Performance-based Navigation (PBN)

Operations Plan

VERSION 1.1

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1. INTRODUCTION

1.1. Advances in navigation defined performance and functionality have enabled changes in airspace design, separation minima, route spacing, airport access, procedure design and air traffic management. This document is an update to and expansion of the material originally presented and accepted as the 2009 PBN Concept of Operations. Since 2009 many of the concepts for potential changes using Performance-based Navigation (PBN) to improve air traffic management (ATM) operations have become a reality and are in various stages of implementation.

2. BACKGROUND

2.1. In March, 2008, a meeting was hosted by NAV CANADA in Ottawa to bring together some of the major stakeholders that had an interest in implementing PBN in Canada. Stakeholder representation included aviation regulators, service providers and customers. A Strawman was subsequently drawn up and circulated that outlined an initial plan for the incremental adoption of PBN in Canada. An avionics equipment survey was issued to all NAV CANADA customers to establish the Canadian equipage levels and confirm the feasibility of proposed timelines. The initial PBN Con Ops was developed, reviewed and accepted by NAV CANADA's customers at the November 2009 Air Transport Operations Consultation Committee meeting. This document is the PBN Operations Plan following four years of advancement in PBN operations.

2.2. The PBN concept is an ICAO initiative. The first resolution related to PBN originated at the 36th ICAO General Assembly documented in resolution No.23, requiring States to complete PBN implementation plans by 2009. Resolution A36-23 was reviewed and superseded at the 37th ICAO General Assembly by resolution A37-11 Performance-based navigation global goals. This resolution stands as global guidance for air navigation service provides in the area of PBN.

Resolution A37-11 states:

> *Whereas a primary objective of ICAO is that of ensuring the safe and efficient performance of the global Air Navigation System;*
>
> *Whereas the improvement of the performance of the air navigation system on a harmonized, worldwide basis requires the active collaboration of all stakeholders;*
>
> *Whereas the Eleventh Air Navigation Conference recommended that ICAO, as a matter of urgency, address and progress the issues associated with the introduction of area navigation (RNAV) and required navigation performance (RNP);*
>
> *Whereas the Eleventh Air Navigation Conference recommended that ICAO develop RNAV procedures supported by global navigation satellite system (GNSS) for fixed wing aircraft, providing high track and velocity-keeping accuracy to maintain separation through curves and enable flexible approach line-ups;*
>
> *Whereas the Eleventh Air Navigation Conference recommended that ICAO develop RNAV procedures supported by GNSS for both fixed and rotary wing aircraft, enabling lower operating minima in obstacle-rich or otherwise constrained environments;*

Whereas Resolution A33-16 requested the Council to develop a programme to encourage States to implement approach procedures with vertical guidance (APV) utilizing such inputs as GNSS or distance measuring equipment (DME)/DME, in accordance with ICAO provisions;

Recognizing that not all airports have the infrastructure to support APV operations and not all aircraft are currently capable of APV;

Recognizing that many States already have the requisite infrastructure and aircraft capable of performing straight-in approaches with lateral guidance (LNAV approaches) based on the RNP specifications and that straight in approaches provide demonstrated and significant safety enhancements over circling approaches;

Recognizing that the Global Aviation Safety Plan has identified Global Safety Initiatives (GSIs) to concentrate on developing a safety strategy for the future that includes the effective use of technology to enhance safety, consistent adoption of industry best practices, alignment of global industry safety strategies and consistent regulatory oversight;

Recognizing that the Global Air Navigation Plan has identified Global Plan Initiatives (GPIs) to concentrate on the incorporation of advanced aircraft navigation capabilities into the air navigation system infrastructure, the optimization of the terminal control area through improved design and management techniques, the optimization of the terminal control area through implementation of RNP and RNAV SIDs and STARs and the optimization of terminal control area to provide for more fuel efficient aircraft operations through FMS-based arrival procedures; and

Recognizing that the continuing development of diverging navigation specifications would result in safety and efficiency impacts and penalties to States and industry;

Noting with satisfaction that planning and implementation regional groups (PIRGs) have completed regional PBN implementation plans; and

Recognizing that not all States have developed a PBN implementation plan by the target date of 2009:

The Assembly:

1. Urges all States to implement RNAV and RNP air traffic services (ATS) routes and approach procedures in accordance with the ICAO PBN concept laid down in the Performance-based Navigation (PBN) Manual (Doc 9613);

2. Resolves that:

a) States complete a PBN implementation plan as a matter of urgency to achieve:

1) implementation of RNAV and RNP operations (where required) for en route and terminal areas according to established timelines and intermediate milestones;

2) implementation of approach procedures with vertical guidance (APV) (Baro-VNAV and/or augmented GNSS), including LNAV only minima, for all instrument runway ends, either as the primary approach or as a back-up for precision approaches by 2016 with intermediate milestones as follows: 30 per cent by 2010, 70 per cent by 2014; and

3) implementation of straight-in LNAV only procedures, as an exception to 2) above, for instrument runways at aerodromes where there is no local altimeter setting available and where there are no aircraft suitably equipped for APV operations with a maximum certificated take-off mass of 5 700 kg or more;

b) ICAO develop a coordinated action plan to assist States in the implementation of PBN and to ensure development and/or maintenance of globally harmonized SARPs, Procedures for Air Navigation Services (PANS) and guidance material including a global harmonized safety assessment methodology to keep pace with operational demands;

