International Civil Aviation Organization

WORKING PAPER

AN-Conf/12-WP/148
31/10/12
English and French only[1]

TWELFTH AIR NAVIGATION CONFERENCE

Montréal, 19 to 30 November 2012

Agenda Item 2: Aerodrome operations – improving airport performance
2.2: Performance-based navigation (PBN) – a practical way to improve airport performance with safety and efficiency

PBN IMPLEMENTATION

(Presented by Canada)

SUMMARY

This paper presents a summary of the performance-based navigation (PBN) activities already underway and planned for near-term implementation in Canada to advance the use of PBN.

Action: The Conference is invited to agree to the recommendation in paragraph 4.2.

1. INTRODUCTION

1.1 NAV CANADA is the private sector, non-share capital corporation that owns and operates Canada's civil air navigation system. Transport Canada is Canada's regulator for the civil air navigation system. NAV CANADA coordinates the safe and efficient movement of aircraft in Canadian domestic airspace and in international airspace assigned to Canadian control. Through its operations, NAV CANADA delivers air traffic control, flight information, weather briefings, aeronautical information, airport advisory services and electronic aids to navigation.

1.2 Transport Canada and Canada's Air Navigation Services provider (NAV CANADA) have been active contributors to the development of ICAO performance-based navigation (PBN) guidance material from the initial formation of the Required Navigation Performance Special Operational Requirements Study Group (RNP SORSG) through its transition to the PBN Study Group (PBN SG). PBN has been acknowledged by Canada and by NAV CANADA as a critical component in improving safety, increasing efficiency and reducing aviation's environmental footprint for en route, terminal and approach operations.

1.3 Implementation of PBN in Canada will be completed as an incremental series of qualification upgrades to aircraft, operator training, and ATM. The timing for the provision of upgrades by NAV CANADA and their adoption for use by system users is one of the greatest implementation complexities. There will be no "big bang" implementation for PBN. This means that there will be system users who choose to be early adopters and those who choose to delay the adoption of new technology or procedures.

[1]English and French translation provided by Canada.

1.4 Moving forward, NAV CANADA will endeavour to accommodate those system users who lag in capabilities as long as practicable; however, in respect of the overall system efficiency and capacity they will not fully realize efficiencies and may face operational delays and restrictions.

2. BACKGROUND

2.1 PBN improves the safety of air operations by providing consistent and repeatable flight path trajectories. Lateral and vertical track-keeping is much more accurate and reliable, due to three-dimensional guided arrival, approach, missed approach, and departure procedures that cannot be defined using conventional navaids.

2.2 Canada agreed with ICAO Resolution 36-23, Implementation of PBN and Approach Procedures with Vertical Guidance that will provide vertical guidance to all instrument runway ends in Canada as equipage, navigation system availability, and airport infrastructure will allow. Vertical guidance reduces controlled flight into terrain (CFIT) risks commonly associated with non-precision approach procedures. PBN provides consistent, predictable and stabilized approaches aligned with the runway centreline. PBN will enable aircraft to reliably access airports with lower approach minima, thus reducing diversions caused by adverse weather conditions with minimum fuel.

2.3 PBN reduces the flight crew’s exposure to operational errors by providing flight crews with an enhanced interface designed to minimize manual insertion and control errors, enhanced situation awareness, and improved indication of equipment failure. RNP provides higher integrity through onboard monitoring and performance alerting. Operations using PBN enhance safety by employing approach and departure procedures that are consistent from aerodrome to aerodrome. That consistency is a key component of safe operations.

2.4 From an air traffic management (ATM) perspective, safety will be improved because the controller will know the trajectory the aircraft will follow, because of the consistency and repeatability of PBN based flight path trajectories. PBN will permit the introduction of flight path monitoring and alerting tools for controllers, reducing the probability of loss of separation.

2.5 Future PBN developments will address emergency situations, such as when an engine fails. RNP allows crews to focus on flying rather than having to attend to complex emergency navigation procedures. This is particularly critical when the aircraft is operating in challenging terrain, poor weather or low visibility. In some cases of engine failure, the RNP guidance can reroute the aircraft to fly through less obstacle-challenged airspace to compensate for degraded aircraft performance.

