



USE OF PERFORMANCE BASED NAVIGATION (PBN) FOR NOISE MANAGEMENT



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Contents

Foreword	4	Particular Issues Relevant to PBN	18
Executive Summary	5	Balancing potential trade-offs between	
Introduction	6	efficiency and noise	19
	,	Proponent	19
Purpose	0	Stakeholder Definition	19
Background	6	Engagement Activities	10
Methodology	6		
Benefits and Challenges of PBN	7	Lessons Learned and Good Practice	20
Bonofite	7	Commitment to Review	21
Environmental and Efficiency	7	Appendix A	
Safety	8	Case Studies	22
Economia		Case Study:	
Economic	O	Toronto Pearson International Night RNAV approaches	23
Challenges	9	Case Study:	
Communities	9	Hybrid SIDs at Toronto Pearson International	24
Equipage	9	Case Study:	
Regulatory Framework	9	London Stansted Airport	25
Redundancy	10	Case Study:	
Other Challenges	10	Departure optimisation in Amsterdam:	
		RNAV1 with RF legs	27
Noise management options using PBN	11	Case Study:	
Airspace design principles	11	Departure optimisation at John Wayne Airport: RNAV	28
Continuous Descent Operations (CDO)		Appendix B	
and Continuous Climb Operations (CCO)	11	Reference Documents	31
Using PBN as a noise mitigation technique	12	Appendix C	
		Abbreviations and References	32
New PBN-driven Separation Standards	13		
Concentration versus dispersion	14		
Noise patterns			
Roles and responsibilities			
ANSP			
Airport operators	14		
Aircraft operators	17		
Regulatory organisations	17		
Planning and land use authorities	17		
Public Engagement			

Foreword

Civil Air Navigation Services Organisation (CANSO) and Airports Council International (ACI), in collaboration with partners in the aviation industry, continuously strive to help their members address, minimise, and mitigate the effects of aviation noise. Airports and air navigation service providers (ANSPs) look to CANSO and ACI to provide leadership in identifying opportunities to enhance operational efficiency and capacity while maintaining the highest level of safety.

Performance Based Navigation (PBN) is an advanced, satellite-enabled form of air navigation that creates precise three dimensional (3D) flight paths. These procedures and routes offer a number of operational benefits, including enhanced safety, increased efficiency, reduced carbon footprint, and reduced cost. The ability to have aircraft fly a precise vertical and lateral flight path has tangible benefits for ANSPs and airline operators. These benefits, and a corresponding reduction in aircraft emissions and concentration of aircraft noise (which can cause more noise) must be balanced with the potential negative impacts during airspace redesign.

CANSO and ACI recognise the varying responsibilities across multiple States with regard to their environmental outreach activities. This joint CANSO-ACI document may be used to complement a State's unique requirements for stakeholder consultation and collaboration.

This information will be helpful to support coordinated airspace and flight path improvements amongst affected stakeholders and will address some of the methods proven to provide clarity for stakeholders on the opportunities and limitations involved in reaching decisions on airspace design.

While PBN offers benefits to safety, airspace capacity and operational efficiency, the focus of this document is managing the potential impacts of noise on local communities, while understanding how PBN can be used as a noise mitigation technique in appropriate circumstances.

Although the focus of this publication is on using PBN as a change enabler, the strategies outlined in this document are equally applicable to non-PBN influenced flight path changes.

This document is a joint publication of the CANSO and ACI. It was developed by the CANSO Performance Based Navigation Workgroup (PBNWG) of the CANSO Operations Standing Committee (OSC), the Noise Task Force of the ACI World Environmental Standing Committee (WEnSC) and international contributors from ACI based on extensive expertise and experience of several members.

Executive Summary

This document provides a snapshot of lessons learned and good practices from recent case studies how PBN can be used as a noise mitigation technique in appropriate circumstances.

The document addresses the benefits and challenges of PBN and presents noise management options using PBN. PBN procedures and operations allow aircraft to fly very precise lateral flightpaths and improved climb and descent profiles. Depending on the geography of where the airport is located and other additional elements such as the available equipage and redundancy, PBN procedures can introduce arriving and departing flight paths that are safely placed in areas avoiding densely populated areas. Topographical features, such as rivers, highways or agricultural areas, can be used when available.

All stakeholders involved in the design and implementation of PBN need to be clearly identified and their roles understood. While it is the responsibility of the sponsor (normally ANSP or airport) to identify the affected stakeholders, each stakeholder has a responsibility and right to participate in the change process so that a balanced and sustainable outcome can be achieved.

It is essential that the ANSP, the aircraft operator, and the airport operator collaboratively identify the need for change based on current and forecasted traffic, including the capabilities of the aircraft intended to be used for the new procedures. This will facilitate the sponsor to clearly communicate the possible impact to local communities due to the proposed changes in flight path, in collaboration with other agencies that may have a more detailed local knowledge. Airport operators can also promote the benefits, communicate the impacts of the PBN initiative to local stakeholders, and identify and monitor the metrics of expected benefits and impacts of PBN procedures. Some important lessons learned and good practices contained within the ICAO Circular Community Engagement for Aviation Environment Management can be summarised as follows:

- > Start early and continue in the longer term community engagement does not have to be project or PBN-specific
- > Be proactive and wide-reaching
- > Be transparent
- > Manage different expectations as not all parties will be pleased with the outcomes
- > Use where useful different ways to present information, including new technologies, social media, traditional print and broadcast media
- > Make sure the process is as inclusive and collaborative as possible
- > Highlight (relevant case studies) where PBN implementation actually can have positive impact on noise management

Introduction

Purpose

The purpose of this document is to provide guidance material and share best practices with CANSO and ACI members on the implementation of PBN, and potential opportunities to mitigate negative environmental impacts of aircraft operations near airports.

Background

Performance based navigation (PBN) is an advanced, satellite-enabled form of air navigation that creates precise 3D flight paths. These procedures and routes offer a number of operational benefits, including enhanced safety, increased efficiency, reduced carbon footprint, and reduced cost. The ability to have aircraft fly a precise vertical and lateral flight path has tangible benefits for ANSPs and airline operators. These benefits, and a corresponding reduction in aircraft emissions and concentration of aircraft noise, must be balanced with the potential negative impacts during airspace redesign.

While PBN offers benefits to safety, airspace capacity and operational efficiency, the focus of this document is managing the potential impacts of noise on local communities, while understanding how PBN can be used as a noise mitigation technique in appropriate circumstances.

Methodology

The document addresses

- > Benefits and challenges of PBN
- > Noise management options using PBN
- > Roles and responsibilities of stakeholders
- > Public engagement
- > Case studies of PBN implementation supporting noise management

Benefits and Challenges of PBN

This section aims to detail the main benefits of PBN implementation while also highlighting some of the challenges that have been encountered by States that have introduced PBN to their operation. While it is not an exhaustive list, it should be seen as guidance based on those experiences.

The key benefits of PBN can be categorised as safety, environmental and efficiency, and economic, and this section details how each is improved through the deployment of PBN. The challenges can be associated with availability of necessary equipage, redundancy, regulatory frameworks, and community reaction to changes. The challenges are as important to understand as the benefits to maximise the chances of success for any project. PBN is no exception to that rule, particularly because it can be used as part of the solution to challenges related to community concerns. For example, PBN can benefit communities if, given appropriate geography and airspace capacity, the concentration of routes can be used to reduce overflight of residential areas, or provide respite at certain time/location based on community feedback.

Benefits

Environmental and Efficiency

By implementing PBN routes, many States have been able to reduce track mileage flown in all phases of flight. In addition, PBN can significantly improve climb and descent operations and offer more efficient routings throughout the entire flight. This can result in substantial reductions in fuel burn and associated CO_2 and other greenhouse gas emissions, while also providing economic benefits. For example, it is estimated that the introduction of RNP-AR^[1] approaches at multiple airports in Canada will reduce Greenhouse Gases (GHGs) by 367,000 metric tons carbon dioxide emissions (CO2e) by 2020. The corresponding reduction in avoided fuel cost is estimated at CAD \$132 Million.