3. Urges that States include in their PBN implementation plan provisions for implementation of approach procedures with vertical guidance (APV) to all runway end serving aircraft with a

maximum certificated take-off mass of 5 700 kg or more, according to established timelines and intermediate milestones;

4. Instructs the Council to provide a progress report on PBN implementation to the next ordinary session of the Assembly, as necessary;

5. Requests the Planning and Implementation Regional Groups (PIRGs) to include in their work programme the review of status of implementation of PBN by States according to the defined implementation plans and report annually to ICAO any deficiencies that may occur; and

6. Declares that this resolution supersedes Resolution A36-23.

2.3. The guidance reference document for PBN is ICAO Document 9613, Fourth Edition - Performance-based Navigation Manual. The Doc 9613 contains navigation specifications (nav specs) and the means of supporting these applications, in terms of required performance, equipment functionality and enabling infrastructure. It provides practical guidance for the development of documents related to; standards, regulations, certification, advisories, guidance and operational approvals. Its use avoids the potential for unnecessary proliferation of differing global RNAV and RNP standards.

2.4. Reference to existing State Advisory Circulars (ACs) and other regulatory enablers are also beneficial as guidance to enable early adoption of PBN capabilities. In particular, the United States of America's Federal Aviation Administration (FAA) and the European Aviation Safety Agency (EASA) have published ACs supporting various RNAV and RNP operations. Where and to the extent applicable, use of these published ACs should be enabled in Canadian operations to expedite the availability of the regulatory infrastructure.

3. TERMINOLOGY

3.1. RNAV and RNP systems are fundamentally similar. The key difference between them is the requirement for on-board performance monitoring and alerting. A nav spec that includes a requirement for onboard navigation performance monitoring and alerting is referred to as an RNP specification. RNAV specifications do not require on-board performance monitoring and alerting. An area navigation system capable of achieving the alerting performance requirement of an RNP specification is referred to as an RNP System.

3.2. The PBN concept specifies that aircraft area navigation system performance requirements be defined in terms of the accuracy, integrity, continuity and functionality, which are needed for the proposed operations in the context of a particular airspace concept; availability is a function of the navigation signal in space. This represents a shift from sensor-based to performance-based navigation. Performance requirements are identified in nav specs, which also identify the choice of navigation sensors and equipment that may be used to meet the performance requirements.

4. PBN IN CANADA - OVERVIEW

4.1. Implementation in Canada is leveraging NAV CANADA's ATM and customer investments in capabilities with progressive advances in service initiatives. To this end, the implementation of PBN uses the most appropriate nav spec, either RNAV or RNP, needed to meet the demands of the airspace.

4.2. All future area navigation applications will identify the navigation requirements through the use of performance specifications rather than defining equipage of specific navigation sensors. However, owing to Canada's geography and population distribution, the Global Navigation Satellite System (GNSS) is an

essential component in the evolution to more efficient airspace management and is expected to become mandatory in some airspace in the short-term (2014-2016). Throughout the world GNSS is currently the only system that meets the RNP nav spec requirements.

4.3. Implementation is following an ongoing series of qualification upgrades to aircraft, crew, and the ATM environment. Operators falling behind on these upgrades may temporarily be accommodated but will not fully realize efficiencies and may face delays and/or future airspace restrictions. As customers upgrade their avionics, greater ATM opportunities will be presented with the potential for future four dimensional, gate-to-gate operations.

4.4. PBN implementation is using existing, as well as newer aircraft and ATM functionality. During transitions not all air navigation system (ANS) customers are initially able to participate and benefit. The policy of "first come, first served" is being reviewed with the objective of allowing for early return on investment in technology by customers, while not being overly punitive to customers unable to equip until later in a transition.

4.5. It is a fact that moving towards more advanced capabilities will often be required to enable system wide benefits and an appropriate level of value extraction. Although NAV CANADA has already implemented many RNAV and RNP applications both in the terminal and en-route environments, and has demonstrated the ability to derive benefits in "mixed-mode" operations, there will be times when operations require a homogeneous traffic capability to meet projected benefit targets. In these circumstances ATM change will be sought to enhance efficiency through restricted access temporally and/or geographically while continuing to ensure safety of flight operations.

4.6. Owing to the fact that some PBN operations are still not fully integrated into common usage, NAV CANADA will continue to incrementally build on successful implementations, evolving service delivery as appropriate.

5. NAVIGATION STRATEGY – HIGH LEVEL GOALS

5.1. NAV CANADA's high level PBN goals reinforce the company's overarching goals regarding; maintaining safety, managing customer service charges, introducing ANS technology, achieving operational efficiencies, and reducing aviation's environmental footprint.

5.2. The PBN high level strategic goals are:

5.2.1. To achieve a total PBN environment with ICAO nav spec designated values (RNAV and/or RNP) for all operations;

5.2.2. To facilitate the implementation of customer preferred trajectories (lateral and vertical) to the maximum extent possible;

5.2.3. To provide a return on investment for customers having equipped with advanced functionality avionics while continuing to support operations of aircraft with less advanced capabilities as long as operationally and financially practical;

5.2.4. To leverage the availability of a space-based navigation infrastructure to enable a rationalization of the ground-based infrastructure for all phases of flight; and

5.2.5. To leverage advances in PBN into other CNS/ATM benefits.

6. PBN NAVIGATION SPECIFICATIONS - OVERVIEW

6.1. ICAO Doc 9613, Fourth Edition contains eleven distinct nav specs and two attachments that can be combined with a nav spec. By defining these nav specs, PBN supports a globally-harmonized transition to area navigation. Certification and/or operational approval for any one nav spec does not automatically grant approval for any other nav spec. Aircraft approved to a more stringent accuracy requirement may not necessarily meet all of the functional requirements of a navigation specification having a less stringent navigation accuracy requirement.

