Chapter 4 RNAV 1 and 2

4.1 General

RNAV 1 and 2 navigation specifications constitute harmonization between European Precision RNAV (P-RNAV) and United States RNAV (US-RNAV) criteria.

The RNAV 1 and RNAV 2 navigation specification applies to:

- all ATS routes, including those established in the en-route domain;
- standard instrument departures and arrivals (SID/STAR); and
- instrument approach procedures up to the final approach fix (FAF)/final approach point (FAP).

As RNAV 1 and 2 operations can be based on DME/DME or DME/DME IRU, the navaid infrastructure must be assessed to ensure adequate DME coverage. This is the responsibility of the ANSP and is not part of the operational approval.

There is no difference in the operational approval for RNAV 1 and RNAV 2, and a single RNAV 1 and 2 approval only is issued. An operator with an RNAV 1 and 2 approval is qualified to operate on both RNAV 1 and RNAV 2 routes. RNAV 2 routes may be promulgated in cases where the navaid infrastructure is unable to meet the accuracy requirements for RNAV 1.

4.2 Operational Approval

For operators holding either a P-RNAV approval or a US-RNAV approval or both the operational approval is relatively simple and minimal regulatory effort is required.

However, as there are some small differences between the existing European and US specifications, migration to RNAV 1 and 2 approval is not automatic unless the operator holds both US and European approvals.

Operators holding *both* P-RNAV and US-RNAV approvals qualify for an ICAO RNAV 1 and 2 operational approval without further examination.

For operators holding only a P-RNAV approval, or a US-RNAV approval, it is necessary to ensure that any additional requirements for RNAV 1 and 2 are met. The PBN Manual provides tables identifying these additional requirements. (Part B, Chapter 3 para 3.3.2.7)

Operators not holding a B-RNAV or US-RNAV approval need to be evaluated to determine that they meet the requirements for RNAV 1and 2.

It should be noted that there is no obligation on an operator to obtain an RNAV 1 and 2 approval or to migrate an exiting approval to ICAO RNAV 1 and 2 if their existing approval is applicable to the area of operation. Operators that operate only in P-RNAV airspace or only in US-RNAV airspace can continue to do so in accordance with a P-RNAV or US-RNAV approval respectively.

4.3 Summary

For RNAV 1 and 2 operational approval:

- A single RNAV system only is required.
- The RNAV system may be based on:
    - DME/DME
    - DME/DME/IRU
    - GNSS (including GNSS/IRU)
- A navigation database is required.
- Navigation displays in the pilot's forward view must be sufficient to permit track following and manoeuvring.
- The maximum cross-track error deviation permitted is ½ navigation accuracy
    - 0.5NM for RNAV 1
    - 1.0 NM for RNAV 2
- An RNAV system failure indication is required.

4.4 GNSS

GNSS approved in accordance with ETSO C129(A), FAA TSO C129 (A) or later meets the requirements of RNAV 1 and 2.

Stand-alone receivers manufactured to ETSO C129 or FAA TSO C129 are also applicable provided they include pseudo-range step detection and health word checking functions.

GNSS based operations require prediction that a service (with integrity) will be available for the route. Most GNSS availability prediction programs are computed for a specific location (normally the destination airport) and are unable to provide predictions over a route or large area. However for RNAV 1 and 2 the probability of a loss of GNSS integrity is remote and the prediction requirement can normally be met by determining that sufficient satellites are available to provide adequate continuity of service.

The PBN Manual makes reference to the possibility of position errors cased by the integration of GNSS data and other positioning data and the potential need for deselection of other navigation sensors. This method of updating is commonly associated with IRS/GNSS systems and the weighting given to radio updating is such that it is unlikely that any potential reduction in positioning accuracy will be significant in proportion to RNAV 1 and 2 navigation accuracy.

4.5 Functionality

The PBN Manual lists the functional requirements for RNAV 1 and 2.

For the majority of air transport aircraft equipped with FMS, the required functionalities, with the exception of the provision of a non-numeric lateral deviation display are normally available. For this category of aircraft lateral deviation is displayed on a map display, usually with a numeric indication of cross-track error in 1/10th NM. In some cases a numeric indication of cross-track error may be provided outside the primary field of view (e.g. CDU). Acceptable lateral tracking accuracy for both RNAV 1 and RNAV 2 routes is adequate provided the autopilot is engaged or flight director is used.

