECTION DATABASE

- 6.1 The flight inspection should be carried out before the procedures are released for public use. This generally means before the procedures are published in the AIP. If the flight inspection aircraft is equipped with an RNAV system and a navigation database, the database has to contain the new procedures¹⁰.
- 6.2 One way to achieve this is by use of a special test database produced by the appropriate navigation data provider and packed for the RNAV system in use on the flight inspection aircraft. If this involves the use of navigation databases produced by the commercial datahouses, the procedure owner must take account of the likely lead times.

¹⁰ The RNAV system may be part of the flight inspection system or may be part of the standard aircraft navigation system.

7 FLIGHT INSPECTION FREQUENCY

- 7.1 Every new RNAV procedure should undergo a flight inspection prior to it being made available for public use. Changes to existing RNAV procedures and changes in the supporting infrastructure should be reviewed by an expert group, including flight inspection specialists, to determine whether an additional flight inspection is required.
- 7.2 RNAV procedures should be re-inspected on a regular basis. The frequency of such re-inspections should be decided by the State. The following factors may be taken into account when determining the periodicity:
- a) **GNSS**: Risk of GNSS interference and available mitigations
 - b) **DME**: Frequency of inspection of ground stations; maintenance history and risk of multipath,

8 AIRCRAFT EQUIPAGE AND CREW TRAINING

- 8.1 The flight inspection aircrew should have received suitable training in RNAV applications. In addition, the inspection equipment on board the aircraft and the analysis software to evaluate the coverage and accuracy should be sufficient to meet the intents of this document. .
- 8.2 While it is not the purpose of this document to specify an equipage standard, it is considered that a truth system is necessary.
- 8.3 EUROCONTROL is developing guidance material concerning the flight inspection equipment appropriate to conduct the flight inspection of DME/DME based RNAV procedures.

DEFINITION OF TERMS

Area Navigation	A method of operation that permits aircraft operation on any desired flight path within the coverage of station-referenced navigation aids, or within the limits of capability of self-contained aids, or a combination of these. (ICAO Doc 8168)
Continuity	The continuity of a system is 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. The continuity risk is the probability that the system will be unintentionally interrupted and not provide guidance information for the intended operation. More specifically, continuity is the probability that the system will be available for the duration of a phase of operation, presuming that the system was available at the beginning of that phase of operation. [derived from ICAO Doc. 9650]
Flight Inspection	A series of flight tests carried out to establish the operational classification of a facility (ICAO Doc 8071 Para 1.3.3), and, for Instrument Flight Procedures, assure that the navigation source(s) supports the procedure, ensure obstacle clearance and check flyability (ICAO Doc 8071 Para 8.3.1 & 8.3.15)
Flight Test	Tests carried out in the air by a trained flight crew using a suitably equipped aircraft. (ICAO Doc 8071 Para 1.4.1)
Verification	Verification checks carried out in the air/or on the ground.
Flyability	The ability to keep an aircraft within predefined tolerances of the designed track. This has been expanded within the context of Flight Inspection to include the operational suitability of a procedure to meet its intended purpose.
Inspection	A series of tests carried out to establish the operational classification of a facility. (ICAO Doc 8071 Para 1.3.3)
Position Estimation	The means of determining the aircraft's position over the surface of the earth using data from radio sensors (with signals from ground-based navaids or satellites) or from onboard autonomous navigation sensors (IRS). (ED75/DO236 Para 1.3.1)
Position Estimation Error	The difference between true position and estimated position. (ED75/DO236)(see explanation in Annex B)
Test	A specific measurement or check of facility performance that may form a part of an inspection when integrated with other tests. (ICAO Doc 8071 Para 1.3.3) May be carried out on the ground – ground test – or during a flight – flight test.