Examples from US Metroplex operations show similar economic and environmental benefits.^[2]

Metroplex	Daily Average by Fiscal Year		Projected Annual B	Metroplex		
	2017 Total Operations	2017 Scheduled Flights	Fuel Savings (Gallons of fuel in millions)	Value of Fuel Savings (Fuel costs in millions)	Carbon Savings (Metric tons of carbon in thousands)	Phase
Atlanta	3,165	2,335	2.2**	\$6.3	18.8	Complete
Charlotte	2,735	1,884	4.2***	\$12.1	36.0	Complete
Cleveland-Detroit	2,200	1,309	3.4*	\$9.7	28.9	Implementation
Washington D.C.	2,785	1,998	2.0***	\$5.6	16.5	Complete
Denver	2,904	1,503	0.6*	\$1.8	5.4	Design
Florida	7,316	3,050	5.4*	\$15.5	46.1	Design
Houston	2,275	1,475	1.8***	\$5.3	15.7	Complete
Las Vegas	2,189	954	2.6*	\$7.5	24.8	Design
North Texas	4,368	2,062	2.6**	\$7.5	22.4	Complete
Northern California	3,349	2,020	0.7**	\$2.0	5.6	Complete
Phoenix						Cancelled
Southern California	6,106	2,889	3.1***	\$8.8	26.0	Complete

Last Updated November 2018

* Indicates data is derived from study team notional models, ** Indicates data is derived from design team refined models, *** Indicates analysis is based on radar track data collected during the first three months after the final implementation for that project

¹ RNP Authorisation Required Approach (RNP AR APCH). RNP AR APCH procedures have stringent equipage and pilot training standards and require special authorisation to fly

² <u>https://www.faa.gov/nextgen/snapshots/metroplexes/summary</u>

The reduction in track miles and introduction of more efficient routings also has the added benefit of a reduction in flight time and 'time in system' (amount of ATC services used). This provides benefits to aircraft operators, airports, ANSPs and the wider flying public.

PBN allows for greater track assurance greater accuracy and integrity which can lead to tighter concentration of flight tracks. Leveraging the inherent concentration created by the accuracy of PBN routes, along with placement in appropriate locations where viable, it is possible to provide a reduction in overall noise to a large proportion of local communities. Communities will experience benefits when PBN routes are designed to prioritise the overflight of non-residential areas (e.g., agricultural, commercial, or industrial lands). Alternatively, it is sometimes possible to design alternate routes through an area to provide predictable respite for affected communities, provided this does not impact safety or compromise airspace capacity.

Further efficiencies can also be realised when the predictability of PBN is combined with flow management and other airspace systemisation measures, such as time/trajectory based operations. This can greatly reduce airborne holding and extended low altitude downwind tracks and improves stand-to-stand operations on the ground, leading to a reduction in fuel burn and greenhouse gas (GHG) production.

Safety

Satellite-based navigation has enhanced airborne navigation accuracy and reliability, providing greater access to remote, terrainchallenged, or less equipped airports. In addition, it has also improved track keeping ability during all phases of flight. It is now possible to design routes that fly accurate vertical and lateral flight profiles that provide terrain and obstacle clearance. For example, remote or obstacle challenged airports can benefit from required navigation performance (RNP) approaches with no requirement for ground infrastructure changes or additions.

This capability can also be used to structure air route separations more efficiently to make best use of the airspace available, providing safety improvements in en-route, terminal and approach operations, while utilising enhanced separation standards. On board conformance monitoring provided by advanced PBN-equipped aircraft further improves the safety benefits of the airspace.

As the adoption of PBN continues to increase, enhanced separation standards coupled with greater accuracy in vertical profiles will lead to an increase in airspace capacity and optimised runway throughput without a corresponding reduction in safety.

As the skies become busier, PBN allows the most efficient use of available airspace, through appropriately managed reductions in separation standards during the en route, approach and landing phases. PBN and GNSS allow straight-in approaches, ICAO data shows that straight-in approaches are 25 times safer than circling approaches. Adding vertical guidance to the approach brings a further safety gain.

PBN reduces unproductive flight time, unnecessary delays and fuel burn, providing economic benefits to operators and the environment. Advanced PBN applications now under development will deliver further efficiencies through time-of-arrival control and continuous descent arrivals (CDFA). Four dimensional (4D) trajectory based air traffic management will bring even more efficiency, with aircraft operating on direct routes at optimum altitudes, thus avoiding the congested arrival holding pattern adding to safety.

Economic

In addition to cost benefits of reduced fuel burn for operators in PBN airspace, there are corresponding infrastructure cost benefits for ANSPs. Most airports are served by satellite-based approaches. In many cases, these procedures have replaced approaches using non-directional beacon (NDB) and VHF Omnidirectional Radio Range (VOR) radio-navigation aids. These ground-based aids are 70-year-old technology, which is becoming increasingly expensive to install and maintain. A reduction in infrastructure deployment and maintenance costs comes as a result of no longer needing to develop and maintain procedures that are reliant on ground-based navigational aids. Several States have already commenced projects to rationalise navigational aids, particularly NDBs and VORs, and associated procedures that have become redundant because of migration to PBN.

Responsible growth is also enabled through the ability to increase capacity through closer route spacing, while tying it together with the environmental and safety benefits previously described. This growth brings benefits not only to the airspace users and operators, but also to local and national economies.

Challenges

Communities

As mentioned earlier, the inherent accuracy of PBN provides many benefits, but this is not necessarily the case when an increased concentration of flights occur over populated areas.

The introduction of PBN could bring potential benefits for those communities living in the vicinity of airports, whereby aircraft could be concentrated over non-residential areas. However, where this would not be possible, there could also be challenges which States, airport authorities ANSPs and other stakeholders would face during airspace redesign. Creative solutions, sometimes involving non-PBN procedures, would be required to ensure the desired results.

Throughout the planning and design process, it is vital that early and frequent engagement takes place with communities and stakeholders to improve the awareness and knowledge of PBN, to reinforce the benefits of the concept, and to understand local issues or restrictions.

In addition, change in noise footprint can have negative impact from communities. Aircraft noise-related annoyance is a complex issue, as it is not only related to acoustic annoyance but can be identified by several personal and situational variables. There is influence of such non-acoustical factors on annoyance which are age, fear, and noise sensitivity, and "visual noise" which is associating noise with an aircraft on the horizon even outside the noise parameters. Some of these non-acoustic factors could be addressed by the airport authorities factors directly as part of a comprehensive approach to noise impact mitigation.

Equipage

While modern aircraft are well equipped for PBN, there are still many aircraft in the global fleet that have a less capable avionics equipage. This represents a challenge for the implementing agencies where there is a necessity to ensure that less equipped aircraft are still able to utilise the airspace, leading to the possibility of having multiple procedures for the same area.

In many cases, adapting older aircraft can be very costly; therefore, consideration should be given to fleet capability for a given airspace before beginning any design of PBN procedures. Training for the new procedures, especially where regulatory approval is needed, can also be costly and time consuming. Engagement with the airspace users is key to ensuring that proposals are fit for purpose and will be utilised.

Military and general aviation airspace users may have challenges meeting required equipage levels; procedures will need to be developed to integrate them into the overall network, or alternatively, retention of some legacy procedures may be required to ensure access to airspace for these users.

For some States, data processing and hardware upgrades to air traffic management systems may also be necessary. The costs of these upgrades should be considered as part of the whole project.

Regulatory Framework

State Regulators have an important role to play in the adoption of international design criteria and the approval processes related to the implementation of PBN, in order to ensure safety while supporting effective and timely deployment of PBN. Some proponents have worked closely with their regulators in order to develop new separation standards, training manuals, and certification practices I that support a streamlined implementation process from start to finish.

It is also important for proponents to closely follow any regulatory processes, as failure to do so could hinder understanding the benefits of PBN implementation or, ultimately, result in the refusal of the necessary permissions. Post-implementation reviews should be considered in order to evaluate performance, to promote transparency, to maintain good relations with communities and regulators, and to consider amendments to procedures where necessary.