Aircraft equipped with stand-alone GNSS navigation systems, should be installed to provide track guidance via a CDI or HSI. A lateral deviation display is often incorporated in the unit, but is commonly not of sufficient size nor suitable position to allow either pilot to manoeuvre and adequately monitor cross-track deviation.

Caution should be exercised in regard to the limitations of stand-alone GNSS systems with respect to ARINC 424 path terminators. Path terminators involving an altitude termination are not normally supported due to a lack of integration of the lateral navigation system and the altimetry system. For example, a departure procedure commonly specifies a course after takeoff until reaching an specified altitude (CA path terminator). Using a basic GNSS navigation system it is necessary for the flight crew to manually terminate the leg on reaching the specified altitude and then navigate to the next waypoint, ensuring that the flight path is consistent wit the departure procedure. This type of limitation does not preclude operational approval (as stated in the PBN Manual functional requirements) provided the operator's procedures and crew training are adequate to ensure that the intended flight path and other requirements can be met for all SIDs and STAR procedures.

4.6 Operating procedures

Operators with en-route RNAV experience will generally meet the basic requirements of RNAV 1 and 2 and the operational approval should focus on procedures associated with SIDs and STARs.

Particular attention should be placed on selection of the correct procedure from the database, review of the procedures, connection with the en-route phase of flight and the management of discontinuities. Similarly an evaluation should be made of procedures manage selection of a new procedures, including change of runway, and any crew amendments such as insertion or deletion of waypoints.

As RNAV 1 and 2 operations are typically conducted in areas of adequate navaid coverage, contingency procedures will normally involve reversion to conventional ground-based radio navigation.

4.7 Pilot Knowledge and Training

During the operational approval, particular attention should be placed on the application of the pilot knowledge and training to the conduct of RNAV 1 and 2 SIDs and STARs. Most crews will already have some experience RNAV operations, and many of the knowledge and training items will have previously been covered in past training.

Execution of SIDs and STARs, connection with the enroute structure and transition to approach procedures require a thorough understanding of the airborne equipment, and its functionality and management.

Particular attention should be placed on:

- The ability of the airborne equipment to fly the designed flight path. This may involve pilot intervention where the equipment functionality is limited
- Management of changes (procedure, runway, track)
- Turn management (turn indications, airspeed & bank angle, lack of guidance in turns)
- Route modification (insertion/deletion of waypoints, direct to waypoint)
- Intercepting route, radar vectors

Where GNSS is used, flight crews must be trained in GNSS principles related to en-route navigation.

Flight training for RNAV 1 and 2 is not normally required, and the required level of competence can normally be achieved by classroom briefing, computer based training , desktop simular training, or a combination of these methods. Computer based simulator programs are available from a number of GPS manufacturers which provide a convenient method for familiarity with programming and operation of stand-alone GNSS systems.

Although not specifically mentioned in the PBN Manual RNAV 1 and 2 navigation specification, where VNAV is used for SIDs and STARs attention should be given to the management of VNAV and specifically the potential for altitude constraints to be compromised in cases where the lateral flight path is changed or intercepted.

Chapter 5 RNP 4

5.1 General

RNP 4 is a navigation specification applicable to oceanic and remote airspace, and supports 30NM lateral and 30NM longitudinal separation.

5.2 Operational Approval

Operators holding an existing RNP 4 operational approval do not need to be re-examined as the PBN Manual requirements are essentially unchanged.

5.3 ATS communications and surveillance

The PBN Manual does not address communication or air traffic services (ATS) surveillance requirements that may be specified for operation on a particular route or area. These requirements are specified in other documents, such as the aeronautical information publications (AIP) and ICAO Regional Supplementary Procedures (Doc 7030). An operational approval conducted in accordance with the requirements of the PBN Manual assumes that operators and flight crews take into account all the communication and surveillance requirements related to RNP 4 routes.

5.4 Summary

For RNP 4 operational approval:

- Two long range navigation systems are required
- At least one GNSS receiver is required
- A navigation database is required.
- Navigation displays in the pilot's forward view must be sufficient to permit track following and manoeuvring
- The maximum cross-track error deviation permitted is 2NM

5.5 GNSS

GNSS is fundamental to the RNP 4 navigation specification, and carriage avoids any need to impose a time limit on operations. The consequences of a loss of GNSS navigation need to be considered and there are a number of requirements in the navigation specification to address this situation.