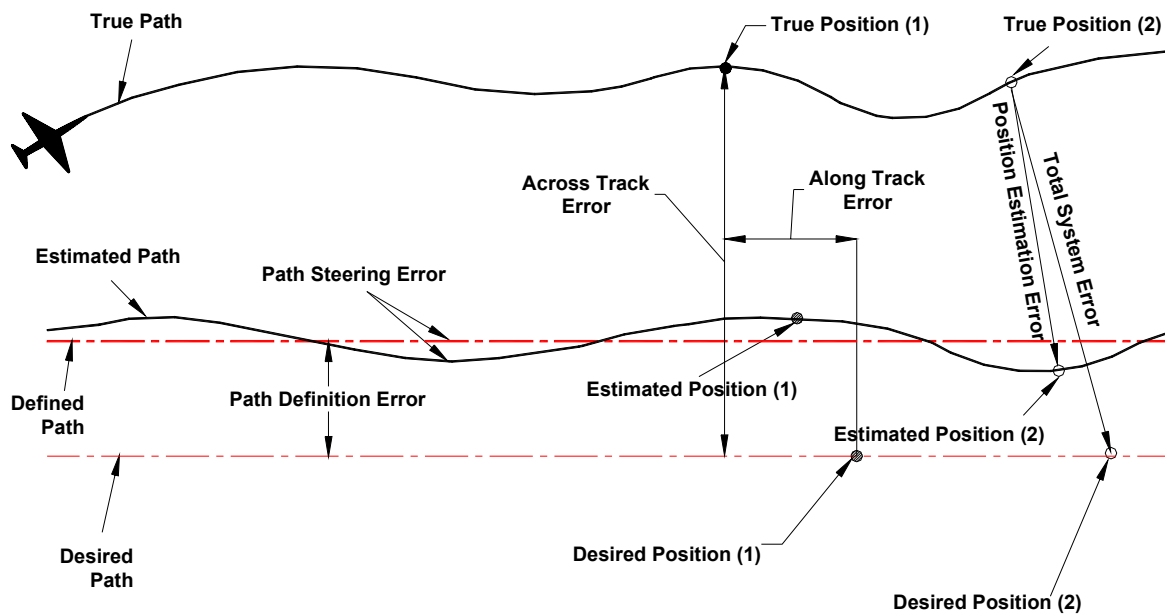
ANNEX A - LIST OF ACRONYMS

AIP	Aeronautical Information Publication
AIRAC	Aeronautical Information Regulation and Control
AIS	Aeronautical Information Service
ATC	Air Traffic Control
ATS	Air Traffic Service
B-RNAV	Basic RNAV
DER	Departure End of Runway
DME	Distance Measuring Equipment
ECAC	European Civil Aviation Conference
FMS	Flight Management System
GNSS	Global Navigation Satellite System
ICAO	International Civil Aviation Organisation
IRS	Inertial Reference System
MSA	Minimum Sector Altitude
NAVAID	Navigation Aid
PANS	Procedures for Air Navigation Services
PANS-OPS	ICAO Document 8168.
PEE	Position Estimation Error
P-RNAV	Precision RNAV
RNAV	Area Navigation
RNP-RNAV	Required Navigation Performance RNAV
SARPS	Standards and Recommended Practices
SID	Standard Instrument Departure
STAR	Standard Instrument Arrival
VHF	Very High Frequency

ANNEX B – EXPLANATION OF TERMS

Error Terms

There are a number of error sources and error terms that must be considered when evaluating RNP-RNAV compliance. The figure below shows the error terms considered in the lateral dimensions. These terms refer to the actual error, and not an uncertainty. Both cross-track and along-track components of position estimation error have been included in order to facilitate evolution to along-track containment. The definition of these terms follow.



DEFINED PATH The output of the path definition function.

DESIRED PATH The path that the flight crew and air traffic control can expect the aircraft to fly, given a particular route leg or transition.

ESTIMATED POSITION The output of the position estimation function.

PATH STEERING ERROR (PSE) The distance from the *estimated position* to the *defined path*. The PSE includes both FTE and display error (e.g., CDI centering error).

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. It does not include blunder errors.

PATH DEFINITION ERROR (PDE) The difference between the *defined path* and the *desired path* at a specific point.

POSITION ESTIMATION ERROR (PEE) The difference between true position and *estimated position*.

TOTAL SYSTEM ERROR (TSE) The difference between true position and *desired position*. This error is equal to the vector sum of the *path steering error*, *path definition error*, and *position estimation error*.

NAVIGATION SYSTEM REQUIREMENTS AND INFRASTRUCTURE CHARACTERISTICS

1 Introduction

The following paragraphs lay out the assumptions made by the RNAV system developers concerning the navigation infrastructure which the system expects to have available and provide some guidance to States on assessing infrastructure performance.

Paragraph 2 describes the sensor performance that is assumed to be provided by each type of navigation facility if it is to be used to promulgate a route for RNP, and with Vertical Performance requirements, where appropriate. This performance is assumed by the aircraft when demonstrating compliance to the system requirements in ED75A/DO236A.

Paragraph 3 provides information for the airspace planner in assessing what RNP types may be supported by a particular navigation infrastructure.

Infrastructure integrity is not considered as part of the airborne evaluation; the Signal-in-Space (SIS) is assumed to have the error distributions described below. The only exception is GPS, which has a SIS failure rate that must be compensated by an augmentation (See paragraph 2.4).

