



<b>MANUAL</b>	<b>REF</b>	<b>DSA.AOC.MAN.002</b>
<b>PERFORMANCE BASED NAVIGATION OPERATIONAL APPROVAL HANBOOK</b>	<b>ED</b>	<b>01 DU 01/11/2014</b>
	<b>REV</b>	<b>00 DU 01/11/2014</b>

## **PART 1 PBN TECHNOLOGY**

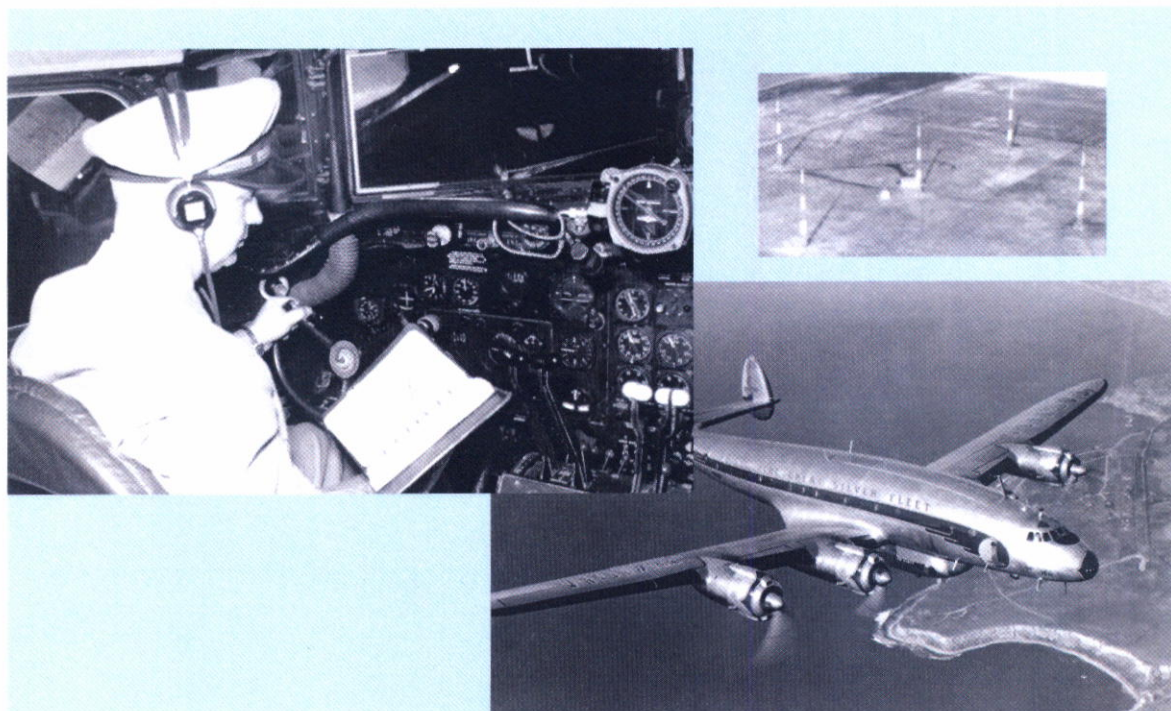
### **Chapter 1 OVERVIEW**

#### **1.1 Introduction.**

The information in this Part is intended to provide inspectors with the necessary technical knowledge necessary to manage an application for operational approval in accordance with a navigation specification contained in the PBN Manual. This Part contains information relative to the full complement of PBN Manual navigation specifications and in general individual PBN operations are not discussed in detail.

#### **1.2 Transition from Conventional Navigation to PBN**

Conventional navigation, that is navigation dependent upon ground-based radio navigation aids, has long been the mainstay of aviation. Pilots, operators, manufacturers and ANSPs are all familiar with the technology, and the avionics, instrumentation, operations, training and performance are very much standard throughout the world. Consequently, apart from some more demanding operations such as Cat II/III ILS, specific operational approval is not necessary.







<b>CAMEROON CIVIL AVIATION AUTHORITY – DIRECTION OF AVIATION SAFETY</b>		
<b>MANUAL</b>	<b>REF</b>	<b>DSA.AOC.MAN.002</b>
<b>PERFORMANCE BASED NAVIGATION OPERATIONAL APPROVAL HANBOOK</b>	<b>ED</b>	<b>01 DU 01/11/2014</b>
	<b>REV</b>	<b>00 DU 01/11/2014</b>

Performance Based Navigation is dependent on area navigation, and while various methods of RNAV have been in existence for many years, the use of RNAV has not yet reached the same level of common use as conventional navigation. The Performance Based Navigation concept is intended to better define the use of RNAV systems and provide a means to eventually reach a similar level of common use. However, until there is general standardisation in aircraft, operating procedures, training and ATS application, there is a need for an operational approval process.

While there is a need for an approval process, the fundamentals of PBN operations are relatively straightforward, and operational approval need not be a complicated process for either applicant or regulator. Even the highest performing type of operation (RNP AR APCH), once implemented, due the capability of modern avionics and auto-flight systems, is a simple and safe operation when conducted in an appropriately equipped aircraft operated by a properly trained crew.

However the transition to new technology, new navigation and operational concepts and the dependence on data driven operations requires careful management. It is the purpose of the operational approval process to ensure that for all PBN operations the appropriate level of oversight is provided to ensure that in the current environment where there are many variables in terms of equipment and experience that the benefits of PBN can be achieved consistently and safely.

The key to successful PBN implementation is knowledge and experience. For many States, both operators and regulators lack both, and this handbook is intended to assist in improving that level of knowledge. Experience can only be gained by doing, and an operational approval will commonly be required before relevant experience is gained. In this handbook guidance is also provided on strategies for implementation which allow experience to be gained (by all parties) in a controlled environment, allowing progression to full capability in stages as experience is gained.

### **1.3 Performance Based Navigation**

Performance Based Navigation encompasses a range of operations which are all based upon Area Navigation. Area navigation, commonly abbreviated as RNAV, has been available for around 30 years using a variety of technologies, however some difficulties arise in the dual application of the term RNAV as a fundamental method of navigation (area navigation) and also as a particular type of operation (e.g. RNAV 5). Further complications arise with the implementation of Required Navigation Performance (RNP) operations which by definition are also area navigation operations.



<b>CAMEROON CIVIL AVIATION AUTHORITY – DIRECTION OF AVIATION SAFETY</b>		
<b>MANUAL</b>	<b>REF</b>	<b>DSA.AOC.MAN.002</b>
<b>PERFORMANCE BASED NAVIGATION OPERATIONAL APPROVAL HANBOOK</b>	<b>ED</b>	<b>01 DU 01/11/2014</b>
	<b>REV</b>	<b>00 DU 01/11/2014</b>

There has been some difficulty in identifying the differences between RNAV operations and RNP operations, and some lack of definition in the requirements for both RNAV and RNP operations. A number of regions established local RNAV and RNP standards which led to complexity in international operations and operational approvals.

ICAO established the Required Navigation and Special Operational Requirements Study Group (RNPSORSG) to resolve these issues. The RNPSORSG (now called the PBN Study Group) developed the concept of Performance Based Navigation to encompass both RNAV and RNP operations.

#### **1.4 RNAV vs. RNP**

One of the issues that the RNPSORSG had to deal with was to differentiate between area navigation operations which are described as either RNAV or RNP. It was recognised that while both RNAV and RNP operations could be described in terms of navigation performance (e.g. accuracy), RNP operations can be identified by the capability of the on-board navigation system to monitor in real time the achieved navigation performance and to alert the operating crew when the specified minimum performance appropriate to a particular operation could not be met. This additional functionality provided by RNP allows the flight crew to intervene and to take appropriate mitigating action (e.g. a go-round), thereby allowing RNP operations to provide an additional level of safety and capability over RNAV operations.

As GNSS systems incorporate performance monitoring and alerting, the distinction between RNAV and RNP operations in practice is the requirement for GNSS. While there are exceptions to this rule, in simple terms RNP operations are GNSS based, and for RNAV operations are based on older technology.