The International Civil Aviation Organization (ICAO) document, Guidance on the Balanced Approach to Aircraft Noise Management, can.be used as additional information to consider when applying national regulations at airports (example: for US Federal Aviation Regulations (FAR) parts 150 and 161). The balanced approach stresses the need for considering various measures available according to the noise assessment at each airport while preserving potential benefits gained from aircraft-related measures. The four principal elements of the balanced approach are:

- Reduction at source
- Land-use planning and management
- > Noise abatement operational procedures
- > Operating restrictions, with the goal of addressing the noise problem in the most cost-effective manner
- Community engagement is a cross-cutting element which should support the above four pillars, with the goal of identifying practical solutions which includes communities' feedback, whenever possible

Redundancy

The Global Navigation Satellite System (GNSS) is the primary means of support for PBN and is currently based on GPS augmented by aircraft-based augmentation systems (ABAS), spaced based augmentation systems (SBAS) and ground based augmentation systems (GBAS). This is possible due to the advanced avionics equipage within aircraft fleets for these capabilities. The GNSS equipment on board aircraft will fully support the required PBN specifications within an airspace, although an ANSP will have to consider the vulnerabilities and redundancy of these systems in order to maintain safe and efficient operations in the event of local or extended system outages.

A GNSS-independent means of navigation support will be required in this case, to varying levels dependent on an ANSP's specific airspace management requirements. This alternate means of support is necessary to provide a reversion capability for GNSS and to support aircraft not equipped with GNSS or suffering from failure of their GNSS system. This GNSS independence is provided via retention of a limited navigation aid structure, including VOR, distance measuring equipment (DME) and instrument landing system (ILS) equipment, in order to maximise interoperability at the aircraft.

Non-Directional Beacon (NDB)	A ground-based, low frequency radio transmitter used as an instrument approach for airports platforms. The NDB transmits an omni-directional signal that is received by the ADF or Automatic Direction Finder, a standard instrument onboard aircraft NDB is not capable of supporting any of the defined PBN specifications; therefore, the need for NDB infrastructure to support aircraft operations appropriately equipped for PBN is non-existent.
Very High Frequency Omni- Directional Range (VOR)	A type of short-range radio navigation system for aircraft, enabling aircraft with a receiving unit to determine its position The VOR is a beacon that projects 360 separate radio beams, one in every compass degree. Each beam is called a radial. The bearing indicator in the cockpit can differentiate between the radials and tell you which one you are currently on. VOR is capable of supporting the RNAV 5 PBN specification and a Minimum Operational Network (MON) should provide reversion for all airspace prescribed to operate RNAV 5. Consideration for the risk of GNSS reversion needs within RNAV 5 airspace (accounting for additional INS support), should lead to this MON being based only on single redundant VOR coverage.
Distance measuring equipment (DME)	Radio navigation technology that measures the slant range between an aircraft and a ground station. Line-of-visibility between the aircraft and ground station is required. DMEs are usually coupled with a VOR beacon, to enable aircraft to measure their position relative to that beacon. DME may be capable of supporting the RNAV 1 and RNAV 5 PBN specifications and a Minimum Operational Network (MON) should provide reversion for all airspace prescribed to operate RNAV 1 or RNAV 5. RNAV 1 is generally designated within terminal and more congested areas of airspace, which can enable an optimisation of DME ground sites specifically supporting these areas.

Other Challenges

Acceptance of change and recognition of associated benefits of PBN deployment by stakeholders are important during all phases of implementation from design to post-implementation. Designs should be flyable and easily understood by users.

For example, where procedures exist that are not followed, either due to pilot/airline preference and/or controller intervention (or lack of intervention), there are risks that the benefits are not attained, which in turn can lead to mistrust, fear and/or irritation from parties involved (users, communities, etc.). Furthermore, many large airports currently rely heavily on operations based on flexible vectoring patterns (sequencing areas) to optimise/increase landing capacities and the overall use of existing infrastructure to accommodate increasing traffic demands.

Finally, air traffic controllers may perceive the implementation of PBN routes as a limitation to their current way of working by reducing the opportunity to interact with the traffic. However, by leveraging a suite of automated technologies and advanced procedures, ANSPs have the opportunity to deliver increased airspace capacity and fuel efficiency. In addition to the benefits to the environment, the technology supported air traffic controllers in managing their workload. The existing workforce was trained to control aircraft in a very tactical and "hands-on" manner. The introduction of these new technologies and procedures fundamentally changed the work that air traffic controllers love to do. To maximise the benefits of the automation, the ANSP needs to understand the air traffic controller perspective in implementing these new technologies and procedures. A change in Operational Concept, including new system support and training for the air traffic controllers and other relevant stakeholders involved in the deployment of PBN, may be needed to successfully implement new PBN routes.

Noise management options using PBN

This section provides an overview of airspace design principles, PBN procedures, and a number of noise mitigation strategies that can be deployed to address PBN issues or to use PBN as a noise mitigation tool.

Airspace design principles

Airspace and procedures are designed in accordance with criteria and standards established by a State's regulator and in accordance with International Civil Aviation Organization (ICAO) Standards and Recommended Practices (SARPs). These SARPs have been established and are used to ensure a high level of safety for aircraft operations. While adhering to these criterion, PBN procedures can be developed while taking several principles into consideration as explained below.

Traditional aircraft sequencing techniques have required aircraft to navigate by overflying ground-based navigation aids and be subsequently vectored to the final approach course. Due to the unpredictability of track-mileage to be flown allowing for optimum descent profiles, pilots were inclined to descend sooner and level off prior to final approach. As previously mentioned, these level-off segments of the flight resulted in increased aircraft noise through the addition of thrust while level and the resulting aircraft configurations that increased air frame noise.

Continuous Descent Operations (CDO) and Continuous Climb Operations (CCO)

Two operational performance concepts enabled by PBN are Continuous Descent Operations (CDO) and Continuous Climb Operations (CCO). CDOs see aircraft commencing descent from high level cruise altitudes, and use minimum thrust during the descent phase of the flight to a point on final approach lined up with the runway. The continuous descent profile of the CDO sees aircraft remain at higher altitudes for as long as possible and once descent has started, avoids aircraft leveling off at low altitudes, reducing the need for increased engine thrust. Aircraft leveling off at lower altitudes and speeds also require the deployment of lift generating devices such as flaps and slats which result in increased aircraft airframe noise. PBN procedures can be designed to facilitate continuous descent, with lateral paths designed as such to be clear of departure routes, and with a vertical profile that facilitates the continued descent. The quieter profile of CDOs have been shown to reduce aircraft noise by 1 to 5 decibels.



CDO versus conventional "step down" approach

CCOs allow aircraft to depart and climb using optimum climb engine thrust, without interruption or leveling off which, as with descent, requires increased engine power and noise-generating aircraft configurations. As with arrival procedures, PBN departure procedures can be designed to be as clear as possible of arrival procedures and allow aircraft to continuously climb to higher altitudes.

Area navigation (RNAV) and RNP procedures can also allow for multiple departure paths from a runway, as well as multiple paths for arriving traffic. The ideal solution would be for flight paths to be designed in a manner that avoids densely populated areas. However, if this is not feasible due to airport and population density, the possibility of using multiple departure routes, or departure procedures that allow for track dispersion through initial heading assignment prior to the RNAV portion of the procedure, should be considered.

To facilitate CDO and CCO, standard arrival and departure routes (standard instrument arrival (STARs) and standard instrument departure (SIDs)) utilising RNAV and RNP navigation specifications can be implemented. Ideally, arrival route structure would be such that an aircraft descent profile would remain uninterrupted from top of descent to the point where it intercepts final approach. In a busy terminal airspace, this may not always be possible, so a balance may be needed, where arriving and departing aircraft pass at higher altitudes or are assigned tracks that are laterally separated to every possible extent.