Irrespective of the number of GNSS receivers carried, as there is a remote probability that a fault may be detected en-route, a fault detection and exclusion (FDE) function needs be installed. This function is not standard on TSO C129a receivers and for oceanic operations a modification is required.

With FDE fitted, integrity monitoring is available provided there are sufficient satellites of a suitable configuration in view. Some reduction in availability of a positioning service with integrity results, as additional satellites are required, although for RNP 4 as the alerting requirements are large, it is highly improbable that service will not be available.

The RNP 4 navigation specification does not require a dispatch prediction of the availability of integrity monitoring (with FDE) in the case of a multi-sensor system. In this context a system integrating GNSS and IRS is a suitable multi-sensor system. A prediction of GNSS availability is therefore not considered necessary the multi-sensor system will revert to IRS in the remote possibility that GNSS is unavailable.

Other methods of integrity monitoring, discussed under the heading *Aircraft Autonomous Integrity Monitoring (AAIM)* in Part 1, utilise hybrid GNSS/IRS monitoring systems which provide increased availability sufficient to not require a dispatch prediction to be conducted. Examples of these systems are Honeywell HIGH and Litton AIME.

A difficulty is that most availability programs are based on a specific location (normally the destination airport) and are unable to provide predictions over a route or large area. For RNP 4, as the alerting limits are large, provided a minimum number of satellites are available, availability can be assured without the need to carry out a prediction for each flight.

5.6 Functionality

For the majority of air transport aircraft equipped with FMS, the required functionalities, *with the exception of the provision of a non-numeric lateral deviation display* are normally available. For this category lateral deviation is not normally displayed on a CDI or HSI, but is commonly available on a map display, usually with a numeric indication of cross-track error in 1/10th NM. In some cases a numeric indication of cross-track error may be provided outside the primary field of view (e.g. CDU).

Aircraft equipped with stand-alone GNSS navigation systems, should be installed to provide track guidance via a CDI or HSI. The CDI/HSI must be coupled to the RNAV route providing a direct indication of lateral position reference the flight planned track. This type of unit in en-route mode (normal outside 30NM from departure and destination airports) defaults to a CDI/HSI full-scale display of 5NM, which is adequate for RNP 4. A lateral deviation display is often incorporated in the unit, and may be suitable if of sufficient size and position to allow either pilot to manoeuvre and monitor cross-track deviation.

The navigation specification includes some requirements for fly-by transition criteria. The default method for RNAV systems to manage turns at the intersection of "straight" route segments (TF/TF), is to compute, based on groundspeed and assumed angle of bank, a position at which the turn should commence so that the resulting radius will turn inside the angle created by the two consecutive segments and "fly-by" the intermediate waypoint. For aircraft fitted with a stand-alone GNSS system or an FMS fly-by transitions are a standard function and should not require specific evaluation. However a stand-alone GNSS receiver may require a pilot action to initiate the turn. All turns are limited by the physical capability of the aircraft execute a turn of suitable radius. In normal cases where the angle between track is small there is seldom a problem, but operators need to be aware that large angle turns, particularly at high altitude where TAS is high and bank angle is commonly limited can be outside the aircraft capability. While this condition is rare, flight crews need to be aware of the aircraft and avionics limitations.

5.7 Operating Procedures

The standard operating procedures adopted by operators flying on oceanic and remote routes should normally be generally consistent with RNP 4 operations, except that some additional provisions may need to be included to specifically address NP 4 operations.

A review of the operator's procedure documentation against the requirements of the PBN Manual and the [State] regulatory requirements should be sufficient to ensure compliance.

The essential elements to be evaluated are that the operator's procedures ensure that:

- The aircraft is serviceable for RNP 4 ops
- RNP 4 capability is indicated on the flight plan
- En-route loss of capability is identified and reported
- Procedures for alternative navigation are described

GNSS based operations also require the prediction of FDE availability. Most GNSS service prediction programs are based on a prediction at a destination and do not generally provide predictions over a route or large area. However for RNP 4 operations the probability that the constellation cannot support FDE is remote and this requirement can be met by either a general route analysis or a dispatch prediction of satellite availability. For example a specified minimum satellite constellation may be sufficient to support all RNP 4 operations without specific real-time route prediction being required.