RNAV navigation specifications have been developed to support existing capability in aircraft equipped with systems which in the general case were not designed to provide on-board performance monitoring and alerting.

RNP navigation specifications have been developed from a need to support operations that depend upon GNSS to provide the required performance.







<b>CAMEROON CIVIL AVIATION AUTHORITY – DIRECTION OF AVIATION SAFETY</b>		
<b>MANUAL</b>	<b>REF</b>	<b>DSA.AOC.MAN.002</b>
<b>PERFORMANCE BASED NAVIGATION OPERATIONAL APPROVAL HANDBOOK</b>	<b>ED</b>	<b>01 DU 01/11/2014</b>
	<b>REV</b>	<b>00 DU 01/11/2014</b>

## **Chapter 2 AREA NAVIGATION**

### **2.1 Area Navigation Principles**

Area navigation (RNAV) is a term applied to navigation between any two selected points on the earth's surface. RNAV has been around since the 1960s and the earliest avionics used triangulation measurements from ground-based navigation aids to compute an RNAV flight path between waypoints.

A number of self-contained navigation systems which are independent of any ground based navigation systems have also been developed, including OMEGA (now obsolete) LORAN C, GPS, Glonass, Inertial Navigation Systems (INS) and Inertial Reference Systems (IRS).

Perhaps the most common type of RNAV system in use in commercial aviation today involves the use of IRS positioning updated by reference to ground-based radio navigation aids (DME and VOR) or GPS. Updating by reference to ground-based aids is limited by the availability of sufficient navigation aids, and in many parts of the world, including oceanic and remote areas, position updating is unavailable.

Commonly referred to by the generic term GNSS (Global Navigation Satellite System) satellite navigation has revolutionised area navigation and provides highly accurate and reliable positioning. For modern air transport operations area navigation is managed using a Flight Management System, using IRS position updated by GNSS.

However, as there are many and varied area navigation systems in use throughout the world, the PBN Manual provides a number of navigation specifications to accommodate a range of RNAV and RNP performance levels. One of the tasks of the operations approval inspector is to ensure that the equipment available meets the requirements of the relevant PBN operation.

### **2.2 Geodetic Reference**

An area navigation system computed position must be translated to provide position relative to the real position on the earth's surface. Horizontal datums are used for describing a point on the earth's surface, in latitude and longitude or another coordinate system.

A specific point on the earth can have substantially different coordinates, depending on the datum used to make the measurement. There are hundreds of locally-developed horizontal datums around the world, usually referenced to some convenient local reference point. The WGS 84 datum is the common standard datum now used in aviation.

### **2.3 Path Terminators**

In its simplest form area navigation system computes a track between two selected waypoints. However the demands on aircraft navigation require the definition of complex flight paths, both lateral and vertical. The international





<b>CAMEROON CIVIL AVIATION AUTHORITY – DIRECTION OF AVIATION SAFETY</b>		
<b>MANUAL</b>	<b>REF</b>	<b>DSA.AOC.MAN.002</b>
<b>PERFORMANCE BASED NAVIGATION OPERATIONAL APPROVAL HANBOOK</b>	<b>ED</b>	<b>01 DU 01/11/2014</b>
	<b>REV</b>	<b>00 DU 01/11/2014</b>

standard for definition of path and terminator is ARINC 424. A flight path is described in coded ARINC 424 language which is interpreted by the RNAV system to provide the desired navigation function and inputs to flight guidance systems.

The path between any two waypoints can be specified, depending upon the coding. Each segment is also defined by a terminator or end statement, which provides information to the navigation system on the intended method of connection of one segment (path) with the next.

For example two waypoints could be connected by a great circle track between two waypoints (TF) or perhaps by the arc of a circle of defined radius (RF). Other options include a path defined from the current position to a waypoint (DF), or a path defining a holding pattern (HF). In general usage path and terminator is commonly abbreviated to path terminator or sometimes leg type. A complex series of ARINC 424 rules govern the definition of leg types and their interaction with each other.

One example a common sequence of leg types is TF to TF. Effectively this is a series of "straight lines" as in the diagram below. In the normal case, the aircraft avionics interprets the ARINC 424 coding to require that the two legs are joined by a curved flight path, and the aircraft will "fly by" the intermediate waypoint.

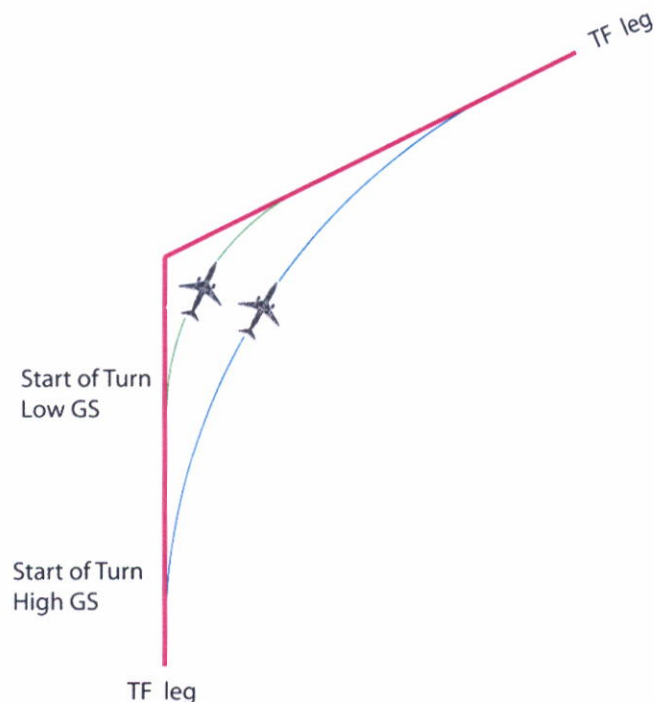


Figure 2.1: TF to TF Transition





<b>CAMEROON CIVIL AVIATION AUTHORITY – DIRECTION OF AVIATION SAFETY</b>		
<b>MANUAL</b>	<b>REF</b>	<b>DSA.AOC.MAN.002</b>
<b>PERFORMANCE BASED NAVIGATION OPERATIONAL APPROVAL HANBOOK</b>	<b>ED</b>	<b>01 DU 01/11/2014</b>
	<b>REV</b>	<b>00 DU 01/11/2014</b>

The aircraft navigation system is programmed to provide a start of turn prompt (turn anticipation) based the current groundspeed and a programmed bank angle, which will normally provide a turn of sufficient radius to allow the subsequent segment to be intercepted. As each aircraft will compute a different start of turn point the result is a spread of turns, between the tracks of faster aircraft using lower bank angles, to slow aircraft with larger bank angles.

Turn anticipation does not provide track guidance during the turn, and until the aircraft is established on the subsequent leg, cross-track error cannot be monitored. The effectiveness of the turn anticipation algorithm is limited by variation in groundspeed during the turn (e.g. headwind to tailwind) and the achieved bank angle. Undershooting or overshooting of the turn can occur and crew intervention may be required.

Using a range of leg types available with ARINC 424 coding, (approx 18) complex flight paths can be designed. However it must be noted that not all navigation systems are capable of accommodating all leg types. Two common examples of leg types that may not be supported are RF and CA legs.

An RF or Radius to Fix leg defines a circle of specified radius enabling an aircraft to fly a precise curved flight path relative to the surface of the earth, rather than an undefined path as in the previous example of a TF/TF.