For arriving aircraft during busy daytime periods, the safe management of air traffic requires airspace and procedures to be structured in such a manner that allow air traffic control (ATC) to facilitate a safe, orderly and expeditious flow of traffic. Also, during these busy periods, new PBN-based ATC separation standards and procedures can be incorporated into the operation to reduce the need for arriving aircraft to level at low altitudes for extended periods of time. Outside of these busy periods or during night "quiet hours" operations, traffic volumes may be such that the use of RNAV or RNP procedures will allow for low power, low drag, continuous descent, reducing the impact of aircraft engine or airframe noise. (See Appendix * – Night RNAV procedures implemented at Lester B Pearson International Airport (CYYZ).

Another example is the San Francisco RNP approach to runway 19R which was redesigned to improve the speed and altitude profile during descent. The objective of a low energy approach is to minimise the use of added drag (e.g., speed brakes, configuring the landing gear early). The revised RNP to GLS procedures to 19R features an efficiency optimised profile that utilises a near-continuous, idle-thrust descent to landing.

The reduction in community noise is due mostly to the avoidance of overflight of the densely populated Oakland region. In addition, the required thrust throughout the profile is less due to the low energy, continuous and near idle descent. Removing the 4,000 ft level segment, typical for this approach, reduces the required thrust for the approach, the fuel burn and source noise at the aircraft.



Community Noise Exposure for Approaches to Runway 19L/19R (San Francisco RNP to GLS Demo) 🛽

Using PBN as a noise mitigation technique

PBN procedures and operations allow aircraft to fly very precise lateral flight paths and improved climb and descent profiles. A common question that arises during public consultation for airspace changes is why flights are directed over densely populated areas instead of less populated/unpopulated areas. Depending on the geography of where the airport is located and other additional elements mentioned before such as the available equipage and redundancy, PBN procedures can introduce arriving and departing flight paths that are safely placed in areas avoiding densely populated areas. Topographical features, such as rivers, highways or agricultural areas, can be used when available.

Precise lateral confines of PBN procedures allow for some flexibility as to the location where a procedure may commence with respect to position over the ground. The initial waypoint for an RNAV or RNP AR arrival procedure may be positioned to link to a standard arrival route (open STAR) or may be part of the arrival route (closed STAR). See below example of avoidance areas of RNP AR procedures for Ottawa airport.

³ <u>https://laas.tc.faa.gov/documents/Docs/KSFO_RNP_to_GLS_Report_13_Dec_16.pdf</u>



Red circles indicate the communities which RNP AR procedures at Ottawa Airport have been designed to avoid

New PBN-driven Separation Standards

The precise track containment of RNP AR procedures has also allowed for the implementation of new ATC separation standards in high density, parallel operations. Traditional simultaneous parallel approach operations have required ATC to sequence arriving aircraft to the final approach course using vectors, while maintaining 3 nautical miles or 1,000 ft vertical separation until aircraft were established on the final approach course. Aircraft on one downwind to the parallel runway are required to be 1,000 ft higher than those on the opposite downwind, until established on the straight in final approach course. This "High – Low" parallel operation sees aircraft on the "Low" downwind legs be pushed down to lower altitudes and level off for a significant portion of the downwind. The resultant engine and aircraft airframe noise from the "Low" side of the operation can be significant.t



The Established on RNP AR (EoR) standard approved by ICAO now allows simultaneous approaches to be conducted with aircraft flying an efficient CDO RNP AR procedure on one parallel runway, and aircraft on the opposite downwind sequenced to final without the need to run a "Low" side of the operation.



The eventual goal of a PBN-centric airspace model will see the full-scale development of arrival and departure procedures that, by design, allow for uninterrupted climb and descent of aircraft. Known as 'Procedure Design Based Separation', these "tunnels in the sky" will be routes that will be assigned Navigation Specifications that will provide the lateral and vertical containment to facilitate the efficiencies and resultant environmental and noise benefits of PBN.

Concentration versus dispersion

Traditional navigation methods and ATC vectoring did see a natural "dispersion" of flights, with aircraft not consistently passing over the same point at the same altitude on a regular basis. Due to the precise track nature of PBN-based procedures, more aircraft may fly over the same place on the ground more often, with the resultant concentration of engine and airframe noise. These concentrations may be close in to or further away from the airport, depending upon population density and communities.

The concentration aspect of PBN can be a valuable noise mitigation if used appropriately and if the local conditions allow. Ideally, procedure design should be maximised to concentrate aircraft over non-residential areas.



Orange shaded areas represent industrial or commercial areas near Lester B Pearson International Airport (CYYZ)

"Hybrid" procedures may provide benefits where initial tracks for departing aircraft are based on ATC vectors, after which the aircraft is provided with guidance via vectors or PBN navigation to the en route portion of the flight. The PBN-concentrated portion of the procedure, such as the start of an RNAV SID transition, can be placed such that the concentration occurs away from densely populated areas.



Hybrid departure procedure at Lester B Pearson International Airport (CYYZ) – initial departure track divergence after which aircraft navigate to the PBN portion of the flight.



Departure tracks showing dispersal and concentration

Noise patterns

When undertaking PBN procedure design and attempting to determine the associated noise impact and patterns, noise modelling can be used to understand the benefits and impacts of any proposed procedure implementation or changes. Noise modelling can be used as a useful tool to support community consultation or communication process associated with the introduction of

PBN procedures. Care needs to be taken to minimise jargon and to convey complex concepts in simple terms. Experience has shown that graphical presentations over recognisable basemaps (i.e., with identifiable roads, landmarks, etc.) are most effective.

In attempting to better understand and communicate aircraft noise patterns, different modeling metrics can be utilised to best explain the impact or benefits. Single noise event modelling associated with a specific flight path or procedure can be used to provide a direct comparison between existing arrival or departure procedures and any proposed PBN procedure. The single noise event can display what the noise footprint or pattern for a single aircraft flying the procedure may look like. Single noise event modelling can also assist when attempting to compare noise patterns between different locations surrounding an airport.

When looking at the noise patterns of operations involving runway usage or prolonged use of a procedure or track, noise averaging metrics and threshold analysis may provide more clarity and support for analysis and communication requirements. Noise threshold data can provide an indication of the number of instances a specific noise threshold level will be reached or exceeded. Noise averaging analysis provides a baseline noise level over a defined period of time.

It is also possible to use modern technology in order to demonstrate the noise effects likely in an area affected by airspace change. London's Heathrow Airport^[4] have used sound booths at public consultation events in order to allow participants to understand the likely noise levels, any changes this brings over current operations, and also to show how insulation may be used within houses and buildings to mitigate the effects.

Roles and responsibilities

All stakeholders involved in the design and implementation of PBN need to be clearly identified and their roles understood. While it is the responsibility of the change sponsor (normally ANSP or airport) to identify the affected stakeholders, each stakeholder has a responsibility and right to participate in the change process so that a balanced and sustainable outcome can be achieved.

ICAO Resolution A37-11^[5] states that the improvement of the air navigation system on a harmonised, worldwide basis requires active participation and collaboration of all stakeholders. This list of stakeholders should extend to regulatory authorities, aircraft operators, ANSPs, airports and the local communities/municipalities which will be affected by the changes of airspace operations.

An important aspect of PBN regarding local communities is that populations located farther away from the areas that are normally considered "noise-impacted" may also be affected by the changes in flight paths. The wider community has generally become more interested in aviation growth and GHG emissions.^[6] This has made local communities a necessary stakeholder to engage, especially considering that PBN procedures have introduced the concentration of aircraft tracks and related noise and visual intrusions.

Stakeholders can be represented in many forms. For example, aircraft operators' interests may be represented individually, by a company, or as a collective, through aviation associations. The same can be true for each participating community group, making it imperative that when seeking input, the breadth of stakeholders' impact is well understood.