5.8 Pilot Knowledge and Training

Unless the operator is inexperienced in the use of RNAV, flight crews should possess the necessary skills to conduct RNAV 4 operations with minimal additional training.

Where GNSS is used, flight crews must be familiar with GNSS principles related to en-route navigation.

Where additional training is required, this can normally be achieved by bulletin, computer based training or classroom briefing. Flight training is not normally required.

Chapter 6 RNP 2 *Reserved*

Chapter 7 Basic RNP 1

7.1 General

Basic RNP 1 is based on GNSS positioning. The navigation specification is intended to support arrival and departure procedures without the dependence on a DME/DME infrastructure.

Other than the requirement for GNSS there is no significant difference between the RNAV 1 and 2 navigation specification and basic RNP 1.

7.2 Operational Approval

Operators of GNSS equipped aircraft holding an RNAV 1 and 2 operational approvals qualify for Basic RNP 1 subject to the following conditions:

- Manual entry of SID/STAR waypoints is not permitted
- Pilots of aircraft with RNP input selection capability (typically equipped FMS aircraft) should select RNP 1 or lower for Basic RNP 1 SIDs and STARs
- If a Basic RNP 1 SID or STAR extends beyond 30NM from the ARP in some cases the CDI scale may need to be set manually to maintain FTE within limits (see below)
- If a MAP display is used, scaling must be suitable for Basic RNP 1 and a FD or AP used.

Operators of GNSS equipped aircraft holding both P-RNAV and US RNAV approvals also meet the requirements for RNAV 1 and 2 and therefore also qualify for Basic RNP 1 subject to the additional conditions listed in the previous paragraph.

Applicants without previous relevant approvals will need to be assessed against the requirements of the Basic RNP 1 navigation specification.

7.3 Summary

- A single RNAV system only is required.
- GNSS is required
- A navigation database is required.
- Navigation displays in the pilot's forward view must be sufficient to permit track following and manoeuvring
- MAP display (without CDI) is acceptable provided FD or AP is used
- The maximum cross-track error deviation permitted is 0.5NM

7.4 Stand-alone GNSS systems

The most basic qualifying system is a stand-alone GNSS receiver (TSO C129(a)) which should coupled to a CDI or HSI display providing course guidance and cross-track deviation indications. This type of system may also be integrated with a map display, however primary guidance is provided by the CDI/HSI. The receiver normally incorporates a self-contained control and display unit but the interface may also be provided by a separate CDU.

In this arrangement Basic RNP 1 capability is provided when in *terminal* mode. In terminal mode:

CDI scaling is automatically set at +/- 1NM full scale deflection

HAL is automatically set to 1 NM (RAIM alert limit)

In the default mode (en-route) CDI scaling increases to +/- 5NM and HAL increases to 2NM. Terminal mode cannot be manually selected but will be system selected provided certain conditions exist.

For departure, provided the current flight plan includes the departure airport (usually the ARP) terminal mode will be active and annunciated. (An annunciator panel should be installed in accordance with the manufacturer's recommendations and State airworthiness regulations). In the general case terminal mode will automatically switch to en-route mode at 30NM from the departure ARP. If the Basic RNP 1 SID extends past 30NM, the CDI scaling will no longer be adequate to support the required FTE limit (+/- 0.5NM), and flight crew action is necessary to manually select +/-1NM CDI scaling.

On arrival, provided the current flight plan route includes the destination airport (ARP) the receiver will automatically switch from en-route to terminal mode at 30NM from the ARP. If the STAR commences at a distance greater than 30NM radius from the destination, then en-route CDI scaling of +/-5NM is inadequate for Basic RNP 1 and must be manually selected to +/-1NM.

Note: Manual selection of +/- 1NM CDI scale (terminal scaling) does not change the mode, and en-route RAIM alert limits apply.

7.5 RNP Systems

Aircraft equipped with a flight management system, normally integrate positioning from a number of sources (radio navaids, GNSS) often using a multi-mode receiver (MMR) with IRS.

In such systems the navigation capability, alerting and other functions are based upon an RNP capability, and the RNP for a particular operation may be a default value, a pilot selected value or a value extracted from the navigation database.

There is normally no automatic mode switching (as in the case of a stand-alone receiver), although the default RNP may vary with the phase of flight.

For this type of operation it is necessary for the flight crew to select either RNP 1 or accept a lesser default value before commencement of a Basic RNP 1 SID or STAR.