6.2. Although PBN specifications are being adopted world-wide, that does not imply that all nav specs will have a practical application in the Canadian context.

6.3. Unique Canadian airspace designations of Required Navigation Performance Canada (RNPC) and Canadian Minimum Navigation Performance Specification (CMNPS) predated the PBN concept and already contain some of the types of performance parameters found in the ICAO nav specs. RNPC and CMNPS designations do not have a direct ICAO nav spec equivalent.

6.4. In contrast to other States that may need to immediately make use of nav specs to enable area navigation or for smaller aircraft containment areas to alleviate chronic airspace congestion, Canada will transition on a schedule dictated by the benefits that can be extracted in line with the five high level strategic goals. Benefit extraction will be closely tied to our customers' ability to operate under defined nav specs as a result of their equipment and operational approvals.

6.5. Within the nav specs, RNAV and RNP specs share many common elements. Differentiation for certification and operational approval is based on the capability to provide on-board performance monitoring and alerting. A nav spec requiring on-board navigation performance monitoring and alerting is classified as an RNP nav spec. RNAV nav specs do not require this functionality. Area navigation systems that meet the performance requirements of an RNP nav spec are referred to as RNP systems. Very brief nav spec summaries follow.

7. RNAV 10 (HISTORICALLY DESIGNATED AND AUTHORIZED AS RNP 10)

7.1. Aircraft equipped with at least two independent long range navigation systems; any combinations of INS/IRU or GNSS meet the RNAV 10 requirements. During operations in airspace or on routes designated as RNAV 10 (RNP 10), the lateral total system error must be within ±10 NM for at least 95% of the total flight time. The along-track error must also be within ±10 NM for at least 95% of the total flight time. For normal operations, cross-track error/deviation (the difference between the RNAV system computed path and the aircraft position relative to the path) should be limited to plus or minus one half of the navigation accuracy associated with the route (i.e. 5 NM). Brief deviations from this standard (e.g., overshoots or undershoots) during and immediately after route turns, up to a maximum of 1 times the navigation accuracy (i.e. 10 NM), are allowable.

7.2. Operations in oceanic or remote airspace using procedural-based separation and RNAV 10 (RNP 10) are supported in ICAO Doc 4444 – Procedures for Air Navigation Air Traffic Management (PANS ATM) with a 50 NM lateral and 50 NM longitudinal distance-based separation minima.

7.3. RNAV 10 (RNP 10) operational requirements are defined in ICAO Doc 9613, Volume II, Part B, Chapter 1. Canadian RNAV 10 operational requirements are defined in Advisory Circular AC 700-006 and the associated Operations Specification 611.

8. RNAV 5

8.1. RNAV 5 operations are based on the use of RNAV equipment that automatically determines aircraft position in the horizontal plane using inputs from one or a combination of the following types of position sensors, together with the means to establish and follow a desired path:

- VOR/DME
- DME/DME
- INS or IRS
- GNSS

8.2. RNAV 5 is an en-route navigation specification. In addition to en-route navigation, applications could include initial Standard Arrival Routing (STAR) segments or ending Standard Instrument Departure (SID) segments, where these leg segments are beyond 30 NM from an aerodrome.

8.3. Introduction of RNAV 5 in Canadian airspace applications is of low value since current RNPC airspace requirements already require performance that exceeds RNAV 5 when conducting area navigation.

8.4. VOR/DME and DME/DME based RNAV 5 have limited opportunities for application in Canadian airspace owing to the required numbers and geometry of ground based aids to provide a robust infrastructure.

8.5. RNAV 5 operational requirements are defined in ICAO Doc 9613, Volume II, Part B, Chapter 2. Canadian RNAV 5 operational requirements are defined in Advisory Circular AC 700-015 and the associated Operations Specification 613.

9. RNAV 1 AND RNAV 2

9.1. RNAV 1 and RNAV 2 operations are based on the use of the same aircraft receivers as required for RNAV 5. There are other additional aircraft functional and navigation aid infrastructure requirements needed to meet the more demanding RNAV 1 and RNAV 2 performance.

9.2. The RNAV 1 and RNAV 2 nav spec is applicable to all routes, inside or outside of controlled airspace, SIDs, and STARS. It also applies to instrument approach procedure leg segments up to the Final Approach Course Fix (FACF). RNAV 1 and RNAV 2 routes are expected to be conducted in a surveillance environment with direct controller pilot communication (DCPC). In Canada, RNAV 1 has an appropriate application for terminal RNAV use with SIDs and STARs.

9.3. RNAV 1 and 2 operational requirements are defined in ICAO Doc 9613, Volume II, Part B, Chapter 3. Canadian RNAV 1 and 2 operational requirements are defined in Advisory Circular AC 700-019 and the associated Operations Specification 612.

10. RNP 4

10.1. For RNP 4 operations in oceanic or remote airspace, the aircraft must have at least two fully serviceable independent Long Range Navigation Systems (LRNSs) listed in the flight manual; both must be operational at the point of entry into RNP 4 airspace. RNP 4 position integrity bounding can currently only be met

using certified GNSS receivers. The GNSS receivers may be part of a stand-alone navigation system or as one of the sensors in a multi-sensor system. Where GNSS is an input as part of a multi-sensor system, the aircraft's position source must use GNSS positions exclusively during RNP 4 operations.