2.6 Canada’s Action Plan to Reduce Greenhouse Gas Emissions from Aviation (TP15187 http://www.tc.gc.ca/aviation-emissions/) was released in June of this year. This Action Plan underwent wide consultation and was jointly signed by the Minister Of Transport, Infrastructure and Communities, Transport Canada, the President and CEO of NAV CANADA, the President and CEO of the Air Transport Association of Canada, the President and CEO of the Canadian Business Aviation Association, the President and CEO of the Aerospace Industries Association of Canada, the President of the Canadian Airports Council, and the President of the National Airlines Council of Canada.

2.7 PBN reference in the Action Plan states:

> Building on existing PBN activities, further implementation could improve average annual fuel efficiency by 1 to 2 percent between 2005 and 2020. The benefits resulting from PBN will be dependent upon the following:
>
> - Approval by Transport Canada for use of the United States Federal Aviation Authority (FAA) Order 8260.54A and 8260.52 instrument procedure design criteria;

- Development and approval of guidance by Transport Canada for Operations Specifications in support of the use of FAA Order 8260.52 criteria;

- Acceptance of new ICAO PBN Navigation Specifications; and

- Timely identification and incorporation of necessary regulatory changes to support PBN.

Transport Canada, NAV CANADA and the Canadian aviation industry will work together to develop and put in place an ICAO State PBN Implementation Plan for Canada. To support Canada's PBN Plan:

- Transport Canada will develop a PBN policy framework by Fall of 2012. It will set out the scope, opportunities, and guiding principles for adopting PBN in Canada. This framework will be informed by the work of the CARAC Working Group, the October 2012 ICAO PBN Symposium, and this Air Navigation Conference.

- Transport Canada will continue to move short- and medium-term solutions forward to advance PBN in Canada. These measures include:

  - Incorporating new PBN-based Canadian air navigation procedures, aligned with those of the United States FAA; and

  - Continuing to work with ICAO to develop and incorporate new international procedures for Canada's air navigation system.

- The Canadian Aviation Regulation Advisory Council (CARAC) PBN Working Group, which includes representatives from Transport Canada, NAV CANADA, and the Canadian aviation industry, will identify, within the next two years, the regulatory requirements and any other non-regulatory mechanisms to help determine short-, medium-, and long-term opportunities for adopting PBN. The work of the PBN Working Group began in fall 2011.

2.8 In the past 12 months the work of the Canadian Aviation Regulation Advisory Council (CARAC) PBN Working Group has already lead to a priority list of recommendations that respond to the needs of the State, the aviation industry and NAV CANADA. This working group prompted an unprecedented process of consultation amongst the PBN stakeholders on the content of new advisory circulars and operations specifications that will enable the use of PBN navigation specifications.

2.9 The value of consultation between subject matter experts and decision makers across all disciplines of PBN stakeholders cannot be understated. In this regard, time and resource efficiencies are realized by all parties through leveraging expertise and ensuring a timely end product that meets the needs of all constituents.

2.10 NAV CANADA has forecast the material impact on reducing Canada's GHG emissions related to the implementation of PBN procedures and published them in the Collaborative Initiatives for Emission Reductions (CIFER) Report 2011 update:

(http://www.navcanada.ca/NavCanada.asp?Content=ContentDefinitionFiles\AboutUs\Environment\CIFER\2011\default.xml).

2.11 CIFER publishes an expected savings of $448 Million CAD and a reduction of 1 768 000 metric tonnes of CO2e as a result of the use of area navigation (RNAV) improved access to point-to-point operations from the start of the project period until 2016. Over the same time period, required navigation performance (RNP) descent optimization is forecast to contribute savings of $83 Million CAD and a reduction of 231,000 metric tonnes of CO_2e.

2.12 Responses from system users has been favourable stating the following.

The measurable benefits are:

a) more reliable (repeatable), predictable flight paths;

b) time and fuel savings;

c) shorter route distances;

d) higher take-off weights/reduced thrust;

e) consistent common instrument approach for all operations; and

f) fewer weather-related diversions, cancellations.

In Canada 4 000 RNP approaches are flown each month. NAV CANADA supports system users' RNP programs throughout all phases particularly during the addition of RNP tracks that shorten the miles flown on published standard instrument arrivals.