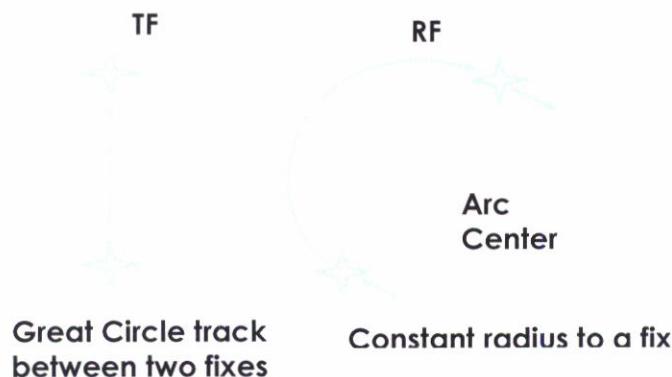


Figure 2.2: Common Path Terminators

A CA or Course to Altitude leg defines a nominated course until a specified altitude is reached. On reaching the altitude the path is "terminated" and the avionics will follow the path defined by the next leg or path and terminator. The CA leg which is commonly used to specify the initial leg of a departure is not normally supported by general aviation GPS receivers, which are not usually integrated with the aircraft's vertical navigation system. Consequently the flight







<b>CAMEROON CIVIL AVIATION AUTHORITY – DIRECTION OF AVIATION SAFETY</b>		
<b>MANUAL</b>	<b>REF</b>	<b>DSA.AOC.MAN.002</b>
<b>PERFORMANCE BASED NAVIGATION OPERATIONAL APPROVAL HANBOOK</b>	<b>ED</b>	<b>01 DU 01/11/2014</b>
	<b>REV</b>	<b>00 DU 01/11/2014</b>

planned departure route may not be followed and pilot intervention (manual selection of next leg) is required.

In the example in Figure 2.3 two aircraft are cleared on a departure with the same instruction. Depending on the climb performance, the position at which the aircraft reaches 3000ft and the CA leg is terminated will vary. If the aircraft is equipped with an integrated vertical navigation system the termination will be automatic and the active route will sequence to the next leg which may be (for example) a Direct to Fix (DF) leg.

If vertical navigation capability is not available, the termination must be initiated by the flight crew. For manually sequenced navigation systems the track to the next fix will depend on the point at which the direct to function is selected. In the example, the pilot has selected Direct To immediately on reaching 3000ft and the track is generated from that position. If Direct To is selected after the turn a different track will be displayed. In this and similar examples, the actual flight path is variable and may not meet operational requirements. A different sequence of Path Terminators may be needed to better define the flight path but may result in the inability to place a minimum altitude requirement on the turn initiation.

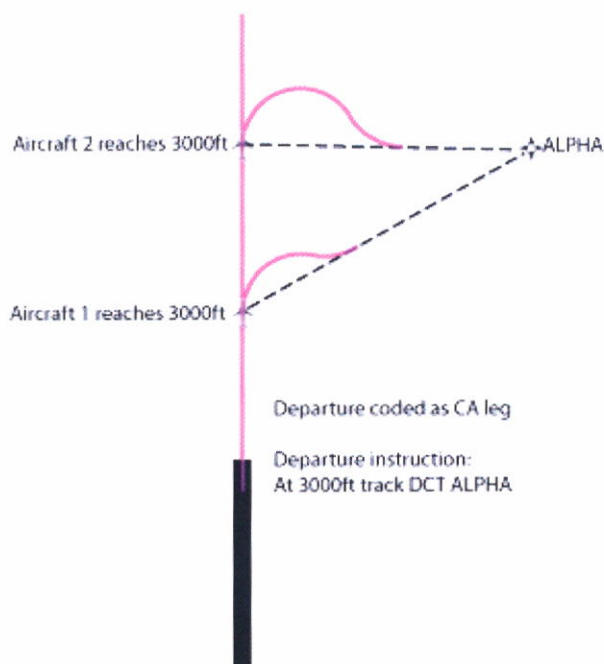


Figure 2.3: CA Path Terminator Example

It is necessary that operational approval inspectors gain a working knowledge of common path terminators, the basics of flight path design, and the functionality of



<b>CAMEROON CIVIL AVIATION AUTHORITY – DIRECTION OF AVIATION SAFETY</b>		
<b>MANUAL</b>	<b>REF</b>	<b>DSA.AOC.MAN.002</b>
<b>PERFORMANCE BASED NAVIGATION OPERATIONAL APPROVAL HANBOOK</b>	<b>ED</b>	<b>01 DU 01/11/2014</b>
	<b>REV</b>	<b>00 DU 01/11/2014</b>

aircraft avionics and flight control systems in order to properly manage operational approvals. For example, while an operation might meet the requirements of a specific PBN Manual navigation specification, the operational approval may need to ensure that crew procedures are defined in order to fly a certain type of procedure, as in the case of the CA example described above.

## **2.4 Radius to Fix segments**

The use of an RF segment or multiple segments including TF and RF legs provides great flexibility in route design enabling flight paths to be designed to avoid terrain, manage noise footprint, better utilise airspace and provide many other benefits.

RF leg capability is available on most late model FMS equipped aircraft but the lack of general availability can limit its broader use. Currently only the RNP AR APCH navigation specification supports the use of RF legs but it is expected that application will be extended in due course.

Capability for RF legs, while extremely useful, is not without limitation, and it is important that the FMS functionality, aircraft flight control logic, and the application of RF legs to flight procedure design are properly understood.

A segment coded as an RF leg creates a circular flight path over the surface of the earth, defined by a start and end point, a turn radius and an origin. ARINC 424 coded segments before and after the RF legs must join at a tangent to the circle defined by the RF leg. Consequently the sequence of legs used can be TF/RF or RF/TF and RF/RF. Joining of RF legs to other RF legs is acceptable and turn reversal and change of radius may occur. This capability allows great flexibility in design.

While complex flight paths can now be designed and displayed as the active route, the aircraft must have the capability to accurately follow the defined flight path. Pilots are familiar with flying turns at a constant airspeed and angle of bank which enables a circular flight path to be flown *with reference to the air mass* and are trained to manually compensate for the presence of wind if necessary. Pilots now need to understand that the FMS will fly an exact circular flight path *over the ground* and the angle of bank will be adjusted by the flight control system to maintain that circular flight path.

The physics of flight are such that the radius of a circle (over the ground) is limited by groundspeed and angle of bank. The minimum radius that can be flown is therefore limited by the maximum available bank angle, and the groundspeed.

Bank angle limits are determined by the aircraft manufacturer, and are also limited by crew selection, aircraft configuration and phase of flight. In normal approach/departure configuration a typical bank angle capability for modern jet transport aircraft is 30° but may be as low as 20°. The bank angle limit can be 8° or less at low altitude, and similarly bank angle limits are also applied at high altitude. The RNP AR APCH navigation specification requires aircraft to be capable of 25° angle of bank in normal circumstances and 8° below 400ft. The procedure





<b>CAMEROON CIVIL AVIATION AUTHORITY – DIRECTION OF AVIATION SAFETY</b>		
<b>MANUAL</b>	<b>REF</b>	<b>DSA.AOC.MAN.002</b>
<b>PERFORMANCE BASED NAVIGATION OPERATIONAL APPROVAL HANBOOK</b>	<b>ED</b>	<b>01 DU 01/11/2014</b>
	<b>REV</b>	<b>00 DU 01/11/2014</b>

designer uses these limits in the design of RF turns, and pilots need to be aware of the aircraft capability in all flight phases. Inspectors should familiarise themselves with aircraft capability documentation during the operational approval process, for aircraft that will utilise RF leg capability.

Groundspeed is a function of TAS, and consequently IAS, plus or minus the ambient tailwind or headwind component. In order to ensure that the flight path during an RF turn can be maintained under all normal weather conditions the procedure designer allows for a maximum tailwind component or “rare-normal” wind. The maximum tailwind component is selected from a wind model which is intended to represent the maximum winds likely to be encountered at various altitudes, generally increasing with altitude. A tailwind component of up to 100KT may be applied in some cases.

As groundspeed is also affected by TAS, the flight crew needs to manage the IAS within acceptable limits to ensure that the bank angle limits, and hence the ability to maintain the flight path, are not exceeded in circumstances where high winds exist. In normal routine operations, where ambient winds are generally light, quite low bank angles are sufficient to maintain RF turns of average radius. However, if the IAS is allowed to exceed normal limits, the limiting bank angle may be reached at less than the maximum design tailwind component, leading to a potential loss of track adherence.

Generally applicable maximum indicated airspeeds are specified in the RNP AR APCH navigation specification, however the designer may impose specific limiting speeds in some cases.