10.2. RNP 4 is intended for use in oceanic or remote airspace where a robust ground-based navigation infrastructure is not available. It supports procedural-based separation defined in ICAO Doc 4444 –PANS ATM with a 30 NM lateral and 30 NM longitudinal distance-based separation minima. In order to use this 30/30 separation standard RNP 4 must be combined with additional communication capabilities, specifically Automatic Dependent Surveillance – Contract (ADS-C).

10.3. RNP 4 operational requirements are defined in ICAO Doc 9613, Volume II, Part C, Chapter 1. Canadian RNP 4 operational requirements are defined in Advisory Circular AC 700-006 and the associated Operations Specification 614.

11. RNP 1

11.1. RNP 1 position integrity bounding can currently only be met using certified GNSS receivers. The GNSS receivers may be part of a stand-alone navigation system or as one of the sensors in a multi-sensor system. Where GNSS is an input as part of a multi-sensor system, the aircraft's position source must use GNSS positions exclusively during RNP 1 operations.

11.2. During operations in airspace or on routes designated as RNP 1, the lateral total system error must be within ±1 NM for at least 95% of the total flight time. For normal operations, cross-track error/deviation (the difference between the system computed path and the aircraft position relative to the path, i.e. FTE) should be limited to plus or minus one half of the navigation accuracy associated with the procedure (i.e., 0.5 nm for Basic-RNP 1). Brief deviations from this standard (e.g., overshoots or undershoots) during and immediately after turns, up to a maximum of 1 times the navigation accuracy (i.e., 1.0 nm for RNP 1), are allowable.

11.3. For RNP 1 routes, pilots must use a lateral deviation indicator, flight director, or autopilot in lateral navigation mode. Pilots of aircraft with a lateral deviation display must ensure that lateral deviation scaling is suitable for the navigation accuracy associated with the route/procedure (e.g., full-scale deflection: ± 1 nm for RNP 1).

11.4. The RNP 1 nav spec is intended to be applied on SIDs and STARs within 30 NM of the aerodrome reference point (ARP) where there is no or limited surveillance. The STARs provide a means to connect the en route structure to a variety of approach procedures, including; RNP APCH, RNP AR, and ILS.

11.5. Use of the RNP 1 nav spec enables the use of radius-to-fix (RF) leg segments in applications such as the STAR, transition to the approach or approach initial segments. The RF leg type cannot be used in conjunction with RNAV 1 or RNAV 2.

11.6. RNP 1 operational requirements are defined in ICAO Doc 9613, Volume II, Part C, Chapter 3. Canadian RNP 1 operational requirements are defined in Advisory Circular AC 700-025 and the associated Operations Specification 618.

12. RNP 2

12.1. RNP 2 requires the use of certified GNSS receivers. Operators are required to have the means to predict the availability of GNSS fault detection (e.g. ABAS RAIM) to support operations along an RNP 2 route. The on-board RNP system, GNSS avionics, the ANSP or other entities may provide a prediction capability. The AIP will indicate when a prediction capability is required and an acceptable means to satisfy that requirement.

12.2. RNP 2 is intended for en-route applications, primarily in areas where there is sparse or no ground NAVAID infrastructure, limited or no ATS surveillance, and low to medium density traffic. Use of RNP 2 in continental applications requires a lower continuity requirement than used in oceanic/remote applications. In oceanic/remote applications, the target traffic is primarily transport category aircraft operating at high altitude, whereas, continental applications may include a significant percentage of general aviation (GA) aircraft.

12.3. ICAO sanctioned RNP 2 route spacing has not yet been published; however, that does not preclude the use of RNP 2 for designation on an ATS route or within an airspace volume.

12.4. RNP 2 operational requirements are defined in ICAO Doc 9613, Volume II, Part C, Chapter 2, but have not yet been defined in a Canadian Advisory Circular; therefore, there is also no currently available associated Operations Specification.

13. RNP 0.3

13.1. RNP 0.3 requires the use of certified GNSS receivers; its implementation is not dependent on the availability of space-based augmentation systems (SBAS). DME/DME based RNAV systems are not capable of consistently providing RNP 0.3 performance, and RNP 0.3 operations through application of DME/DME-based navigation is not viable. Operators are required to have the means to predict the availability of GNSS fault detection (e.g. ABAS RAIM) to support RNP 0.3 operations. The on-board RNP system, GNSS avionics, the ANSP or other entities may provide a prediction capability. The AIP will indicate when a prediction capability is required and an acceptable means to satisfy that requirement. Owing to the high availability of RNP 0.3 performance available to SBAS receivers, prediction will not be required where the navigation equipment can make use of SBAS augmentation and the planned operation will be contained within the service volume of the SBAS signal.

13.2. RNP 0.3 was developed in response to the helicopter community's desire for narrower IFR obstacle free areas to allow operations in obstacle rich environments and to allow simultaneous non-interfering operations in dense terminal airspace. While this specification has been defined primarily for helicopter applications, it does not exclude the application to fixed wing operations where demonstrated performance is sufficient to meet the functional and accuracy requirements of this specification for all phases of flight.

13.3. RNP 0.3 operational requirements are defined in ICAO Doc 9613, Volume II, Part C, Chapter 7, but have not yet been defined in a Canadian Advisory Circular; therefore, there is also no currently available associated Operations Specification.