2.13 Since the move to PBN operations will be an evolutionary process, the transition will see times and geographic distribution of non-homogeneous operational capabilities amongst system users. Depending on how it is implemented into the air navigation system, this can add to the complexity and therefore the cost of service delivery. As more system users become capable of PBN operations, the frequency and extent of their use by air traffic control will increase. Neither party can afford an approach of "if you build it they will come", nor "if we buy it you must accommodate its use". Therefore, a critical aspect of PBN planning is the shared knowledge between system users and service provider to allow timed investment in new capabilities which is input as part of a business case analysis (BCA) for the proposed changes.

3. NAV CANADA PBN IMPLEMENTATION

3.1 Short-term priorities covering the three year period ending in 2014 are defined in NAV CANADA's ANS Plan, described. Each project undertaken will be supported by a BCA to ensure a return for investment NAV CANADA's PBN priorities are:

a) major terminal airspace;

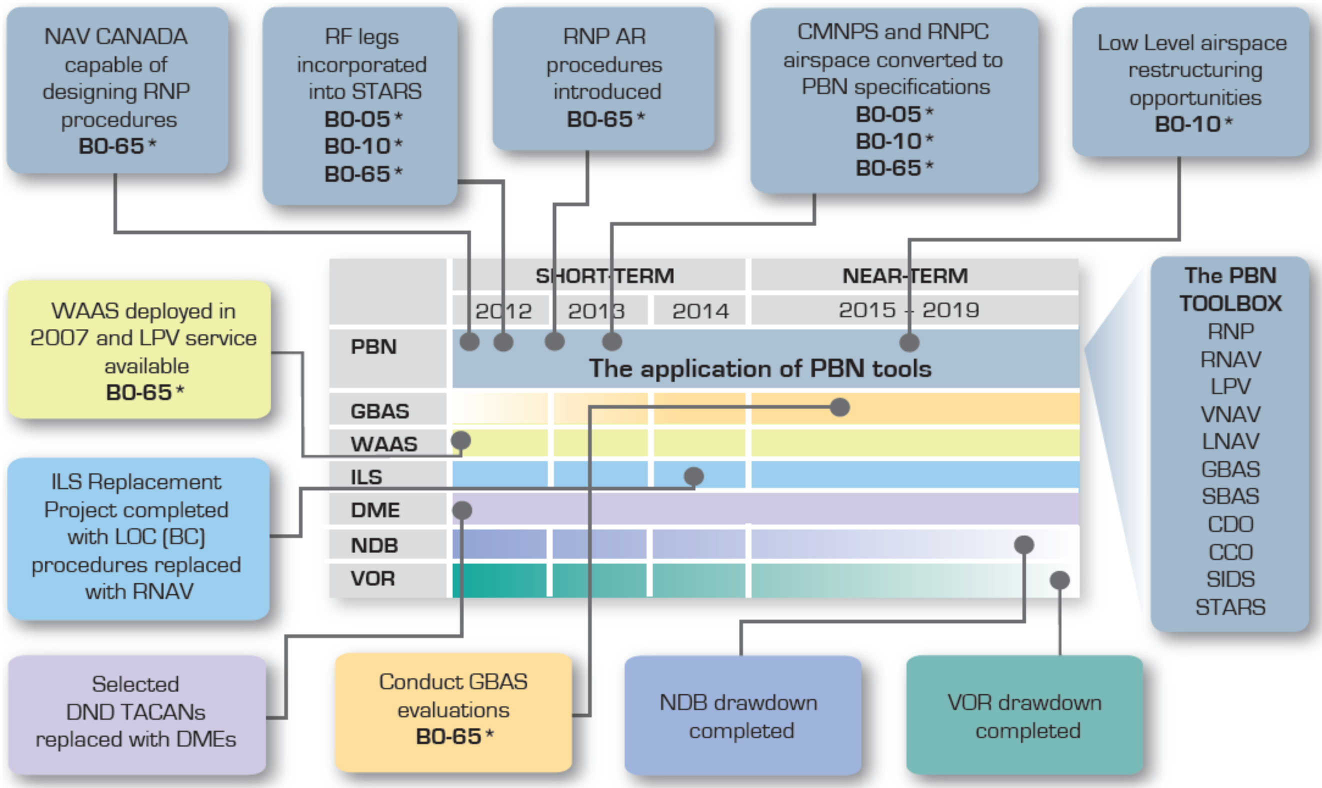
b) second and third level airports;

c) northern/remote airspace and airports, and

d) targets of opportunity.