ANSP

Participation is more effective when there is a common understanding of the proposed change and its context. When the ANSP is the proponent of the airspace change, it should be responsible for outlining the overall change management process. ANSPs have an important role in providing education on the underlying aspects of ATC, and how a proposed change will be of benefit. Knowledge of PBN and ATC will vary widely across stakeholders and cannot be assumed in advance. Therefore, preparation for the provision of a variety of educational sessions and guidance material is required to ensure a baseline level of understanding PBN concepts and initiatives.

Education material should include the role that the ANSP plays in air traffic management (ATM) and the governing standards, recommended practices, and procedures that are followed by the ATC unit. Other associated information should include, to the extent practicable, the criteria and regulations that govern the allowable design of flight paths that are proposed to be published in the State Aeronautical Information Publication (AIP). Relevant ATM considerations can include an overview of the local aircraft operations, aircraft types, aircraft equipage, traffic density, traffic complexity and traffic distribution. The airspace classification, and how it relates to the type of ATC or advisory services applicable in the affected airspace, should be explained as appropriate. Comparisons can be drawn to similar environments within the State or abroad. Specific technology applications should be well explained in a way that can be understood by a layperson, particularly if they are unique to the operation being proposed. Whenever possible, graphical depictions should be used to demonstrate traffic patterns, their interaction with each other, and the combined effects of various scenarios on stakeholders' values.

Airport operators

Airport operators are essential for the successful implementation of PBN. Their support in the planning and implementation phases of PBN can help ensure compatibility with the needs of the local community, as airport operators have a keen understanding of the community sensitivities and expectations built on decades of work with these communities.

Therefore, airport operators are in an excellent position to leverage their knowledge of local communities, noise sensitive land use, and political and social situations and considerations surrounding the airport. Airports conduct regular consultations with the communities around them; hence, they likely are aware of the noise and other environmental concerns of their local communities.

⁴ mylondon.news/news/west-london-news/heathrow-soundlab-airports-hi-tech-14406828

⁵ www.icao.int/safety/pbn/PBN%20references/Assembly%20Resolution%2037-11_%20PBN%20global%20goals.pdf

⁶ According to the definition of wider community used at ICAO Circular 351, the wider community is interested in the growth of aviation and GHG gases. ICAO Circular 351 "Community Engagement for Aviation Environmental Management"

Similar to aircraft operators, airport operations are usually governed by regulations, as well as having a set of Standard Operating Procedures (SOPs). Assuring that these governing regulations are well understood by all stakeholders and SOPs as well as all agreements and possible restrictions on operations are shared among them is required to create viable options of new PBN procedures. Specific agreements on runway utilisation, noise abatement procedures or other agreements made with local communities will have significant influence on the outcome of the PBN implementation.

Airport operators should be given the opportunity to provide input into the PBN procedure development, review, and selection processes. The level of participation should be determined by the airport operator and the ANSP, in collaboration and based on the specific situation.

It is essential that the ANSP, the aircraft operator, and the airport operator collaboratively identify the need for change based on current and forecasted traffic, including the capabilities of the aircraft intended to be used for the new procedures. This will facilitate the change sponsor to clearly communicate the possible impact to local communities due to the proposed changes in flight path, in collaboration with other agencies that may have a more detailed local knowledge. Airport operators can also promote the benefits, communicate the impacts of the PBN initiative to local stakeholders, and identify and monitor the metrics of expected benefits and impacts of PBN procedures.

Moreover, airport operators can identify issues with legacy flight procedures, by providing information on the local operational or environmental considerations for the proposed changes, including potential impacts on the surrounding communities and knowledge of airport construction and obstacles that may affect the design of the procedures. Local knowledge useful to the PBN project may include preferred runway configurations and routes, obstructions, noise-sensitive areas, aircraft operator characteristics, airport survey data, concerns of the community, and current and forecasted equipage types and traffic levels at the airport.

Occasionally, airport operators may be the primary proponent of the airspace change (e.g. addition of a runway, land development affecting obstacle clearance and noise mitigation). In these cases, the airport operator's leadership role in planning and conducting stakeholder and community engagement, working closely with ANSPs, is even greater.

Aircraft operators

Aircraft operators are generally the major proponents and benefactors of PBN adoption. "PBN is the most practical solution for the regulation of new navigation systems technology" (IATA)^[2]. Stakeholder representation by aircraft operators may encompass a broad cross-section of the industry depending on the location of the airspace change. Changes may also simultaneously affect a diverse set of operations, i.e., PBN changes at a busy international airport that has airspace boundaries with regional or general aviation airports or flight paths. The interests and values brought forward by the individuals will vary accordingly. However, there is one common shared value amongst all participants: the safety of operations must come first and cannot be compromised for other stakeholder considerations.

Aircraft operators' role is to share their operational practices with particular attention to any limitations that could preclude a potential option from being explored. These would be governed by a combination of: aircraft types, avionics equipage, crew training, and SOPs for the subject aircraft. Where there is a possibility for a wide performance divergence or unpredictability of operations owing to the traffic mix, procedure designs may be needed to specifically address the need to operate to defined parameters to meet the broader stakeholders' expectations. Commercial operators may present a more homogeneous representation owing to their requirement to meet operating certificate standards.

Regulatory organisations

Having a clear regulatory framework is relevant to facilitate implementation. Stakeholders need to be aware of the existing regulations that govern air traffic and its management can be addressed given the volume of airspace under consideration for change. In addition, the civil aviation regulatory body should coordinate with all stakeholders involved and help explaining the context and application of these regulations, as well as whether there is an opportunity to make modifications as part of the change process in the interests of achieving an improved operation. Regulations may apply to the air operator, the airport and/or the ANSP.

Other government organisations may have a regulatory or non-regulatory interest in the operation of the airport. They need to be made aware of the change process and it is their responsibility to bring forward their issues for consideration.

Planning and land use authorities

Land use planning is generally a local issue and responsibilities may be distributed amongst various stakeholders. Coordination with these stakeholders can support the effective implementation of PBN. Compatible land-use planning and management is also a vital instrument in ensuring that the gains achieved by the reduced noise of the latest generation of aircraft are not offset by further residential development around airports.

⁷ https://www.iata.org/training/subject-areas/Pages/civil-aviation-courses.aspx

ICAO's main policies on land use planning and management are contained in Assembly Resolution A39-1, Appendix $F^{[8]}$, which urges States, where the opportunity still exists to minimise aircraft noise problems through preventive measures, to:

- a. Locate new airports at an appropriate place, such as away from noise-sensitive areas
- **b.** Take the appropriate measures so that land-use planning is taken fully into account at the initial stage of any new airport or of development at an existing airport
- c. Define zones around airports associated with different noise levels taking into account population levels and growth as well as forecasts of traffic growth and establish criteria for the appropriate use of such land, taking account of ICAO guidance
- d. Enact legislation, establish guidance or other appropriate means to achieve compliance with those criteria for land use
- e. Ensure that reader-friendly information on aircraft operations and their environmental effects is available to communities near airports

ANSPs need to ensure procedure designers are aware of land use planning factors. Local developers will often resist proposals to limit residential development even in areas affected by noise. Planning (Resolution No. 5/2017 Urging States and Airports to Continuously Work Together on Land use Planning)^[9]

Airports and other aviation stakeholders, especially airlines and ANSPs, must work with local governments; requesting and recommending appropriate rules to protect airport operations. While fleet modernisation has reduced the extent of airport noise, residential encroachment can pressure airports not to grow traffic.

Public Engagement

Thorough and effective public engagement is essential to the successful implementation of PBN and to achieving some level of community understanding and acceptance or minimising adverse community reaction. Some jurisdictions require specific processes or general levels of consultation, community engagement or outreach; at many airports community noise forums already exist and meet regularly.

The general rule is that engagement should occur as early as possible, preferably in the design stage when there is more flexibility and time to accommodate changes. Understanding stakeholders' concerns and trying to address them from the beginning can save time and resources by avoiding costly changes in later stages.

It is important to have a defined strategy and clear engagement plan. Airports are in a unique position to contribute to a continued engagement process, because they generally keep an open channel with their communities and are used to receiving feedback whenever airspace changes happen. They are an essential stakeholder that should be included from the beginning.