Infrastructure continuity is not considered as part of the airborne evaluation, but must be considered by the State prior to defining RNP airspace predicated on a particular navigation infrastructure. It is assumed that an RNP operation will not be initiated unless the SIS continuity is sufficient. If the aircraft uses the infrastructure identified by the State, no additional assessment of SIS continuity is required. However, if the aircraft uses components of the infrastructure not identified by the State, an assessment of the SIS continuity must be performed. This Annex provides the outage rates for different navigation facilities which are used when such an assessment is carried out.

In addition, it is assumed that the State publishes the correct location for each navigation facility, so that any error arising from inaccurate survey of a navigation facility is consistent with the following accuracy assumptions.

2 Navigation Facility Assumptions for the Airborne System

2.1 Distance Measuring Equipment (DME)

The basic expression for DME error is:

$$\sigma_{DME}^2 \sim (GS \text{ Error})^2 + (\text{Air Error})^2 + (K \cdot D)^2$$

where GS Error = ground station timing error

K = constant

D = distance to the DME

When demonstrating compliance, the airborne system assumes that the DME infrastructure will provide a ranging signal with a Gaussian slant range error that has a mean of zero and a standard deviation of 0.05 NM. DME signals shall not be used at ranges greater than defined in Table C-2:

Table C-2 Maximum DME Ranges

Range	max. D
RNP-0.3 RNAV to RNP 0.9 RNAV	25NM
RNP- 1 RNAV to RNP- 1.9 RNAV	55 NM
RNP-2 RNAV and above	140 NM

Note: The DME range error will be less than 0.2 NM (95%) for systems installed after 1 January 1989 (ICAO Annex 10). Before this date, accuracy was addressed in Annex 10 as a recommended 0.25 NM + 1.25% indicated range.

When designating RNP airspace based upon a DME infrastructure, the State may assume that the DME contribution to error (slant-range to the DME) is equal to:

$$\sigma_{DME}^2 = (0.05 \text{ NM})^2 + \text{MAX} \{ (0.085)^2, (0.0125 * D)^2 \}$$

Note: This assumption is based upon the achievable performance of airborne equipment, as defined in RTCA/DO-189 and EUROCAE ED-54.

DME facilities are assumed to have a mean time between failures of 10,000 hours.

2.2 Global Positioning System (GPS)

When demonstrating compliance, the airborne system assumes that the GPS infrastructure will provide a signal with a Gaussian pseudorange error that has a mean of zero and a standard deviation of 33 meters.

$$\sigma_{GPS} \text{ range error} = 33 \text{ meters}$$

When establishing compliance to the containment requirements, GPS satellites are assumed as having a major service failure rate of 10^{-5} /hour/satellite. A major service failure is defined to be a pseudorange error greater than 150 meters received from a satellite not designated

"unhealthy". The overall failure rate is assumed to be 10^{-5} /hour/satellite (the failure rates are equivalent because the major service failure rate is conservative).

Note: GPS provides a unique signal-in-space in that it is not directly monitored to a level commensurate with aviation requirements (time-to-alarm and probability of missed detection). In order to use GPS for IFR navigation, augmentation is required to provide the monitoring function [airborne augmentation such as fault detection and exclusion (FDE), space-based augmentation, or ground-based augmentation]. The requirements for the augmentation are based upon the potential effect of a GPS satellite failure on multiple users. These requirements will be determined for each type of augmentation, and will be more stringent than that required to satisfy the containment requirements of a single aircraft. For GPS systems using FDE as the requisite augmentation, the probability of missed detection and failed exclusion have both been established as 10^{-3} (RTCA/DO-229, FAA Notice 81 IO. 60).

3 Effect of PEE on Route or Procedure Airspace Design

It is assumed that RNP procedures will not be developed unless the navigation infrastructure supports the procedure. In order to assess whether or not a particular infrastructure supports RNP-(x), the State will identify the desired RNP type and assess the feasibility. The assessment of feasibility involves the following steps:

- 1) Determine the maximum σ PEE that supports the desired type: σ PEE = 0.3(x),
- 2) Identify the navigation facilities which support the σ PEE, selecting at least one type of airborne integration, and
- 3) Assess continuity of the selected navigation infrastructure.

These steps are discussed in detail in the following sections. Alternatively, the entire process can be reversed by assessing a particular navigation infrastructure and determining the RNP type that it supports.