3.2 The following graphic maps NAV CANADA's navigation plans against the ICAO aviation system block upgrades (ASBUs). The details of the graphic can be found in NAV Canada's air navigation system plan at:

http://www.navcanada.ca/ContentDefinitionFiles/Publications/CorpPublications/AdditionalPublications/ANS_Plan_2012_EN.pdf



3.3 NAV CANADA has recently completed the first draft of a BCA examining the benefits to be derived from including radius-to-fix (RF) path terminators into terminal and approach operations across Canada. Cooperative efforts with three system users supplying simulator and flight crew time were highly beneficial to supplement the operational data already available to NAV CANADA as well as to examine aircraft/ATC scenarios. Benefits were assessed for 300 runway ends at 120 airports against a variety of base case scenarios dependent on the location, terrain and surveillance environment. The draft report is expected to soon be released to system users for their review and concurrence as it moves forward with the process of priority setting for procedure development that will match system users capabilities to the investment timing for service delivery.

3.4 A component of PBN planning is evident in numerous past, present and future major airspace initiatives. NAV CANADA is developing a common set of PBN performance parameters designed to meet the current and near-term capabilities of system users. A few of the considerations include items such as: continuous descent profile from top of descent for jet aircraft with more flexibility for prop aircraft, altitude “windows” for STAR waypoint crossing altitudes to accommodate cost index descents, speed applications on STAR waypoint crossing altitudes to accommodate aircrew planning in descent and assist ATC “compression” management from the en route, sequencing at high altitude (en route) versus low altitude in terminal, and separate jet/prop SIDs and STARs where large performance differences exist.

3.5 The Windsor-Toronto-Montreal (WTM) Airspace Redesign Phase I was completed this past February, and implemented many PBN concepts while also laying the groundwork for future applications. Revised RNAV SIDs and STARs were developed taking into account the performance characteristics associated with RNAV 1. However, the procedures are not yet explicitly charted as RNAV 1, waiting for the broader customer base operating into this airspace to receive the required operations specifications to allow them to use such a charted procedure.

3.6 Parallel closely spaced unidirectional routes through the WTM airspace were implemented and charted as Q-Routes, T-Routes and L-Routes. These fixed RNAV routes provide more opportunities for aircraft to execute unrestricted climbs, descents and transits of the airspace using customer preferred vertical profiles. The result was reduced time in system and reduced fuel burn and GHG emissions which contributed to the estimated

5.4 million in annual fuel savings and 14 300 metric tonnes of avoided GHG emissions associated with Phase 1 of the WTM project. While the separation standards on these routes remain surveillance based, the route separation widths would lend themselves to an RNP route spacing designation in the future. In general terms, the use of closely spaced unidirectional routes will facilitate optimum routes and will support more efficient climbs and descents between conflicting pairs of aircraft.

3.7 The Alberta Airspace and Services Project (AASP) is preparing a major airspace redesign to coincide with the addition of a 14,000 foot north-south parallel runway at the Calgary International Airport in 2014. The requirement for revised routes, STARs, SIDs and approach procedures are taking into account future capabilities of the customer fleet mix for the 2014 starting date and looking at RNAV and RNP options, including the potential to use of RF legs. To what extent the optimized use of a combination of RNAV and RNP navigation specifications can be implemented will depend highly on the customer fleet capabilities.

3.8 Canada currently has some unique (non-PBN) navigation specifications applied in two airspace designations. Airspace identified as required navigation performance capability (RNPC) requires long range RNAV systems to be certified and capable of navigation performance that permits position determination within ±4 NM to be able to conduct RNAV operations (fixed or random routes) in the designated airspace, in which reduced ATC separation criteria can be applied.