7.6 Integrity availability

GNSS based operations require prediction that a service (with integrity) will be available for the route. Most GNSS availability prediction programs are computed for a specific location (normally the destination airport) and are unable to provide predictions over a route or large area. However for Basic RNP 1 the probability of a loss of GNSS integrity is remote and the prediction requirement can normally be met by determining that sufficient satellites are available to provide adequate continuity of service.

7.7 Deselection of radio updating

The PBN Manual makes reference to the possibility of position errors cased by the integration of GNSS data and other positioning data and the potential need for deselection of other navigation sensors. This method of updating is commonly associated with IRS/GNSS systems and the weighting given to radio updating is such that it is unlikely that any potential reduction in positioning accuracy will be significant in proportion to Basic RNP 1 navigation accuracy.

7.8 Functionality

The PBN MANUAL lists the functional requirements for Basic RNP 1 which are identical to RNAV 1 and 2.

For the majority of air transport aircraft equipped with FMS, the required functionalities, with the exception of the provision of a non-numeric lateral deviation display are normally available. For this category of aircraft lateral deviation is displayed on a map display, usually with a numeric indication of cross-track error in 1/10th NM. In some cases a numeric indication of cross-track error may be provided outside the primary field of view (e.g. CDU). Acceptable lateral tracking accuracy for Basic RNP 1 routes is adequate provided the autopilot is engaged or flight director is used.

Aircraft equipped with stand-alone GNSS navigation systems, should be installed to provide track guidance via a CDI or HSI. An lateral deviation display is often incorporated in the unit, and may be suitable if of sufficient size and position to allow either pilot to manoeuvre and monitor cross-track deviation.

Caution should be exercised in regard to the limitations of stand-alone GNSS systems with respect to ARINC 424 path terminators. Path terminators involving an altitude termination are not normally supported due to a lack of integration of the lateral navigation system and the altimetry system. For example, a departure procedure commonly specifies a course after takeoff until reaching an specified altitude (CA path terminator). Using a basic GNSS navigation system it is necessary for the flight crew to manually terminate the leg on reaching the specified altitude and then navigate to the next waypoint, ensuring that the flight path is consistent wit the departure procedure. This type of limitation does not preclude operational approval (as stated in the PBN MANUAL functional requirements) provided the operator's procedures and crew training are adequate to ensure that the intended flight path and other requirements can be met for all SID and STAR procedures.

7.9 Operating procedures

Operators with en-route RNAV experience will generally meet the basic requirements of Basic RNP 1 and the operational approval should focus on procedures associated with SIDs and STARs.

Particular attention should be placed on selection of the correct procedure from the database, review of the procedures, connection with the en-route phase of flight and the management of discontinuities. Similarly an evaluation should be made of procedures manage selection of a new procedures, including change of runway, and any crew amendments such as insertion or deletion of waypoints.

7.10 Pilot Knowledge and Training

During the operational approval, particular attention should be placed on the application of the pilot knowledge and training to the conduct of Basic RNP 1 SIDs and STARs. Most crews will already have some experience RNAV operations, and many of the knowledge and training items will have previously been covered in past training.

Execution of SIDs and STARs, connection with the enroute structure and transition to approach procedures require a thorough understanding of the airborne equipment, and its functionality and management.

Particular attention should be placed on:

- The ability of the airborne equipment to fly the designed flight path. This may involve pilot intervention where the equipment functionality is limited
- Management of changes (procedure, runway, track)
- Turn management (turn indications, airspeed & bank angle, lack of guidance in turns)
- Route modification (insertion/deletion of waypoints, direct to waypoint)

- Intercepting route, radar vectors

Where GNSS is used, flight crews must be trained in GNSS principles related to en-route navigation.

Flight training for Basic RNP 1 is not normally required, and the required level of competence can normally be achieved by classroom briefing, computer based training, desktop simular training, or a combination of these methods. Computer based simulator programs are available from a number of GPS manufacturers which provide a convenient method for familiarity with programming and operation of stand-alone systems.

Although not specifically mentioned in the PBN MANUAL Basic RNP 1 navigation specification, where VNAV is used for SIDs and STARs attention should be given to the management of VNAV and specifically the potential for altitude constraints to be compromised in cases where the lateral flight path is changed or intercepted.

Chapter 8 Advanced RNP *Reserved*