This section outlines some recommended practices for public consultation or engagement on the implementation of PBN at an airport or in a region, especially for jurisdictions where there are no regulated requirements. A good reference document and source of guidance is the ICAO Circular 351 *Community Engagement for Aviation Environmental Management*.

Particular Issues Relevant to PBN

Airspace changes associated with the introduction of PBN can raise some particular concerns with communities that should be carefully considered when approaching consultation or engagement. Not all of these are necessarily related to noise levels, as the perception of change and the attitude of the individuals can be significant factors. These are sometimes referred to as non-acoustic factors (NAF).

Aircraft noise issues resulting from PBN implementation can include the following:

- > Aircraft flying lower or with different operational parameters than previously observed
- > Aircraft over-flying new areas
- > Greater concentration of flight tracks

Some examples of non-acoustic factors (not necessarily unique to PBN implementation) are as follows:

- > Attitude towards the airport and aviation
- > Perceived fairness
- > Level of trust or perceived transparency of information communicated by airport
- > Satisfaction with airport mitigation work such as sound insulation
- > Level of empowerment to influence the situation

⁹ https://aci.aero/Media/76c29f2d-fc8a-4fba-ad00-555da72b59ade/07us9Q/About%20ACI/Overview/ACI%20World%20Resolutions/Port%20Louis,%20 Mauritius%202017/27WAGA-MRU17%20Resolution%205.pdf

⁸ <u>https://www.icao.int/environmental-protection/Documents/Resolution_A39_1.PDF</u>

Balancing potential trade-offs between efficiency and noise

Since PBN can be used to improve efficiency and/or reduce noise footprints, and that these two objectives may not always be reached at the same time, considerations should be given to communities' feedback while balancing these two elements: improving efficiency and reducing noise. Decision regarding which element should prevail should include communities' concerns, but also other relevant aspects such as safety and security.

In some jurisdictions, certain operational changes or conditions can guide or modify statutory requirements relating to community engagement. For example, both the Canadian and Australian airspace change protocol requirements outline scenarios where consultation may not be warranted, such as flightpath changes required for safety or security reasons or visual flight routes. Additionally, these documents provide impact-related guidance in terms of flight frequency and altitude to help determine appropriate engagement levels. Regardless of the impacts, proactive communication is often recommended. Care should be taken and explanation and information provision to impacted communities should be considered in a manner that is reflective of the degree of change and potential impacts.

Proponent

The lead responsibility for consultation resides with the organization that proposes making the change (the 'proponent'), while working in close collaboration with other industry partners. The proponent often will be the ANSP for changes in airspace design, or the airport operator in the case of airport infrastructure changes or changes in operational procedures leading to a need for changes in airspace design.

Stakeholder Definition

In all cases, regardless of the proponent initiating the change, industry stakeholders will need to collaborate on communications and consultation planning. Stakeholders are identified and defined in ICAO Circular 351. Industry or aviation stakeholders will usually include the following:

- > The ANSP
- > The airport operator
- > The aircraft operators or a representative body
- > The government regulators or other authorities such as the civil aviation authority or transport department
- > Manufactures
- > Passengers

Local community stakeholders will usually include:

- > Local governments or municipal or county councils who are usually also responsible as the land-use or planning authority;
- > Elected officials;
- > Community members in the local area or broader society, either individually or in organised groups;
- > Environmental groups and NGO's.

Engagement Activities

Again, ICAO Circular 351 provides guidance on engagement activities, including the following definitions on levels of engagement:

- > Informing, where information is provided by a party to another
- > Involving, where information and views are exchanged between parties
- > Collaborating, where information is exchanged and taken into account in decision making

Descriptions of a broad range of engagement activities are also provided. These cover information dissemination, via print and electronic media, meetings, mediation, open days, and various project works and interactive activities.

Lessons Learned and Good Practice

Although not designed for specific PBN purposes, lessons learned and good practices as described in ICAO Circular 351 can be summarised in six basic principles that can guide, in general, any type of consultation:

- > Start early and continue in the longer term. Community engagement does not have to be project or PBN-specific
- Be proactive and wide-reaching
- > Be transparent
- > Manage different expectations as not all parties will be pleased with the outcomes
- Use where useful different ways to present information, including new technologies, social media, traditional print and broadcast media
- > Make sure the process is as inclusive and collaborative as possible

Lessons learned on stakeholder engagement generally reflect common-sense guidance on how consultation should occur. Things like identifying stakeholders in advance, defining a plan, and involving everyone from early stages are identified as good practices. In addition, it is important to keep stakeholders' engagement consistent. Airports can assist other stakeholders in incorporating these practices as they have experience and a critical role in these consultations, as well as stewardship of public engagement vehicles.

It is also important to recognise that it is often not possible to accommodate everyone's concerns. Managing different expectations in a transparent way is key to success. Stakeholders must be able to understand the impacts of the change and what can be done when there are several needs on the table. Safety and technical limitations to accommodate requests should be acknowledged to all to avoid unrealistic expectations.

Effective consultation should also be as inclusive as possible. Different stakeholders can also require different language to facilitate understanding. Using different methods of communication and dissemination are recommended.

In addition, it should also be noted that local community consultation should not be restricted to the communities that are already adversely impacted by air operation but include communities that are potentially impacted by the change arising from PBN implementation. Although such consideration may not be easily incorporated, anecdotal evidence suggests that previously unaffected communities may be particularly sensitive to any changes in airspace use. Hence, it is crucial for authorities and technical stakeholders to understand the views from previously unaffected communities in order to balance the conflicting needs and impacts of PBN implementation and refine airspace change options as appropriate.

Airports' internal management frameworks vary considerably and can affect the airport audiences that should be involved in the consultation process. For instance, the Radio Technical Commission for Aeronautics (RTCA) gives some examples of potential departments that may need to be involved: airport planning and development, airport operations, airport noise abatement office and community affairs/public relations. In addition, there are other airport sponsors (e.g., city, county, state or authority), organisations and city planning, commercial development, legal, and zoning that are potentially relevant audiences too.^[10]

The FAA's Community Involvement Plan^[11] includes sections dedicated to PBN projects, with the agency's recognition that simply complying with legal requirements does not satisfy stakeholder needs; and, hence, more and varying opportunities for airports and communities to be involved allows better incorporation of community concerns and communication of procedural amendments.

Furthermore, to maximise the effectiveness of stakeholder engagement, the findings of the studies should be prepared in a concise and easily comprehensible manner for non-technical stakeholders. This non-technical summary of the study would not only ensure that the public and the local community understand the potential impact, but also allow high-level decision makers to make decisions and take necessary actions to help balance conflicting needs arising from the change of airspace. When communicated effectively, the non-technical summary may assist with the acceptance of proposed changes and the management of expectations in an open and transparent manner.

Even when the analysis indicates more numerically-attractive safety, efficiency and overall environmental benefit from airspace change, the associated cost due to change in impact to individual local community cannot be fully converted to numerical values. Hence, the analysis should guide and allow policy direction and decisions to balance the best possible decisions.

¹⁰ PBN Blueprint for success. Available online at: <u>https://www.rtca.org/sites/default/files/2016_pbn_blueprint_community_outreach.pdf</u>

¹¹ FAA Community Involvement Plan. Available online at: <u>https://www.faa.gov/air_traffic/community_involvement/</u>

Briefings and meetings are suggested as a primary means to achieve an effective dialogue during the consultation process. There are different formats in which these meetings can be carried out, such as, open houses, where stakeholders can meet on an informal basis with specialists; public hearings, where formal presentation is performed to wider groups of stakeholders; workshops, where stakeholders and specialists present and discuss relevant information; focus group sessions, dedicated to specific topics and/or targeted stakeholder group; community advisory group meetings, which include residents, business, and other groups interested in the community around an airport; and roundtables and working group meetings that bring together stakeholders on a regular basis, among others.^[12]

The internet is also another valuable tool for outreach. Several airports have readily available information on their websites concerning airspace changes, modernisation, environmental impact, including noise and emissions, and their related consultation process. In addition, printed press and media broadcasts are often used, as they can reach many stakeholders, although the media interest may fluctuate depending on public interest in the issue.^[13] Airports have also used mail and e-mail to disseminate information about consultation. They generally keep a list of recipients that have agreed to receive such information.^[14]

Commitment to Review

This document is intended to guide communications and consultation with communities potentially impacted by changes to flightpath design.