3.9 Within CMNPS (Canadian minimum navigation performance specification) airspace, for RNAV operations in which reduced ATC separation criteria can be applied, aircraft must be certified as being capable of navigating within the standard deviation of lateral track errors less than 6.3 NM with the proportion of total flight time spent by aircraft 30 NM or more off the cleared track less than 5.3 x 10-4, and the proportion of total flight time spent by aircraft between 50 and 70 NM off the cleared track is less than 13 x 10-5.

3.10 The navigation performance capability must be verified by the State of Registry or the State of the Operator, as appropriate. Foreign and domestic operations in each airspace currently require a unique operational approval.

3.11 The current separation standards are as per the table below:

	Present Canadian Navigation Specs	
	CMNPS Airspace	**RNPC Airspace**
ATC Separation Standards	Lateral – 60 NM or one degree Longitudinal – 15 minutes, 10 minutes using Mach technique or 20 NM with GPS + DCPC	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.
Aircraft navigation equipment and performance requirements (equipment performance certification is the responsibility of the State of Registry of the Operator)	Long range RNAV lateral performance error shall not exceed +/-12.6 NM Nav accuracy 95% of the total flying time. *Aircraft that have the required navigation equipment for operations in CMNPS and NAT MNPS airspace satisfy all of the equipment requirements for RNPC.*	Long range RNAV lateral performance error in RNPC airspace shall not exceed ±4 NM.

3.12 The current operational fleet consist of Transport Category aircraft with at least 80% equipped with certified GPS receivers. Flight operations include: domestic point-to-point, long range trans-polar, and long range transit connecting to oceanic routes.

3.13 In order to meet ICAO recommendations to transition to PBN, two unique Canadian airspace specifications (RNPC and CMNPS), could be replaced with PBN navigation specifications. The performance requirements defined by RNPC airspace compliance for RNAV operations already exceed those identified in RNAV-5; therefore, this is not a viable replacement. Lowering the existing navigation performance requirements would result in a necessity to review the existing separation standards with the likelihood that the required separation would increase. In areas where ground-based navigation aids combined with an appropriate communication and surveillance infrastructure, a suitable PBN navigation specification could be RNAV-2, provided that an equivalent separation standard could be achieved. This would apply to certain areas of Canada's Southern Domestic Airspace.

3.14 In northern and remote areas where long range navigation with required availability of accuracy, integrity and continuity is only supported by GNSS, RNP-2 is expected to support the development of the needed separation criteria for both fixed track and random route separation. Current RNP-4, while having similar navigation system requirements, has been applied in airspace applications with a route spacing as low as 30 NM lateral and 30 NM longitudinal. While it is conceivable that under certain communication and surveillance infrastructures the 30/30 separation standard could be reduced, the anticipated minimum route spacing would likely need a primary and secondary area between track centrelines of not less than 2 times RNP from each route. Therefore, the minimum expected route spacing would not be expected to be less than 16 nautical miles under RNP-4. This does not allow the optimization of routes to meet the needs of the airspace for closely spaced operations. Using the same assumptions, with an RNP-2 it may be possible to achieve route separations as low as 8 NM, an improvement of approximately 75% over the current lateral separation supported by RNP-4. Under the same assumption, in RNPC airspace a 60% improvement in separation could be achieved over current operations using GPS and DCPC.

3.15 Additionally, if the RNP designation within an airspace (using RNP routes and an airspace to be protected concept for the RNP certified aircraft) can support a non-surveillance separation standard that is close to an en route surveillance standard, then the airspace implementation becomes much less complicated. Transition from surveillance to procedural separation becomes easier and more efficient for both the aircraft and NAV CANADA, resulting in greater availability of random routing and user preferred trajectories.

3.16 The conversion of RNPC and CMNPS Canadian airspace designations, each requiring an operational approval, to ICAO approved PBN navigation specifications, will serve as a cost savings to all air carriers that operate in Canadian airspace who were previously required to get another additional country specific certification for their aircraft and flight crew.

3.17 Opportunities are possible to improve airspace capacity, improve efficiency and reduce Greenhouse Gas (GHG) emissions through the use of RNP-2 in arctic and remote airspaces. This is based on the assumption that track-to-track separation will be reduced to a value less than what RNP 4 can support, allowing for practical and efficient use of unidirectional parallel routes. It has been determined that RNP-4 will support ½ degree lateral separation in the North Atlantic Track operations; therefore, RNP-2 would easily meet the navigation performance requirements. Northern Canadian airspace operations include flights operating on long range Polar routes, high altitude long range transit flights, and flights operating between remote destinations in the Arctic. Many of these routes also connect to North Atlantic Oceanic tracks. Over flight traffic would also benefit from greater airspace capacity from reduced separation between aircraft on routes and those on random routes within non-surveillance airspace.