14. ADVANCED RNP

14.1. Advanced RNP (A-RNP) is the only nav spec that enables operations under other associated nav specs. The aircraft navigation accuracy and functional requirements of other nav specs that are met when A-RNP is certified are:

- RNAV 5
- RNAV 1
- RNAV 2
- RNP 2
- RNP 1
- RNP APCH

14.2. RF is an additional required functional element in A-RNP. The following list of other additional functional elements are optional:

- RNP Scalability
- Higher continuity
- Fixed Radius Turns (FRT)
- Time of Arrival Control (TOAC)
- Baro-Vnav

14.3. A-RNP has a very broad operational application; for operation in oceanic/remote airspace, on the continental en-route structure as well as on arrival and departure routes and approaches. Operations would rely solely on the integrity of the RNP system without a reversionary capability to conventional means of navigation since a conventional infrastructure may not be available.

14.4. Carriage of a single RNP system is considered generally acceptable; however, where more stringent requirements exist (e.g. dual RNP system to meet a defined continuity performance), these requirements will be defined in the AIP and/or in a regional supplement (ICAO Doc 7030). The implementation of a particular operation would be established through safety cases.

14.5. The advantage in utilizing a designation of A-RNP for a flight operation is the combined performance and functionality of a range of nav specs encompassing all phases of flight. A-RNP operational requirements are defined in ICAO Doc 9613, Volume II, Part C, Chapter 4; however, A-RNP operational requirements in Canada have not yet been defined by Advisory Circular; therefore, there is also no currently available associated Operations Specification.

15. RNP APCH

15.1. The RNP APCH (RNP Approach) nav spec position integrity bounding can currently only be met using certified GNSS receivers. The GNSS receivers may be part of a stand-alone navigation system or as one of the sensors in a multi-sensor system. Where GNSS is an input as part of a multi-sensor system, the aircraft's position source must use GNSS positions exclusively during RNP APCH operations.

15.2. RNP APCH is the ICAO nav spec designation for procedures currently published in Canada as "RNAV (GNSS)" and authorized under Operations Specification 100. They include approach operations with minima designated as "LNAV", "LNAV/VNAV", and "LPV".

15.3. RNP APCH operational requirements are defined in ICAO Doc 9613, Volume II, Part C, Chapter 5. The revised Canadian specific requirements are published in Advisory Circular AC 700-023 and the associated Operations Specification 620.

16. RNP AR APCH

16.1. As with all other RNP nav specs, position integrity bounding for RNP AR (Authorization required) APCH can currently only be met using certified GNSS receivers. There are numerous other aircraft equipment and functional requirements needed to meet the more demanding performance requirements of RNP AR APCH defined in ICAO Doc 9613, Volume II, Part C, Chapter 6. The Canadian specific requirements are published in the RNP AR APCH Advisory Circular AC 700-024 and the associated Operations Specification 621.

16.2. RNP AR APCH procedures can be built with various levels of RNP lateral containment values on the Initial, Intermediate, Final and Missed approach segments. There are increasingly demanding aircraft certifications and operational approvals required when RNP values lower than 0.3 NM are applied in any of these segments.

16.3. RNP AR APCH procedures will initially be published in either the Canada Air Pilot (CAP) or Restricted CAP using the title “RNAV (RNP)”.

17. RADIUS TO FIX (RF) PATH TERMINATOR

17.1. The RF path terminator operational requirements are defined in ICAO Doc 9613, Volume II, Part C, Appendix 1. The Canadian specific requirements are published in Advisory Circular AC 700-027 and the associated Operations Specification 623.

17.2. The RF path terminator may be found in instrument procedures based on RNP performance; therefore, AC 700-027 and Operations Specification 623 are applicable for use in conjunction with any of the RNP nav specs. Additional specific authorization to operate using RF path terminators is not required for RNP AR APCH and A-RNP; this capability is already mandatory within these two Ops Specs.

17.3. RF path terminators cannot be used in conjunction with an RNAV nav spec.

17.4. RF path terminators will be used where there is a benefit to having the more predictable, tighter containment over the use of a fly-by or fly-over waypoint leg transition on an RNP route segment.

18. FIXED RADIUS TRANSITION (FRT)

18.1. The FRT operational requirements are defined in ICAO Doc 9613, Volume II, Part C, Appendix 2. The operational requirements in Canada have not yet been defined by Advisory Circular and there is no associated Operations Specification.

18.2. The FRT appendix defines the navigation functionality which may be associated with RNP nav specs; RNP 4, RNP 2, and A-RNP.

18.3. FRT will be used to define transitions along RNP airways of less than 90 degrees where the separation between parallel routes cannot be achieved with fly-by transitions.

19. TIME OF ARRIVAL CONTROL (TOAC)

19.1. There is a place holder indicating *"To be developed"* in the Fourth Edition of ICAO Doc 9613, Volume II, Part C, Appendix 3, for Time Of Arrival Control (TOAC). Without a global standard defined for equipment certification and operational approval for the application of TOAC, it is unlikely that operations requiring precise TOAC using relatively small time values will be developed in the near term.

20. CANADIAN PBN IMPLEMENTATION

20.1. Transport Canada has been approving PBN operations through the issuance of Advisory Circulars (ACs) and Operations Specifications. AC guidance is principally drawn from the guidance material available in the ICAO Doc 9613 PBN Manual navigation specifications. Consideration has been given to other States' Advisory Circulars, Acceptable Means of Compliances and Temporary Guidance Leaflets in drafting the acceptable means of compliance outlined in the Canadian ACs.

20.2. Through the process of developing the Transport Canada ACs and the numerous ongoing air navigation system implementation consultations, customers are being kept abreast of PBN requirements and their responsibilities in acquiring suitable equipment, training and operational authorities.