Flight crews needs to be thoroughly conversant with the principles and practice of RF turns, limiting airspeeds, bank angle/aircraft configuration, the effect of high winds, and contingency procedures for manual intervention which although rare, may be required.

## **2.5 Area Navigation Systems**

Although there are many different types of area navigation systems the most common systems are:

*Legacy systems.* Self contained DME/DME and VOR/DME navigation systems.

*Stand-alone GNSS systems* comprising a receiver and a pilot interface which may be combined with the receiver unit, or installed as a separate control and display unit.

(Note: A control and display unit (CDU) should not be confused with a Flight Management System as the interface unit (CDU) is similar.)



CAMEROON CIVIL AVIATION AUTHORITY – DIRECTION OF AVIATION SAFETY		
MANUAL	REF	DSA.AOC.MAN.002
PERFORMANCE BASED NAVIGATION OPERATIONAL APPROVAL HANBOOK	ED	01 DU 01/11/2014
	REV	00 DU 01/11/2014



Figure 2.4: Typical Stand-alone GNSS Receiver

This type of GNSS installation should provide steering commands to HSI or CDI displays in the pilot's primary field of view. Many GNSS units provide an integrated navigation display and/or map display as part of the receiver unit, however in many cases the size, resolution and location of the display may not be suitable nor in the pilot's primary field of view.

*Flight Management Systems.* There are many types of flight management systems with varying complexity and some attention is required to determine the capability of each particular installation. In modern transport operations the FMS usually incorporates two Flight Management Computers which are provided with position updating from a number of sensors. These sensors will normally be inertial, radio and GNSS (as installed). The inertial information is normally provided by two or more Inertial Reference Systems (IRS) with radio and GNSS information provided by two or more Multi Mode Receivers (MMR). Prior to the FMC accepting a sensors positional update, a gross error check is performed to ensure that the sensor position falls within the ANP or EPE value.

The computed aircraft position is commonly a composite position based on the IRS position corrected by inputs from the navigation information received from the MMR. Recently manufactured aircraft will usually be equipped with GNSS and the computed position in this case will normally be based on IRS updated by GNSS, excluding less accurate inputs from ground-based navigation aids.





**CAMEROON CIVIL AVIATION AUTHORITY – DIRECTION OF AVIATION SAFETY**

<b>MANUAL</b>	<b>REF</b>	<b>DSA.AOC.MAN.002</b>
<b>PERFORMANCE BASED NAVIGATION OPERATIONAL APPROVAL HANDBOOK</b>	<b>ED</b>	<b>01 DU 01/11/2014</b>
	<b>REV</b>	<b>00 DU 01/11/2014</b>



Figure 2.5: FMS Equipped Aircraft with Large Screen Multifunction Displays

## 2.6 Data Management

In all but the simplest area navigation systems, navigation data is contained in an airborne database. From a human factors standpoint navigation data should only be extracted from a valid database, although some PBN Manual navigation specifications permit pilot entry of waypoint information. Where pilot entry of coordinates is permitted it should be limited to en-route operations only and above the minimum obstacle clearance altitude. For all other operations pilot entry or modification of waypoint data should be prohibited.

Arrival, approach and departure operations should be extracted from the database by the selection of a named flight procedure. (See Figure 2.6.) User construction of procedures even if waypoints are extracted from an airborne database should be prohibited.

PBN operations are dependent upon valid navigation data. Unlike conventional navigation where the basic navigation guidance is originated from a physical point (e.g. a VOR transmitter) area navigation is totally dependent on electronic data and gross errors can occur due to erroneous data or mismanagement of valid data. In general PBN Manual navigation specifications require or recommend that data is obtained from an approved supplier who has implemented appropriate quality control procedures. Despite a data supplier meeting such quality control standards, there still remains a risk that invalid data may be contained in the airborne database and caution should be exercised. In



<b>CAMEROON CIVIL AVIATION AUTHORITY – DIRECTION OF AVIATION SAFETY</b>		
<b>MANUAL</b>	<b>REF</b>	<b>DSA.AOC.MAN.002</b>
<b>PERFORMANCE BASED NAVIGATION OPERATIONAL APPROVAL HANBOOK</b>	<b>ED</b>	<b>01 DU 01/11/2014</b>
	<b>REV</b>	<b>00 DU 01/11/2014</b>

the case of operations conducted where collision with terrain is a risk, (approach/departure) additional checks at each data update cycle are required. Electronic comparison of data against a controlled source is preferred, but manual or simulator checks may be used where this method is not available. It should also be noted that whilst every precaution may be taken to ensure the validity of the airborne database, that valid data can in some circumstances be incorrectly interpreted and managed by the airborne navigation system. It is extremely difficult to protect against this type of problem, however in evaluating PBN operating procedures, due attention should be made to ensure that crew review procedures are appropriate and sufficient to constitute a last line of defence.





## CAMEROON CIVIL AVIATION AUTHORITY – DIRECTION OF AVIATION SAFETY

MANUAL	REF	DSA.AOC.MAN.002
PERFORMANCE BASED NAVIGATION OPERATIONAL APPROVAL HANDBOOK	ED	01 DU 01/11/2014
	REV	00 DU 01/11/2014

### Chapter 3 NAVIGATION PERFORMANCE

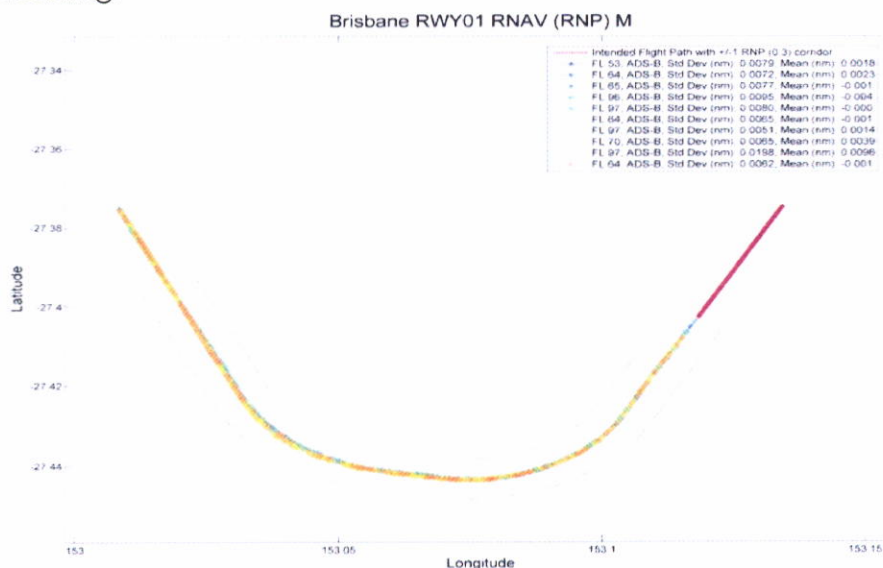
#### 3.1 General

All navigation systems can be described in terms of performance. For example, a ground based navigation aid such as VOR delivers a measurable level of performance which is applied in terms of accepted navigational tolerances.

PBN operations are similarly based on navigation performance, but the concept of performance is fundamentally different. Whereas an operation based on a ground based navigation aid is dependent upon the performance of the radiated signal and the ability of an aircraft to accurately utilise that signal, in Performance Based Navigation the performance itself is specified and the navigation system is required to meet the minimum level of performance. In principle any method of navigation that achieves the specified level of navigation performance is acceptable. However, in practice a particular navigation system is required in some cases in order to meet the requirements of a particular navigation specification. For example RNP 4 requires the mandatory carriage of GNSS as no other current navigation system is available to meet the requirements of the navigation specification. In theory at least, if another means of navigation became available which met the performance requirements for RNP 4 without GNSS, then the requirement for GNSS could be removed from the navigation specification.

#### 3.2 Performance Evaluation

A navigation specification requires performance which is defined by a number representing the accuracy of the navigation system measured in nautical miles. Throughout the PBN manual, accuracy is specified as the probability that the computed position will be within the specified radius of the actual position 95% of the time. While this is the basis for the specification of the accuracy requirement, the achieved accuracy may be many times much better and this can be somewhat misleading.