3.1 Determine Maximum σ PEE

The maximum standard deviation of position estimation error is defined as

$$\text{MAX } \{ \sigma \text{ PEE } \} = 0.3(\text{desired RNP Value})$$

By allocating a fraction of the allowable total system error to the signal-in-space, the remaining error budget is allocated to the aircraft. The value of 0.3 was based upon an evaluation of reasonable airborne errors, so that the effective error allocation is:

$$\sigma_{TSE}^2 = \sigma_{PEE}^2 + \sigma_{PSE}^2$$

$$(\text{RNP Value})^2 = (2*0.3*\text{RNP Value})^2 + (0.8*\text{RNP Value})^2,$$

where the path definition error is assumed to be zero for this feasibility assessment. The aircraft has been allocated an error of

$$2\sigma_{PSE} = 0.8 * RNP \text{ Value.}$$

3.2 Identify Navigation Facilities Which Provide Required Accuracy

The State should identify the facilities within range of the intended procedure. Because the airborne equipment assumes that the SIS have the characteristics defined in this Annex, the State should also use these assumptions in assessing the RNP type supported by an infrastructure. Paragraph 2 provides sufficient information to determine the error distribution for each navigation aid. These error distributions are combined

3.3 Assess Infrastructure Continuity

Depending on the type of facilities provided and the intended operation, the State may elect to have redundant facilities to ensure that the continuity is consistent with air traffic requirements. If multiple facilities are required to satisfy the air traffic service requirements, then the worst-case operational configuration should be used for the assessment in paragraph 3.2.

For example, an RNP procedure may be created based on a DME/DME environment. Although only two DMEs are required to provide navigation, the State may determine that three DMEs are necessary to achieve the desired continuity and account for DME ground station maintenance and failures. In this case, the two DMEs with the worst geometry should be used (the third DME should be assumed to be out of service).

SOFTWARE TOOLS AVAILABLE TO SUPPORT THE ANALYSIS OF NAVAID COVERAGE AND INTERFERENCE

DEMETER:

DEMETER is a stand-alone desktop application, developed as an extension for the commercially available GIS software, ArcView Version 3.x, to aid airspace planners and navaid engineers with the positioning and decommissioning of ground-based navigation aids. DEMETER allows the degree of multi-navaid coverage and redundancy to be assessed. It includes the following features:

- NavAid database for VOR, DME, VOR-DME, TACAN, and VORTAC.
- Terrain database supporting DTED levels 0, 1 and 2.
- Coverage, performance and redundancy calculations.
- Route definition using pre-defined ICAO identifiers, or user-defined positions.
- Route calculation giving best (and alternate) navaid pairs for use along a pre-defined route.
- Enhanced performance calculations (approximating to RNP) based on accuracy/continuity.

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EMACS

EMACS is a modular analysis tool, developed to solve the Maxwell equations in complex environments. The system is based upon CAD and GIS software packages supported by a digital terrain model. It provides the following functionality:

- Basic Coverage – this includes terrain profile extractions, Fresnell ellipse analysis, coverage evaluation along a route or at a constant altitude, antenna pattern definition and modelling.
- DME – this includes omni and sectorial antenna modelling, performance simulation and signal analysis.

- EMI – numerical analysis tools including interference ratio analysis.
- MLAT – computes the area of coverage for each sensor, the number of sensors in view and the dilution of precision

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SISMOS

SISMOS stands for Signal in Space MONitoring System. SISMOS allows measurement of the true Signal in Space. It is a ground and in-flight measurement system, and NOT a software simulation tool. SISMOS has several modules, one of which is for capturing DME pulse signals in the time domain using a dedicated RF front end architecture. This is realized on a customized FPGA, which triggers on received pulses using a specifically developed autocorrelation algorithm. Additionally, SISMOS applies 3-dimensional antenna gain corrections based on simulated and measured installed antenna gain patterns.

This approach allows the significant accuracy limitations of field strength measurements using a calibrated AGC voltage from typical DME avionics in combination with only horizontal gain pattern corrections to be overcome. The latter especially have limited validity for RNAV applications. Furthermore, since the actual pulses including their distortions are visualized, multipath and interference effects can be detected. SISMOS/DME is especially suitable for cases where DME flight inspection results are inconclusive (such as excessive AGC unlocks / memory mode events) and where DME's are being used for RNAV applications near the edge of coverage.

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CALNAV

CAL-RNAV is a software tool developed by Aena to study RNAV compliance for both DME/DME and VOR/DME modes. The application evaluates accuracy, availability and continuity at any desired flight level, giving more detailed information at any specific point.

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