21. CANADIAN AIRSPACE AND ATC SEPARATION STANDARDS

21.1. Canadian airspace is divided in to Northern & Southern domestic airspace with further classification into Required Navigation Performance Capability (RNPC) and Canadian Minimum Navigation Performance Specifications (CMNPS). Minimum Navigation Performance Specifications (MNPS) airspace designation is used for those portions of the North Atlantic airspace over which Canada has been granted authority by ICAO to exercise air traffic control. Navigation performance requirements in CMNPS airspace are equivalent to MNPS airspace.

21.2. In RNPC airspace aircraft performing long range RNAV must be able to achieve a lateral performance error that does not exceed ±4 NM. This is a tighter lateral containment than the current RNAV 5 nav spec.

21.3. In CMNPS airspace long range RNAV lateral performance errors must be able to achieve a lateral performance accuracy error that does not exceed ±12.6 NM, 95% of the total flying time.

21.4. The associated aircraft performance enables the availability of procedural separation minima to be applied by ATC in non-surveillance airspace as follows.

- CMNPS:
  - Lateral – 60 NM or one degree of latitude
  - Longitudinal – 15 minutes, 10 minutes using Mach technique, 20 NM with GPS and DCPC
- RNPC:
  - Lateral – 20 NM (10 NM either side of track)
  - Longitudinal – 10 minutes, or 30 NM with DCPC or 20 NM with GPS and DCPC

21.5. In the near-term, the unique Canadian RNPC & CMNPS designations will be replaced by PBN nav specs that will meet the safety, capacity and efficiency requirements of the airspace. ICAO nav specs and their associated approved procedural separation standards are as follows.

- RNAV 10 (RNP 10)

- Lateral - 50 NM
- Longitudinal – 50 NM

- RNP 4:
  - Lateral - 30 NM
  - Longitudinal – 30 NM
- RNAV 2:
  - Lateral – 20 NM lateral (10 NM either side of track)
  - Longitudinal – 10 minutes, or 30 NM with DCPC or 20 NM with GPS and DCPC

21.6. While not associated with a PBN nav spec, initial lateral track separation associated with GNSS and DCPC has been established for parallel or non-intersecting tracks or ATS routes; 15 NM separation and 7 NM for climb/descent separation. Where other than DCPC is used for communication the climb/descent track separation will be a minimum of 20 NM.

21.7. ICAO is in the process of developing separation standards for RNP 2 for use in the en route phase of flight. RNP 2 aircraft would qualify for the above referenced separation and it is expected that when the track separation for RNP 2 is determined, it will be an improvement over the basic GNSS lateral separation.

22. IMPLEMENTATION SEGMENTS

22.1. PBN implementation is a continuum of meeting operational challenges with air navigation service provider initiatives. These opportunities are made possible through the adoption of ATM advances that also leverage technology advances adopted by our customers'. They are applied when justified by safety and/or financial considerations in areas where the appropriate regulatory and geo-political environment exist.

22.2. Implementation is linked to ATM and customers' adoption of new technologies and can be subdivided into chronological segments identified as:

- Short-term (2014 to 2016)
- Near-term (2017-2021)
- Long-term (2021+)

23. SHORT-TERM (2014-2016)

23.1. **En route** changes will see the progressive removal or conversion in the short-term of Jet, Victor and Low Frequency (LF) airways into Q, T and L routes.

23.2. Q routes are area navigation routes above FL180. Leading up to the end of the short-term they will begin to be designated with an ICAO nav spec of either RNAV 2 or RNP 2. The designation will be dependent on the available navigation infrastructure, the surveillance and communication infrastructure and the need to provide airspace capacity through tighter aircraft containment.

23.3. Owing to the number of required ground-based nav aids needed to support a robust RNAV 2 route structure, Canadian Q routes will be identified as "GNSS required". When a regulatory path for customers to achieve an RNP 2 operating authority is available, the Canadian "GNSS required" Q routes can be re-designated RNP 2 routes.

23.4. T routes are area navigation routes below FL180 in controlled airspace, and L routes are those same low level routes in uncontrolled airspace. Line-of-sight limitations on ground-based navigation aids dictate that all Canadian T and L routes will require GNSS. As with the Q routes, they will initially be labelled "GNSS required" and when a means to achieve an RNP 2 operating authority is available, they will also be re-designated as RNP 2 routes.

23.5. Having a published nav spec designation on Canadian routes will ensure customers' compliance with a common aircraft equipage and training that will result in a high assurance of track conformance. This enables ATM operations optimizing capacity and efficiency through the use of available obstacle and aircraft separation standards.

23.6. RNAV 10 (RNP 10) currently supports track centerline separations and aircraft to aircraft longitudinal separation on those tracks of 50 NM laterally and 50 NM longitudinally respectively. RNP 10 separation standards are in use in portions of the Edmonton FIR that do not have a surveillance capability in order to facilitate the more efficient transition of aircraft on and off the polar routes and North Atlantic tracks.

23.7. RNP 4 will be investigated for opportunities to increase efficiency in non-surveillance airspaces. Current track-to-track separation identified in ICAO Doc 4444 may not provide sufficient opportunities for service improvements and further investigation of the use of RNP 4 using the application of "airspace to be protected" may be required.

23.8. As part of the North Atlantic (NAT) Regional plan to transition the MNPS airspace to operations using a PBN nav spec, as of 2013 aircraft approved (certified) for RNAV 10 (RNP 10) and/or RNP 4 may be issued an MNPS operational authorization without further examination of the navigation specification component. Commencing in 2015, new MNPS operational approvals will discontinue the use of the MNPS navigation specification and thereby require that all new MNPS operational approvals be based on RNAV 10 (RNP10) or RNP 4 navigation specifications.