<b>CAMEROON CIVIL AVIATION AUTHORITY – DIRECTION OF AVIATION SAFETY</b>		
<b>MANUAL</b>	<b>REF</b>	<b>DSA.AOC.MAN.002</b>
<b>PERFORMANCE BASED NAVIGATION OPERATIONAL APPROVAL HANBOOK</b>	<b>ED</b>	<b>01 DU 01/11/2014</b>
	<b>REV</b>	<b>00 DU 01/11/2014</b>

Fig 3.1: In-service tracking data showing TSE in relation to 0.3 NM (1 x RNP) tolerance

Figure 3.1 is an example of in-service data collected for RNP AR APCH operations at Brisbane Australia. The observed standard deviation of TSE is typically of the order of 18m or less, or less than 36m 95% of the time. In this example, where the navigation accuracy for the approach is RNP 0.3 the navigation specification requirement is 95% of 0.3NM or 528m, the observed accuracy is over 15 times better than the minimum.

Navigation systems that utilise GNSS are able to provide very high levels of accuracy with a probability far exceeding 95% of the navigation accuracy. Consequently it can be confusing and even misleading to quote a 95% probability of accuracy for GNSS navigation when the actual positioning can be measured in metres, irrespective of any particular navigation specification performance requirement. In general, when considering performance for GNSS based applications, reference to a 95% probability should be avoided as it suggests a level of accuracy far below that which provides sufficient confidence to flight crews and indeed far less than that observed in actual operations.

Accuracy is only one of a number of considerations when evaluating performance and the overall capability of the navigation system, including cockpit displays, flight control systems and other factors are considered in determining the aircraft's navigation performance capability.

The computation of navigation performance is normally carried out by the aircraft manufacturer, and in many cases the manufacturer will provide a statement in the AFM giving the computed capability. However the basis upon which performance is computed varies between manufacturers and in some cases the methodology differs between aircraft types from the same manufacturer.

In most cases the manufacturer's published navigation performance was computed some years prior to the publication of the PBN Manual and other relevant State RNAV/RNP guidance. Consequently the operational approval must consider the circumstances in which the manufacturer computed the navigation performance, and the role (if any) of the regulatory authority in accepting the manufacturer's claims. In many cases, the regulatory authority has "accepted" the manufacturer's calculations there being no available standard available at the time of initial certification against which the performance statement could be "approved".





<b>CAMEROON CIVIL AVIATION AUTHORITY – DIRECTION OF AVIATION SAFETY</b>		
<b>MANUAL</b>	<b>REF</b>	<b>DSA.AOC.MAN.002</b>
<b>PERFORMANCE BASED NAVIGATION OPERATIONAL APPROVAL HANDBOOK</b>	<b>ED</b>	<b>01 DU 01/11/2014</b>
	<b>REV</b>	<b>00 DU 01/11/2014</b>

Following publication of the PBN manual and similar State PBN documentation some manufacturers have demonstrated aircraft navigation capability against those published requirements and such aircraft can be accepted as meeting the specified performance without further evaluation. It is expected that in due course many manufacturers will demonstrate compliance with PBN Manual requirements, and this will reduce the workload associated with operational approval.

Other aircraft will require evaluation in order to determine that the required level of performance is consistent with the operational approval. The applicant should be asked to provide substantiation of the aircraft navigation performance supported by manufacturer documentation.

### **3.3 Performance Components**

Navigation performance is computed by considering the following components:

*Navigation System Error (NSE).* Sometimes called PEE or Position Estimation Error, this value represents the capability of the navigation avionics to determine position, relative to the aircraft's actual position. NSE is dependent on the accuracy of the inputs to the position solution, such as the accepted accuracy of DME or GNSS measurements.

*Flight Technical Error (FTE).* Also referred to as Path Steering Error, this value represents the ability of the aircraft guidance system to follow the computed flight path. FTE is normally evaluated by the aircraft manufacturer based on flight trials, although in cases where the manufacturer is not able to provide adequate data the operator may need to collect in-service data. FTE values will usually vary for a particular aircraft depending on the flight control method, and for example, a lower FTE may be applicable to operations where the autopilot is coupled compared to the FTE for manual flight using flight director. This variation may in turn lead to different overall performance values depending on the method of control.

*Path Definition Error (PDE).* An area navigation route is defined by segments between waypoints. The definition of the path therefore is dependent on the resolution of the waypoint, and the ability of the navigation system to manage the waypoint data. However, as waypoints can be defined very accurately, and a high level of accuracy is able to be managed by most navigation systems this error is minimal and is generally considered to be zero.

*Total System Error (TSE)* is computed as the statistical sum of the component errors. An accepted method of computing the sum of a number of independent statistical measurements is to compute the square root of the sum of the squares of the component values, or the Root Sum Square (RSS) method.

The computation for accuracy is:



<b>CAMEROON CIVIL AVIATION AUTHORITY – DIRECTION OF AVIATION SAFETY</b>		
<b>MANUAL</b>	<b>REF</b>	<b>DSA.AOC.MAN.002</b>
<b>PERFORMANCE BASED NAVIGATION OPERATIONAL APPROVAL HANDBOOK</b>	<b>ED</b>	<b>01 DU 01/11/2014</b>
	<b>REV</b>	<b>00 DU 01/11/2014</b>

$$TSE = \sqrt{NSE^2 + FTE^2 + PDE^2}$$

As discussed PDE is normally considered to be zero and can be ignored.

No measurement can be absolute and some error or variation will always occur. Therefore errors are normally stated in terms of the probability that the specified accuracy is achieved. For example, the FTE might be described as +/- (X) NM / 95%.

In the general PBN Manual case where accuracy is specified as the 95% value, then the 95% TSE is calculated for the 95% values for NSE and TSE.

The risk that an aircraft capable of a particular navigation performance (95%) will exceed a specified navigation tolerance can then be estimated for any desired probability. It is convenient and reasonably reliable to consider that navigation errors are "normally distributed" and are represented by a Gaussian distribution. A Gaussian or Normal distribution is a representation of the probable errors that may be expected for many common random events. If the probability of a particular event is known, (e.g. 95% TSE) then using a Gaussian distribution the estimated error for another probability can also be calculated.

Standard deviation is a widely used measure of the variability or dispersion. In simple terms, it shows how much variation there is from the "average" (mean). It may be thought of as the average difference of the scores from the mean of distribution, how far they are away from the mean. A low standard deviation indicates that the data points tend to be very close to the mean, whereas high standard deviation indicates that the data are spread out over a large range of values.

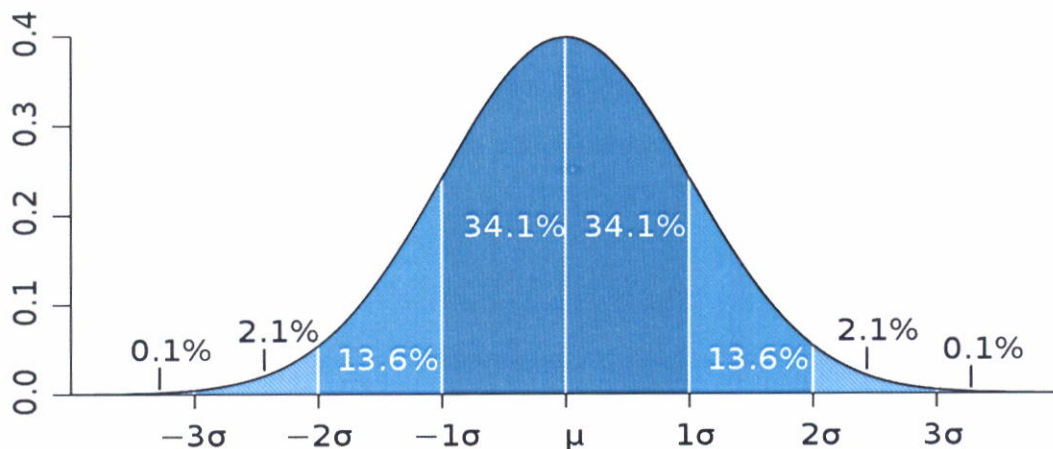


Figure 3.2: A plot of a Gaussian or Normal distribution curve.