3.18 Specifically, closely spaced parallel Polar routes will support aircraft competing for the same optimum altitude and will enable more efficient cruise climb profiles. It is envisaged that aircraft pairs that are seeking the same altitude in a non surveillance airspace volume would have a greater likelihood of being cleared on their preferred trajectory owing to the reduced separation requirement. An example of this can be seen in aircraft departing the same airport for long haul flights on the Polar tracks where fuel economy is even more critical. Reduced separation could also expand the investigation of cruise climb applications.

3.19 NAV CANADA has a major interest in the operation of the North Atlantic (NAT). The NAT planning groups are formulating a PBN transition plan to convert the NAT minimum navigation performance specification (MNPS) airspace to reflect a PBN navigation specification. Canada will need to consider re-designation of CMNPS airspace to a PBN designation in the same timeframe being considered for NAT MNPS transition planning.

3.20 The North Atlantic Planning Groups have identified RNP-4 as meeting the requirement to reduce lateral track separations from one degree to ½ degree of longitude between adjacent tracks. The accuracy, integrity and continuity requirements of the navigation system defined in the RNP-2 navigation specification, along with the defined flight technical error (FTE) bounding makes RNP-2 an additional option to meet the navigation performance. Use of a common navigation specification to connect North Atlantic operations with high level Canadian operations will remove the need for yet another approval as well as improving efficiencies in NAV CANADA service provision.

3.21 It should be recognized that there is a significant body of aircraft in operation today certified for RNP-4 that meet many of the navigation accuracy requirements of RNP-2. Owing to additional requirements in RNP-2 that address issues such as FTE bounding to support a closer separation standard, an equivalency declaration should be able to be completed between RNP-4 and RNP-2 by a simple examination of installation configuration for either display scaling or flight director/autopilot installation. An omnibus operational equivalency statement could be possible for aircraft that currently operate RNP-4 certified aircraft with the autopilot engaged as being equivalent in performance to RNP-2. This activity could lead to the eventual retirement of the RNP-4 navigation specification in favour of a replacement by RNP-2 which better represents the true operational capability of the same certified navigation system.

3.22 Based on survey responses from NAV CANADA's domestic and international system users it is an expectation that the majority of the current traffic fleet meets RNP-2 requirements today and that in less than 10 years the target aircraft population will be 100% equipped.

3.23 Aircraft that currently meet RNP-4 aircraft configuration requirements using GPS, likely meet the RNP-2 aircraft requirements without need for any certification activity. Future applications could be able to replace RNP-4 with RNP-2.

3.24 The intended en route implementation areas for PBN in Canada's northern domestic airspace do not currently have sufficient communications infrastructure to support direct controller-pilot communications (DCPC) and do not currently have sufficient surveillance continuity to be considered equivalent to secondary surveillance radar (SSR). For these reasons, airspace capacity efficiencies (reduced track-to-track or aircraft-to-track separations) could benefit from the accuracy, integrity, continuity, functional requirements and operational considerations as defined by the RNP-2 navigation specification.

3.25 Separation requirements based on a required GNSS sensor have already been developed associated with ADS-B operations. The availability of position accuracy, integrity and continuity is well documented. Equivalent separation standards are required to be associated with tracks defined by the RNP-2 navigation specification based on existing models of primary and secondary protection areas associated with the RNP value.

4. CONCLUSION AND RECOMMENDATION

4.1 This paper provides a brief overview of Canada's approach to PBN, and specifically to NAV CANADA's PBN activity and implementation plans. The Conference is invited to take note of Canada's incremental approach to PBN implementation and the critical linkage to NAV CANADA's system users' capabilities.

4.2 The Conference is invited to agree to the following recommendation:

Recommendation 2/x – Performance-based navigation implementation

That the Conference request ICAO to develop separation standards associated with the required navigation performance (RNP-2) navigation specification.

— END —