23.9. **Terminal** area navigation by NAV CANADA has been in use for over ten years; with major terminal airspaces that already use area navigation exclusively for their STARs. In the short-term as terminals redesign their arrival and departure routes for regulatory compliance or to improve efficiencies, more RNAV SIDs will be introduced, some vector SIDs will remain, and all non-RNAV STARs will be withdrawn.

23.10. Although existing terminal RNAV procedures were designed to meet RNAV 1 or RNAV 2 performance, the current restriction to operate on them rests solely on an equipment requirement. In the short-term, these RNAV STARs and SIDs will be designated as RNAV 1 or RNAV 2 procedures which will require the majority of our customers to have Ops Spec 612 in order to use them. This will increase the level of conformity in their execution since the Ops Spec requires both equipment and associated training.

23.11. RNP 1 terminal procedures will be advantageous for terminal implementation in a number of situations including, but not limited to:

- At airports with limited or no surveillance;
- Where there is a requirement to include an RF leg in a STAR or SID; or,
- Where navigation containment is required that cannot be achieved through the use of an RNAV nav spec.

23.12. RNP 1 STARs demand a higher level of aircraft and aircrew performance over an RNAV 1 operation and therefore support narrower obstacle free areas. Consequently, where there is a requirement to enable

terminal operations that are procedurally separated from each other (surveillance separation is either not available or not practical), RNP 1 will be the preferred required nav spec. Also, since RF legs cannot be flown while operating under an RNAV nav spec, when terminal airspace redesigns identify efficiencies through the use of RF legs attached to a STAR or SID, RNP 1 will need to be the underlying nav spec.

23.13. **Approach** operations using the ICAO RNP APCH nav spec are widely available in Canada identified as RNAV(GNSS) approaches. Over the short-term they will continue to be developed and implemented with a lateral path (LNAV) and a vertical path (Baro VNAV or LPV).

23.14. The Regional GNSS implementation program has subdivided Canada into eight regions grouped based on common links primarily related to customers' route structures and geography. Based on operators within each region meeting a minimum equipment baseline, RNAV(GNSS) procedures will be developed to each IFR runway end with at least two distinct decision altitudes (DA); one lateral only DA (LNAV) and one lateral and vertical DA (LNAV/VNAV, LPV, or RNP and Baro VNAV). The priority list will start with a focus on airports defined in areas A and B of the program document; Nunuvut, Northwest Territories, Yukon Territories as well as some selected sites in Northern Saskatchewan, Manitoba and Ontario.

23.15. Based on business case analysis and operational requirements developed in consultation with our customers, work will progress to implement RNP AR APCH procedures at the four airports that have parallel runways. These procedures are expected to have segments with RNP values ranging from 1.0 to 0.3 NM. If there are operational and financial considerations that demonstrate a material benefit to having RNP values lower than 0.3 NM, in these circumstances an additional line of minima will be added to the procedure. A standard design template for these procedures does not yet exist; however, the basic constructions are expected to include a transition to final using an RF leg that intersects the final approach segment at an optimal lateral and vertical point while weighing all of the design considerations gathered from the airport environment stakeholders. Use of RNP AR APCH procedures offer opportunities for additional time-in-system savings that reduce fuel consumption and GHGs over standard RNP APCH designs. Therefore, the focus for customer consultation will be on RNP AR APCH development for these four airports.

23.16. RNP AR APCH procedures will also be designed for airports that otherwise would not have suitable access owing to the obstacle environment, or where sufficient benefits can be realized from the use of the narrower obstacle clearance areas to improve overall efficiency. A list of runway ends provided by NAV CANADA's customers' forms the basis of the priority order for design development in the short-term.

23.17. In the short-term new non-RNAV approach procedures will be limited to new ILS installations requiring designs. Retention and maintenance of approach procedures dependent on ground-based navigation aids will be addressed as part of a broader ground-based navigation aids plan that will be consulted with a broad range of stakeholders.

24. NEAR-TERM (2017-2021)

24.1. In the near-term it is expected that all of the required Canadian Advisory Circulars, Operations Specifications, and other regulatory/advisory documents necessary for equipment certification and operational approvals for all of the nav specs identified in the ICAO PBN Manual will be available. In addition, many of the more basic PBN operational approvals are expected to become part of the basic

instrument flight rating (IFR) licencing requirements thus simplifying the process and alleviating the need for multiple approvals by our customers.

24.2. **En route** operations will all be performance identified by an ICAO nav spec designation. Canadian high level airspace (above FL180) is expected to be identified as RNAV required; with either RNAV 2 or RNP 2 as the primary underlying nav spec associated. In airspace where RNP 2 is required as the minimum, unless another means of achieving the required on-board performance monitoring and alerting is certified, this will create a de facto GNSS mandate in these airspaces.

24.3. The development of ATS routes will continue where structured flows are required to ensure airspace capacity can be achieved through either surveillance or non-surveillance aircraft-to-aircraft and aircraft-to-airspace/obstacle separation. In the near-term there may be opportunities to enhance airspace capacity through the construction of closely spaced parallel routes offering opportunities for fewer restrictions in climb, descent and overtake scenarios in congested airspace. Where these parallel routes also require a change in direction of less than 90 degrees A-RNP FRT legs may be used. Elsewhere, wider spread use of user preferred trajectories combined with a combination of "pitch-and-catch" waypoints will be available.