In Figure 3.2 each colored band has a width of one standard deviation. The percentage of results within 2 standard deviations of the mean is:





<b>CAMEROON CIVIL AVIATION AUTHORITY – DIRECTION OF AVIATION SAFETY</b>		
<b>MANUAL</b>	<b>REF</b>	<b>DSA.AOC.MAN.002</b>
<b>PERFORMANCE BASED NAVIGATION OPERATIONAL APPROVAL HANDBOOK</b>	<b>ED</b>	<b>01 DU 01/11/2014</b>
	<b>REV</b>	<b>00 DU 01/11/2014</b>

$$2 \times (34.1\% + 13.6\%) = 95.4\%.$$

(A probability of 95% is equivalent to 1.96 standard deviations.)

In the table below probabilities for various standard deviations are shown.

Standard Deviation	Probability	Fraction
1σ	68.2689492%	1 / 3.1514871
1.960σ	95%	1 / 20
2σ	95.4499736%	1 / 21.977894
3σ	99.7300204%	1 / 370.398
4σ	99.993666%	1 / 15,788

For example, if the demonstrated performance (TSE) is 0.3 NM/95% then the probability that the aircraft will be within 0.6 NM of the computed position can be calculated.

For simplicity we will assume that the 95% value is equal to 2 standard deviations rather than the actual value of 1.96. Therefore 0.6 NM is equal to twice the 95% value or 4 standard deviations which is equivalent to 99.993666%. This in turn can be approximated as 99.99% which indicates at only .01% of all computed positions will be greater than 0.6NM. For convenience, .01% can be described as 1 in 10,000 or  $1 \times 10^{-4}$ .

### 3.4 Required Navigation Performance

RNP is a means of specifying the performance for a particular type of operation. In order to meet a particular performance level a number of requirements must be met.

*Accuracy* Position accuracy can be defined as the probability that the computed position will be within a specified distance of the actual position. This performance measure assumes that the reliability of the computation (i.e. the system is operating within its specification without fault), and we have seen in the previous section how this can be computed.

*Integrity* For aviation purposes which are safety critical we must be assured that the navigation system can be trusted. Even though we may be satisfied as to the accuracy of the determination of position, we must also ensure that the computation is based on valid or "trusted" information. Various methods (e.g. RAIM) are used to protect the position solution against the possibility of invalid position measurements.





<b>CAMEROON CIVIL AVIATION AUTHORITY – DIRECTION OF AVIATION SAFETY</b>		
<b>MANUAL</b>	<b>REF</b>	<b>DSA.AOC.MAN.002</b>
<b>PERFORMANCE BASED NAVIGATION OPERATIONAL APPROVAL HANBOOK</b>	<b>ED</b>	<b>01 DU 01/11/2014</b>
	<b>REV</b>	<b>00 DU 01/11/2014</b>

*Availability* means that the system is usable when required. For GNSS operations, unless augmented, availability is high but normally less than 100%. Operational means are commonly needed to manage this limitation.

*Continuity* refers to the probability that a loss of service will occur whilst in use. For RNP operations the navigation system must meet accuracy and integrity requirements but operational procedures may be used to overcome limitations in availability and continuity. In addition to the four performance parameters RNP also requires on-board performance monitoring and alerting.

In practice, RNP capability is determined by the most limiting of the characteristics listed above.

As discussed, in the general case RNP is based on GNSS. The position accuracy for GNSS is excellent and can support operations with low RNP. The lowest current RNP in use is RNP 0.10, although considering position accuracy alone, GNSS would be able to support lower RNP.

However it will be recalled that accuracy is also dependent on FTE and this component is by far the dominant factor. Consequently, the RNP capability of GNSS equipped aircraft is dependent not on navigation system accuracy, but the ability for the aircraft to follow the defined path. FTE is commonly determined by the ability of the aircraft flight control system, and the lowest FTE values are commonly achieved with auto-pilot coupled.

A further consideration is the requirement for on-board performance monitoring and alerting. For GNSS systems, navigation system performance monitoring and alerting is automatic. Except in some specific installations, FTE monitoring and alerting is a crew responsibility, and the ability of the crew to perform this function depends on the quality of information displayed to the crew.

While an aircraft may be capable of a particular RNP capability, it is not always necessary or desirable that the full capability is applied. In addition to the consideration of accuracy and performance monitoring, the operation must always be protected against invalid positioning information, i.e. integrity is required.

In order to support low RNP operations, an appropriate level of integrity protection is necessary. The lower the RNP type, the greater level of integrity protection is required, which in turn reduces the availability and continuity of the service. Consequently a trade-off needs to be made between the RNP selected and availability.

PBN Manual Navigation specifications are based on a level of navigation performance appropriate to the intended purpose, rather than the inherent







<b>CAMEROON CIVIL AVIATION AUTHORITY – DIRECTION OF AVIATION SAFETY</b>		
<b>MANUAL</b>	<b>REF</b>	<b>DSA.AOC.MAN.002</b>
<b>PERFORMANCE BASED NAVIGATION OPERATIONAL APPROVAL HANBOOK</b>	<b>ED</b>	<b>01 DU 01/11/2014</b>
	<b>REV</b>	<b>00 DU 01/11/2014</b>

capability of the navigation system. For example a GNSS equipped aircraft has very high positioning accuracy, and if flown using autopilot exhibits low FTE, however for terminal SID/STAR operations, RNP 1 is adequate for the intended purpose, resulting in virtually 100% availability, and reduced crew workload in FTE performance monitoring.

### 3.5 Performance Limitations

The overall system performance is limited by the most constraining case. For DME/DME systems the most constraining condition is likely to be accuracy, and the positioning is dependent upon measurements which are limited by the accuracy of DME.

Systems which use GNSS as the primary means of position fixing are inherently extremely accurate, and the navigation system accuracy is independent of the navigation application. i.e. the underlying positioning accuracy is the same for RNP 10 as it is for RNP 0.10.

GNSS system performance is normally dependent on FTE and in particular the capability for monitoring and alerting of FTE. In the performance formula  $TSE = \sqrt{NSE^2 + FTE^2 + PDE^2}$  NSE is small, PDE is considered negligible and FTE becomes the dominant contributor.

FTE is normally dependent upon the capability of the flight control system (A/P or FD) to maintain the desired flight path, and commonly varies with phase of flight. In climb, decent and cruise, the sensitivity of flight control systems is normally less than in the approach phase for obvious reasons.

Despite the capability of the flight control system to achieve low FTE values, RNP also requires that the flight crew is able to monitor cross-track error and provide an alert if deviation limits are exceeded (normally achieved by flight crew procedures). In many cases, the cockpit display of cross-track error limits the crew's ability to monitor cross-track error, irrespective of the demonstrated FTE, and this may limit the RNP performance. Some aircraft AFMs contain statements of RNP performance which are valid when the accuracy of the flight control system alone is considered, but it may be difficult to justify the same performance when the display of cross-track deviation is taken into consideration.

GNSS integrity monitoring consistent with the manufacturer's stated RNP performance is normally provided and is seldom a limitation on overall RNP capability. In practice, however, the satellite system may not be capable of supporting the full aircraft RNP capability, and the available RNP capability can be limited by the satellite constellation.







<b>CAMEROON CIVIL AVIATION AUTHORITY – DIRECTION OF AVIATION SAFETY</b>		
<b>MANUAL</b>	<b>REF</b>	<b>DSA.AOC.MAN.002</b>
<b>PERFORMANCE BASED NAVIGATION OPERATIONAL APPROVAL HANDBOOK</b>	<b>ED</b>	<b>01 DU 01/11/2014</b>
	<b>REV</b>	<b>00 DU 01/11/2014</b>

In Europe, for RNP AR APCH, RNP performance also considers the effect of non-normal events, and different RNP performance may be stated depending on the operational circumstances. Typically differing RNP values will be published for all engines operating and one engine inoperative cases. ICAO approach procedure design does not consider non-normal conditions and the all-engines operating RNP is applicable, however the manufacturer's stated limitations should be considered during the FOSA.