A periodic review of the document may be undertaken by CANSO and ACI with additional case studies and/or a set of aviation environmental indicators have been developed and could be used to evaluate the performance of aviation operations and the effectiveness of standards, policies and measures to mitigate aviation's impacts on the environment.

Aviation stakeholders have a role in contributing to framework amendments, and to managing the impact of noise and emissions from aircraft operations.

¹² NextGen for Airports, Volume 2: Engaging Airport Stakeholders: Guidebook, at 17

¹³ NextGen for Airports, Volume 2: Engaging Airport Stakeholders: Guidebook at 20

¹⁴ NextGen for Airports, Volume 2: Engaging Airport Stakeholders: Guidebook at 21

Appendix A – Case Studies

- 1. Toronto Pearson International Night RNAV approaches
- 2. Hybrid SIDs at Toronto Pearson International
- 3. London Stansted Airport
- 4. Departure optimisation Amsterdam: RNAV1 with RF legs
- 5. John Wayne Airport: RNAV departure

Case Study: Toronto Pearson International Night RNAV approaches

In 2016, following significant public engagement on aircraft noise issues with communities surrounding Toronto Pearson International (CYYZ), NAV CANADA initiated an independent review of the airspace that serves the country's busiest airport in order to identify potential opportunities to reduce community noise exposure. Toronto worked with the communities to better identify noise reduction opportunities in residential areas. These conversations led to the creation of the Toronto Noise Mitigation Initiatives Engagement Plan, commonly known as the Six Ideas. The official comment period for the public consultation offered several different options to provide input. More than 430 people attended 19 public meetings throughout the region. Feedback was received from more than 900 people through a survey.

A resulting third party report made a number of noise mitigation recommendations, including a recommendation that NAV CANADA consider developing new RNAV arrival procedures that could be used during nighttime restricted hours (0030-0630 local) when traffic levels are typically lower and aircraft noise can be more impactful due to lower ambient community noise levels.

During this lighter density traffic period it is possible to reduce reliance on the existing downwind structure – normally required to safely sequence aircraft and meet capacity demands – and target overflight of non-residential use land such as highways, industrial areas and agricultural space rather than residential areas.

Not only are these approaches designed to avoid residential areas, but also to allow flight crew to manage their descent in a low power-low drag CDO (continuous descent operation) profile, significantly reducing the noise footprint over thousands of residents in the Greater Toronto Area (GTA). Depending on the procedure being flown, as many as 125,000 fewer homes are overflown at noise levels above 55 dBA when compared to the use of the downwind structure.

Alternate approaches were designed for all of Toronto runways and results of all approaches are available at <u>www.torontopearson</u>. <u>com/en/community/get-involved/community-conversations/quieter-operations-roadmap/idea-1-night-time-approaches</u>

Below is an example of the changes and new procedures for Runway 05 at Toronto Pearson International.



Figure 1. Standard traffic sample



Figure 2. "Night" RNAV X approaches to Runway 05 and associated footprint

Case Study: Hybrid SIDs at Toronto Pearson International

Conventional navigation methods and ATC vectoring can result in a natural "dispersion" of flights tracks, with aircraft not consistently passing over the same point at the same altitude on a regular basis. Due to the precise track nature of PBN-based procedures, more aircraft may fly over the same place on the ground more often, with the resultant concentration of engine and airframe noise.

Hybrid SIDs were deployed at Toronto Pearson International (CYYZ) to leverage the operational benefits inherent in PBN procedures while reducing low altitude track concentration over residential areas. The optimised departure paths, support initial departure separation with a resultant reduction of the noise footprint over the built-up population around the airport.

Conventional SID procedures have all aircraft departing over the same area following prescribed tracks from the runway. Utilising the hybrid SID philosophy, the lateral profile of the departure is disconnected from the runway and the concentrated RNAV portion of the procedure begins away from the airport. This allows controllers to use tactical headings off the runway, dispersing traffic and the resulting noise, over the ground below.

The "Hybrid" procedures at Toronto Pearson provide such benefits, where initial tracks for departing aircraft are based on ATC vectors, after which the aircraft is provided with guidance via vectors or PBN navigation to the first waypoint of the SID transition and then enroute. The PBN concentrated portion of the procedure, in this case the RNAV SID transition, can be placed such that the first waypoint of the transition is over water, or in a low-population area.



Hybrid departure procedure – initial departure track divergence after which aircraft navigate to the PBN portion of the flight.



Departure tracks showing dispersal and concentration

Case Study: London Stansted Airport

London Stansted Airport, one of the busiest airport in the United Kingdom, has implemented RNP with RF routes in order to meet the regulatory requirement laid down by EASA I, whilst also improving flight efficiency for the airport users and the environmental impact on local communities.

The airport, which handles approximately 200k movements per year, followed a robust process of engagement and consultation with its stakeholders in order to ensure as many interested parties had input into the project. This not only included the airlines and airport users but also the local communities affected by the existing departure routes from the airport.

As can be seen from the following image, the spread of departure tracks (Runway 22, CLN departure) was broad and affected many small towns and villages all whilst remaining within the Noise Preferential Route (NPR) swathe.



Spread of tracks prior to 4000ft is approx 1500m / Radar vectoring not allowed below 4000ft.

An initial trial of RNP(RF) procedures took place in 2013 with a single airline participant and with the support of NATS (the UK enroute ANSP) and CAA (the UK regulatory authority) in order to prove the benefits of utilising PBN at Stansted with a commitment to seek input from the public throughout the design phase.



Villages now not directly overflown by departing traffic/ Swathe reduced to approx 500m

The output of the trial lead to a public consultation in 2015 on making the procedures permanent. During this consultation the overall responses were positive toward the change (71% of respondents were supportive), particularly from the villages of Hatfield Broad Oak and Hatfield Heath and other villages. In total the reduction in the number of people overflown by departures on this route was approximately 85%.

Use of Performance Based Navigation (PBN) for Noise Management

The CAA approved the airspace change proposal for this procedure, along with another from runway 04, in August 2017 at which point Stansted became the first airport in the UK to have permanent RNP (RF) procedures.

	All Movements	% Track Keeping against+/- 500m swathe All Movements	No of PBN Departures	%PBN Departures	% Track Keeping against +/- 500m swathe PBN Movements
December 2013	1525	21.11	64	4.19	96.82
December 2017	3179	95.41	2892	90.97	99.38

Table showing overall improvement in track keeping (pbn & non-pon-pbn departures)



Depiction of reduction in area overflown - this leads to an 85% reduction in the number of people overflown at Stansted

Case Study: Departure optimisation in Amsterdam: RNAV1 with RF legs

In 1974 the first Standard Instrument Departure (SID) route for traffic to the North was published for Runway 24 of Amsterdam Airport Schiphol (EHAM). At first, this departure route was based on conventional navigation only. Since the SID overflies the SPY VOR, it was named accordingly. An RNAV-1 definition of the SPY SID was added later.

Due to differences in aircraft performance and navigation methods, a relatively large spread in flown tracks could be observed in the first turn of the SID (see yellow tracks in figure below).



Since 2008, a second alternative of the RNAV SPY SID is used that contains a Fixed Radius (RF) turn. The RF turn allows aircraft to navigate more accurately in the first turning part of the departure between the residential areas of Hoofddorp and Nieuw-Vennep.