24.4. The North Atlantic will have initiated the transition from its unique MNPS designation to using the published ICAO nav specs of either RNAV 10 (RNP 10) or RNP 4. As of 2020, all aircraft that regularly operate in the NAT Regional high level (formally MNPS) structure will have obtained an operational approval based on the RNAV 10 (RNP 10) or RNP4 nav spec. Based on the premise of system efficiencies and priority handling, non-approved aircraft planning to operate in this airspace will be unlikely to get either a clearance onto the preferred tracks or at the optimum altitudes.

24.5. The introduction of more widely available surveillance capabilities through space-based ADS-B will provide opportunities to use surveillance separation standards in conjunction with PBN to improve efficiencies, particularly in remote and oceanic airspace. Availability of ADS-B Out avionics to a broad range of customers and their ability to utilize them without undue restriction will form the critical path in future implementation. The ADS-B Out requirements will only need to meet the appropriate performance for the required separation being applied based on the airspace traffic density and complexity. Discussions will be initiated into the use of ADS-B Out as both an incentive to increased efficiency and as a potential for airspace mandates.

24.6. **Terminal** environments will become more dependent on RNP navigation specifications in order to take advantage of the tighter aircraft containment and narrower obstacle clearance areas that the associated designs offer. In addition, the more predictable lateral path definitions will enable more precise vertical path construction. Customer equipage will remain on the critical path for opportunities to implement efficiency gains. In the near-term NAV CANADA will consult with airport operators and its customers on the priority handling options for nav spec capabilities to operate in more complex high traffic areas. These options may include a combination of geographic and temporal incentives to enhance overall airspace safety and capacity.

24.7. The use of the A-RNP nav spec is expected to be introduced as a means to manage traffic during high density periods. More SIDs will be developed that are procedurally separated from STARs and the potential for creating lateral and vertical terminal corridors will be introduced. ATM advances will need to keep pace with aircraft PBN capabilities in order to be able to extract the potential considerable savings in

fuel and other ANS operating costs. Aircraft that are not capable may be accommodated but will not have access to optimal routings or operations during peak demand periods.

24.8. **Approach** procedure construction will continue to address ICAO Resolution A37-11; ensuring an appropriate level of airport access by both lateral and vertically guided designs. The regional GNSS implementation program will be completed and attention will be placed on the overall inventory of approach procedures. As a result of the completed ground-based navigation aids plan an objective assessment of required procedures will be possible.

24.9. As operations using ground-based augmentation systems (GBAS) are certified for Category I/II/III operations their use at Canadian airports will become more financially viable. Customer equipage will again play a critical role in the operational and financial decisions. GBAS is also expected to support the potential to provide precise lateral and vertical terminal area paths. The possibility of introducing GBAS ground stations at airports to provide CAT I/II/III operations will be investigated in terms of technical, operational and financial viability.

24.10. New PBN nav specs are expected to be available; as a minimum the completion of the current placeholder for TOAC. Depending on availability of certified avionics for our customers, the potential will exist to introduce time of arrival control in the terminal environment when it can be used to increase capacity.

24.11. Advances in operational approvals associated with autonomous aircraft systems such as heads-up guidance systems (HGS) and enhanced vision systems (EVS) will see an increase in the number of aircraft able to make use of lower decision heights, possibly with less NAV CANADA invested infrastructure. HGS use today is approved in the US for flight to Cat II limits when flown within a Cat I infrastructure. As another example, reassessment of lighting requirements for CAT I/II/III approach systems could improve the financial viability of both the service provision and the customers' ability to achieve these operational capabilities.

25. LONG -TERM (2021 AND BEYOND)

25.1. A planning horizon beyond 2021 could include new nav specs, including definition of the vertical portion of RNP. Without current outcomes from groups such as RTCA Special Committee 227 that define the minimum standard and performance specifications for aircraft avionics, it is difficult to envisage a drastic change in the way that aircraft will be managed after 2021. The necessarily long process of systems definition, building and adoption of new avionics into common usage means that the changes tabled today and in the near-term will not be seen until well beyond 2021.

25.2. The navigation specifications found in the fourth edition of the ICAO PBN Manual will be fully implemented by 2021. The processes required for aircraft certification and customer approval will be fully incorporated into everyday operations. Special authorization will not be required for any but the most demanding navigation specifications. Criteria for development of procedures that map to the customers' nav specs will be in common use.

25.3. En route, terminal and approach navigation requirements will see a natural evolution of the common practices developed in the near-term, with more standardization of their application as initial implementations and operational experience prove out optimal designs.

25.4. There will be airspace mandates that require specific nav spec capabilities. These mandates will be in place for volumes of airspace that have pressures owing to traffic density and/or complexity. The mandates will be enforced over geographic areas and/or on a temporal basis.

25.5. The airspace in Canada above FL180 is expected to be mandated RNP nav spec airspace. Much of the non-surveillance airspace in Canada will also require RNP equipage.

26. REFERENCES

26.1. International Civil Aviation Organization (ICAO) PBN manual-Doc 9613 AN 937 Fourth Edition 2012

26.2. ICAO General assembly – 37th ICAO General Assembly resolution No.11

26.3. Aeronautical Information Publication (AIP) CANADA

26.4. Aeronautical Information Manual (AIM)

26.5. Aeronautical Information Circulars (AIC) - FAA

26.6. Advisory Circulars (ACs) 90-100A, AC 90- 101, AC 90-105