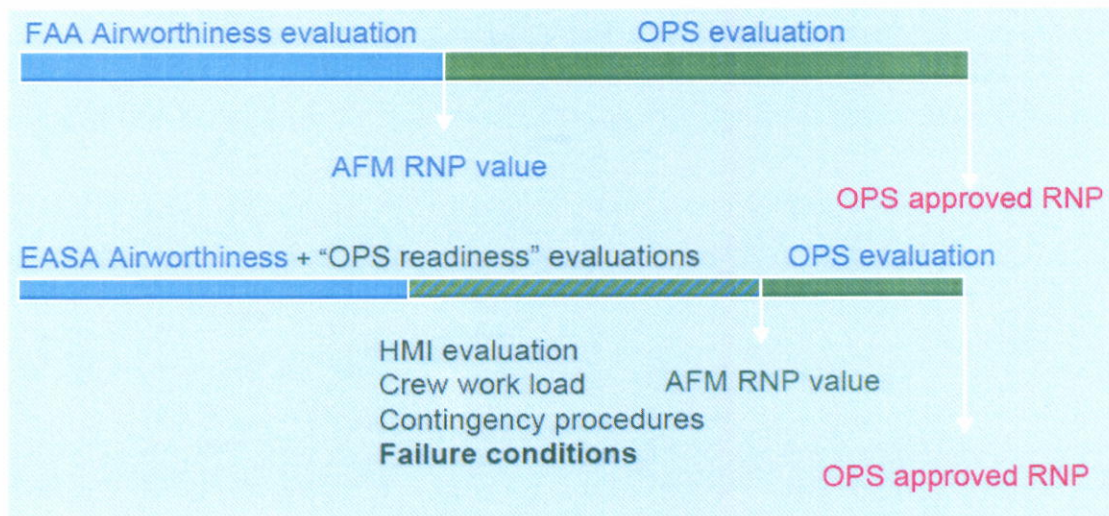


Figure 3.3: Difference between FAA and EASA OPS Approval philosophy

### 3.6 Flight Technical Error Management

FTE is a term that is generally unfamiliar to pilots and operators, although the notion of expected standards of track-keeping is well established. However as pilots we have traditionally associated the management of cross-track tolerances with pilot skill levels and flight crew proficiency. This limited concept is no longer adequate, and for PBN operations is somewhat irrelevant as cross-track error is more commonly managed by the aircraft system rather than the pilot manipulating the controls.

In the PBN context we need to expand the concept of FTE and there are a number of measures that we need to apply.

Demonstrated FTE: As noted previously, the aircraft performance can be determined on the basis of flight trials, depending on the method of control. Pilot skill is less important and more commonly FTE is a measure of autopilot performance.

PBN Manual FTE tolerance: The normal cross-track FTE limit for each navigation specification ( $\frac{1}{2}$  navigating accuracy.)





<b>CAMEROON CIVIL AVIATION AUTHORITY – DIRECTION OF AVIATION SAFETY</b>		
<b>MANUAL</b>	<b>REF</b>	<b>DSA.AOC.MAN.002</b>
<b>PERFORMANCE BASED NAVIGATION OPERATIONAL APPROVAL HANBOOK</b>	<b>ED</b>	<b>01 DU 01/11/2014</b>
	<b>REV</b>	<b>00 DU 01/11/2014</b>

Procedure Design FTE value: The procedure designer uses a value of FTE in the assessment of lateral flight tolerance computation.

Limiting FTE: An operational limitation is placed on the value of FTE acceptable in flight. Beyond this value the procedure must be discontinued.

The general PBN Manual requirement is that accurate adherence to track is expected for all operations. For all normal operations a deviation of up to ½ the navigation accuracy is considered acceptable, however it is assumed that any deviation will be corrected and accurate tracking regained. Brief deviations up to 1 x navigation accuracy during and immediately after turns are allowable but in practice such deviations should be considered poor technique and action taken to limit such excursions.

However for most PBN applications an accuracy of ½ navigation accuracy is not observed in normal operations, and a cross-track error of this order would be considered

Navspec	Nav Accuracy	Design FTE 95%	PBN Max FTE	Lateral Protection (either side of track)
RNAV 5 <sup>1</sup> >30NM ARP	5	2.5	2.5	5.77
RNP 4	4	2	2	8
RNAV 1 (<15NM ARP)	1	0.5	0.5	2
RNP 1 (<15NM ARP)	1	0.5	0.5	2
RNP APCH (MAPt)	0.30	0.25	0.15	0.95
RNP AR APCH (min)	0.10	N/A <sup>1</sup>	0.05 <sup>2</sup>	0.20

<sup>1</sup> FTE for RNP AR APCH must be consistent with the RNP capability. Design is based on 2 x RNP obstacle evaluation area either side of track.

<sup>2</sup> A missed approach must be conducted if the FTE exceeds 1 x RNP.

Some inconsistencies may be noted where values have been adopted prior to the development of the PBN Manual

Figure 3.4: Typical FTE values (NM)

excessive by most pilots and operators.

Although navigation performance is determined by a statistical calculation, in practice a limit is placed on cross-track deviations. This effectively cuts off the "tails" of the probability distribution, and avoids the statistically rare but nevertheless real possibility of large cross-track errors. The selection of a point at





<b>CAMEROON CIVIL AVIATION AUTHORITY – DIRECTION OF AVIATION SAFETY</b>		
<b>MANUAL</b>	<b>REF</b>	<b>DSA.AOC.MAN.002</b>
<b>PERFORMANCE BASED NAVIGATION OPERATIONAL APPROVAL HANDBOOK</b>	<b>ED</b>	<b>01 DU 01/11/2014</b>
	<b>REV</b>	<b>00 DU 01/11/2014</b>

which the FTE is limited, and the flight crew intervenes, (e.g. a go-round), is arbitrary and a matter of judgement rather than mathematics.

For RNP AR APCH mandatory discontinuation of an approach is required if the cross-track tolerance exceeds 1 x RNP.

Note: It can be demonstrated mathematically that for the lowest available RNP (0.10) that RNP performance is maintained for cross-track deviations of up to 1 x RNP. As GNSS accuracy does not decrease with increasing RNP, for values of RNP in excess of RNP 0.10 application of a 1 x RNP FTE limit becomes conservative.

However, for RNP APCH the PBN Manual requirement implies a mandatory go-round at ½ navigation accuracy. The design FTE for RNP APCH (0.25NM on final) is the value used in the development of RNAV (GNSS) design criteria prior to the development of the PBN Manual, and was based on manual piloting tolerances using stand-alone GNSS equipment and a 0.3NM CDI scaling. For FMS equipped aircraft, a go-round requirement of ½ navigation accuracy limit may be impractical in many aircraft. A more general view exists that immediate recovery action should be taken when a deviation exceeds ½ navigation accuracy and a go-round conducted if the deviation exceeds 1 x RNP (0.3).

The validity of the performance capability calculation, or the design of the procedures, is not in question as the normal achieved FTE is likely to be extremely small. The issue is merely what indication of a cross-track error as a trigger for discontinuation is acceptable, and in some cases this may be higher than preferred. The safety of the operation and the confidence in the navigating accuracy is in no way compromised, but the operating procedures may need to recognise the limitations of the display of cross-track information, and reasonable instructions provided to the crew regarding the point at which action should be taken.

Training should emphasise that for all PBN operations accurate adherence to track is required. A misconception exists that for en-route operations, where the navigation accuracy is relatively large (RNP 10, RNP 4, RNAV 5) that unauthorised off-track deviations up to the navigation accuracy are acceptable without ATC approval. Pilots need to understand that aircraft separation standards are based on the statistical FTE probability assuming that the aircraft follows the defined track as closely as possible. Inspectors should take care to ensure that training programs provide proper guidance on the management of FTE.