The goal of the RF alternative of this SID is to reduce the spread in flown tracks in between built-up areas. The SPY departure was the first route from Schiphol using the RF technique. In the first year the route was restricted to Boeing 737 aircraft from the main operator, in order to perform an operational trial and to assess the effects on noise nuisance in the surrounding communities. Currently many aircraft types and operators are flying the RF coding. There is still a mixture of non-RF traffic (see yellow lines in figure below) and RF traffic (green lines) on the SPY SID.



Because noise is concentrated around the trajectory of the RF turn, the resulting nuisance in the residential areas of Hoofddorp and Nieuw-Vennep is reduced. It however also leads to concentration of noise over Floriande, a new housing development in the northwest of Hoofddorp. Nevertheless, the effect on noise is smaller here because traffic flies higher above Floriande.

The RF departure was designed in several iterations. Since RF legs are not part of the RNAV1 navigation specification, it was deemed necessary to execute various simulator trials before the first live experiments. Both aircraft operators and local communities were continuously involved in the design process. The final design consists of two consecutive RF legs for optimised flyability. Overall, the RF departure has led to a reduction of nuisance complaints in the entire municipality.

Case Study: Departure optimisation at John Wayne Airport: RNAV

John Wayne Airport (SNA) is one of the busiest and most noise sensitive airports in the United States. The airport is located in the centre of Orange County, California, with residential areas in close proximity. To mitigate potential noise impacts from aircraft operations and to enhance compatibility with surrounding communities, the Airport maintains some of the most stringent noise rules in the United States. In addition to the stringent noise abatement procedures SNA implemented an RNAV departure (RNAV STAYY One) which basically follows the river valley avoiding dense populated areas as much as possible. Departures to the south can be conventional (MUSEL EIGHT), RNAV (PIGGN TWO), or RNAV off the ground^[15] (STAYY ONE). Below graphics highlight the difference of the flight paths of the different procedures, these are actual flights presented in Volansi.^[16]



Number of People overflown within 1,000 feet of the procedure centerline for the specific departures

Conventional MUSEL	4190
RNAV PIGGN	3390
RNAV STAYY	2973

The RNAV STAYY One is the most accurate procedure with the least overflown population and the best concentration (most accurate) along departure centerline. At the waypoint PAPAU the following percent flights within procedure centerline were tracked for the different departures.

For Musel 48% of departing aircraft were within 100ft of centerline, for PiGGN 96%, and STAYY 99%.

The STAYY ONE RNAV procedure provides the benefits that SNA was looking for.

¹⁵ RNAV off the ground departures are RNAV departures that begin at the departure runway rather than a vector to an initial RNAV fix.

¹⁶ VOLANS is a web-based application, a data visualization tool for airspace and noise modeling designed to create, evaluate, and display flight operations in 3D. The software includes environmental and operational efficiency analysis tools to determine benefits and risks associated with new procedure development. Volans is customized for integration with airport noise and operations monitoring systems (NOMS), noise modeling tools, and flight procedure design tools.



Number of People overflown within 1,000 feet of the procedure centerline for the specific departures

The graphic below outlines that the preferred departures are RNAV SIDs with approximately 80% of all departures being filed and flown as RNAV departures.



All RNAV/Conventional Departure (SID) Filed/Amended & Conformed > 30%

SNA also established a life noise monitoring system established in vicinity of the sensitive areas and the departure track, which can be tracked on line in real time.



All RNAV/Conventional Departure (SID) Filed/Amended & Conformed > 30%



Appendix B – Reference Documents

- 1. Airservices Communication and Consultation Protocol (Australia) www.airservicesaustralia.com/wp-content/uploads/Communication-and-consultation-protocol_WEB.pdf
- 2. Airspace Change Communications and Consultation Protocol (Canada) www.navcanada.ca/EN/media/Publications/Aviation%20Industry%20Airspace%20 Change%20Communications%20and%20Consultation%20Protocol-EN.pdf
- CAA CAP 1378 PBN Airspace Design Guidance: Noise mitigation considerations when designing PBN departure and arrival procedures publicapps.caa.co.uk/docs/33/CAP%201378%20APR16.pdf
- 4. CAP1385: Performance-based Navigation (PBN): Enhanced Route Spacing Guidance https://publicapps.caa.co.uk/docs/33/CAP%201385%20APR16.pdf
- 5. CANSO Performance-Based-Navigation Best practice guide for ANSPs www.canso.org/performance-based-navigation-best-practice-guide-ansps
- CANSO-ACI: Managing the Impacts of Aviation Noise www.canso.org > managing-impacts-aviation-noise
- 7. FAA Community Engagement Program www.faa.gov/nextgen/communityengagement/
- **8.** FAA Community Involvement Manual www.faa.gov/about/office_org/headquarters_offices/apl/environ_policy_guidance/guidance/media/faa_cim.pdf
- 9. Independent Toronto Airspace Review Final Presentation spaces.hightail.com/receive/SJvmz3y6GU/fi-fcdf4181-ec47-4101-b83c-9e2110e28cdc/fv-b6ea56a9-47e8-42bc-908c-2d90dbb12bec/Final%20Presentation%2018th%20Sept%202017.pdf
- **10.** San Francisco RNP to GLS Demonstration, 18 November 2016 laas.tc.faa.gov/documents/Docs/KSFO_RNP to GLS_Report_13_Dec_16.pdf
- **11.** ICAO Doc 9829, Guidance on the Balanced Approach to Aircraft Noise Management. <u>www.icao.int/environmental-protection/Pages/noise.aspx</u>
- ICAO Resolution A39-1: Consolidated statement of continuing ICAO policies and practices related to environmental protection – General provisions, noise and local air quality. <u>www.icao.int/environmental-protection/Documents/Resolution_A39_1.PDF</u>
- ASSEMBLY 40TH SESSION, Agenda Item 15: Environmental Protection General provisions, Aircraft Noise and Local Air Quality– Policy and Standardization www.icao.int/Meetings/A40/Documents/WP/wp_260_en.pdf
- 14. A QUIETER OPERATIONS ROADMAP, NAVCANADA and Toronto Pearson www.torontopearson.com/en/community/get-involved/community-conversations/quieter-operations-roadmap

Appendix C – Abbreviations and References

AC	Advisory circular	IAS	Indicated airspeed
ACI	Airports Council International	IFP	Instrument flight procedure
AGL	Above ground level	ILS	Instrument landing system
AIC	Aeronautical information circular	ІМС	Instrument meteorological conditions
AIRAC	Aeronautical information regulation and control	LNAV	Lateral navigation
ANSP	Air navigation service provider	LPV	Localiser performance with vertical guidance
АРСН	Approach	MAPT	Missed approach point
APV	Approach procedures with vertical guidance	MDH	Minimum decision height
A-RNP	Advanced RNP (PBN navigation specification)	NAVAID	Navigation(al) aid
ATC	Air traffic control	Nav-spec	Navigation specification
ΑΤCΟ	Air traffic control officer	NextGen	Next generation air transportation
ATM	Air traffic management		Non directional radio boacon
ATS	Air traffic services		Nautical mile
САА	Civil aviation authority (regulator)	PRN	Performance based pavigation
CANSO	Civil Air Navigation Services Organisation	DE	Constant radius are to a fix
ссо	Continuous climb operations		
CDO	Continuous descent operations		Required pavigation performance
CNS/ATM	Communications, navigation and surveillance / air traffic management	RNP AR	RNP authorisation required (approach)
DH	Decision height	RTF	Radiotelephone
DME	Distance measuring equipment	SBAS	Satellite-based augmentation system (GNSS augmentation)
FMS	Flight management system	SESAR	Single European Sky ATM Research
FRP	Fixed radius path	SID	Standard instrument departure
FRT	Fixed radius transition	STAR	Standard instrument arrival
FTE	Flight technical error	ТМА	Terminal control area
GNSS	Global navigation satellite system (e.g. GPS, GLONASS)	VOR/DME	VHF omnidirectional range /
GPS	Global positioning system	VNAV	Vertical navigation
ΙΑΤΑ	International Air Transport Association	VINAV	vertical havigation
ICAO	International Civil Aviation Organization		
IAP	Instrument approach procedure		



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