### **3.7 Lateral Deviation Monitoring**

The monitoring of FTE requires that suitable information is displayed to the flight crew indicating any deviation from the lateral or (for VNAV) vertical path. The PBN Manual includes some guidance on the use of a "lateral deviation indicator" or other means such as flight director or autopilot to manage FTE but in practice





<b>CAMEROON CIVIL AVIATION AUTHORITY – DIRECTION OF AVIATION SAFETY</b>		
<b>MANUAL</b>	<b>REF</b>	<b>DSA.AOC.MAN.002</b>
<b>PERFORMANCE BASED NAVIGATION OPERATIONAL APPROVAL HANBOOK</b>	<b>ED</b>	<b>01 DU 01/11/2014</b>
	<b>REV</b>	<b>00 DU 01/11/2014</b>

some judgement on the part of inspectors is required in order to assess that the information displayed to the flight crew is adequate for a particular application.

No difficulty should be experienced with aircraft equipped with stand-alone GNSS receivers which should be installed to provide a display of cross-track information on a CDI or HSI. Normal TSO C129a and TSO C146a functionality provides automatic full-scale deflection scaling appropriate to the phase of flight, and provided the flight crew is properly trained in the operation of the receiver, suitable indications of cross-track deviations will be available.

Unfortunately FMS equipped aircraft are generally not equipped with a course deviation indicator when operated in an RNAV mode and this type of installation will require evaluation during the approval process.

Although it is not possible to generalize, and there is some variation between manufacturers, in this type of aircraft the Navigation Display (ND) is commonly used to indicate the aircraft position relative to the flight planned path. As it is common practice to operate with autopilot engaged, track adherence is generally good and manufacturers have historically not taken the view that the indication of cross-track error either by the use of a CDI-type graphical indicator, or a numerical indication on the ND is of importance.

With the development of RNAV approach operations, where accurate track adherence is of significance, the suitability of displays has become a topic of interest.

Typical sources of cross-track information in production aircraft include:

Navigation (MAP) Display – Graphical indications. Graphical indication of track deviation relative to the flight planned track. Depending on the selected map scale, the size of the aircraft symbol can be used to estimate the cross-track deviation. This type of indication is sufficient to allow reasonable estimation, depending on the map scale selected and the aircraft symbol, of deviations as small as 0.1NM. For operations where the cross-track tolerance is relatively large, (RNAV 10, RNAV 5, RNP 4, and RNAV 1 or RNP 1) this may be considered adequate. This type of indication, although limited, is available in the pilot's forward field of view and in this regard contributes to satisfying some of the basic requirements for track monitoring.

Navigation (MAP) Display - Numeric indications. In addition to a graphical display of position relative to flight planned track, many manufacturers also provide a digital indication of cross-track deviation on the ND. Commonly this is limited to one decimal place e.g. 0.1, 0.2, 0.3 NM. Some aircraft apply a rounding to the display of digital cross-track deviation. For example, in at least one case, the display of deviation is not indicated until the deviation reaches 0.15NM, and then





<b>CAMEROON CIVIL AVIATION AUTHORITY – DIRECTION OF AVIATION SAFETY</b>		
<b>MANUAL</b>	<b>REF</b>	<b>DSA.AOC.MAN.002</b>
<b>PERFORMANCE BASED NAVIGATION OPERATIONAL APPROVAL HANDBOOK</b>	<b>ED</b>	<b>01 DU 01/11/2014</b>
	<b>REV</b>	<b>00 DU 01/11/2014</b>

a rounded value of 0.2NM is displayed. In this case the initial digital indication to the crew is 0.2NM which is displayed when the actual deviation is 0.15NM. Similarly, as the XTK deviation reduces the last digital indication shown is 0.10NM which occurs when the actual deviation is 0.15NM. Increasingly manufacturers are offering as either standard or as a customer option, digital indications to 2 decimal places e.g. .01, .02, .03 NM. Two digital place cross-track deviation indication is becoming the industry standard and operators should be encouraged to select this option if available. Unfortunately on older aircraft this is often not available due to software or display limitations.

**Control and Display Unit Numeric Display** Many systems display a numeric indication of cross-track and/or vertical deviation on the CDU (MCDU). In cases where the ND does not provide a numeric display, an initial graphical indication of deviation may be supplemented by a cross-reference to the appropriate CDU page to obtain a numeric indication. Numeric indications may be one or two decimal places. The disadvantage of this indication is that it is not in the primary field of view. When CDU indications are taken into account in the evaluation of the adequacy of cockpit track monitoring, the crew procedures need also to be evaluated. A procedure needs to be in place such that at least one member of the crew (normally the PNF/PM) has the appropriate CDU page displayed during the operation and there is a system of cross-checking and crew callouts in place.

**Primary Flight Display (PFD) CDI displays** A number of manufacturers are now offering either as standard or as a customer option, the display of cross-track deviation on the PFD in a manner similar to the display used for ILS. A different symbol is used to identify that the information is RNAV rather than LOC. Implementations vary from relatively simple fixed scale displays to more sophisticated displays which provide an estimate of "available" cross-track tolerance based on the current estimate of navigation performance.

### **3.8 Vertical Deviation Monitoring**

Many VNAV indicators have been installed to provide relatively coarse indications of vertical path adherence, intended to provide adequate monitoring for en-route climb/descent and cruise operations. Commonly this type of display was not intended for use on approach operations where a resolution of as low as 10ft is expected. The size of the display may be quite small and the full scale indication can be as much as +/-400ft. More commonly a vertical deviation indicator, similar to an ILS glide slope indicator is provided on the PFD. Numeric indications of vertical deviation may also be available on the CDU.

### **3.9 Evaluation of Deviation Displays**

While each case must be evaluated some broad guidelines can be applied.







<b>CAMEROON CIVIL AVIATION AUTHORITY – DIRECTION OF AVIATION SAFETY</b>		
<b>MANUAL</b>	<b>REF</b>	<b>DSA.AOC.MAN.002</b>
<b>PERFORMANCE BASED NAVIGATION OPERATIONAL APPROVAL HANBOOK</b>	<b>ED</b>	<b>01 DU 01/11/2014</b>
	<b>REV</b>	<b>00 DU 01/11/2014</b>

Consideration must be given to the means of flight control. Where AP or FD is the means of flight control, lateral and vertical deviations can be expected to be small, and displays sufficient only for adequate monitoring of performance are necessary.

1. The display of information is be related to the required navigation tolerance. For en-route and terminal operations, a lesser standard, such as a graphical or basic numeric XTK indication is normally adequate.
2. For RNP APCH operations, the final approach tolerance is stated to be ½ the navigation tolerance i.e. 0.15NM. Consequently indication of small XTK deviation is necessary. The use of a graphical (MAP) display and a digital XTK indication either on the ND or CDU is generally adequate, provided the flight control method (AP or FD) and crew monitoring procedures are appropriate.
3. For VNAV approach operations a PFD indicator is normally the minimum requirement, although an alternative means might be assessed as adequate provided the crew can readily identify vertical track deviations sufficient to limit the flight path within the required tolerances (- 50ft or 75ft and +100ft)
4. For RNP AR APCH operations not less than RNP 0.3, the same tracking accuracy as for RNP APCH applies and a similar standard of display is generally adequate. A CDI indication on the PFD while preferred is not essential, as is the display of 2 digit numerical XTK deviation on the ND. Flight control using AP or FD is normally used and adequate procedures should be in place for the crew to manage cross-track error.
5. For RNP AR APCH operations less than RNP 0.3 the generally accepted standard is a graphical display of XTK on the PFD and a numeric display to two decimal places on the ND.

In assessing the displays and procedures for monitoring of XTE consideration should also be given functions such as flight path prediction, vertical situation displays, HUGS etc., It should also be noted that the manufacturer's statement of RNP capability is dependent on the method of flight control, which determines the statistical value of FTE used in the demonstration of RNP capability. Some manufacturers and/or regulatory authorities require a minimum standard of cockpit displays for RNP AR APCH operations.

